Deliverable D.T.3.2.1

STEP BY STEP GUIDE FOR USING THE CEST

Final version 12 2021

Step by step guide for using the Carpathian Ecosystem Services Toolkit (CEST)

The ecosystem services assessment procedure

This document has been elaborated thanks to the project *Building management capacities of Carpathian protected areas for the integration and harmonisation of biodiversity protection and local socio-economic development* (Centralparks), supported by Interreg CENTRAL EUROPE Programme.

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Acknowledgements

The editors would like to thank other members of the Thematic Transnational Task Force on Ecosystem Services Toolkit for their valuable contributions and comments in developing this guide: Andrzej Affek, Ildikó Arany, Filippo Favilli, Jiří Lehejček, Juraj Švajda

Contents

Introduction

Step by step guide for using the Carpathian Ecosystem Services Toolkit (CEST) is a basic part of the Activity A.T3.2 of the Centralparks project[1] - the training programme for local/regional authorities on using the CEST. It will serve as the technical guide for the use of CEST developed by the expert group for public authorities and local protected areas administrations (project deliverable D.T3.1.3). The deliverable D.T3.2.1 focuses on outlining the appropriate procedure for the Ecosystem Services (ES) assessment. It is intended for use in various contexts and scales - contains the basic inputs, steps and outputs of the evaluation. The available approaches and methodical toolkits are used as inspiration; other recommended sources are also provided.

The guide is closely related to theoretical chapters of the Carpathian Ecosystem Services Toolkit, therefore will be included in the CEST as its integral part.

1. Basic ecosystem services assessment framework

In general, before embarking on an ESs assessment, it is necessary to ask the **basic questions**, what is the main reason for the evaluation and what issues need to be addressed in a given specific situation (NESP 2016, Maes, Liekens & Brown 2018, Ruskule, Vinogradovs & Pecina 2018). For example, Preston & Raudsepp-Hearne (2017) provide a sequence of such questions as follows:

- Which ES are priorities in a given situation?
- What to measure or assess and which analysis tools to use?
- How are various ES produced and how do they interact with each other ecologically?
- How do ES benefit different groups of people (whether they are aware of it or not)?
- What are the values of these ES benefits to those groups of people?
- Are ES benefits increasing or decreasing over time?
- What are the likely effects of a project or policy on ES and associated ES benefits?
- How can specific policy objectives be achieved without undue negative impacts on important ES?

It is also necessary to clarify the **basic conceptual framework** of ES assessment - the extent to which the evaluation should focus on the individual main "boxes" of the so-called *ES cascade model* (Potchin & Haynes-Young 2011). Within the ecological assessment of a given territory, it is crucial to recognise the ecosystem categories, state of ecosystems, their structure, natural processes, function; and how they are affected by anthropogenic pressures and drivers. On the other hand, in a planning document such as a local development strategy, it is essential to know what benefits for people could be achieved by wise management of natural resources.

An example of such a framework gives e.g. Preston & Raundsepp-Hearne (2017) – see Figure 1. It shows that ES evaluation needs combining of the biophysical, socio-cultural, and economic information. The main goal is to reveal the processes of ES production and benefit distribution,

[1] Interreg CENTRAL EUROPE project Building management capacities of Carpathian protected areas for the integration and harmonisation of biodiversity protection and local socio-economic development

the role of management and governance in affecting these processes, as well as the broader social and natural drivers of change that influence how ES are produced and managed.

A simplified conceptual framework of ES assessment expressing the links between society and nature through causal relationships in accordance with the often used DPSIR (Drivers – Pressures – State – Impact – Response) framework is presented in Figure 2 (the relationships between ES and this framework is given e.g. by Rounsevell et al. 2010). It would be ideal if the ES assessment was comprehensive and included all components of the cascade (or the D-P-S-I-R sequence shown). However, this is often not possible or necessary – usually, the “D-R” and/or “R” components of the framework are not considered in the ES assessment. Before the evaluation itself, it is useful to “rethink” your evaluation conceptual model and then adapt the content of the assessment steps.

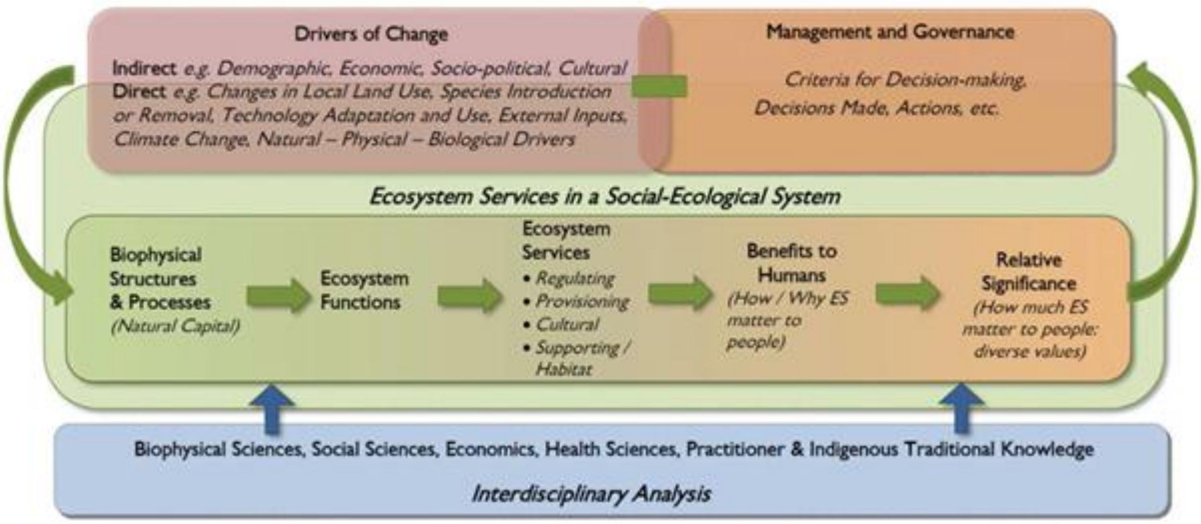

Figure 1 – Conceptual and analytical framework for the Canadian toolkit (Preston & Raudsepp-Hearne 2017)

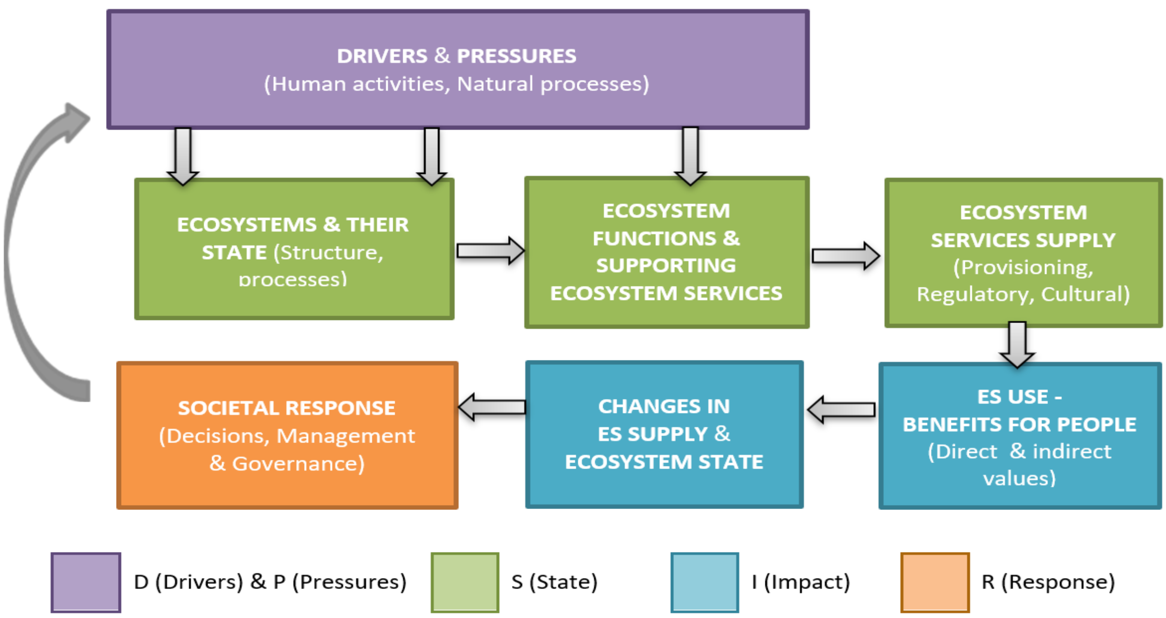

Figure 2 – Simplified DPSIR framework for ES assessment

There are several possibilities for how to design the process of ES evaluation in detail. For example, *Canadian Ecosystem Services Toolkit* could be considered as "a technical guide to ecosystem services assessment and analysis that offers practical, step-by-step guidance for governments at all levels, as well as for consultants and researchers" (Preston & Raundsepp-Hearne 2017). The proposed process distinguishes six basic steps and accompanies the researchers and practitioners with the task from the beginning of the process to its completion, using worksheets and tables. An overview of the proposed procedure is provided in Table 1. Note that these steps do not include the full final phase of the proposed process (phase C), they pass through phases A (steps 1-3) and B (steps 4-5). Final step 6 is only an introduction to the implementation phase of the process.

Table 1 - Six-step ES assessment framework (Preston & Raundsepp-Hearne 2017)

Step 1. Defining the issue and context
• Setting up a lead team • Defining the issue(s) that are driving the assessment • Reviewing the key terms and considerations
Step 2. Identifying priority ES and beneficiaries for assessment
• Identifying priority ES and beneficiaries
Step 3. Identifying what needs to be evaluated to answer assessment questions
• Organising assessment team and process • Identifying what will be evaluated to answer assessment questions
Step 4. Going into detail: Identifying and using indicators, data sources, and analysis methods
• Identifying which indicators are most relevant for assessing each ES • Identifying and gathering existing data sources or developing new data • Selecting and using analysis methods and tools to answer the assessment questions • Choosing analysis approach
Step 5. Synthesising results to answer assessment questions
• Integrating and synthetising results
Step 6. Communicating assessment outcomes
• Understanding what results mean and do not mean • Communicating results to different audiencies • Distilling complex, integrated results into key messages

Within the *LIFE EcosystemServices project* in Latvia (NCAL 2020), an eight-step conceptual framework for integration of ecosystem services approach into planning processes was proposed (see Table 2). As seen, more emphasis is put on the ES economic valuation and the post-research steps (decision-making and implementation). This could be a proper approach in case of the need for practical assessment outcomes; it is in full accordance with our approach and the closest to the Carpathian toolkit purpose and goals.

Table 2 – Eight steps of the Latvian approach to the ES assessment (NCAL 2020)

Integration of ecosystem services approach into planning processes
1. Assessment of ecosystems (mapping of ecosystems and assessment of ecosystem condition)
2. Assessment of ecosystem services (assessment and mapping of ecosystem services)
3. Economic valuation of the ecosystem services (benefits of ecosystem services, determination of monetary, non-monetary value and trade-offs)
4. Assessment of existing management and alternatives
5. Involvement of stakeholders
6. Support mechanisms
7. Decision-making (support mechanisms, aggregating and integrating of information)
8. Implementation and monitoring (implementation of the concrete land use and management solutions; assessment of implementation)

Another relevant source of methodological guidance could be found e.g. in the *Local Integrated Planning Toolkit for Biodiversity and Ecosystem Services* report (Pierce 2014). In the case of integrated assessment and planning process, it emphasises the role of combining the knowledge from research and practice (Figure 4). The proposed steps are very similar to our approach – the difference is that Step 1 is beyond the introductory phase of our framework. Such simplifying understanding is worth using in the "pure" practical and participative focusing of the assessment process.

Corresponding planning stages		Complementary stages for multi-stakeholder, integrated planning		Barriers
Recognition of the problem	Step 1	Recognition of the problem systematically		Need to understand biodiversity loss as a significant problem that affects nearly all sectors
				Confusion about the root drivers of biodiversity loss
				Reflexive small-scale and isolated thinking
Desire for action	Step 2	Commonly held desire for action		Lack of awareness about potential benefits of diverse stakeholder involvement
				Culture of competition between interests
				Disempowerment of long-term and environmental interests
Ability to implement solution	Step 3	Coordinated implementation		Misallocated resources
				Mistrust of shared ownership outcomes
				Discomfort with cooperation-building organizational methods
				Lack of interactive feedback mechanisms

Figure 3 - Common stages for integrated planning

Within several *European research projects* oriented on the ES assessment and their practical implementation, at least two have great implementation potential: **OpenNESS** and **ESMERALDA** (for more information and outputs, see section 3). ESMERALDA project is related to several previous projects on ES within the European Union and summarizes the state of knowledge. We focus on this project also because it has a relevant representation in the Carpathian countries (EU members) included in the Centralparks project. One of the outputs of the ESMERALDA project is available as an online guidance tool ESMERALDA MAES Explorer[2] and provides directions on the process of mapping and assessment of ecosystem services. It has seven topics (Questions and Themes - see Figure 4), from which three are oriented on the "scoping" phase, two on the "appraisal" phase and two on the "implementation" phase. Each topic is briefly described and provides useful information and guidance through the process of ES assessment.

Figure 4 - Main Questions and Themes of ESMERALDA MAES Explorer (Source: http://www.maes-explorer.eu/)

2. Ecosystem services assessment phases and steps

2.1 Ecosystem services assessment

The ES assessment process itself contains the **main phases and individual evaluation steps (Fig. 5)**. In the beginning, after clarifying the main purpose of the assessment, it is appropriate to implement the "**Scoping**" - a conceptual phase in which the individual steps and methods of evaluation are clarified. The main "**Appraisal**" phase follows, which is usually divided into several steps. The assessment process is completed by the "**Implementation**" phase, or at least by its initial step.

[2] http://www.maes-explorer.eu/

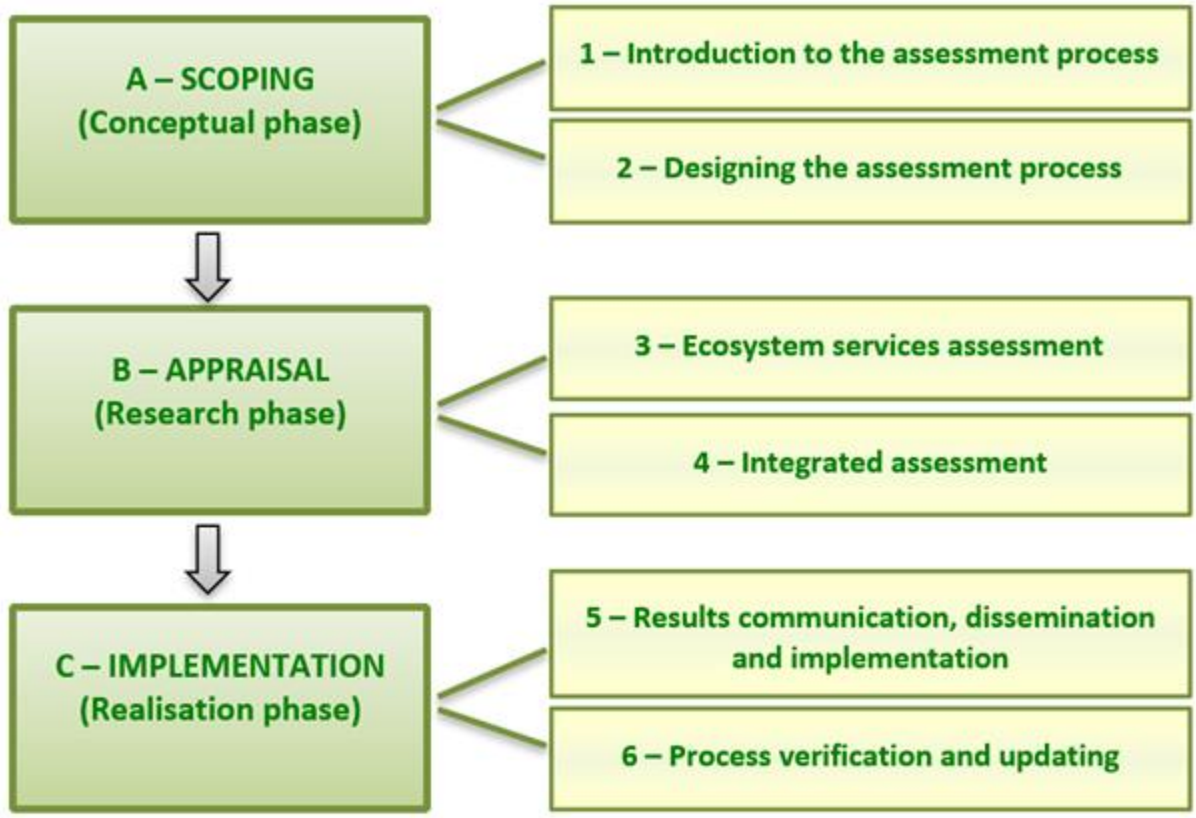

Figure 5 – ES assessment phases and steps

This procedure suggests that the "pure" scientific ES assessment is only part of the whole evaluation process (phase B). However, due to the applied nature of the ES concept, we emphasise that especially in the initial and final assessment phase (A, C) the participation of stakeholders operating in the concerned area is necessary. Without their involvement, ES assessment does not make practical sense. Such understanding is in accordance with e.g. the approach proposed by the US National Ecosystem Services Partnership (NESP 2016) or ICLEI ES toolkit (Pierce 2014). According to NESP, integrating ES consideration into the decision-making process requires changes through the decision process, particularly in the scoping and assessment phases - the full process requires stakeholder engagement. ICLEI, in turn, calls for multi-stakeholder integrated planning. Nevertheless, many examples of ES evaluation remain mainly based on expertise (phase B).

Figure 5 shows the main phases and steps of the proposed assessment process, which are described further in the following sub-chapter.

2.2 Brief description of the main phases and steps of ES assessment

In general, we recommend splitting the whole ES assessment process into three main phases. Each phase could consist of two main steps (topics), resulting in the outcome (written report or document) – see table 3. The whole proposed process of ES assessment is briefly described in the following text.

Table 3 – ES assessment phases and steps

Phase	Step	Milestone/Outcome
A - SCOPING (Conceptual phase)	*1 - Introduction to the assessment process*	*Introductory report (Terms of reference)*
	2 - Designing the assessment process	*Procedure and methodology of the ES assessment (Scoping document)*
B - APPRAISAL (Research phase)	*3 - Ecosystem services assessment*	*Ecosystem services assessment report*
	4 - Integrated assessment	*Integrated and/or context specific ES assessment report*
C - IMPLEMENTATION (Realisation phase)	*5 - Results communication, dissemination and implementation*	*Implementation plan*
	6 - Process verification and updating	*Monitoring & re-assessment report*

Stage A – SCOPING (Conceptual phase)

The main aim of this stage is to set up the whole process of ES assessment and tailor it for the given context and purpose. Usually, the core team of researchers and key stakeholders are involved in this assessment phase. First, it is appropriate to carry out an initial review, which will set the basic framework for the evaluation. This step should end with a "terms of reference" document. The next step is scoping and planning the whole process, in which it is necessary to specify as precisely as possible: inputs and outputs of the process, selection of ES for evaluation, identification of target groups, research methodology, research team, specification of other practicalities. A comprehensive "scoping" document should complete the whole initial phase.

Step 1 – Introduction to the assessment process

- Identifying the **purpose and needs** of the ES assessment: context (policy support, planning, resource management, impact assessment, funding and investments, human well-being, knowledge base…), requested outcomes (Implementation measures? Planning outcomes? Measurable indicators?); schedule (long-term and mid-term results, short-term tasks); financial resources (for both assessment and implementation) … and other essential issues (depending on the project specifics)
- Creating the overall **conceptual model** for ES assessment
- Setting up the core **research team** (key researchers – e.g. team leader, natural science coordinator, social science coordinator, GIS and modelling expert, planning expert…) and **stakeholder board** (primary users, affected subjects, contracting authority, concerned agencies…)
- Preparing the **terms of reference** – main aim and partial goals of the assessment, schedule, planned outcomes, milestones, human resources, control mechanisms…

Milestone & Outcome 1 – Introductory report (Terms of reference).

Step 2 – Designing the assessment process

- Choosing the **ecosystems and ecosystem services for assessment**: their definition, context and importance
- Defining the **target groups** of the assessment: ES providers, ES users - beneficiaries, other affected groups
- Identifying the **stakeholders** and their roles in the process; involving key stakeholders in the research team
- Elaborating the **methodology for ES assessment**: assessment framework (capacity, demand, flow, balance); methodology for individual ES appraisal (data, methods, assessment procedures); integrated assessment methods and procedure
- Designing and completing the **research team**, refining the schedule and resources needed for the assessment
- **Sharing the knowledge** between the researchers and stakeholders, awareness-raising in the ES issue.

Milestone & Outcome 2 – Procedure and methodology of the ES assessment (Scoping document).

Useful information sources for steps 1 and 2 (see also Section 3):

- Canadian ES Toolkit: Chapter 1: Foundations; Worksheets: W1 - Defining the issue and context; W2 - ES priority screening tool; W3 – Summarize screening / Confirm priority ES; W4 – Characterize the priority ES; W6 – Develop detailed ES assessment plan; W7 – Select relevant indicators to assess ES; W8 – Determine an approach to analysis methods and tools;
- MAES Explorer, Theme 1: What kind of questions do stakeholders have? Theme 2: Identification of relevant stakeholders; Theme 3: Network creation and involvement of stakeholders; Theme 4: Mapping and assessment process;
- ICLEI toolkit (Pierce 2014)
- NESP Guidebook and NESP toolkit
- ARIES methodology (Villa et al. 2014).

<u>**Stage B – APPRAISAL (Research phase)**</u>

- The most time- and knowledge-consuming phase of the assessment. It is appropriate to carry out several research cycles carried out by researchers and their verification realised at joint meetings of researchers and stakeholders. The first step is focused on the evaluation of individual ES and their main groups (the level of detail and research methods should be specified in the scoping document), followed by the presentation of results to stakeholders, and their refinement according to comments with the creation of a detailed assessment report. The second step is a synthesis ES appraisal (integrated assessment), which should already be tailored to the requirements and needs of the end-users. The main outputs should be presented in the form of key indicators of ES delivery. The main context-specific goals should be identified - for ES indicator values, pathways, and measures to achieve them within the specified timeframe. The integrated assessment report will be the input for the final stage of the assessment.

Step 3 – Ecosystem services assessment

- **Individual assessment** of ecosystems, selected ES and their groups:
  - ✓ ecosystem mapping, assessment the state of crucial ecosystems
  - ✓ using appropriate methods (biophysical, socio-cultural, economic)
  - ✓ targeting different problem areas (ES capacity, ES demand, ES flows…)
  - ✓ synthesising main ES groups (provisioning, regulating & maintenance, cultural).
- **Communicating the results** – review of results, getting the stakeholder attitudes and requirements, compiling the information for integrated assessment
- **Refinement of the results** – elaborating the final output from the first assessment phase.

Milestone & Outcome 3 –Ecosystem services assessment report

Step 4 – Integrated assessment

- Compiling the **requests and needs** for integrated and/or context-specific assessment – setting the process content and schedule based on assessment targets and needs (involvement of stakeholders)
- Elaborating the **integrated assessment** – e.g. balance between ES and their groups; ES hotspots (core areas) and coldspots (deficit areas), ecosystem disservices and their importance; monetary valuation (balance) of selected ES…
- Evaluating the selected key **socio-economic indicators of ES** – shifting from services to the benefit values (using monetary and non-monetary values)
- Elaborating the **context-specific outcomes** as a basis for the implementation process (policy support, planning, resource management, impact assessment, funding and investments, human well-being, knowledge base…).

Milestone & Outcome 4 – Integrated and/or context-specific ecosystem services assessment report

Useful information sources for steps 3 and 4 (see also Section 3):

- Canadian ES Toolkit: Chapter 2: Completing an ES assessment, Worksheets: W8 - Determine an approach to analysis methods and tools Worksheet, W9 - Synthesize analysis results;
- MAES Explorer: Theme 4 Mapping and assessment process, Theme 5 MAES case study applications;
- MESH ES modelling platform (USA);
- NEAT Toolkit (UK);
- NESP Guidebook; Overview of benefits assessment;
- OPPLA marketplace: Methods, Topics;
- LEED Toolkit: The Local Environment and Economic Development (Sunderland & Butterworth 2016);
- RESPA: The Rapid Ecosystem Services Participatory Appraisal (Rey-Valette et al. 2017);
- ARIES methodology (Villa et al. 2014);
- TESSA toolkit (Peh et al. 2013).

<u>**Stage C – IMPLEMENTATION (Realisation phase)**</u>

The final phase of the process is represented by the implementation. In most of the projects, however, it is already “beyond the scope” of the assessment; nevertheless, we consider it essential for the successful conclusion of the entire process.

The content and extent of this phase depend on the assessment objectives and the expectations of users and key stakeholders. First, the results achieved by the ES assessment need to be communicated and disseminated across stakeholders. The implementation of the results means the realisation of the conclusions. It can be achieved in various ways - e.g. planning process, changes in decision-making and political priorities, specific measures, and activities. For the process monitoring and feedback, it is appropriate to use particular indicators that help to verify the implementation and possible revision or restart of the assessment process. However, it must be acknowledged that this phase is rare - often the whole process ends with results communication and dissemination.

Step 5 – Results communication, dissemination and implementation

- **Communicating and disseminating** the final results – methods based on specific needs, stakeholder groups and local conditions. Emphasis: collaboration and mutual supporting effects of ES promotion for the whole community.
- Setting the context-specific **framework for the implementation process** (main tasks and actions based on stakeholders’ preferences, financing, schedule) – main issue for stakeholders, researchers as advisors

Milestone & Outcome 5 – Implementation plan

- **Implementation** of the actions and measures proposed by the final assessment and chosen for the realisation.

Step 6 – Process verification and updating

- **Monitoring and verification** of the implementation process (e.g. using indicators) – a collaboration between implementation agency and various stakeholder groups
- **Assessment the results**, periodical reporting & decision making

Milestone & Outcome 6 – Monitoring & re-assessment report

- **Feedback** – reassessing the process.

Useful information sources for steps 5 and 6 (see also Section 3):

- Canadian ES Toolkit, Chapter 3: Addressing ES in different policy and decision contexts.
- ICLEI toolkit (Pierce 2014).
- MAES Explorer: Theme 6: Dissemination and communication, Theme 7: Implementation.
- OPPLA marketplace: Implementation.
- Outcomes of the EU projects (OpenNESS, OPERAs, ESMERALDA).

3. Further reading - resources for the ES assessment process, methods and tools

Toolkits (methodical guidance):

- Preston & Raundsepp-Hearne (eds.) (2017). Canadian ES toolkit: https://biodivcanada.chm-cbd.net/documents/ecosystem-services-toolkit
- Olander et al. (2018). NESP toolkit: https://nicholasinstitute.duke.edu/project/ecosystem-services-toolkit-for-natural-resource-management
- NESP (2016). NESP guidebook: https://nespguidebook.com
- Pierce (2014). ICLEI toolkit: https://cbc.iclei.org/wp-content/uploads/2017/09/Mainstreaming-toolkit-1GA.pdfhttps://cbc.iclei.org/wp-content/uploads/2017/09/Mainstreaming-toolkit-1GA.pdf
- NCAL (2020). Latvian ES toolkit: https://ekosistemas.daba.gov.lv/public/eng/toolkit/
- NEAT (2014). National Ecosystem Approach Toolkit: http://neat.ecosystemsknowledge.net/ecosystem-services-tools.html

Websites (methods & data):

- ECOservice models library (US EPA) - Online ES modelling database: https://esml.epa.gov
- Ecosystem Knowledge Network (UK) – Environmental tools assessor: https://ecosystemsknowledge.net/tool
- IPBES Policy Support Gateway: https://ipbes.net/policy-support
- MESH - ES integrative modelling platform (WLE 2016): https://wle.cgiar.org/solutions/mapping-ecosystem-services-human-well-being-mesh
- OPPLA – European Union ES information repository: https://oppla.eu/
- USDA – ES assessment portal: https://www.oem.usda.gov/content/es-portal

OpenNESS project publications: http://www.openness-project.eu/library:

- Barton, Harrison (eds.) (2017); Braat et al. (2014); Gómez Baggethun et al. (2017)

ESMERALDA project publications: http://www.esmeralda-project.eu/documents/1/:

- Geneletti, Adem Esmail (2018); Geneletti, Adem Esmail et al. (2018); Haines-Young et al. (2018); Nikolova et al. (2018); Santos-Martín et al. (2018); Vihervaara et al. (2018)

EU projects case studies:

- ESMERALDA project: http://www.maes-explorer.eu/page/overview_of_esmeralda_case_studies
- OpenNESS project: http://www.openness-project.eu/cases
- OPERAs project: https://operas-project.eu/exemplars

Other publications:

- Burkhard, Maes (Eds.) (2017): https://doi.org/10.3897/ab.e12837
- Burkhard, Maes et al. (2018): https://doi.org/10.3897/oneeco.3.e29153
- Burkhard et al. (2018): https://doi.org/10.3897/oneeco.3.e22831
- Maes et al. (2018): https://doi.org/10.3897/oneeco.3.e25309
- Neugarten et al. (2018): https://doi.org/10.2305/IUCN.CH.2018.PAG.28.en.

4. Examples of step by step ES assessment for policy and decision making

Section 2. presents the “ideal” procedure for the ES assessment in 3 stages and 6 steps recommended for the conditions of the Carpathian countries. However, either an incomplete process or a process focused on specific objectives is used in practice. Therefore, it is not easy to find an example that would apply the proposed "Step by step" procedure in practice. ES experts are also aware of ES assessment procedures' inconsistency, calling for the need for evaluation studies to compare empirical examples in terms of **linking the ES assessment and decision-making process**. Such an approach includes case studies of European projects OpenNESS and ESMERALDA (some general features provide e.g. Dick et al. 2018; Dunford et al. 2018; Geneletti et al. 2020).

The study of Geneletti et al. (2020) entitled “Ecosystem services mapping and assessment for policy- and decision-making: Lessons learned from a comparative analysis of European case studies” presents a **comprehensive comparison of 14 ESMERALDA case studies** (see Table 4) focused on mapping and evaluating the ES in different decision-making contexts, in different types of ecosystems and several spatial scales. This study specifically describes and critically analyses the main steps of ES mapping and assessment. Based on this, it formulates recommendations for each step of the ES mapping and assessment process. The research uses the ESMERALDA MAES Explorer conceptual framework[3] (see section 2.), close to the Carpathian toolkit approach. It considers the key stages of the ES mapping and assessment process - the comparison of case studies goes through the identification of relevant questions from policy, society and business, stakeholder involvement, then follows the procedures of ES mapping and assessment, dissemination and communication of the results and finally, deals with the actual implementation in policy- and decision-making[4].

The following text provides an **overview of the procedures and methods used in ESMERALDA case studies**, following the proposed “step by step” assessment process. The information is based on the article by Geneletti et al. (2020) and case studies booklets[5].

[3] http://www.maes-explorer.eu/
[4] The full article is available at the link https://oneecosystem.pensoft.net/article/53111/
[5] http://www.maes-explorer.eu/page/overview_of_esmeralda_case_studies

Country	Case Study	Scale*	Area (Km²)
Belgium	Mapping green infrastructures and their ES in Antwerp	L	205
Bulgaria	Mapping and assessment of ES in Central Balkan area at multiple scales	L/SN	2,999
Czechia	Pilot National Assessment of ES	N	78,000
Finland	Green infrastructure and urban planning in the City of Järvenpää	L	40
Germany	Mapping ES dynamics in an agricultural landscape	L/SN	60
Hungary	ES mapping and assessment for developing pro-biodiversity businesses in the Bükk National Park	L	432
Italy	ES mapping and assessment for urban planning in Trento	L	156
Latvia	Mapping marine ES in Latvia	N	28,518
Malta	Assessing and mapping ES in the mosaic landscapes of the Maltese Islands	SN/N	316
Netherlands	ES-based coastal defense	L	810
Poland	ES in the biggest 10 Polish urban areas	L/SN	2-6,000
Portugal (Azores)	BALA - Biodiversity of Arthropods from the Laurisilva of Azores (Terceira island)	SN	400
Spain	Spanish National Ecosystem Assessment	N	505,990
Sweden	ES mapping and assessment in the Vindelälven-Juhtatdahka river valley	SN	13,300

Table 4 - ESMERALDA case studies of ecosystem services mapping and assessment to support policy- and decision-making (Source: Geneletti et al. 2020)

Step 1 – Introduction to the assessment process

- Identifying the purpose and needs of ES assessment: context, requested outcomes

All ESMERALDA case studies provide support for the stakeholders in terms of **planning and decision making** (design and assessment of alternative planning actions in the urban, rural and natural areas while ensuring that impacts on ES are included and their equal provision for all citizens is provided) – roughly half of the studies are direct **policy-orientated**, the rest is more **science-orientated**.

Within case studies, **9 policy areas are addressed** representing the variety of policy and planning processes, e.g. nature conservation and protected area planning; land use, green infrastructure and spatial planning; water resource protection and management; climate adaptation and energy policy; agriculture and forestry management; natural risk issues; business, industry and health issues.

For most of the case studies, the context of **multi-functionality** is typical, as they addressed more than one key research question – about half of cases combined nature conservation and green infrastructure planning. Figure 6 provides the context of the studies as an overview of addressed policy domains.

Case Study	EU-relevant Policy Domains								
	Nature Conservation	Climate, Water, Energy	Marine and Maritime Policy	Natural Risks	Urban and Spatial Planning	Green Infrastructure	Agriculture and Forestry	Business, Industry and Tourism	Health
Belgium		X		X	X	X			
Bulgaria	X			X	X	X	X	X	
Czechia	X			X					
Finland	X				X	X			X
Germany		X					X		
Hungary	X						X	X	
Italy		X			X	X			X
Latvia	X	X	X		X			X	
Malta						X	X		
Netherlands	X	X		X		X	X	X	
Poland	X	X		X	X	X	X	X	
Portugal (Azores)	X					X	X		
Spain	X								
Sweden	X				X	X	X	X	

Figure 6 - An overview of the policy domains (themes) addressed in the selected case studies (Source: Geneletti et al. 2020)

- <u>Schedule & financial resources of ES assessment</u>

Schedule and financing of the projects are **case-specific**. Regarding ESMERALDA case studies, most of them were realized earlier and financed by other European, national and local funding resources. It is also not realistic to find out the recommended schedule for the ES assessment process – it is based on the project's expectations and initial assignment. But generally, such a process takes at least one year.

- <u>Creating the overall conceptual model for ES assessment</u>

In most cases, no such model is explicitly stated. Generally, the well-known **ES Cascade model** is accepted as a theoretical background for problem framing. There is also an agreement on three **basic groups of research methods** used for the assessment process (biophysical, socio-cultural and economic) and on the **basic classification of ES** (3-4 main groups). The research model itself depends on the objectives and needs of the assessment.

- <u>Setting up the core research team</u>

Most research teams are led by **natural scientists**, supplemented by **social science experts**. Representation of ecologists and biologists is essential; geographers, environmentalists, and spatial planning experts are also team members in most cases. The share of **economists** is low, which results from the limited use of economic evaluation methods. Ideally, the **experts from different scientific fields** should be represented within the core research team.

- <u>Preparing the terms of reference</u>

No specific information is available on this point from the case studies. Such a step should be part of each project's setup, although it may not be in writing.

Step 2 – Designing the assessment process

- <u>Choosing the ecosystems and ecosystem services for assessment</u>

This step is usually case-specific - based on the research topic, local conditions and main ecosystem types covering the areas. Within ESMERALDA cases, 11 broad **ecosystem types** are distinguished overall. In some cases, assessing the **ecosystem state/condition** and identifying the ecosystems with critical ES shortages is realised (grasslands, forests and woodland were present in 11 cases). Half of the studies cover most types of ecosystems (see Figure 7). On the other hand, the Italian case addresses only urban ecosystems and the Latvian study covers marine and coastal ecosystems.

The **selection of ES**, setting their **importance** and research context, was mainly scientist-driven (based on experts' opinion) - the stakeholders were actively involved in only 6 cases. Different ES classification systems are used, mostly CICES v. 4.3 (2013) and Millennium Assessment division (MEA 2005). The context-specific selection of ES usually covers **three main ES groups** – provisioning (9 studies), regulating (10 studies) and cultural (11 studies).

	Ecosystem type*											Ecosystem Conditions	Selection of ES		
Case Study	a	b	c	d	r	f	g	h	i	j	k	Assessed	Scientist-driven	Stakeholders-driven	Classification**
Belgium	X		X	X			X					Yes	X	X	CICES 4.3
Bulgaria	X	X	X	X	X	X		X				Yes	X		CICES 4.3
Czechia	X	X	X	X	X	X	X	X				No	X		MA (2005)
Finland	X	X	X	X		X		X				Yes (indirectly)	X	X	CICES 4.3
Germany		X	X	X				X				Yes	X		"KIEL"
Hungary	X	X	X	X	X		X					Yes	X	X	CICES V5.1
Italy	X											Yes (indirectly)	X	X	
Latvia									X	X	X	Yes	X		CICES 4.3
Malta	X	X	X	X	X	X	X			X		Yes (indirectly)	X		CICES 4.3
Netherlands		X					X	X	X	X		No	X	X	MA (2005)
Poland	X	X	X	X		X	X	X				Yes	X		CICES 4.3
Portugal (Azores)		X	X	X	X	X						Yes	X		CICES 4.3
Spain	X	X	X	X	X	X	X	X	X	X		Yes	X		MA (2005)
Sweden			X	X	X	X	X	X	X	X		Yes	X	X	CICES 4.3

*** ECOSYSTEM TYPES**: a. Urban; b. Cropland; c. Grassland; d. Woodland & forest; e. Heathland and shrub; f. Sparsely-vegetated land; g. Wetlands; h. Rivers and lakes; i. Marine inlets and transitional waters; j. Coastal; k. Shelf. ****ES CLASSIFICATION**: CICES 4.3 and 5.1. Common International Classification of ES (version 4.3 and 5.1); MA. Millennium Ecosystem Assessment; KIEL. Kiel own classification of ES.

Figure 7 - An overview of ecosystems condition assessment and ES selection (Source: Geneletti et al. 2020)

- <u>**Defining the target groups of the assessment**</u>

Within the ESMERALDA case studies, setting the assessment target groups was influenced mainly by the study's **political domain** (see Figure 6). That means the **principal audience** could be characterized as local and regional administration officers, planning agencies, landscape and land-use managers.

Both **ES providers and users** were addressed as a target group of the assessment process mainly indirectly. The representatives of agriculture, forestry, water management and nature protection belong mainly to the common providers. Some of the case studies also addressed the ES provision **beneficiaries** - mostly inhabitants living in case study areas (representing the general public) and visitors (involved through questionnaires and online tools).

- <u>**Identifying the stakeholders and their roles in the process**</u>

Representatives of **four basic categories of stakeholders** are involved within ESMERALDA case studies: (1) **competent authorities** for the specific policy area (e.g. decision-makers at different levels and people working for governmental agencies), (2) **ES experts and specialists** (other than those from research teams), (3) **business sector** (concerned people from different sectors – e.g. agriculture, forestry, industry) and (4) **general public** (represented often by people from environmental NGOs). Stakeholders from authorities and experts are involved mostly in all studies, business and public are represented in five cases. Only three studies have successfully involved all categories of stakeholders (see Figure 8).

The **level of stakeholder involvement** in the case studies elaboration is different. The lowest involvement levels representing the stakeholders' information and mutual consultations were successful in most cases. Direct involvement and collaboration within the project are successful in nine cases. Only one study (Latvian) reports the stakeholders' full involvement, including their real empowerment within the decision-making process.

	Involved stakeholders				Level of involvement				
Case Study	Competent authorities	Other experts	Business sector	General Public	Inform	Consult	Involve	Collaborate	Empower
Belgium	X	X					X	X	
Bulgaria	X	X			X	X	X	X	
Czechia	X				X			X	
Finland	X	X		X	X	X	X	X	
Germany	X			X	X				
Hungary	X	X	X	X	X	X	X	X	
Italy	X	X			X	X	X	X	
Latvia	X	X	X	X	X	X	X	X	X
Malta	X	X			X	X			
Netherlands	X	X	X		X	X	X	X	
Poland	X				X	X			
Portugal (Azores)	X	X	X		X	X		X	
Spain	X	X	X	X	X	X	X		
Sweden	X	X			X	X	X		

Figure 8 - An overview of the stakeholders and their involvement in the case studies (Source: Geneletti et al. 2020)

- **Elaborating the methodology for ES assessment**

No specific information is available about the elaboration of an assessment methodology within the ESMERALDA case studies – in all cases is this process depending on the **scientific background and composition of the research team**. Table 5 gives an overview of the used methods in all case studies - as a whole, 29 mapping and assessment methods were used. All cases apply biophysical methods; 5 cases use socio-cultural methods; only Czech and Spanish cases apply economic methods for the assessment of the crucial ES. **Diverse approaches and methods** are used at various spatial levels and contexts. In most cases, the methods are combined for obtaining partial and also final results. For such purposes are used, e.g. normalisation to a common qualitative scale (Bulgaria), multi-criteria analysis (Finland, Italy, Latvia), or interactive web-tool (Belgium).

Case Study	ES	CICES CLASS	APPLIED METHOD*	TYPE
Belgium	Filtration/sequestration/storage/accumulation by ecosystems	(2.1.2.1)	Spatial proxy method (expert scoring)	Biophysical
	Physical use of land- /seascapes in different environmental settings	(3.1.1.2)	Spatial proxy method (expert scoring)	Biophysical
Bulgaria	Surface water for drinking	(1.1.2.1)	Process-based models (swat)	Biophysical
	Aesthetics	(3.1.2.5)	Photo elicitation surveys	Social
Czechia	Surface water for drinking	(1.1.2.1)	Value (benefit) transfer	Economical
	Global climate regulation by reduction of greenhouse gas concentrations	(2.3.5.1)	Integrated modeling frameworks (invest)	Biophysical
	Entertainment	(3.1.2.4)	Integrated modeling frameworks (estimap)	Biophysical
Finland	Educational	(3.1.2.2)	Participatory GIS	Social
	Multiple ES	*Multiple ES*	Integrated modelling framework (spatial multi-criteria decision analysis)	Biophysical
Germany	Plant-based (energy) resources	(1.3.1.1)	Spatial proxy methods	Biophysical
	Buffering and attenuation of mass flows	(2.2.1.2)	Integrated modeling frameworks (Giscame)	Biophysical
	Educational	(3.1.2.2)	Narrative assessment	Social
Hungary	Animals reared to provide nutrition, fibres and other materials	(1.1.1.2, 1.2.1.2)	Spatial proxy methods (rule-based matrix model)	Biophysical
	Touristic attractiveness of nature	(3.1.1.1, 3.1.1.2)	Spatial proxy methods (rule-based matrix model)	Biophysical
Italy	Micro and regional climate regulation	(2.3.5.2)	Process-based models	Biophysical
	Physical use of land- /seascapes in different environmental settings	(3.1.1.2)	Integrated modeling frameworks (ESTIMAP recreation model)	Biophysical
Latvia	Wild plants, algae and their outputs	(1.1.1.3)	Spatial proxy methods	Biophysical
	Maintaining nursery populations and habitats	(2.3.1.2)	Spatial proxy methods (spreadsheet method)	Biophysical
	Experiential interactions + Physical use of landscapes /seascapes in different environmental settings	(3.1.1.1+3.1.1.2)	Integrated modeling frameworks (Multi-criteria ES assessment model)	Biophysical
Malta	Reared animals and their outputs	(1.1.1.2)	Preference assessment	Social
	Pollination and seed dispersal	(2.3.1.1)	Spatial proxy methods + field data	Biophysical
Poland	Filtration/sequestration/ storage/accumulation by ecosystems	(2.1.2.1)	Spatial proxy methods	Biophysical
	Physical use of land / seascapes in different environmental settings	(3.1.1.2)	Spatial proxy methods	Biophysical
Portugal (Azores)	Pollination and seed dispersal	(2.3.1.1)	Macro-ecological models	Biophysical
	Maintaining nursery populations and habitats	(2.3.1.2)	Macro-ecological models	Biophysical
Spain	Cultivated crop	(1.1.1.1)	Market price methods	Economical
	Surface water for drinking	(1.1.2.1)	Integrated modeling frameworks (invest)	Biophysical
Sweden	Reared animals and their outputs	(1.1.1.2)	Participatory GIS	Social
	Experiential (physical) use of plants, animals and landscapes	(3.1.1.1 & 3.1.1.2)	Integrated modelling framework (integrated monitoring data gam-modelling framework)	Biophysical

Table 5 - An overview of selected ES analysed in the case studies and related methods (Source: Geneletti et al. 2020)

- <u>Designing and completing the research team, refining the schedule and resources</u>
- <u>Sharing the knowledge between the researchers and stakeholders</u>

No related information is available from the case studies assessment. However, these steps are the **natural completion of the first stage** of most projects.

Step 3 – Ecosystem services assessment

- <u>Individual assessment of ecosystems, selected ES and their groups</u>

During the ESMERALDA project, all case studies were evaluated and compared regarding the used methods and results. As specified in step 2, a whole range of methods are used for the individual ES assessment and the results' expression (for more information, see the case studies booklets). Nevertheless, it is possible to specify some commonalities.

All cases highlight the crucial importance of ecosystems, their properties and state for ES provision. For such purpose, most cases use **indicators on ecosystem conditions**, relevant for different ecosystem types in the study area. The selection of indicators and assessment methods depends mainly on the data availability and expertise of researchers. On the other hand, it was considered useful to involve stakeholders and use local knowledge at this research stage.

The ES assessment process was based on the above-mentioned research scope and methods used in case studies. Most of the methods are scientifically based, with a specific demand for expertise and time. This is a real playground for the researchers. As seen in Table 5, the most used are **biophysical methods**; the share of **socio-cultural methods** with direct or indirect inputs of stakeholders and/or concerned citizens is relatively low. The representation of **economic methods** and experts is even rarer, which points to the complexity of incorporating this issue into the ES concept. The market price and benefit transfer method were the only used in the case studies.

In terms of ES provision, most of the studies use the concept of **ES capacity and/or real flow**. Capacity is expressed mostly in the qualitative scale (e.g. from low to high, from 0 to 5), in the biophysical units (resource stock, polluting substance absorption level etc.) or in the financial value of the service. Real flow is usually connected to the statistical data about the real extraction of the resources or specific service use. The problem of **demand for ES** is omitted in most studies – it needs stakeholders' input (as, e.g. in Italian or Latvian study).

After assessing individual ES, there is usually a need for the **comprehensive assessment or synthesis** of ES bundles, groups or the whole ES spectrum. This problem turns out to be very complex due to **synergies or trade-offs** between most of ES. It could be relatively easy to present the synthesis within the ES economic valuation (as in the case of the Czech Republic) by summing individual ES values. However, this is only a theoretical value, which does not address trade-offs, as some ES are mutually exclusive. Therefore, most of the case studies remained at the individual ES assessment level, or their bundles evaluated for specific purposes and policies. However, in the background of some cases is a national ES assessment, which is more extensive than the case study presented (e.g. Spain, Malta) and which should also provide a synthesis.

- **Communicating the results**

Generally, the ES assessment should be understood and accepted not only by researchers but also by involved stakeholders. Therefore, the presentation of the results and their shared understanding is essential.

As only preliminary results could be presented at this stage of the research, it is usually done during **project meetings and workshops**. The main goal of such events is obtaining the **attitudes of concerned stakeholders** about the results and gathering their requirements for integrated ES assessment.

Step 4 – Integrated assessment

- **Compiling the requests and needs for integrated and/or context-specific assessment**
- **Elaborating the integrated assessment**

The original **"Integrated Ecosystem Service Assessment Framework"** was developed within the ESMERALDA project (Nikolova et al. 2018) and used to compare the case studies. The studies have confirmed the importance of integrating methods and results for the real use of the ES approach when integrating different perspectives (nature, society, economy). With such integration, the value and credibility of the results are also rising. The reason for the integration (besides the policy relevance) is the need to analyse trade-offs, synergies, and interactions amongst the different ES.

More than half of ESMERALDA case studies (8 from 14) use **integrated modelling framework methods** – mainly with the biophysical background and the inputs of social and economic methods. The most used are spreadsheet method (relatively simple spatial matrix), Multi-Criteria Analysis and spatial modelling approaches.

- <u>Evaluating the selected key socio-economic indicators of ES</u>
- <u>Elaborating the context-specific outcomes as a basis for the implementation process</u>

This step is **beyond the ES evaluation process** in most cases - the potential of such measures is not yet fully recognised and used.

Key indicators are mainly used in the case of **direct application of results** for specific purposes of planning and practice. It was the case of the Finnish, Italian and Lithuanian studies, which directly entered the planning documents - urban spatial plans and maritime spatial plans respectively. Mostly, the non-monetary values are used for expressing the key indicators for the ES implementation.

Step 5 – Results communication, dissemination and implementation

- <u>Communicating and disseminating the final results</u>

ESMERALDA case studies overall use three main types of dissemination and communication of the results. For the research results, the basic way is the publication of **scientific articles/reports** or communication at **conferences** or similar events. Such methods were used for most studies (11 from 14). Addressing the relevant **competent authorities** (decision-makers, people working in agencies) is the second way (e.g. through policy briefs, reports and meetings) – it was realized in all cases (excluding Germany). Thirdly, in about half of the studies, the **general public** was addressed (through newspaper articles, social media and documentaries).

Figure 9 provides an overview of the dissemination and communication of the case studies results.

Case Studies	Dissemination and communication activities		
	Scientific publication	D&C to competent authorities	D&C to general public
Belgium		X	X
Bulgaria	X	X	
Czechia	X	X	
Finland	X	X	X
Germany	X		
Hungary		X	X
Italy	X	X	
Latvia	X	X	
Malta	X	X	X
Netherlands	X	X	
Poland	X	X	(Partially yes)
Portugal (Azores)	X	X	
Spain	X	X	X
Sweden		X	(Partially yes)

Fig. 9 - An overview of the Dissemination and communication activities in ESMERALDA case studies (Source: Geneletti et al. 2020)

- <u>Setting the context-specific framework for the implementation process</u>
- <u>Implementation of the actions and measures</u>

An appropriate **five-degree framework for expressing the degree of implementing the results** presents Ruckelshaus et al. (2015) - this framework is also used for ESMERALDA case studies comparison. The scale expresses the raising impact and implementation level (see Figure 10).

Some of the ESMERALDA case studies represent **good ES implementation examples** in different policy- and decision-making contexts. The highest level is reached by urban planning cases – only Belgian study of green infrastructure planning in the city of Antwerp reported a complete 5-stage implementation level. A high implementation level is also reached within the Italian case (ES mapping and assessment for urban planning in Trento), and the Finnish case (ES as a part of urban and green infrastructure planning in the city of Järvenpää). The Latvian case study involving ES mapping and assessment as a part of the official national maritime planning process is also close to the practice implementation. In the Hungarian case, ES approach is used for participatory local action planning at the local level.

On the other hand, some studies also reported **barriers for implementation** – e.g. lack of data and research-based evidence, land ownership as a critical barrier, or poor understanding of the administrative procedures by the researchers.

7	Increasing Level of Impact				
Case Studies	(i) People aware of, understand and discuss ES	(ii) Stakeholders focus on ES and articulate different positions	(iii) Alternative choices based on ES mapping and assessment	(iv) Plans & policies consider ES mapping and assessment	(v) New policy and finance mechanism established
Belgium	X	X	X	X	X
Bulgaria		X	X		X
Czechia				X	
Finland	X	X	X	X	
Germany					
Hungary	X	X	X		
Italy	X	X	X	X	
Latvia			X	X	
Malta	X	X			
Netherlands					
Poland				X	
Portugal (Azores)		X		X	
Spain			X	X	
Sweden			X	X	

Fig. 10 - An overview of the impact on policies and decisions of the ES mapping and assessment process in the case studies (Source: Geneletti et al. 2020)

Step 6 – Process verification and updating

- <u>Monitoring and verification of the implementation process</u>
- <u>Assessment the results, periodical reporting & decision making</u>

As stated in section 2, **this step is rare** within the ES assessment procedure. Also, ESMERALDA case studies did not have such a topic elaborated. Most of them reached the communication and dissemination of the results, in some cases the implementation process also began (mostly as a part of planning documents).

Nevertheless, we consider monitoring, verification the implementation process and (in case of necessity) also updating the results and proposed measures as **essential for the successful and complete implementation** of the ES approach in practice.

5. Conclusions

The Step-by-step guide on using the Carpathian Ecosystem Services Toolkit (CEST) was presented to relevant stakeholders during workshops in target regions (Czech Republic, Hungary, Slovakia) as the Centralparks project output O.T3.2 and was reviewed by two independent reviewers. As integral part of the CEST (included as Chapter 2) is now translated in 4 Carpathian / Central European languages (Czech, Hungarian, Polish, Slovak) and will be available online as well as in printed version and can be used by project partners and other stakeholders, interested institutions and experts. It can be also replicated in other Central European / EU regions. Users of the guide and the toolkit are encouraged to correspond with the lead authors to provide feedback on their experience.

An initial overview of the provided ecosystem services in the whole Carpathians as a basis for further work using a consistent methodological approach for the identification and evaluation of ESs on the Carpathian level is added to this guide as **Appendix I**. We recommend to continue in this work through a specific project with a comprehensive team of experts from all Carpathian countries and thus promote and highlight the importance of the Carpathian region in terms of the ecological functions of ecosystems.

References

Barton, D.N. & P.A. Harrison (eds.) (2017). Integrated valuation of ecosystem services. Guidelines and experiences. EU FP7 OpenNESS Project Deliverable 33-44, European Commission FP7.

Braat, L. C., E. Gómez-Baggethun, B. Martín-López, D. N. Barton, M. García-Llorente, E. Kelemen & Saarikoski, H. (2014). Framework for integration of valuation methods to assess ecosystem service policies. EU FP7 OpenNESS Project Deliverable 4.2., European Commission FP7.

Burkhard, B. & Maes, J. (eds.) (2017). Mapping Ecosystem Services. Sofia: Pensoft Publishers, 374 pp.

Burkhard, B., Maes, J. et al. (2018). Mapping and assessing ecosystem services in the EU - Lessons learned from the ESMERALDA approach of integration. One Ecosystem 3: e29153.

Burkhard, B., Santos-Martin, F., Nedkov, S. & Maes, J. (2018). An operational framework for integrated Mapping and Assessment of Ecosystems and their Services (MAES). One Ecosystem 3: e22831.

Dick, J., Turkelboom, F., Woods, H., Iniesta-Arandia, I., Primmer, E., Saarela, S.R., Bezák, P., Mederly, P., Leone, M., Verheyden, W., ..., Zulian, G. (2018). Stakeholders' perspectives on the operationalisation of the ecosystem service concept: Results from 27 case studies. Ecosystem Services 29: 552-565.

Dunford, R., Harrison, P., Smith, A., Dick, J., Barton, D.N., Martin-Lopez, B., Kelemen, E., Jacobs, S., Saarikoski, H., Turkelboom, F., Verheyden, W., Hauck, J., ..., Pelkonen, V.Y. (2018). Integrating methods for ecosystem service assessment: Experiences from real world situations. Ecosystem Services 29: 499-514.

Geneletti, D., Adem Esmail, B. (2018). Guidelines and recommendations to support the application of the final methods. Deliverable D5.4, EU Horizon 2020 ESMERALDA Project.

Geneletti, D., Adem Esmail, B. et al. (2018). Report illustrating the application of the final methods in policy and decision-making. Deliverable D5.3, EU Horizon 2020 ESMERALDA Project.

Geneletti, D., Adem Esmail, B., Cortinovic, C., Arany, I., Balzan, M., van Beukering, P., Bicking, S., Borges, P. A., Borisova, B., Broekx, S., Burkhard, B., Gil, A., Inghe, O., Kopperoinen, L., Kruse, M., Liekens, I., Lowicki, D., Mizgajski, A., Mulder, S., Nedkov, S., Ostergard, H., Picanco, A., Ruskule A., Santos-Martín, F., Sieber, I.M., Svensson, J., Vačkář, D. & Veidemane, K. (2020). Ecosystem services mapping and assessment for policy- and decision-making: Lessons learned from a comparative analysis of European case studies. One Ecosystem 5: e53111. https://doi.org/10.3897/oneeco.5.e53111

Gómez-Baggethun, E., Martín-López, B., Barton, D., Braat, L., Kelemen, E., Garcia Llorente, M., Saarikoski, H., Bergh, J., Arias-Arévalo, P., Berry, P., Potschin, M., Dunford, R., Keene, H., Schröter-Schlaack, Ch. & Harrison, P. (2014). State-of-the-art report on integrated valuation of ecosystem services. EU FP7 OpenNESS Project Deliverable 4.1., European Commission FP7.

Haines-Young, R., Potschin-Young, M. & Czúcz, B. (2018). Report on the use of CICES to identify and characterise the biophysical, social and monetary dimensions of ES assessments. Deliverable D4.2, EU Horizon 2020 ESMERALDA Project, 106 pp.

Maes, J., Liekens, I. & Brown, C. (2018). Which questions drive the Mapping and Assessment of Ecosystems and their Services under Action 5 of the EU Biodiversity Strategy? One Ecosystem 3: e25309.

MEA (Millennium Ecosystem Assessment) (2005). Ecosystems and human well-being: wetlands and water. Synthesis. World Resources Institute, Washington, DC.

NCAL (2020). LIFE ecosystem services project toolkit (Latvia). Nature Conservancy Agency of Latvia online toolkit. Online: https://ekosistemas.daba.gov.lv/public/eng/toolkit/

NEAT (2014). National Ecosystem Approach toolkit – Ecosystem services tools. Birmingham University, UK. Online: http://neat.ecosystemsknowledge.net/ecosystem-services-tools.html

NESP (National Ecosystem Services Partnership) (2016). The Federal Resource Management and Ecosystem Services Guidebook. Online: https://nespguidebook.com.

Neugarten, R.A., Langhammer, P.F., Osipova, E., Bagstad, K.J., Bhagabati, N., Butchart, S.H.M., Dudley, N., Elliott, V., Gerber, L.R., Gutierrez Arrellano, C., Ivanić, K.-Z., Kettunen, M., Mandle, L., Merriman, J.C., Mulligan, M., Peh, K.S.-H., Raudsepp-Hearne, C., Semmens, D.J., Stolton, S. & Willcock, S. (2018). Tools for measuring, modelling, and valuing ecosystem services: Guidance for Key Biodiversity Areas, natural World Heritage Sites, and protected areas. Gland, Switzerland: IUCN. x + 70pp.

Nikolova, M., Nedkov, S., Arany, I., Aszalós, R., Kovács-Hostyánszki, A., Czúcz, B., Marta-Pedroso, C., Adamescu, C.M., Cazacu, C., Brown, C., Burns, A., Arnell A., Stępniewska, M., Łowicki, D., Lupa, P., Mizgajski, A., Roche, P., Campagne, C.S., Balzan, M., Haines-Young, R., Potschin-Young, M. & Potschin-Young, M. (2018). Report on Multifunctional assessment methods and the role of map analyse - Using an Integrated Ecosystem Service Assessment Framework: Deliverable D4.8, EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007, 186 pp.

Olander, L., Mason, S., Warnell, K. & Tallis, H. (2018). Building Ecosystem Services Conceptual Models. National Ecosystem Services Partnership Conceptual Model Series No. 1. Durham, NC: Duke University, Nicholas Institute for Environmental Policy Solutions.

Pierce, R. J. (2014). Local Integrated Planning Toolkit for Biodiversity and Ecosystem services. A Report for ICLEI Cities Biodiversity Center. ICLEI Africa Secretariat, 92 pp.

Potschin, M. & Haines-Young, R. (2011). Ecosystem services. Progress in Physical Geography 35 (5): 575-594.

Preston, S. M. & Raundsepp-Hearne, C. (eds.) (2017). Ecosystem Service Toolkit: Completing and Using Ecosystem Service Assessment for Decision-Making: An Interdisciplinary Toolkit for Managers and Analysts. Federal, Provincial, and Territorial Governments of Canada, Ottawa. Ottawa: Environment and Climate Change Canada Enquiry Centre, 276 pp. ISBN: 978-0-660-07074-2.

Rounsevell, M.D.A., Dawson, T.P. & Harrison, P.A. (2010). A conceptual framework to assess the effects of environmental change on ecosystem services. Biodivers Conserv 19: 2823–2842. https://doi.org/10.1007/s10531-010-9838-5

Ruckelshaus, M., McKenzie, E., Tallis, H., Guerry, A., Daily, G., Kareiva, P., Polasky, S., Ricketts, T., Bhagabati, N., Wood, S.A. & Bernhardt, J. (2015). Notes from the field: Lessons learned from using ecosystem service approaches to inform real-world decisions. Ecological Economics 115: 11-21.

Santos-Martín, F. et al. (2018). Guidance report on a multi-tiered flexible methodology for integrating social, economic and biophysical methods. Deliverable D3.4. EU Horizon 2020 ESMERALDA Project.

Vihervaara, P., Mononen, L., Nedkov S., Viinikka, A., Adamescu, C., Arnell, A., Balzan, M., Bicking, S., Broekx, S., Burkhard, B., Cazacu, C., Czúcz, B., Geneletti, D., Grêt-Regamey, A., Harmáčková, Z., Karvinen, V., Kruse, M., Liekens, I., Ling, M. & Zulian, G. (2018). Biophysical mapping and assessment methods for ecosystem services. ESMERALDA Deliverable D3.3.

WLE (2016). Mapping Ecosystem Services to Human well-being (MESH): ES integrative modelling platform. Research Programme on Water, Land and Ecosystems. https://wle.cgiar.org/solutions/mapping-ecosystem-services-human-well-being-mesh

Appendix I

Ecosystem services in the Carpathians

1. Introduction

From a Pan-European perspective, the Carpathians represent a unique region with a significant area of forest habitats, with a high representation of natural forests and in many places still with an original natural wood composition. They form a so-called bridge between Europe's northern and southern forests and are an extremely important corridor for the spread/migration of plants and animals throughout Europe. Dense river network, amount of glacial lakes in mountainous areas, but also double the annual precipitation totals compared to the surrounding areas, together with preserved forest residues, support the appearance of a wide range of species of invertebrates, fish, mammals, plants, and microorganisms, including a large number of endemics (invertebrates - multiple gastropods, insects, multi-bed, spiders; fish, mammals such as *Rupicapra rupicapra tatrica, Microtus tatricus, Triturus montandoni*; 486 plant species, etc.). Through their ecosystems, the Carpathians are an important water supply reservoir.

Although later than in the western countries of Europe, also in the Carpathians, the effects of globalization and the transition of the traditional economy to the market economy, have already begun. Ecosystems are fragmented due to the intensification of interventions in forests, agriculture, urbanization, or increased tourism in certain territories. Traditional management is receding at the expense of new, more modern practices, with which the traditional ecological knowledge of local farmers is also disappearing. Through the Assessment of Ecosystem Services (ESs), the significance and irreplaceable position of the Carpathians within Europe can be better understood and presented, expressed in their ecological, cultural, and economic value, or their important role in mitigating the impacts of climate change.

Some of the Carpathian countries processed their national ESs assessments, e. g. the Czech Republic - Frélichová et al. (2014), Vačkář et al. (2018); Slovakia - Mederly & Černecký et al. (2020), Černecký at al. (2020a); Romania - NEPA (2017); Poland. Other Carpathian countries are in the process of preparing national ESs assessments or these are not published in English. Each country is using different input data, different methods for identifying ESs, different ESs indicators and the results presented vary so much that it is difficult to compare them with each other. Important contribution to the use of assessment of ESs in the Carpathian countries represent the Carpathian Ecosystem Services Toolkit (CEST) and related Step-by-step guide on using the CEST developed within the Centralparks project. The additional Carpathian study presented here shall use a consistent methodological approach for the identification and evaluation of ecosystem services of the Carpathians, the results of the work complement the lack of support of the existing country database for ESs identification and evaluation, support the MAES process or meet the objectives of the EU Biodiversity Strategy for 2030. The results of this work can also highlight and promote the importance of the Carpathians in terms of the ecological functions of their ecosystems and which will play an important role in mitigating the impacts of climate change. The established database also provides a framework for national recovery plans and supports the cooperation of the Carpathian countries.

Biophysical evaluation of ESs - matrix

The evaluation of ESs by matrix (Burkhard et al. 2014) is a flexible method for expressing ESs, which can be applied in different spatial scales, for all ESs, for different multidisciplinary quantification approaches of ESs, and different mapping purposes.

Burkhard et al. (2017) describe the basic steps of the ESs matrix application. The first half of the steps are closely linked to the objective/purpose of the mapping and the available capacities (data, methodologies, period, work effort): 1. Selection of the area of interest; 2. Selection of relevant geo-biophysical spatial units; 3. Collection of appropriate spatial data (e.g. LULC landscape/land use data, habitat map, soil map, hydrological map); 4. Selection of relevant ESs (columns of the assessment matrix); 5. Definition of appropriate indicators for ESs quantification; 6. Quantification of ESs indicators (using different methods). Steps 7 - 9 are specific to the ESs matrix, but also other approaches to ESs mapping: 7. Normalization of ESs values to a relative scale of 0-5; 8. Interconnection of geospatial units and ESs values in the ESs matrix; 9. Link the order of ESs 0 - 5 with geospatial units to create ESs maps. The last step (10th) concerns communication between the creator of maps and users of maps and ESs applications for different purposes. The matrix approach to ESs assessment is based on the normalization of ESs values to a relative scale between 0 and 5 (Figure I.1), in which 0 can be defined as 'no relevant supply or demand for ESs'. 0 does not necessarily mean absolute zero (0,000...) but may reflect the fact that ecosystems consistently provide some ESs, but this provision is not perceived as relevant to human well-being.

Potential is assessed as an optimal (idealized) variant of the provision of ESs under ideal conditions and assuming that all ecosystems are in a favourable condition and provide the ESs with full quality. The ESs potential matrix reflects the human impact on ecosystems, where ecosystem types affected by humans have lower potential values (except for some cultural ESs available in urban areas) compared to e.g. forest ecosystems (coniferous, mixed, and deciduous), peatlands, heathland, or aquatic habitats. The agricultural types of ecosystems have a high potential for the provision of food-related ESs (Burkhard et al. 2014).

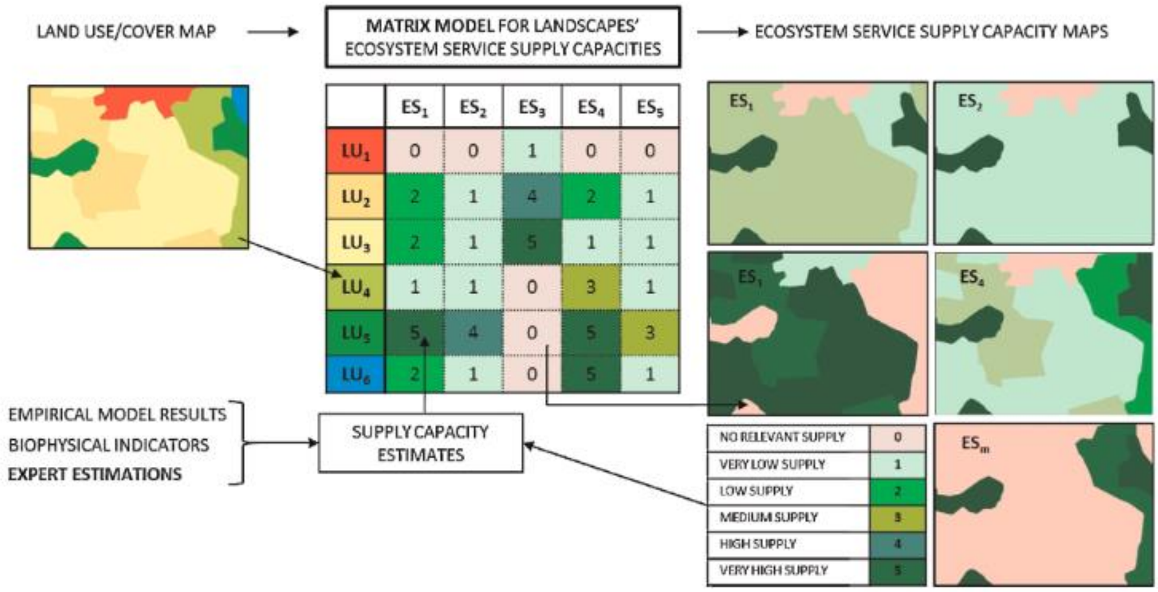

Figure I.1 Overview of the methodology for evaluating ESs according to the matrix approach (Burkhard et al. 2014).

2. Methods

Study area

The Carpathians cover an area of more than 200 000 km^2 and stretch from the eastern border of the Czech Republic to Serbia, with an approximate length of the mountain chain of 1500 kilometres and its range between 100 and 200 kilometres. The highest mountains of the Carpathians are the Tatras, which extend on the northern border of Slovakia and the southern border of Poland. The Carpathians can be divided into 3 main areas: the Western Carpathians (Czech Republic, Poland, Slovakia, Hungary, Austria), Eastern Carpathians (SE Poland, Eastern Slovakia, Ukraine, Romania), and Southern Carpathians (Romania, Eastern Serbia). More than 50% of the area of the Carpathians is in Romania, about 16% of the area is in Slovakia, in Poland and Ukraine it is about 10%, in other countries, it is less than 5%. The climate of the Carpathians can be defined as slightly cold and humid, annual precipitation totals correlate with the altitude - in the Tatras more than 1800 mm per year, in foothill areas about 600 mm per year.

The area of the studied territory (calculated in the GIS) is approximately 261,000 km^2, and this area can only be used in connection with this work and is a slightly expanded area of the Carpathians in the nearby surroundings.

Data collection, processing, and preparation of the map of land cover of the Carpathians

The base for evaluating ESs was the creation of a map of land cover (LC) from current and available sources, which were available in different formats and scales. The Carpathian´s map of LC has been processed in ArcGIS 10.3.1 using the standard as well as advanced vector and raster analyses. Even though some source maps were available only in raster format, the map of ecosystems was created as a vector layer (raster data were converted into vectors - polygons). To set the boundaries of the Carpathians, a layer of orographic units of the Carpathians was processed (source: http://cwi.sk/ & https://geoportal.ccibis.org/) around which a 10 km buffer zone was created to prepare one continuous polygon representing the territory of the Carpathians. As a base layer for the Carpathians map, the CORINE Land Cover layer (CLC) was processed on a scale of 1:100,000 (source: https://land.copernicus.eu/pan-european/corine-land-cover/clc2018?tab=download), which contains geodatabases with 44 categories of land cover with a grid accuracy of 100 x 100 meters. The CLC layer is currently not available for Ukraine and thus the former raster layer of the land cover of Ukrainian Carpathians was used from the published source of Kuemmerle et al. (2010).

The map of the land cover of the Carpathians had to be supplemented because the forest CLC classes (311 - deciduous forests, 312 - coniferous forests, and 313 - mixed forests) mostly represent only continuous forest stands and disjointed forests in the wild, but also in the built-up area (bankside stands, windbreaks, ecotones, gardens, parks, etc.) are classified under another category of non-forest CLC. To this purpose, data from the Global Forest Change 2000-2019 database (Hansen et al. 2013) were processed, namely a raster called "tree canopy layer" with a spatial resolution of 25 m/grid. Raster data with a cell size of 25 x 25 meters were converted into polygons and connected to the map of the Carpathians. CLC classes of freshwater (511 - watercourses and 512 - water bodies) proved as insufficient for the LC map of the Carpathians, and the freely available Openstreetmap geodatabases (source: https://download.geofabrik.de) served to complement them. Some of the watercourses in the Openstreetmap layer were represented by polygons with a defined width, but most were plotted only as lines/curves and therefore it was necessary to create a buffer zone with a defined width around them (river 20 m, channel 5 m, drain, and stream 2 m). Due to the size of the data set, vector analyses were performed separately for each country and only in the last step was the map of the LC of the Carpathians joined into one polygonal layer.

An assessment of ESs

The resulting polygonal map of LC of the Carpathians contains a database with individual classes of land cover, including their area, based on which it was possible to attach index values from the modified ESs potential matrix (Burkhard et al. 2014), which combines 11 regulatory, 14 provisioning and 6 cultural ESs (Tab. I.1).

Table I.1 List of evaluated ecosystem services.

Regulatory ESs	Provisioning ESs	Cultural ESs
Global climate regulation	Crops	Recreation tourism
Local climate regulation	Biomass for energy	Landscape aesthetics inspiration
Air quality regulation	Fodder	Knowledge systems
Water flow regulation	Livestock	Religious spiritual experience
Water purification	Fibre	Cultural heritage cultural diversity
Nutrient regulation	Timber	Natural heritage
Erosion regulation	Wood Fuel	
Natural hazard regulation	Fish and edible algae	
Pollination	Aquaculture	
Pest and disease control	Wild foods resources	
Regulation of waste	Biochemicals medicine	
	Freshwater	
	Mineral resources	
	Abiotic energy sources	

Potential can be defined as the optimal variant for providing ESs under ideal conditions and assuming that all ecosystems are in a favourable condition and provide the ESs with full quality (Burkhard et al. 2014). Index values were assigned to individual categories of land cover identified in the area of interest in the range 0 to 5. For the purpose of this work, the scale of indices from the potential matrix has been converted into a range of 0 to 100 %, where 0 = 0 %, 1 = 20 %, 2 = 40 %, 3 = 60 %, 4 = 80 % and 5 = 100 % (Table I.2). The reference index values from the potential matrix represent a 'hypothetical, normal European country in summer' (before the harvest period) and are interpreted as follows: 0 % = no relevant potential/capacity; 20 % = low relevant potential/capacity; 40 % = relevant potential/capacity; 60 % = medium relevant potential/capacity; 80 % = high relevant potential/capacity; 100 % = very high/maximum relevant potential/capacity. The resulting potential/capacity values for individual land cover types as well as for individual ESs have been calculated by arithmetic mean.

Table I.2 Potential/capacity matrix for providing 11 regulatory, 14 provisioning, and 6 cultural ESs based on the work of Burkhard et al. (2014); values in the matrix have been adjusted to percentages between 0 % and 100 %.

CLC category of ecosystem	Code	Global climate regulation	Local climate regulation	Air quality regulation	Water flow regulation	Water purification	Nutrient regulation	Erosion regulation	Natural hazard regulation	Pollination	Pest and disease control	Regulation of waste	Crops	Biomass for energy	Fodder	Livestock	Fibre	Timber	Wood Fuel	Fish seafood edible algae	Aquaculture	Wild foods resources	Biochemicals medicine	Freshwater	Mineral resources	Abiotic energy sources	Recreation tourism	Landscape aesthetics inspiration	Knowledge systems	Religious spiritual experience	Cultural heritage cultural diversity	Natural heritage
Continuous urban fabric	111	0	0	0	0	0	0	40	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	60	60	40	40	20	0
Discontinuous urban fabric	112	0	0	0	0	0	0	20	0	20	20	0	20	0	0	0	0	0	0	0	0	0	0	0	0	20	60	40	40	40	40	0
Industrial or commercial units	121	0	0	0	0	0	0	40	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	40	0
Road and rail networks and associated land	122	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0
Port areas	123	0	0	0	0	0	0	60	60	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	40	0	0	20	0
Airports	124	0	0	0	0	0	0	20	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mineral extraction sites	131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	60	0	0	40	0	20	0
Dump sites	132	0	0	0	0	0	0	0	0	0	0	40	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Construction sites	133	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0
Green urban areas	141	40	40	40	40	40	40	40	20	40	40	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	60	20	0	40	20
Sport and leisure facilities	142	20	20	20	20	20	20	20	0	0	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	20	0	0	20	0
Non-irrigated arable land	211	20	40	20	40	0	20	0	20	20	40	40	100	100	100	0	100	0	0	0	0	20	60	0	0	40	20	20	40	0	60	0
Permanently irrigated land	212	20	60	20	20	0	20	0	20	20	40	40	100	20	40	0	80	0	0	0	0	20	60	0	0	20	20	20	40	0	60	0
Rice fields	213	0	40	20	20	0	20	0	0	20	20	40	100	20	40	0	0	0	0	0	0	0	0	0	0	0	20	20	40	0	60	0
Vineyards	221	20	20	20	20	0	20	20	0	20	20	20	80	20	0	0	0	0	20	0	0	0	0	0	0	0	60	40	60	0	100	0
Fruit trees and berry plantations	222	40	40	40	40	20	40	40	40	100	60	40	80	20	0	0	0	40	40	0	0	0	40	0	0	0	60	40	40	0	80	20
Pastures	231	40	20	0	20	0	20	20	20	0	40	80	0	20	100	100	0	0	0	0	0	40	0	0	0	100	40	40	40	0	60	20
Annual crops associated with permanent crops	241	20	60	20	20	0	20	0	20	20	40	40	100	20	40	0	80	0	0	0	0	20	60	0	0	20	20	20	40	0	60	0
Complex cultivation patterns	242	20	40	20	20	0	20	20	20	40	60	40	80	40	40	20	80	0	20	0	0	20	40	0	0	20	40	40	40	0	60	0
Land principally occupied by agriculture, with significant areas of natural vegetation	243	40	60	40	40	40	40	40	20	40	60	40	60	60	40	40	80	20	20	0	0	40	20	0	0	20	40	40	60	20	60	60
Broad-leaved forest	311	100	100	100	60	100	100	100	80	80	80	80	0	20	20	0	20	100	100	0	0	100	60	0	0	0	100	100	100	60	80	100
Coniferous forest	312	100	100	100	60	100	100	100	80	80	80	80	0	20	20	0	20	100	100	0	0	100	60	0	0	0	100	100	100	60	80	80
Mixed forest	313	100	100	100	60	100	100	100	80	80	100	100	0	20	20	0	40	100	100	0	0	100	60	0	0	0	100	100	100	60	80	100
Natural grasslands	321	100	40	0	20	60	80	100	20	20	20	40	0	20	40	60	0	0	0	0	0	100	20	0	0	40	60	80	100	20	60	60
Moors and heathland	322	60	80	0	40	60	60	40	40	40	40	60	0	20	20	20	0	0	40	0	0	40	20	0	0	0	80	80	100	20	40	80
Sclerophyllous vegetation	323	40	40	20	20	20	40	20	20	40	40	60	0	20	20	20	20	40	40	0	0	20	60	0	0	20	40	60	80	20	40	80
Transitional woodland-shrub	324	40	40	20	20	20	40	20	20	40	40	60	0	40	20	20	20	20	40	0	0	20	20	0	0	20	40	60	80	20	40	40
Beaches, dunes, sands	331	0	0	0	20	20	20	0	100	0	20	20	0	0	0	0	0	0	0	0	0	0	20	0	20	0	100	80	80	20	60	40
Bare rocks	332	0	0	0	0	20	0	40	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	40	60	60	40	40	20
Sparsely vegetated areas	333	0	20	0	20	20	20	20	20	0	20	20	0	0	0	20	0	0	0	0	0	20	0	0	0	40	20	20	60	0	40	20
Burnt areas	334	0	20	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0
Inland marshes	411	40	40	0	60	40	80	20	80	20	40	60	0	0	80	40	0	0	0	0	0	20	0	0	0	0	20	40	60	0	40	40
Peat bogs	412	100	80	0	80	80	80	40	60	40	60	80	0	40	0	0	0	0	0	0	0	20	40	20	0	0	60	40	60	0	40	80
Water courses	511	0	20	0	60	60	60	0	60	0	60	100	0	40	0	0	0	0	0	60	0	80	0	100	0	60	80	80	80	40	60	60
Water bodies	512	20	40	0	100	40	60	0	60	0	60	100	0	20	0	0	0	0	0	80	100	80	0	100	0	20	100	80	80	40	60	60

3. Results

The initial step for the assessment of ESs was the preparation of a land cover (LC) map of the Carpathians (Fig. I.3), which is represented by 35 classes on an area of 261 000 km^2 (rounded). In the map a high representation of forest classes can be distinguished, where the largest area, up to 26 %, is covered by broad-leaved forests, mixed forests cover 14 % and 10 % are occupied by coniferous forest (Fig. I.2). While coniferous forests have the highest density in the Eastern (Ukraine, Romania), Southern (Romania), and Western Carpathians (Slovakia), deciduous forests are largely preserved in the Ukrainian and Romanian parts of the Carpathians. The Western Carpathians (Slovakia, Czech Republic, Poland) are largely fragmented by arable land, with a total share of 19 %, and pastures covering 9 % in the study area.

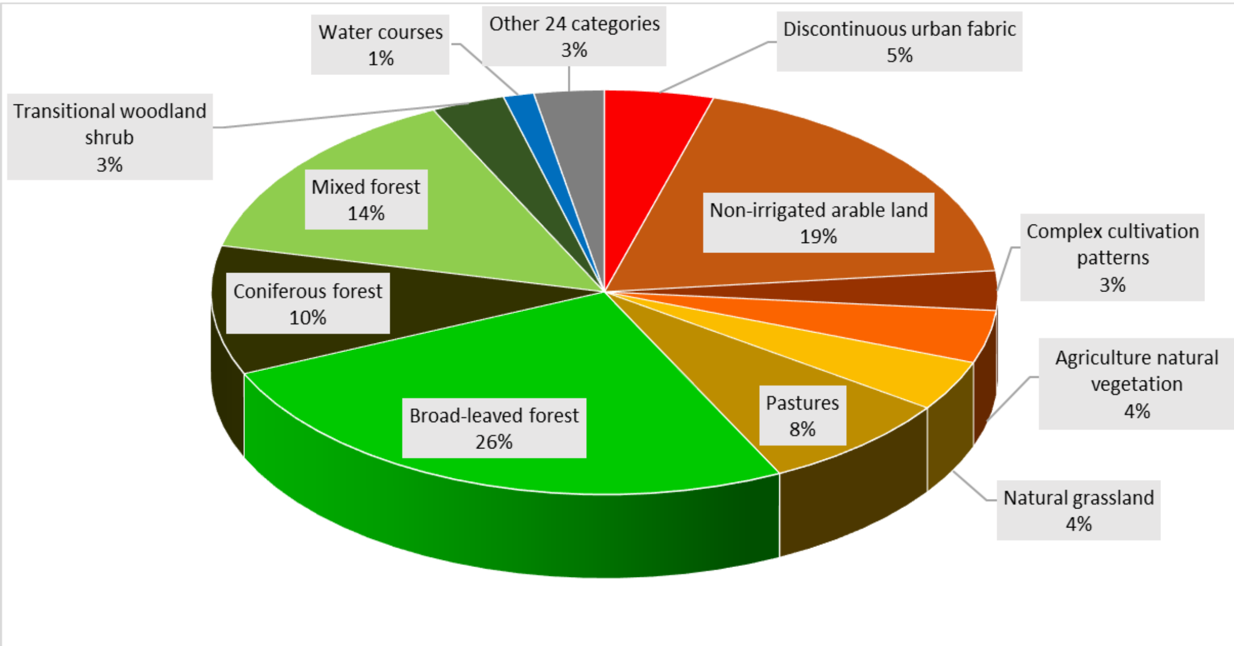

Figure I.2 Percentage of respective land cover classes in the study area of the Carpathians.

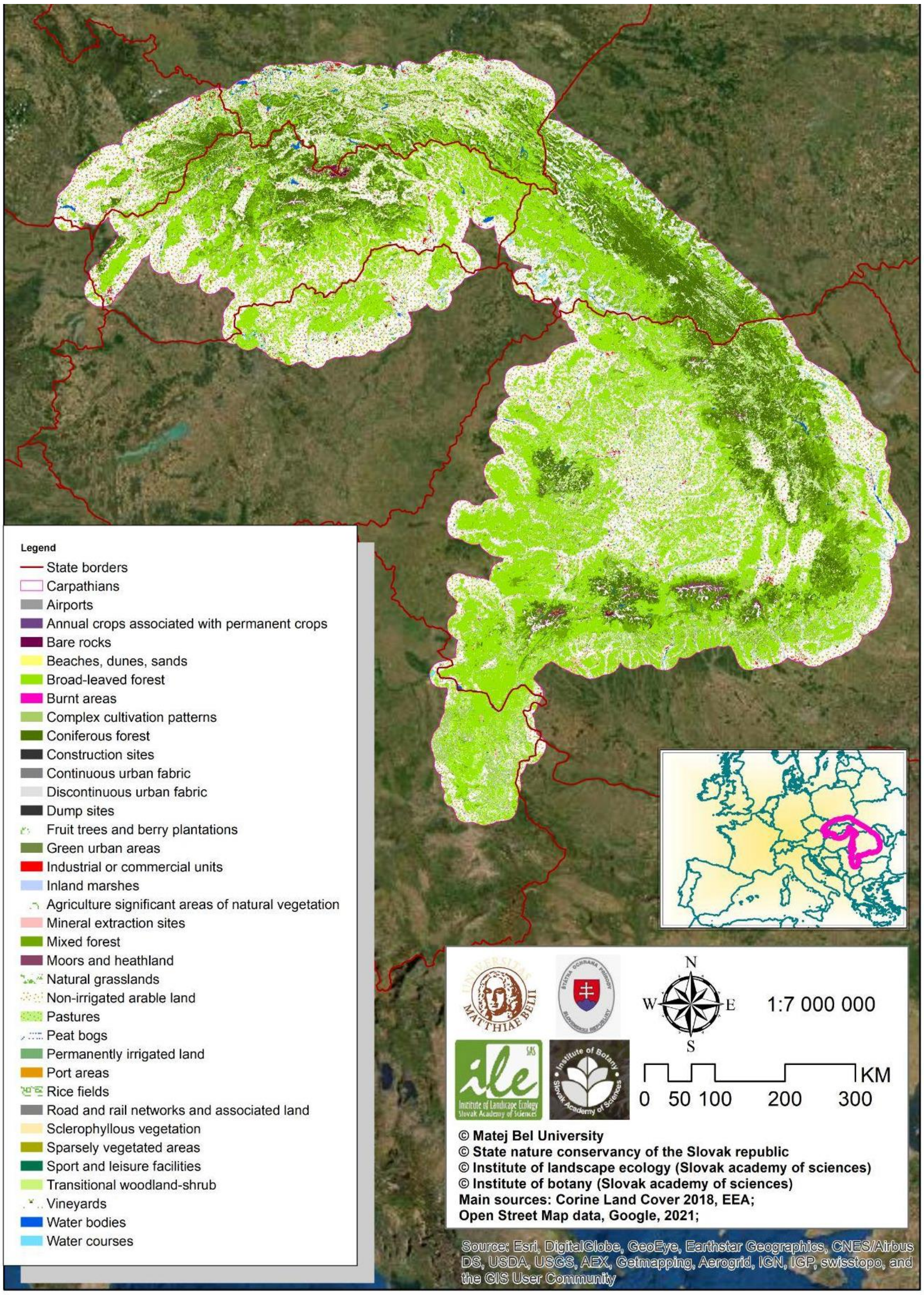

Figure I.3 Land cover classes of the Carpathians - studied area covers approximately 261 000 km^2.

The highest number of assessed ESs (14) belongs to provisioning services and these are provided by 28 LC classes relevant for the Carpathians with an average potential/capacity of 13.10 % (Tab. I.1). It has to be stated that every single provisioning ES is linked to certain class, for example 1 provisioning ES provides on average 10 classes of LC (up to 20, at least 1), e.g. freshwater is provided by peat bogs and at the maximum rate by water bodies and watercourses.

The highest capacity for the provision of 14 provisioning ESs of 37.14 % came out for arable land with a total area of 49,204 km² (Tab. I.3). In Fig. I.6 the dark blue colours represent arable land, at the edges of the Carpathians, at lower altitudes. Following the division of the Carpathian's LC classes into 3 groups by acreage in the study area (Fig. I.7), the average potential of provisioning ESs of the classes with an area of more than 10,000 km² has increased to 25.71 %. It is only positive that natural LC classes, which cover a significant area in the Carpathians, have achieved a higher average potential for the provision of provisioning ESs than those with a smaller area. By contrast, 6 of human-affected LC classes have non-significant relevant potential (potential 0.00 %) which was reflected in the low average value of provisioning ESs.

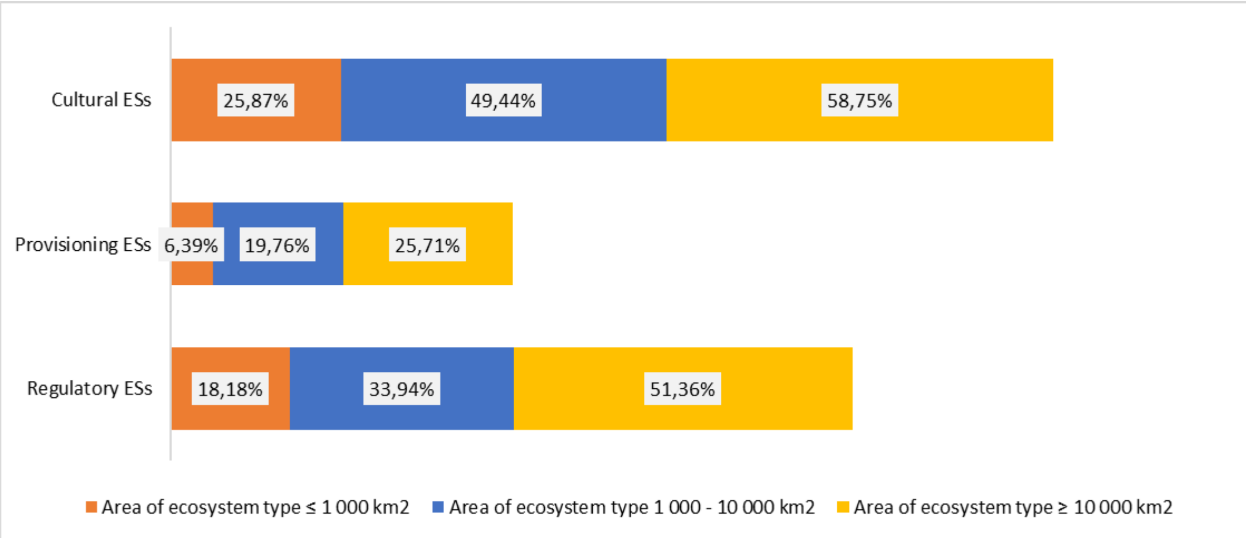

Figure I.4 Comparison of the average potential for providing 11 regulatory, 14 provisioning, and 6 cultural ESs; divided by area of a different class of land cover: area up to 1,000 km², the area from 1,000 to 10,000 km², and an area greater than 10,000 km².

Among the 14 provisioning services assessed, none exceeded the average potential of 25.00 % (Fig. I.5, Tab. I.4). The highest but still low overall, with a potential of 24.57 %, came out for Wild food & resources and the second-highest 20.57 % for Crop. Although some LC classes of large-acre have high potential values for these ESs (60.00 %, 80.00 %, or even 100.00 %), there are still a large number of LC classes with low potential, which significantly reduces the resulting average values.

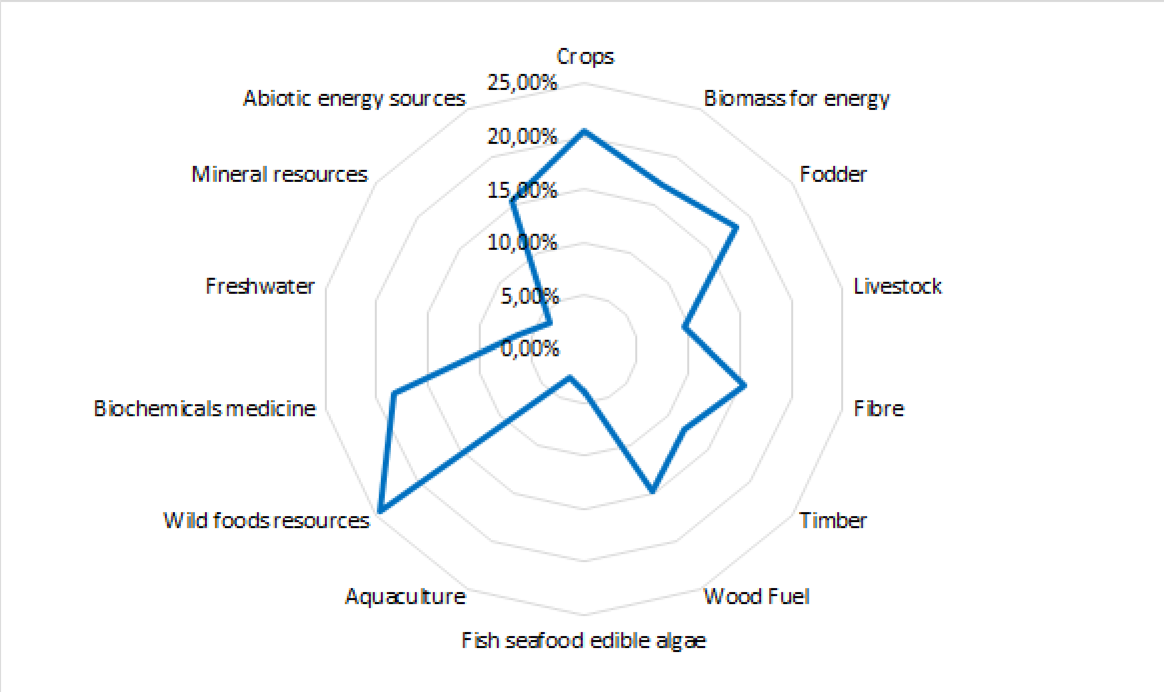

Figure I.5 Comparison of average potential values for provision of 14 provisioning ESs in the Carpathians; range 0-100%; very low (0.00 %) - very high (100.00 %) potential/capacity for ESs provision.

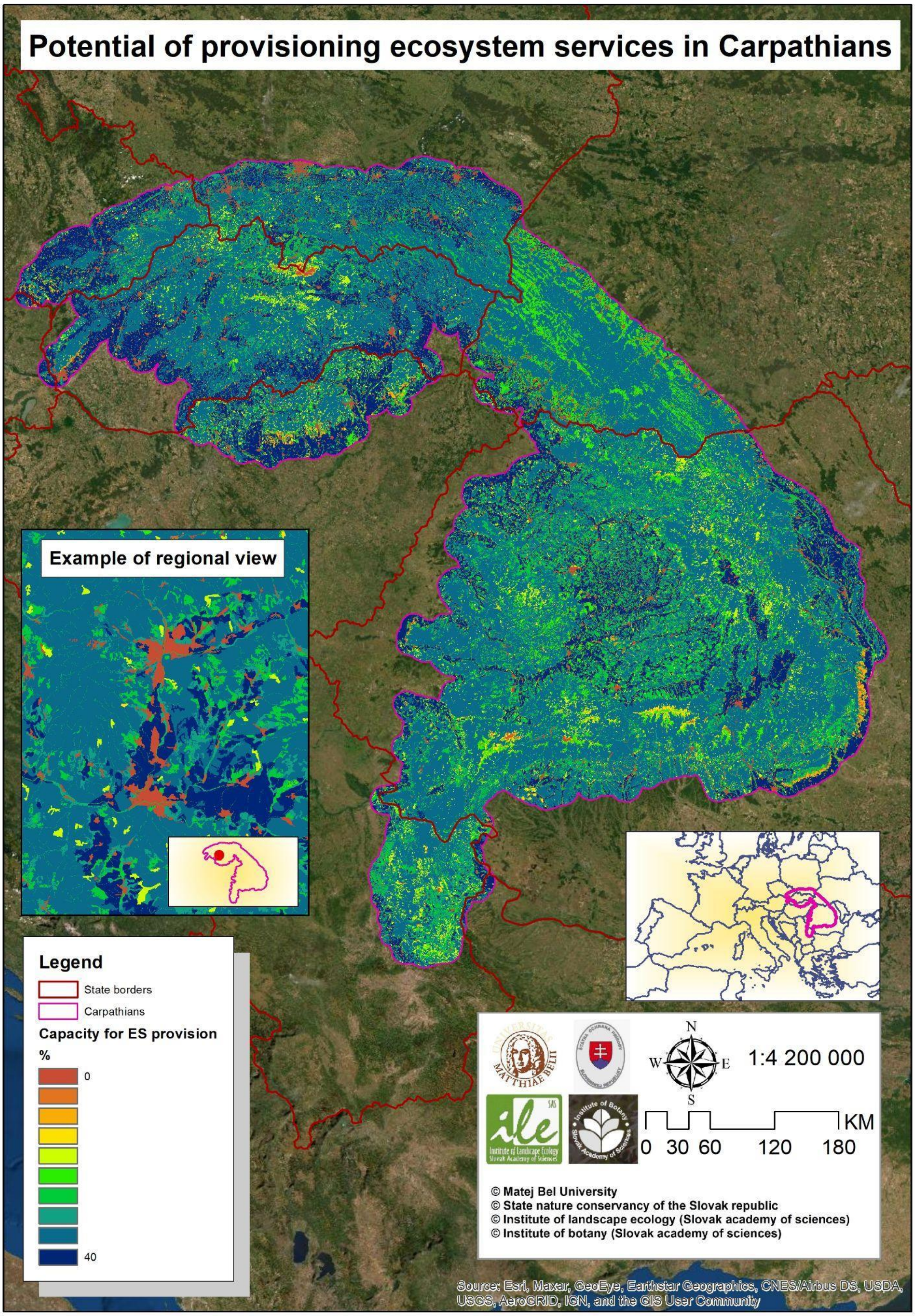

Figure I.6 Map of the capacity/potential of the Carpathians for provision of 14 provisioning ESs. The average capacity/potential is expressed as a percentage; range 0-100 %; very low (0.00 %) - very high (100.00 %) potential/capacity for ESs provision.

The average level of the potential/capacity for the regulatory ESs (Tab. I.3, Fig. I.7, Fig. I.8) is relatively low - only 28.47 %, but again, as in the case of provisioning ESs, the potential value is reduced by numerous classes of LC with a small area of up to 1,000 or even 10,000 km^2. After evaluating the classes that have an area of more than 10,000 km^2 in the study area, the average potential reached 51.36 % (Fig. I.4). The LC classes with the highest acreage and the highest average potential for providing regulatory ESs include forest classes – mixed forest 92.73%, broad-leaved forest and coniferous forest have identical potentials of 89.09 % (Tab. 3). On the other hand, peat bogs - 63.64 %, inland marshes - 43.64 %, and moors and heathland – 47.27 % (Tab. I.3), provide low acreage, but the average potential for regulatory ESs.

Regulation of waste with a potential of 38.86 % (Tab. I.4) reached the highest average level of provision among the 11 regulatory ESs, followed by the Pest and disease control with 34.23 %, the Local climate regulation 33.14 %, and the nutrient regulation 32.00 %.

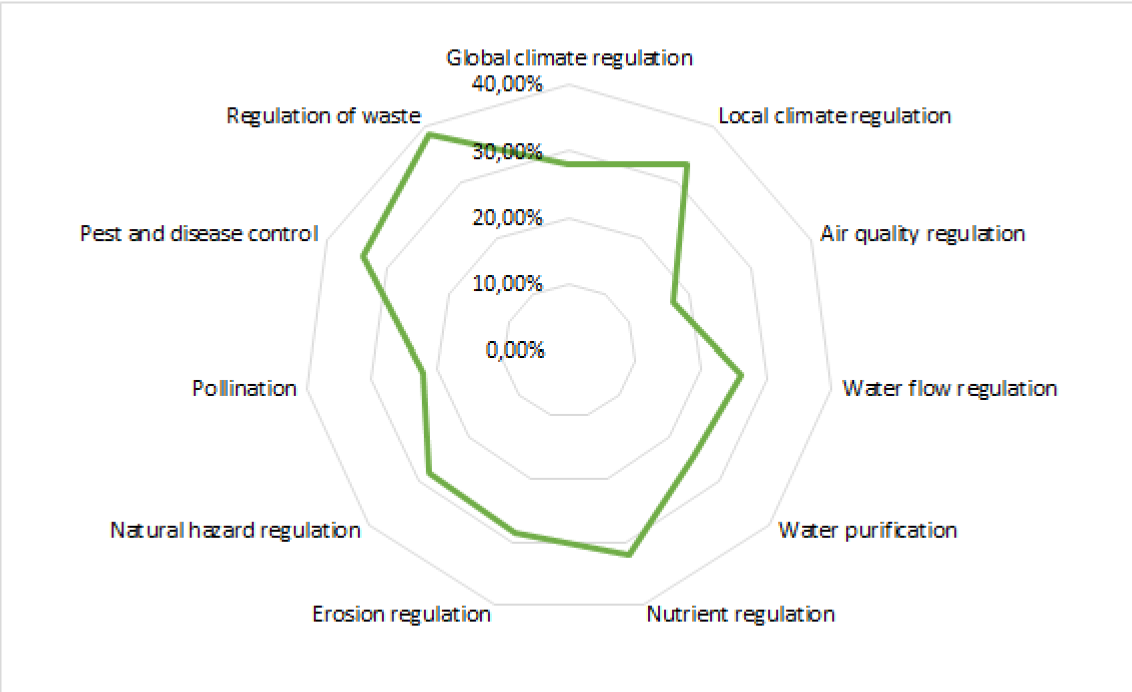

Figure I.7 Comparison of average potential values for provision of 11 regulatory ESs in the Carpathians; range 0-100 %; very low (0.00 %) - very high (100.00 %) potential/capacity for ESs provision.

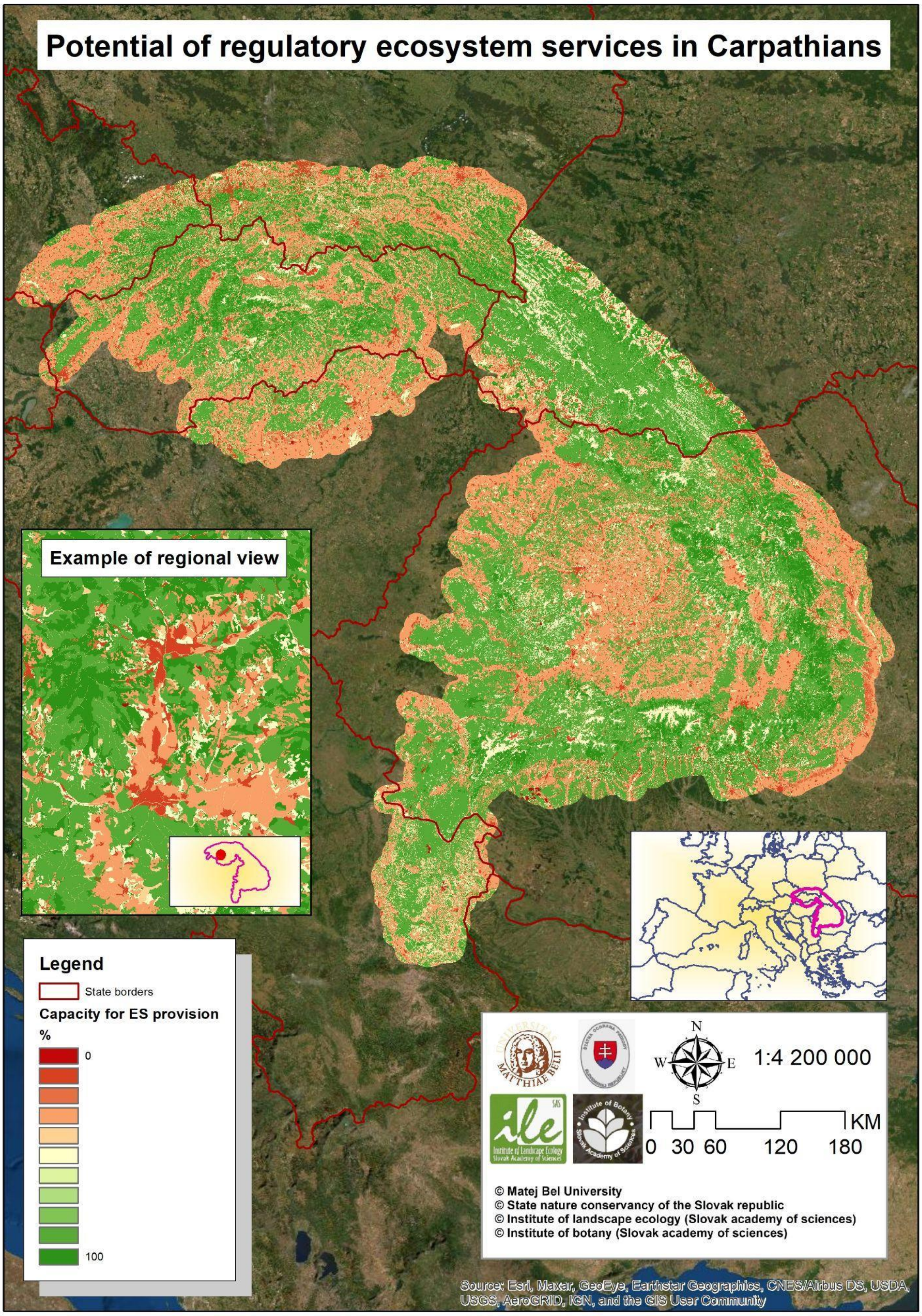

Figure I.8 Map of the capacity/potential of the Carpathians for the provision of 11 regulatory ESs. The average capacity/potential is expressed as a percentage; range 0-100%; very low (0.00 %) - very high (100.00 %) potential/capacity for ESs provision.

The average potential/capacity of six cultural ESs relevant for the Carpathians is 37.43 % (Tab. I.3). Classes of LC over 10 000 km^2 (natural grasslands; land principally occupied by agriculture, with significant areas of natural vegetation; discontinuous urban fabric; pastures; coniferous forest; mixed forest; arable land and broad-leaved forest) provide cultural ESs at 58.75 % (Fig. I.4). It can be concluded that all classes of LC in the Carpathians provide cultural ESs to a certain extent (Tab. I.3, Fig. I.10), even the vast majority in the range of 40 to 90 % (Tab. I.3). The highest capacity for providing cultural ESs (in particular tourism and recreation and landscape aesthetics) indicate a broad-leaved forest and mixed forest at 90 %, as well as a coniferous forest at 86.67 %. Water bodies, watercourses, natural grasslands, together with moors and heathland (Tab. I.4), follow them.

Comparison of individual cultural ESs among themselves in Fig. I.9 shows approximately the same level of provision for the Knowledge systems - 49.14% and Cultural Heritage cultural diversity - 46.29 %, followed by Recreation tourism and Landscape aesthetics inspiration.

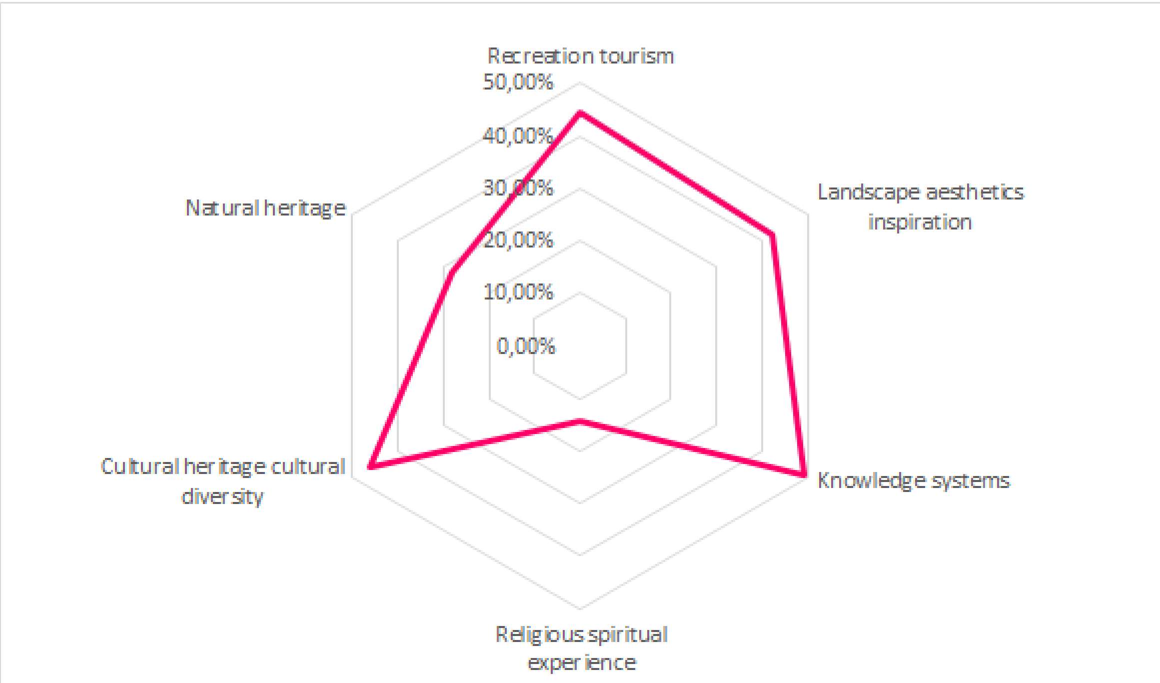

Figure I.9 Comparison of average potential values for providing 6 cultural ESs in the Carpathians; range 0-100%; very low (0.00%) - very high (100.00%) potential/capacity for ESs provision.

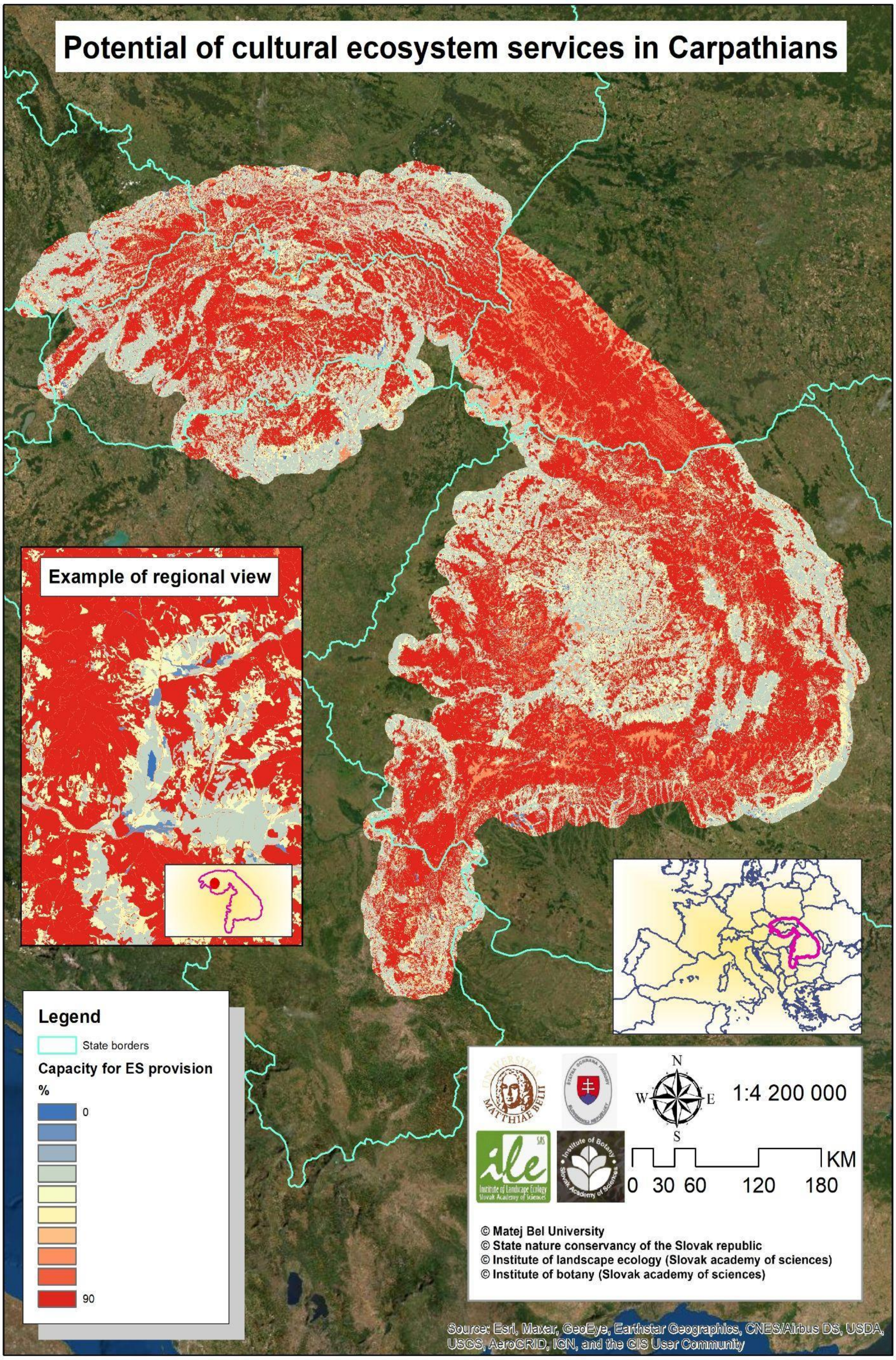

Figure I.10 Map of the capacity/potential of the Carpathians for the provision of 6 cultural ESs. The average capacity/potential is expressed as a percentage; range 0-100%; very low (0.00 %) - very high (100.00 %) potential/capacity for ESs provision.

Table I.3 An average capacity/potential of the land cover of the Carpathians to provide 11 regulatory, 14 provisioning, and 6 cultural ESs; percentage.

CLC class	Code	The average capacity to provide ESs		
		Provisioning ESs	Regulatory ESs	Cultural ESs
Continuous urban fabric	111	1.43 %	5.45 %	36.67 %
Discontinuous urban fabric	112	2.86 %	5.45 %	36.67 %
Industrial or commercial units	121	1.43 %	5.45 %	6.67 %
Road and rail networks and associated land	122	0.00 %	1.82 %	3.33 %
Port areas	123	0.00 %	12.73 %	13.33 %
Airports	124	0.00 %	3.64 %	0.00 %
Mineral extraction sites	131	11.43 %	0.00 %	10.00 %
Dump sites	132	1.43 %	3.64 %	0.00 %
Construction sites	133	0.00 %	0.00 %	6.67 %
Green urban areas	141	0.00 %	38.18 %	33.33 %
Sport and leisure facilities	142	0.00 %	16.36 %	23.33 %
Non-irrigated arable land	211	37.14 %	23.64 %	23.33 %
Permanently irrigated land	212	24.29 %	23.64 %	23.33 %
Rice fields	213	11.43 %	16.36 %	23.33 %
Vineyards	221	8.57 %	16.36 %	43.33 %
Fruit trees and berry plantations	222	15.71 %	45.45 %	40.00 %
Pastures	231	25.71 %	23.64 %	33.33 %
Annual crops associated with permanent crops	241	24.29 %	23.64 %	23.33 %
Complex cultivation patterns	242	25.71 %	27.27 %	30.00 %

CLC class	Code	The average capacity to provide ESs		
		Provisioning ESs	Regulatory ESs	Cultural ESs
Land principally occupied by agriculture, with significant areas of natural vegetation	243	28.57 %	41.82 %	46.67 %
Broad-leaved forest	311	30.00 %	89.09 %	90.00 %
Coniferous forest	312	30.00 %	89.09 %	86.67 %
Mixed forest	313	31.43 %	92.73 %	90.00 %
Natural grasslands	321	20.00 %	45.45 %	63.33 %
Moors and heathland	322	11.43 %	47.27 %	66.67 %
Sclerophyllous vegetation	323	18.57 %	32.73 %	53.33 %
Transitional woodland-shrub	324	15.71 %	32.73 %	46.67 %
Beaches, dunes, sands	331	2.86 %	18.18 %	63.33 %
Bare rocks	332	1.43 %	7.27 %	43.33 %
Sparsely vegetated areas	333	5.71 %	14.55 %	26.67 %
Burnt areas	334	0.00 %	3.64 %	6.67 %
Inland marshes	411	10.00 %	43.64 %	33.33 %
Peat bogs	412	8.57 %	63.64 %	46.67 %
Water courses	511	24.29 %	38.18 %	66.67 %
Water bodies	512	28.57 %	43.64 %	70.00 %
SUM		**13,10%**	**28.47 %**	**37.43 %**

Table I.4 Average capacity/potential of 35 identified classes of landscape cover of the Carpathians for the provision of 11 regulatory, 14 provisioning, and 6 cultural ESs; expressed in percentage.

Capacity of the Carpathians to provide ESs - average value in %		
Regulatory ESs	Global climate regulation	28.00 %
	Local climate regulation	33.14 %
	Air quality regulation	17.14 %
	Water flow regulation	26.29 %
	Water purification	24.57 %
	Nutrient regulation	32.00 %
	Erosion regulation	28.57 %
	Natural hazard regulation	28.00 %
	Pollination	22.29 %
	Pest and disease control	34.29 %
	Regulation of waste	38.86 %
Provisioning ESs	Crops	20.57 %
	Biomass for energy	17.14 %
	Fodder	18.29 %
	Livestock	9.71 %
	Fibre	15.43 %
	Timber	12.00 %
	Wood Fuel	14.86 %
	Fish and edible algae	4.00 %
	Aquaculture	2.86 %
	Wild foods resources	24.57 %

Capacity of the Carpathians to provide ESs - average value in %		
	Biochemicals medicine	18.29 %
	Freshwater	6.29 %
	Mineral resources	4.00 %
	Abiotic energy sources	15.43 %
Cultural ESs	Recreation tourism	44.57 %
	Landscape aesthetics inspiration	42.29 %
	Knowledge systems	49.14 %
	Religious spiritual experience	14.29 %
	Cultural heritage cultural diversity	46.29 %
	Natural heritage	28.00 %

An assessment of selected ESs

Global climate regulation (GRK) is considered one of the most important ESs at the global level (Information System for Biodiversity in Europe 2019). It can be assessed through indicators such as carbon storage or sequestration, net primary production or through LULC (biophysical methods), but also through different monetary methods (avoided cost, benefits transfer, etc.). The assessment of the ecosystem service global climate regulation (ES GRK; Fig. I.11) provides a comprehensive picture of the extent to which the Carpathians contribute to mitigating the impacts of climate change and provides an important basis for setting the sustainable use of this predominantly mountainous region spreading through 8 countries. The large area of forests (natural, semi-natural and economic) so characteristic for the Carpathian region was reflected in the high capacity/potential for GRK provision. In addition to broad-leaved forest, coniferous forest and mixed forest, natural grasslands and peat bogs have very high potential (100 %) for the provision of GRK. We do not recommend a comparison of the capacity of GRK for peatlands and forest classes of LC, as their area within the Carpathians is opposed – peat bogs 14.8 km^2 and e.g. mixed forests 36,994 km^2. Dark blue colours in Fig. I.11 illustrate the high representation of the above LC classes with high potential for GRK provision. In the Slovak, Czech and Polish parts of the Carpathians, fragmentation was mostly caused by the development of transport infrastructure, urban development, or the expansion of agricultural areas. GRK is provided on an area of 244,180 km^2 (out of a total area of 261,000 km^2) with an average potential of 28.00 % (Tab. 4).

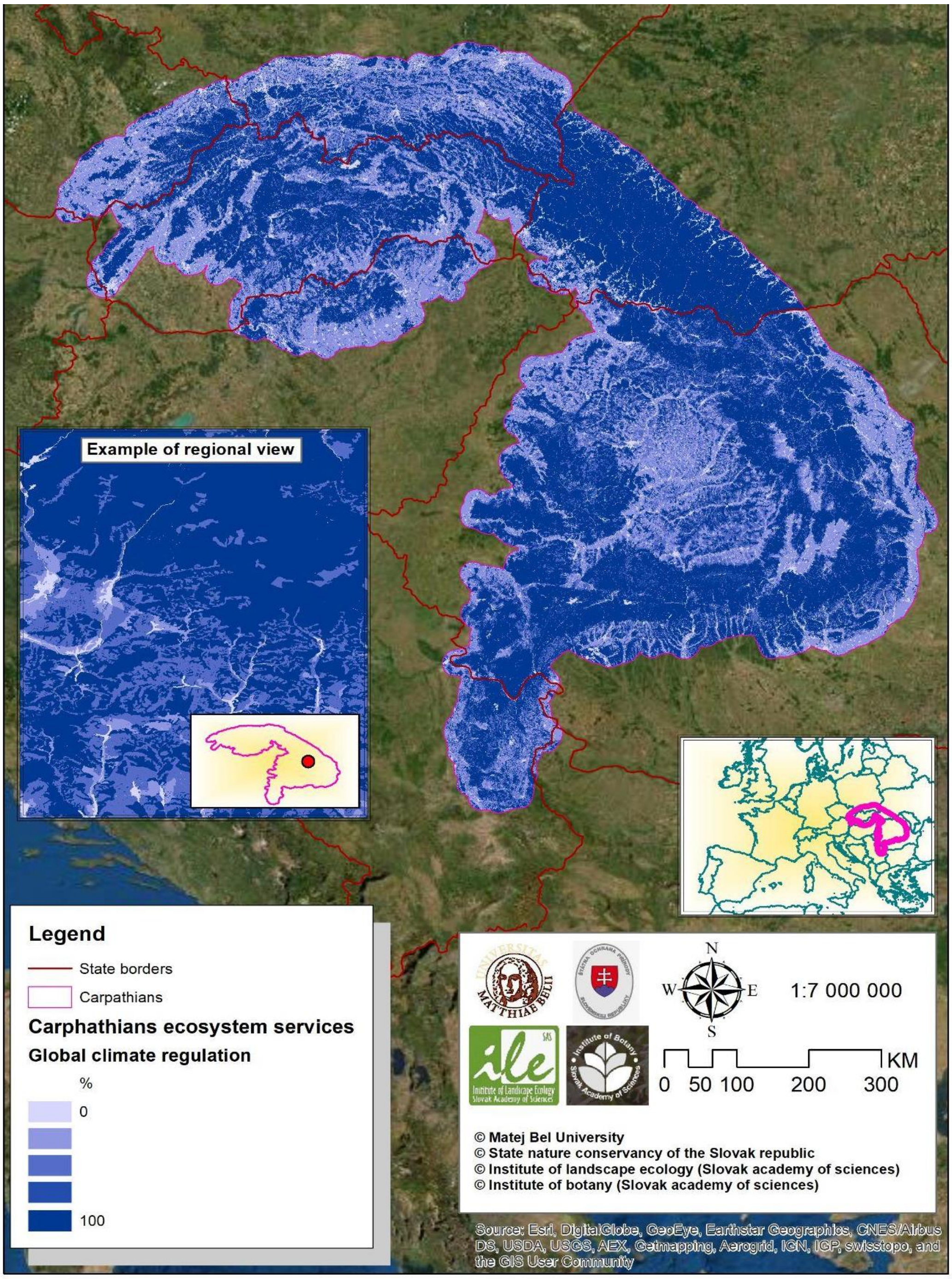

Figure I.11 Map of the capacity/potential of the Carpathians for the provision of a global climate regulation; range 0-100 %; very low (0.00 %) - very high (100.00 %) potential/capacity for the provision of global climate regulation.

Natural phenomena such as fires and floods play an important role in the natural cycle of matter and energy in ecosystems. Fires, for example, are part of the natural behaviour of the biosphere and are originally an effective mechanism for the natural transport of material. However, the ES of natural hazard regulation (NHR; Fig. I.12) can protect against the adverse consequences of natural disasters - especially recently, where the frequency of these phenomena is increasing due to climate change and natural disasters cause high economic damage, in some cases even human loss. Some ecosystems have a higher capacity to mitigate natural disasters than others, e.g. naturally composed soils (which have not been affected by human activity), have a higher capacity for water retention, support groundwater flow, thus prevent or reducing the intensity of floods. Human activities also contribute to mitigating the impacts of floods by unaffected aquatic ecosystems (lakes, wetlands, rivers). High temperature and wind speed generally increase flammability and spread of fire. High flammability combined with a high volume of fossil reserves in the soil increases the likelihood of intense fires. Areas in a temperate climate zone with high reserves of fossil fuels suffer catastrophic fires, while tropical forests can store large quantities of fossil fuels, but humid conditions in aquatic ecosystems naturally prevent or stop the spread of fires (De Guenni et al. 2005). In general, forest ecosystems reduce the intensity of floods, prevent soil loss and erosion. A different approach has been used to evaluate/display the potential for NHR (Fig. I.12), as 0 % means a very high risk of natural disasters, 20 % = high risk of natural disasters, etc. up to 100 % means very low risk of natural disasters. More than a third of the Carpathians are at high risk of natural disasters (20 %, Fig. I.12). These are mainly territories with the following classes of LC: arable land, pastures, land principally occupied by agriculture, with significant areas of natural vegetation, transitional woodland-shrub, natural grasslands and others. The classes with a potential for NHR of 60 % and 80 % (138,280 km^2) and thus a medium to low risk of natural disasters have a relatively high area. In total, 23 classes of LC of the Carpathians provide NHR at the level of 28.00 %.

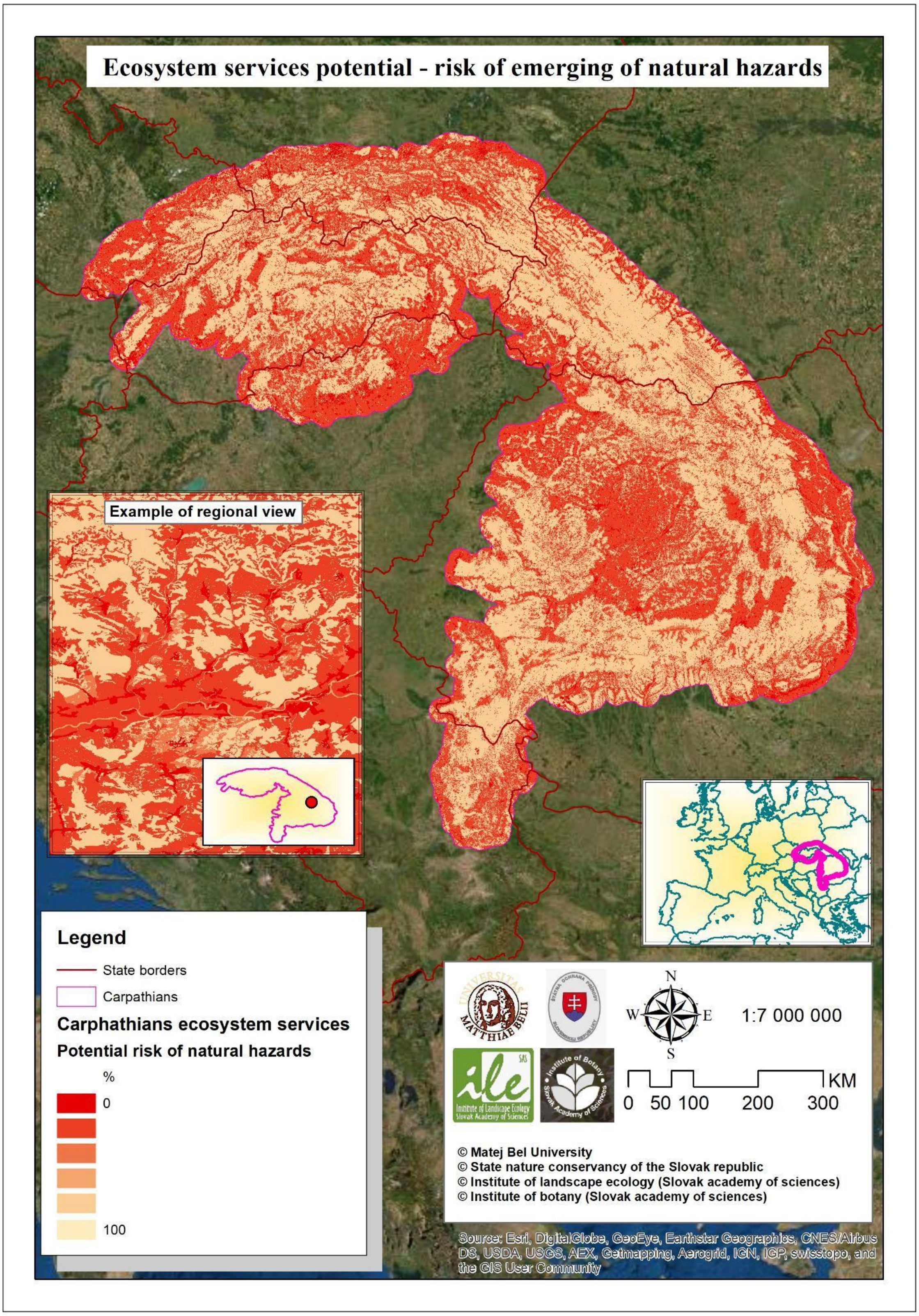

Figure I.12 Map of the risk of natural hazard; range 0-100 %; very low (0.00 %) - very high (100.00 %) risk of natural hazard.

Regarding the ecosystem service - production of crops (Fig. I.13) it should be noted that these are plant products that humans need for biological nutrition or commercial use, and this ES also includes the production of fruits, vegetables, seeds, herbs and others. However, the production of feed for livestock is already classified under another ES (fodder). In particular, economic (e.g. market prices for certain crop types) and biophysical methods (InVest, matrix model) are used for the evaluation of crops. In the study area, ES crops are provided by 9 classes of LC on an area of approximately 83,000 km^2, representing one-third of the area of interest. The areas in Fig. I.13 in light to dark green colours represent crops provision between 20 % and 100 %, but on average at 20.57 %. Although crop production is also important for the ES from the point of view of people's 'well-being', it should be noted to the correct extent that, for example, the production of drinking water, but in particular most regulatory ESs are equally very important and therefore cannot be viewed negatively, that it is provided on a slightly smaller level than other regulatory ES.

The provision of landscape aesthetics inspiration (LAI, Fig. I.14) contributes to 28 classes of LC of the Carpathians with an average potential of 42.29 %. Several classes of LC, which have a high presence within the Carpathians, participate in the provision of LAI with values of 60 % or more, such as transitional woodland-shrub, natural grasslands, broad-leaved forests, coniferous forest and mixed forests. Although the low area, with high potential, watercourses, water bodies, or heathland contribute to the provision of LAI.

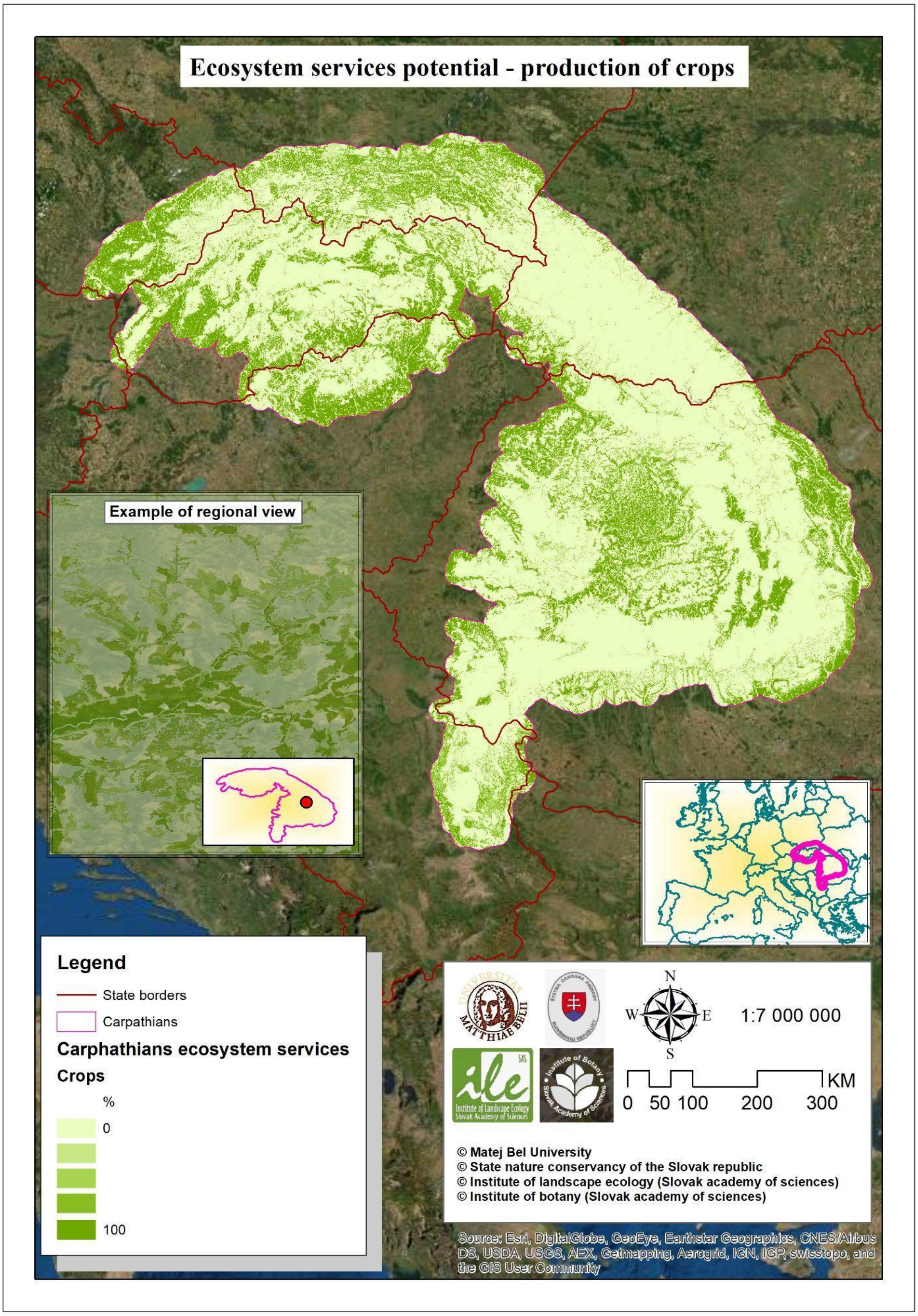

Figure I.13 Map of the capacity/potential of the Carpathians for the provision of crops; range 0-100 %; very low (0.00 %) - very high (100.00 %) potential/capacity for the provision of crops.

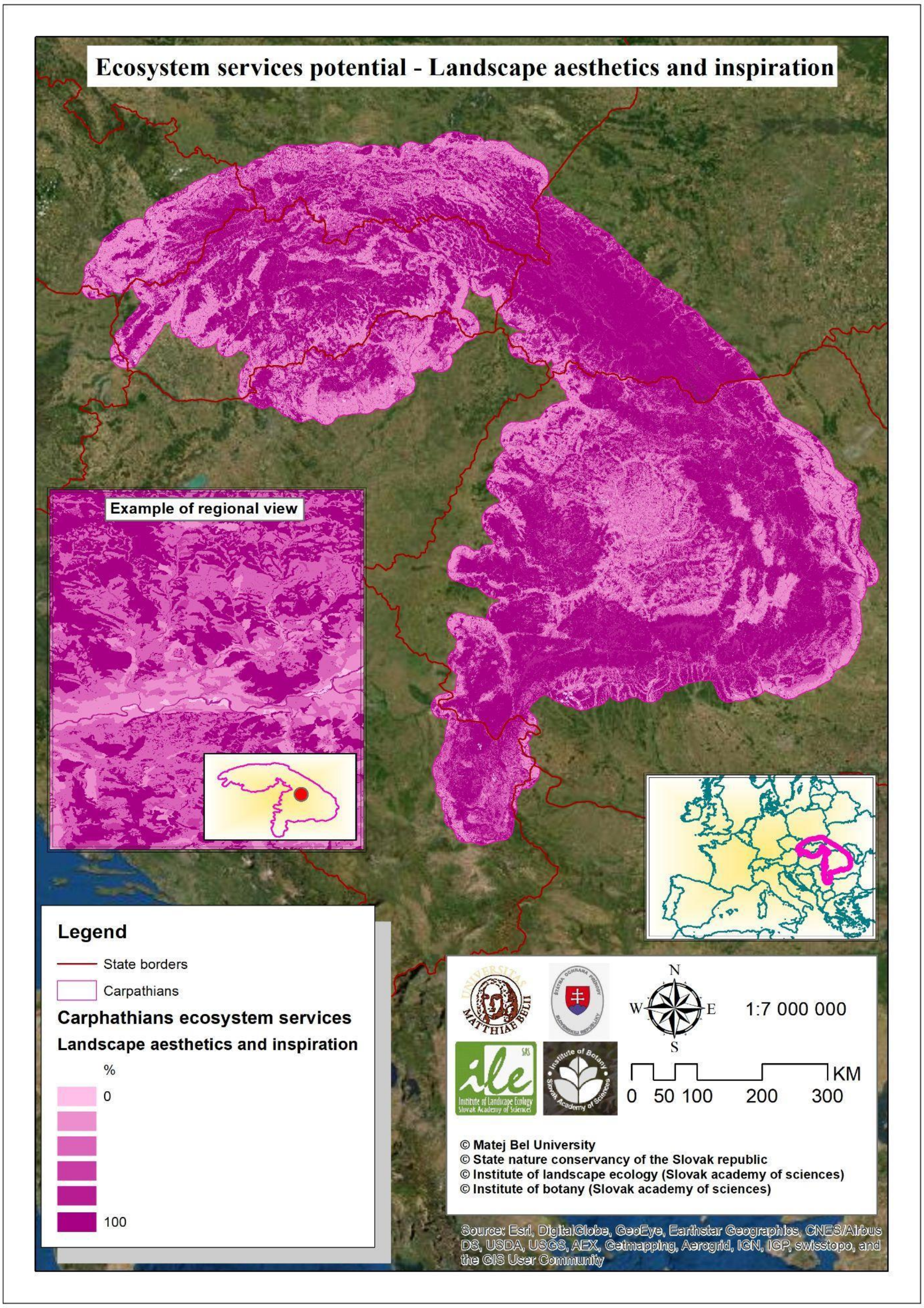

Figure I.14 Map of the capacity/potential of the Carpathians for the provision of landscape aesthetics inspiration; range 0-100 %; very low (0.00 %) - very high (100.00 %) potential/capacity for the provision of landscape aesthetics inspiration.

4. Discussion

The evaluation of the potential/capacity to provide 11 regulatory, 14 provisioning and 6 cultural ESs in the study area, defined based on orographic units of the Carpathians, is only an initial step in the process of evaluation of ESs and seeks to sufficiently emphasise the importance of this territory throughout Europe, not only in a way that is naturally protected, but also an anthropocentric approach in the form of exploiting by humans the benefits produced by ecosystems.

Comparison of the capacity for selected ESs in Carpathian countries is not part of this work, as the Carpathians occupy different percentages of the area in these countries, they only intervene in Hungary, Austria and the Czech Republic on a very small area, and such a comparison would be less relevant. As already outlined in the introduction, the resulting values, as well as the potential/capacity maps themselves for the provision of ESs, should be used and interpreted at the Carpathian level (on a scale of 1:100 000) and it is not correct to compare them with studies at the local level on more accurate scales. Up-to-date land cover data are not yet available for Ukraine and the Kuemmerle et al. (2010) published materials have been used for this study. Significantly, fewer categories of ecosystems entered the analyses to express the ESs of the Ukrainian part of the Carpathians, as the above-mentioned basis did not contain detailed classes in the same accuracy as the CLC for EU countries, which was also reflected in the results in expressing the potential of the ESs. In the future, this assessment needs to be refined once a more relevant and accurate layer of Ukraine's land cover is available.

In the future, it will be important to refine the land cover map of the Carpathians if maps of individual Carpathian countries are available on an adequate scale and accuracy. E.g. Slovakia (Černecký et al. 2020b) and the Czech Republic (Vačkář et al. 2014) have published maps of ecosystems. A wide range of indicators can be used to refine the assessment of ESs of the Carpathians (Egoh et al. 2012, Burkhard et al. 2009, Layke et al. 2012, Müller & Burkhard 2012, Niemeijer & de Groot 2008, Hernández-Morcillo 2013, Bohnke-Henrichs et al. 2013), but they should not be available for all parts of this territory. For the regulatory ESs can be used indicators such as volume of CO_2, NO_2, SO_2 in the atmosphere, carbon stock in forest stands, soil, net primary production, indicators of microclimatic conditions (temperature, precipitation, evapotranspiration). Volume/stocks or market prices of wood, crops, livestock and products made from them, volume/stocks of water, etc. may be used for provisioning ESs. It would also be appropriate to include abiotic factors such as soil composition or slope. In general, it is difficult to collect data with relatively the same accuracy, from different areas for all Carpathian countries, and it is a challenge for the future.

The work does not pay much attention to the description of individual ESs or examples of their evaluation, as they have long been known. For this information, we recommended publications A Catalogue of Ecosystem Services in Slovakia (Mederly & Černecký 2020), Value of Ecosystem and Their Services in Slovakia (Černecký et al. 2020a), Ecosystems and Human Well-Being: Current State and Trends (Hassan, Scholes, Neville eds. 2005), evaluation reports of the MAES process in the EU (Maes et al. 2013, Maes et al. 2014, Maes et al. 2016, Maes et al. 2018, Maes et al. 2020). In addition, CEST itself (Považan & Kadlečík ed. 2021) provides these basic definitions.

The matrix model was first published in 2009 (Burkhard et al. 2009) and has been further improved and refined (Burkhard et al. 2012b, 2014). According to Jacobs et al. (2015), the use of matrix models is very popular because they are efficient, fast, accessible and customizable, but in contrast, their use also poses risks to the scientific credibility and legitimacy of ESs results and evaluations in general. The advantage of the matrix approach is that it allows an evaluation of a larger number of ESs in one process and a consistent methodological procedure, while several underlying data such as CORINE Land Cover or Openstreetmap are freely available for most Carpathian countries. According to the work of Campagne et al. (2020), most studies published in the Scopus and Web of Science databases using the matrix approach for ESs evaluation come from Europe, but the number of assessments of other countries outside Europe is also increasing. The highest number of studies evaluated ESs at the local level, less at the regional/national level and several studies at the continental level. Geospatial units used in different matrixes of ESs were related to Land Use and Land Cover (LULC) classes, and many studies used European CORINE Land Cover or related typology (EUNIS).

5. Conclusions

The submitted study seeks to provide an initial overview of the provided ESs in the Carpathians. This is not an exhaustive assessment, it is only an introductory basis with a partial generalised view of the benefits that ecosystems provide, especially to the inhabitants of the Carpathian region and its visitors. However, the Carpathians are an important source of some ESs, which are also significant from a Pan-European perspective. Following the work on the Carpathian Ecosystem Services Toolkit and prepared first whole Carpathian study, it would be appropriate to continue this work through a separate project with a comprehensive team of experts working on further background and evaluations. The study can therefore be a theme for the preparation of new activities and funding in terms of the aims and objectives of the Carpathian Convention and thus bring new insights into the contribution of the Carpathians not only in the area of natural values but also in terms of direct benefits for humans, which the Carpathians provide in a high rate.

6. References

Bohnke-Henrichs, A., Baulcomb, C., Koss, R., Hussain, S.S. & de Groot, R.S. (2013). Typology and indicators of ecosystem services for marine spatial planning and management. Journal of Environmental Management, 130: 135-145.

Burkhard, B. & Maes, J. (eds.) (2017). Mapping Ecosystem Services. Sofia: Pensoft Publishers, 374 pp.

Burkhard, B., de Groot, R., Costanza, R., Seppelt, R., Jorgensen, S.E. & Potschin, M. (2012a). Solutions for sustaining natural capital and ecosystem services. Ecol. Indic. 21: 1–6. DOI:10.1016/j.ecolind.2012.03.008.

Burkhard, B., Kandziora, M., Hou, Y. & Müller, F. (2014). Ecosystem service potentials, flows and demands-concepts for spatial localisation, indication and quantification. Landscape Online 34: 1-32.

Burkhard, B., Kroll, F., Müller, F. & Windhorst, W. (2009). Landscapes' capacities to provide ecosystem services – a concept for land-cover based assessments. Landsc. Online 15: 1–22. https://doi.org/10.3097/LO.200915 .

Burkhard, B., Kroll, F., Nedkov, S. & Müller, F. (2012b). Mapping ecosystem service supply demand and budgets. Ecol. Indic. 21: 17–29. https://doi.org/10.1016/j.ecolind.2011.06.019.

Campagne, C.S., Roche, P., Müller, F. & Burkhard, B. (2020) Ten years of ecosystem services matrix: Review of a (r)evolution. One Ecosystem 5: e51103. https://doi.org/10.3897/oneeco.5.e51103.

Černecký, J., Gajdoš, P., Ďuricová, V., Špulerová, J., Černecká, Ľ., Švajda, J., Andráš, P., Ulrych, L., Rybanič, R. & Považan, R. (2020a). Hodnota ekosystémov a ich služieb na Slovensku. Banská Bystrica: ŠOP SR, 166 pp. ISBN 978-80-8184-078-4.

Černecký, J., Gajdoš, P., Špulerová, J., Halada, Ľ., Mederly, P., Ulrych, L., Ďuricová, V., Švajda, J., Černecká, L. & Andráš, P. (2020b). Ecosystems in Slovakia. Journal of Maps 16 (2): 28-35.

De Guenni, L.B., Cardoso, M., Goldammer, J., Hurtt, G., Mata, L.J., Ebi, K., House, J. & Valdes, J. (2005). Regulation of natural hazards: Floods and fires. In Ecosystems and Human Well-Being: Current State and Trends; Norgaard, R., Ed.; Island Press: Washington, DC, USA, 2005.

Egoh, B., Drakou, E., Dunbar, M., Maes, J. & Willemen, L. (2012). Indicators for mapping ecosystem services: a review. EUR 25456 EN. Luxembourg: Publications Office of the European Union; ISBN 978-92-79-25821-3.

Frélichová, J., Vačkář, D., Pártl, A., Loučková, B., Harmáčková, Z.V. & Lorencová, E. (2014). Integrated assessment of ecosystem services in the Czech Republic. Ecosystem services 8: 110-117. https://doi.org/10.1016/j.ecoser.2014.03.001.

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O. & Townshend, J.R. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342: 850–853. DOI: 10.1126/science.1244693

Hernández-Morcillo, M., Plieninger, T. & Bieling, C. (2013). An empirical review of cultural ecosystem service indicators. Ecological Indicators 29: 434–444. https://doi.org/10.1016/j.ecolind.2013.01.013.

Jacobs, S., Burkhard, B., Daelea, T.V., Staes, J. & Schneiders, A. (2015). 'The Matrix Reloaded': A review of expert knowledge use for mapping ecosystem services. Ecological Modelling. 295: 21-30. https://doi.org/10.1016/j.ecolmodel.2014.08.024

Kuemmerle, T., Perzanowski, K., Chaskovskyy, O., Ostapowicz, K., Halada, L., Bashta, A.T., Kruhlov, I., Hostert, P., Waller, D. M. & Radeloff, V. C. (2010). European Bison habitat in the Carpathian Mountains. Biological Conservation 143 (4): 908-916. DOI:10.1016/j.biocon.2009.12.038.

Layke, C. (2011). Indicators from the global and sub-global Millennium Ecosystem Assessments: an analysis and next steps. Ecol. Indic., http://dx.doi.org/10.1016/j.ecolind.2011.04.025.

Maes, J., Teller, A., Erhard, M., Condé, S., Vallecillo, S., Barredo, J.I., Paracchini, M.L., Abdul Malak, D., Trombetti, M., Vigiak, O., Zulian, G., Addamo, A.M., Grizzetti, B., Somma, F., Hagyo, A., Vogt, P., Polce, C., Jones, A., Marin, A.I., Ivits, E., Mauri, A., Rega, C., Czúcz, B., Ceccherini, G., Pisoni, E., Ceglar, A., De Palma, P., Cerrani, I., Meroni, M., Caudullo, G., Lugato, E., Vogt, J.V., Spinoni, J., Cammalleri, C., Bastrup-Birk, A., San Miguel, J., San Román, S., Kristensen, P., Christiansen, T., Zal, N., de Roo, A., Cardoso, A.C., Pistocchi, A., Del Barrio Alvarellos, I., Tsiamis, K., Gervasini, E., Deriu, I., La Notte, A., Abad Viñas, R., Vizzarri, M., Camia, A., Robert, N., Kakoulaki, G., Garcia Bendito, E., Panagos, P., Ballabio, C., Scarpa, S., Montanarella, L., Orgiazzi, A., Fernandez Ugalde, O. & Santos-Martín, F. (2020). Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment, EUR 30161 EN, Publications Office of the European Union, Ispra, 2020, ISBN 978-92-76-17833- 0, doi:10.2760/757183, JRC120383

Maes, J., Teller, A., Erhard, M., Grizzetti, B., Barredo, J.I., Paracchini, M.L., Condé, S., Somma, F., Orgiazzi, A., Jones, A., Zulian, A., Vallecilo, S., Petersen, J.E., Marquardt, D., Kovacevic, V., Abdul Malak, D., Marin, A.I., Czúcz, B., Mauri, A., Loffler, P., Bastrup-Birk, A., Biala, K., Christiansen, T. & Werner, B. (2018). Mapping and Assessment of Ecosystems and their Services: An analytical framework for ecosystem condition. Publications office of the European Union, Luxembourg.

Maes, J., Teller, A., Erhard, M., Murphy, P., Paracchini, M.L., Barredo, J.I., Grizzetti, B., Cardoso, A., Somma, F., Petersen, J.E., Meiner, A., Gelabert, E.R., Zal, N., Kristensen, P., Bastrup-Birk, A., Biala, K., Romao, C., Piroddi, C., Egoh, B., Fiorina, C., Santos, F., Naruševičius, V., Verboven, J., Pereira, H., Bengtsson, J., Gocheva, K., Marta-Pedroso, C., Snäll, T., Estreguil, C., San Miguel, J., Braat, L., Grêt-Regamey, A., Perez-Soba, M., Degeorges, P., Beaufaron, G., Lillebø, A., Malak, A., Liquete, C., Condé, S., Moen, J., Östergård, H., Czúcz, B., Drakou, E.G., Zulian, G. & Lavalle, C. (2014). Mapping and Assessment of Ecosystems and their Services. Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. (2nd MAES Report) Publications office of the European Union, Luxembourg.

Maes, J., Zulian, G., Thijssen, M., Castell, C., Baró, F., Ferreira, A.M., Melo, J., Garrett, C.P., David, N., Alzetta, C., Geneletti, D., Cortinovis, C., Zwierzchowska, I., Louro Alves, F., Souto Cruz, C., Blasi, C., Alós Ortí, M.M., Attorre, F., Azzella, M.M., Capotorti, G., Copiz, R., Fusaro, L., Manes, F., Marando, F., Marchetti, M., Mollo, B., Salvatori, E., Zavattero, L., Zingari, P.C., Giarratano, M.C., Bianchi, E., Duprè, E., Barton, D., Stange, E., Perez-Soba, M., van Eupen, M., Verweij, P., de Vries, A., Kruse, H., Polce, C., Cugny-Seguin, M., Erhard, M., Nicolau, R., Fonseca, A., Fritz, M. & Teller, A. (2016). Mapping and Assessment of Ecosystems and their Services. Urban Ecosystems. Publications Office of the European Union, Luxembourg.

Mederly, P. & Černecký, J. (eds). (2020). A Catalogue of Ecosystem Services in Slovakia. Benefits to Society. Springer International Publishing, ISBN 978-3-030-46507-0, 244 pp. https://doi.org/10.1007/978-3-030-46508-7.

Müller, F., Burkhard, B., Kandziora, M., Schimming, C. & Windhorst W. (2012). Ecological Indicators: Ecosystem Health. In: Jørgensen, S. E. (Ed.): Encyclopedia of Environmental Management. Volume 1. CRC Press. Bacon Rouge: 599-613.

NEPA (National Environmental Protection Agency) (2017). Assessment of Ecosystems and Ecosystem Services in Romania. NEPA, NINA, ROSA, WWF Romania, 197 pp. ISBN 978-606-8038-23-0.

Niemeijer, D. & de Groot, R. (2008). A conceptual framework for selecting environmental indicator sets. Ecological Indicators 8, 14-25.

Potschin, M., Haines-Young, R., Fish, R. & Turner, K. R. (2016). Routledge handbook of ecosystem services. 1. ed. New York: Routledge, Taylor & Francis Group, 630 pp.

Vačkář, D., Grammatikopoulou, I., Daněk, J. & Lorencová, E. (2018). Methodological aspects of ecosystem service valuation at the national level. One Ecosystem 3: e25508. https://doi.org/10.3897/oneeco.3.e25508.

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