Value of ecosystems and their services in Slovakia

Ján Černecký et al.

This monography was produced with the support of the Monitoring of species and habitats of European importance in accordance with the Habitat Directive and the Birds Directive project, ITMS 310011P170 (realised witin the Operational Programme Quality of Environment).

Reviewer:

Zita Izakovičová, Peter Mederly

Recommended quotation of the monography:

Černecký J, Gajdoš P, Ďuricová V, Špulerová J, Černecká Ľ, Švajda J, Andráš P, Ulrych L, Rybanič R, Považan R. 2021. VALUE OF ECOSYSTEMS AND THEIR SERVICES IN SLOVAKIA. Banská Bystrica: ŠOP SR, 137 pp.
ISBN 978-80-8184-094-4.

JÁN ČERNECKÝ et al.

Value of Ecosystems and Their Services in Slovakia

Authors of the monography:

Ján Černecký[1,2,7] (80 %), Peter Gajdoš[2], Viktória Ďuricová[1,6], Jana Špulerová[5], Ľudmila Černecká[3], Juraj Švajda[6], Peter Andráš[1], Libor Ulrych[1], Rastislav Rybanič, Radoslav Považan[4]

Authors of the maps and graphs:

J. Černecký, P. Andráš, V. Ďuricová

[1] State Nature Conservancy of the Slovak Republic, Tajovského 28B, 974 01 Banská Bystrica

[2] Institute of Landscape Ecology, Slovak Academy of Sciences, Akademická 2, 949 01 Nitra

[3] Institute of Forest Ecology, Slovak Academy of Sciences, Ľ. Štúra 2, 960 53 Zvolen

[4] Slovak Environment Agency, Tajovského 28, 975 90 Banská Bystrica

[5] Institute of Landscape Ecology, Slovak Academy of Sciences , Štefánikova 3 P.O.Box 254 814 99 Bratislava

[6] Matej Bel University, Faculty of Natural Sciences, Tajovského 40, 974 01 Banská Bystrica

[7] Constantine the Philosopher University in Nitra, Tr. A. Hlinku 1, 949 01, Nitra

ISBN: 978-80-8184-094-4

Content

List of Abbreviations

CBD – Convention on Biological Diversity
CICES – The Common International Classificastion of Ecosystem Services
CLC – Corine Land Cover
DTM – Digital Terrain Model
ES – Ecosystem service/s
ESA – European Space Agency
ESVD – Ecosystem Service Value Database
EU – European Union
FAPAR – The Fraction of Absorbed Photosyntheticaly Active Radiation
GIS – Geographical Information System
GDP – Gross Domestic Product
InVEST – Integrated Valuation of Ecosystem Services and Tradeoffs
IPBES – Intergovernmental Platform for Biodiversity and Ecosystem Services
KIMS – Complex Information and Monitoring System
MEA – Millenium Ecosystem Assessment
NDVI – The Normalised Difference Vegetation Index
NPPC – The National Agriculture and Food Centre
NVM – Non-monetary Valuation
OPaK – Landscape and Nature Conservation
OpenNESS – Operalisation of Natural Capital and Ecosystem Services
RMSE – Root Mean Square Error
SAV –Slovak Academy of Sciences
SEEA – System of Environmental Economic Accounting
SHMÚ – Slovak Hydrometeorological Institute
SR – Slovak Republic
SVP – Slovak watermanagement Enterprise
ŠGÚDŠ – The State Geological Institute of Dionyz Stur
ŠOP SR – The State Nature Conservancy of the Slovak Republic
TEEB – The Economics of Ecosystems and Biodivesity
TESSA – Toolkit for Ecosystem Service Site-based Assessment
TTP – Permanent grassland
WDVI – Weighted Difference Vegetation Index

List of Tables

List of Figures

1 INTRODUCTION

1.1 Definitions of ecosystem services

Mederly, Černecký et al. (2019) state: "Nature and the environment are a key and indisputable value in terms of human existence – perhaps more important the more people in the world live and the more a man influences and changes the environment through his activities. The world community and the European Union are increasingly aware of this fact, as are the various international activities and policy initiatives." The existence of natural capital, such as biodiversity and ecosystems, which provides vital products to the humans – from fertile soils and multifunctional forests, through quality drinking water and clean air to pollination, climate regulation and flood control - is a prerequiste for global economic prosperity and human well-being. Mapping ecosystem services (ES) is key to understanding how ecosystems contribute to the quality of human life and to supporting the argumentation of multisectoral policies that have a major impact on natural resources and their use (Burkhard & Maes 2017). An ecosystem can be defined as a dynamic complex of a community of plants, animals, microorganisms and their non-living environment forming a functional unit together. The ecosystem approach is a strategy for integrated management of land, water resources and biota that supports their conservation and sustainable use (MEA 2005).

At present, the ES's assessment is on the rise, although this concept originated in the 1970s, when the benefits and functions of nature that are beneficial to man were discussed. The intention was to increase people's interest in nature protection or biodiversity conservation. The world's leading experts have set goals such as improving the protection and sustainable use of ecosystems (clean water, food, forest products), restoring and maintaining the sustainability of basic ecosystem functions. Over time, other ecosystem functions were added and characterised as services valued in monetary terms. According to the MEA (2005), the ES create human well-being at local, regional and global levels and reduce poverty. ES are ecological components that are directly consumed or provide benefits and thus contribute to human well-being (Boyd & Banzhaf 2005). The ES contribute to the benefits and advantages of economic and other human activities (SEEA-EEA 2014). The ES concept and their assessment helps to better understand the environmental, social and economic benefits of sustainable use and protection of ecosystems (de Groot et al. 2010). The ES concept represents an integrated approach to landscape assessment with an emphasis on participatory methods and has great potential to streamline spatial planning in Slovakia (Izakovičová et al. 2017). According to Act no. 543/2002 Coll. on nature and landscape protection, as amended, the term ES means "the benefits and advantages of naturally functioning ecosystems". The above definitions of the ES are simple and understandable even for ordinary people and aim to make the value of nature visible. This monography brings a complex assessment of the ES, potential of which lies in their implementation into decision making processes, spatial planning documentation, nature conservation documentation and establishment of ecosystem accounting, which will help to include so far unrated benefits of the nature into economic assessment on national level. Ecosystem accounting (SEEA-EEA 2014) is an integrated approach to assessing the value of the environment and measuring ES flow as part of economic and other human activities.

1.2 Development of the concept of ecosystem services in Europe and Slovakia

A milestone in strengthening the need for ES assessment was the adoption of a global commitment to biodiversity conservation - the **Convention on Biological Diversity (CBD)**, including the Aichi Biodiversity Targets adopted in Nagoya, Japan in 2010. Strategic objective D defines the need to increase biodiversity and ecosystem services for all and sub-target 14 specifies that by 2020, ecosystems that provide essential services, including water-related services, and contribute to health, livelihoods and well-being should be restored and preserved. EU Biodiversity Strategy 2020 imposes ES commitments on Member States - carry out assessments of ecosystems and their services at national level, integrate it into the reporting system by 2020 and implement it in their national policies. A detailed overview of the history of the application of the ES concept and the process of their evaluation in the European Union is given in the publication Catalogue of Ecosystem Services in Slovakia (Mederly, Černecký et al. 2019).

To support the fulfillment of the 2020 Strategy commitments, in 2013 the European Commission set up an expert group for mapping and assessment of ecosystems and their services - **Mapping and Assessment of Ecosystems and their Services (MAES).** The last meeting of the MAES Group (March 2019) concluded that the level of implementation of ES commitments by the Member States of the European Union (EU) is estimated at 70%, while in Slovakia it is only at 20%. The 20% represent partial studies, the implementation of basic concepts into legislation and the establishment of a MAES working group at the national level. National ES assessment, an ES assessment and the implementation of the ES concept through ecosystem accounting is still missing.

In June 2019, the State Nature Conservancy of the Slovak Republic, the University of Constantine the Philosopher in Nitra and the Institute of Landscape Ecology of the Slovak Academy of Sciences published **the Catalogue of Ecosystem Services of Slovakia** (Mederly, Černecký et al. 2019) that presents a list of the most relevant ES in Slovakia as well as the assessment of landscape capacity in their provision. Detailed map of ecosystems of Slovakia (Černecký et al. 2019) was developed in parallel. Together, these publications create an important scientific basis and stimulus not only for the fulfillment of the EU Biodiversity Strategy 2020, but also for further research in the area of ecosystems in Slovakia, their services and various methods of their assessment and valuation.

1.3 Division of the ecosystem services

Currently, the three international ES classifications most used are :
 Millennium Ecosystem Assessment (MEA)
 Economics of Ecosystems and Biodiversity (TEEB)
Common International Classification of Ecosystem Services (CICES)

In essence, they overlap to a large extent, all distinguishing between supply services, regulatory and maintenance and cultural services (Maes et al. 2013). The MEA (2005) classification of ecosystem goods and services based on the Millennium Ecosystem Assessment (Reid et al. 2005) was the first global assessment of ecosystems. It pointed to the interdependence between ecosystems, goods and services, biodiversity and human well-being. It was also used as a basis by the TEEB and CICES classifications. The TEEB proposal (2010), which builds on the division of MEA, contains 22 ES divided into 4 main categories. TEEB has defined the concept of direct and indirect contribution of ecosystems to human well-being. In the CICES system, services are provided either by living organisms (biota) or by a combination of living organisms and abiotic processes. Abiotic outputs and services, such as the provision of minerals through their extraction or the use of wind energy, can affect ecosystem services, but are not dependent on living organisms (Kušíková 2013). CICES categorization of ES (Haines-Young & Potchin 2018) is based on existing classifications, but focuses more on ecosystems. A clear comparison of the basic ES classification systems is given in Tab. 1

Tab. 1 Main classification systems of ecosystem services (Costanza et al. In: Mederly, Černecký et al. 2019)

ES Group	Costanza et al. 1997	Category according to MEA 2005	Category according to TEEB 2010	Category according to CICES 2018
Provisioning services	Food production	Food	Food	Biomass for food Freshwater and marine plants and animals for food
	Water supply	Fresh water	Water	Surface and ground drinking water Surface and ground water for other purposes
	Raw materials	Fibers, timber	Raw materials	Biomass – timber and other fibres
	Genetic resources	Genetic resources	Genetic resources	Genetic resources of biotic origin
		Biochemicals and natural medicine	Pharmaceutical resources	Genetic material for biochemical and pharmaceutical processes
		Ornamental resources	Ornamental resources	Materials of biotic origin (ornamental resources)
				Biomass – energy resources of plant and animal origin
				Abiotic resources
Regulatory and maintenance services	Gas regulation	Air quality regulation	Air purification	Regulation of gas and air flows
	Waste regulation	Water purification, waste regulation	Waste regulation (water purification)	Regulation of waste, toxic substances and other pollutants
	Disturbance regulation (protection from storms and flood control)	Natural risks regulation	Mitigation of extreme events	Regulation of air and liquid flows
	Water regulation (irrigation, draught prevention)	Water regulation	Regulation of water flows	Regulation of liquid flows
	Erosion regulation and sediment retention	Erosion regulation	Erosion prevention	Regulation (directing) of fixed flows
	Climate regulation	Climate regulation	Climate regulation	Atmosphere composition and global climate regulation
	Soil production	Soil production (maintenance service)	Support of soil fertility	Support of soil production and composition
	Pollination	Pollination	Pollination	Support of life cycles (pollination including)
	Places of refuge (nesting and migratory habitats)	Biodiversity	Support of life cycles (nesting) Gene pool protection	Support of life cycles and habitats, protection of gene pool
	Biological control	Regulation of pest and disease spreading	Biological control	Support for pest and disease control
	Nutrition cycle	Nutrition cycle and photosynthesis, primary production		

ES Group	Costanza et al. 1997	Category according to MEA 2005	Category according to TEEB 2010	Category according to CICES 2018
Cultural services	Recreation (ecotourism, outdoor activities including)	Recreation and ecotourism	Recreation and ecotourism	Physical and experiential relationships (recreation, tourism)
	Culture (aesthetics, art, spiritual life, education and science)	Aesthetic values	Aesthetic information	Experiential relationships
		Cultural diversity	Inspiration for the culture and art	Representative relations (promotion, art)
		Spiritual and religion values	Spiritual experience	Spiritual and symbolic relationships (cultural heritage ...)
		Cognitive system and educational values	Information for learning	Intellectual relations (Willingness to protect the nature, moral aspects)

1.4 Methods for ecosystem services assessment

ES evaluation is currently an increasingly used tool for decision-making and planning. The scope of this use is wide, ranging from (environmental) awareness to creating strategic documents, setting priorities, etc. Most ES experts are in agreement that a number of methods are suitable for ES evaluation - in principle they can be grouped into three basic groups according to the main principle of evaluation and expression of results - **biophysical methods, non-monetary / socio-cultural methods** and **monetary / economic methods**. In addition, there are **cross-sectional (integrated) methods** that use several principles and often combine multiple methods (Mederly, Černecký et al. 2019). Frélichová et al. (2014) compiled an overview of ES research and valuation methods.

Non-monetary / socio-cultural methods
Kelemen et al. (2016), Chan et al. (2012) state that non-monetary approaches can be applied at different stages of ecosystem planning and management, e.g. when setting (creating) problems, mapping, valuation and decision making. These methods explore the importance, preferences, needs and requirements of people towards nature and express possible values through qualitative and quantitative measures - other than monetary ones. The expression of the multidimensional character / nature of human well-being in monetary value is only one of the possible aspects of this expression, others are e.g. symbolic, cultural, ecological, spiritual.

Non-monetary valuation (NMV) has a long tradition in some areas of environmental policy-making (eg demarcation of protected areas) and in the last decade various international initiatives have confirmed / acknowledged their role in ES valuation (e.g. MEA, TEEB, IPBES). Despite growing political pressure and scientific interest, NMV of ES does not yet represent a formalized methodological approach (Nieto-Romero et al. 2014). NMV therefore often uses indicative and informalized indicators (Seppelt et al. 2014) and leads to results whose accuracy and reliability are difficult to assess or difficult to implement. To increase the applicability of NMV, it is necessary to clarify the boundaries and terminology and consider the contextual specification of NMV techniques (Kelemen et al. 2016).

The most often used socio-cultural methods according to Santos-Martín et al. (2017) are:

- Preference assessment – a consultation method for analyzing the perception, knowledge and assessment of the need or use of the ES,
- Time use methods – determining the willingness of respondents to allow for changing the quality or quantity of the ES,
- Photo-elicitation survey – a survey of the value of a certain place in terms of ES provision based on the perception and feelings of respondents
- Narrative methods – methods using the description, a specific story to express the value of ecosystems /landscape from ES point of view,
- Participatory mapping – evaluation of ES in participatory manner, with the use of

knowledge of various interested groups of society (stakeholders)

Scenario planning – development of possible future scenarios and evaluating their relationship with the use of the ES (usually by participatory methods)

Deliberative methods – evaluation and decision-making (also in ES issues) in an open discussion with the stakeholder groups' representatives.

Biophysical methods

In the "SEEA" Environmental Economic Accounting System (European Commission 2014), the quantification of the flow of assessed services represents the value in biophysical units, where the ES is expressed as material and energy flows. Gomez-Baggethun & de Groot (sec. Mederly, Černecký et al. 2019) present the following biophysical methods for ES evaluation:

- Ecological Footprint - expresses the area of biologically productive area that the society uses for its consumption - inputs and outputs (similar to the carbon or water footprint)
- Land Cover Flow Analysis - used to monitor changes in the quality of natural capital and the multifunctionality of soil.
- Material Flow Analysis - monitors environmental inputs and outputs within the metabolism of socio-economic systems
- Life Cycle Analysis - monitors the process of a particular activity, activity, production from its inception to completion (liquidation, extinction).
- Energy / Exergy methods - focus on quantifying the amount of energy that must be invested in the performance of a given (e.g. economic) process.

An overview of ES evaluation tools based mainly on biophysical evaluation and modeling according to Neugarten et al. (2018) shows Tab. 2.

Tab. 2 Overview of ecosystem services assessment tools (Neugarten et al. In: Mederly, Černecký et al. 2019)

Name and acronym of the tool	Internet source
„Step by step" tools	
Ecosystem Services Toolkit – EST	publications.gc.ca / site / eng / 9.829253 / publication.html
Protected Areas Benefits Assessment Tool – PA-BAT	wwf.panda.org / our_work / biodiversity / protected_areas / arguments_for_protection /
Toolkit for Ecosystem Service Site-based Assessment v.2.0 – TESSA	tessa.tools /
Tools based on PC models	
Artificial Intelligence for Ecosystem Services – ARIES	aries.integratedmodelling.org
Co$ting Nature v.3 – C$N	www.policysupport.org / costingnature
Integrated Valuation of Ecosystem Services and Tradeoffs 3.4.2 – InVEST	www.naturalcapitalproject.org / invest /
Multiscale Integrated Models of Ecosystem Services – MIMES	www.afordablefutures.com
Social Values for Ecosystem Services – SolVES	solves.cr.usgs.gov
WaterWorld v.2 – WW	www.policysupport.org / waterworld

In practice, biophysical methods based on map data (geographic information systems) are often used, which allow the spatial expression of value or stocks of individual ES and their components. The so-called **"matrix method"** (eg Burkhard et al. 2009, 2014) was used to express selected ES in measuring the country's capacity to provide ecosystem services in Slovakia, e.g. in cadastral register Hriňová (Selecká 2017) and when comparing cultural ES in the territories of the micro-regions Terchovská dolina and Horný Liptov (Vrbičanová et al. 2020). According to Burkhard et al. (2014) the appeal of this method is based on its flexibility in detail and level of abstraction - from a relatively simple to a highly complex approach. The matrix model has the potential to integrate all types of data from expert results to statistical data, interview data, measurements or specialized outputs, which make it applicable in an environment where there is little data or, conversely, in a data-rich environment. Last but not least, results based on a flexible 0-5 rating system and links to geophysical spatial units (such as land cover, habitats, vegetation, soil types) in ES maps provide a wide range of applications in science as well as in decision making. The matrix method has been used in many case studies such as Kandziora et al. (2013), Kaiser et al. (2013), Vihervaara et al. (2012), Kroll et al. (2012), Nedkov & Burkard (2012), Schröter et al. (2012), matrix model in national evaluations of ES Zhiyansky et al. (2018) and others.

Monetary methods

Although the important role of ecosystems for society can be expressed in various ways (ecological, socio-cultural, economic), expression in monetary units is an important tool for raising awareness and transferring the importance of ecosystems and biodiversity to policy decision-making. Information on monetary values makes it possible to make more efficient use of limited funds by identifying where the protection and restoration of ecosystems / biodiversity is most economically necessary and where it can be provided at the lowest cost (Crossman et al. In de Groot et al. 2012). The expression of ES values in monetary units (Farley 2008) provides guidance on understanding the preferences of users (current generations) who consume them, thus enabling a better allocation of resources between competitive benefits. However, it should be noted that monetary pricing based on market prices usually does not reflect the rights / values of future generations. According to De Groot et al. (2012) the ES is out of the market and is considered a non-marketable public benefit. That is why the continuing over-exploitation of ecosystems is at the expense of the livelihoods of the poor and future generations. The provision of multiple positive ecosystem functions may decline or disappear rapidly due to overexploitation of land and natural resources, and therefore better multisectoral decision-making and nature conservation institutions in favor of sustainable use of ecosystems are necessary to better calculate public goods and services provided by ecosystems. ES monetary valuation does not mean that economic incentives are the only solution, but should be seen as complementary to other instruments such as spatial planning.

De Groot et al. (2012) evaluated 10 major biomes of the world in ES monetary units. To this end, they have produced more than 320 publications, covering more than 300 case studies. Approximately 1,350 value estimates are stored and available in the Ecosystem Service Value Database (ESVD). The resulting price of the ES package, which can potentially be provided through an "appropriate" hectare of the ecosystem, is for e.g. grass herb communities 2871 Int. $/ha/year; forests 1588 Int.$/ha/year; wetlands 25682 Int.$/ha/year, rivers and lakes 4267 Int.$ /ha/year.

Frélichová et al. (2014) identified and priced the ES provided in the Czech Republic (CZ). To estimate the total value of ecosystems in the CZ, they developed a geographically specific database of ES values with six main ecosystem types (divided into 41 categories), which provide 17 ES. A specific strategy of reviewing the literature was used to fill the database with biophysical and economic values of the ES - a total of 190 different biophysical and monetary values of the ES. The "benefit transfer" method was used to calculate the total value of ecosystems in the Czech Republic - the resulting average ES value represented 1.5 gross national product (GNP) of the Czech Republic.

Integrated methods of ES evaluation

Integrated evaluation methods represent a link between different ES evaluation methods.

Significant progress in these methods has been made thanks to scientific projects aimed at transferring research results into management and decision-making practice (OpenNESS and ESMERALDA). Integrated methods are used to summarize the overall benefits of the ES to human well-being. They also serve to decide on priorities in the use of individual types of ES, which are expressed in different units and by use of different methods. Therefore, it is not easy to interpret the results obtained with this evaluation method.

Mapping and graphic presentation of the ES

In regards to **ES presentation**, it is the **map presentations and visual displayes** that are an important tool for applying the results to the practical level. Maps can effectively present complex spatial information, and people generally prefer it to text ratings. Interest in maps in various areas or organizations, private companies and the public is constantly growing. However, it is important that the map data and the results of the ES assessment are presented sensitively and not used inadequately to create opportunities for further habitat use or ecosystems' exploitation in places where the ES is currently in unused surplus (Burkhard & Maes 2017). Burkhard & Maes (2017) deals with the issue of mapping and quantification of the ES at the EU level and various approaches to their evaluation.

There is a wide range of categorization systems, evaluation schemes, indicators, methods for ES quantification, including spatial localisation (Burkhard et al. 2014). By linking land use information with data obtained from monitoring or statistics, stocks and demand for individual ES can be assessed on different spatial and temporal scales (Burkhard et al. 2012). The typology and detailed classification of ecosystem goods and services based on 23 ecosystem functions is analyzed by de Groot et al. (2002). **The creation of a comprehensive ecosystem map (Černecký et al. 2019) and a geodatabase of habitat status is an important basis for ES assessment in Slovakia.**

The basis for ensuring the protection and sustainable use of ecosystems is the efficient use of the functions and services that the ecosystems provide. Proper functioning of ecosystems ensures their high ecological resilience and contributes to stability in ecological terms. The ES assessment and valuation is an important step in a more responsible attitude towards future generations, as it will provide us with information not only on areas of high ecological / economic value, but also on areas where the ES are overconsumed at the expense of areas that produce enough or even surplus of services. The value of the current ES is a value not only for the present but also for the future. It can be expressed in financial (monetary) values and it will change over time according to the use of the land and its ecosystems. According to Grizzetti et al. (2016) and Guerry et al. (2015), the ES concept can offer a valuable approach to linking man with nature and as well as arguments for the protection and restoration of natural ecosystems. It highlights the key role of ecosystem and biodiversity functions in promoting multiple benefits for humans. Understanding the links between natural and socio-economic systems can lead to better and sustainable use of ecosystems.

2 Procedure and methodology for the assessment of ecosystems and their services

2.1 Area assessed

The ES assessment was carried out for the whole territory of the Slovak Republic (SR), the area of which is 49,036 km^2 with 5,445,089 inhabitants (31 December 2018; STATdat 2019). The Slovak Republic has a relatively dense network of settlements, there are 2,890 independent municipalities, of which 140 are towns, of which only 2 have more than 100,000 inhabitants and 10 have more than 50,000 inhabitants (STATdat 2019). Slovakia's climate is on the border between continental and oceanic. Individual surface units of Slovakia belong to the Pannonian Basin and the Carpathians, which also results in the division into two biogeographical regions - Alpine and Pannonian. More than 40% of the territory of the republic is forested. The rivers in Slovakia spring there and they are mostly low in water, with the exception of large rivers. Most of the territory of Slovakia is occupied by the Western Carpathians, a zonal mountain range with a significant mantle structure, which is part of the Alpine-Himalayan system. The Western Carpathians are divided into several zones (Kováč & Plašianka 2003).

Slovakia has got a well developed agriculture, which uses about 40% of the country's surface. Nature protection is ensured primarily through the existence of national and European system of protected areas, namely 9 national parks, 14 protected landscape areas and a total of 1,004 small-scale protected areas. There are 642 Site of Community Importance and 41 Special Protection Areas. There are also other categories of protected areas that contribute to the protection of biodiversity in Slovakia. The ES evaluation has taken place at the national level and is available for the entire country. Based on the report under Art. 17 of the Habitats Directive, the greatest threat to ecosystems in recent years is posed mainly by agricultural activities, forestry, abandonment of traditional forms of land management, energy production processes and development of related infrastructure, construction of transport infrastructure, climate change processes, urbanization and other factors (State of nature 2015).

2.2 Data collection and ecosystem map preparation process

The map of ecosystems was prepared on the basis of data and procedures presented in the work "Ecosystems in Slovakia" (Černecký et al. 2019). ES assessment at national level requires a large amount of background data and, above all, a comprehensive and as accurate map of ecosystems as possible. For simplicity, many European countries often rely on map data from the Corine Land Cover (CLC) database only. In Slovakia, more detailed data were used in the preparation of the ecosystem map, which enabled a better and more accurate assessment. As a result, contiguous generalized map of ecosystems in Slovakia was developed using agriculture department data (agriculture and forestry), environment department data supplemented by data processed from CLC layers (CLC 2012) and selected layers from the Open streetmap (Geofabrik 2017) with habitats assigned in the EUNIS classification (EEA 2018) at various levels. This map allows for further analysis and has a variety of uses, including the assessment of ecosystem services.

The sequence of technical steps in the preparation of the ecosystem map is shown in Fig. 1. The process consisted of the following steps:

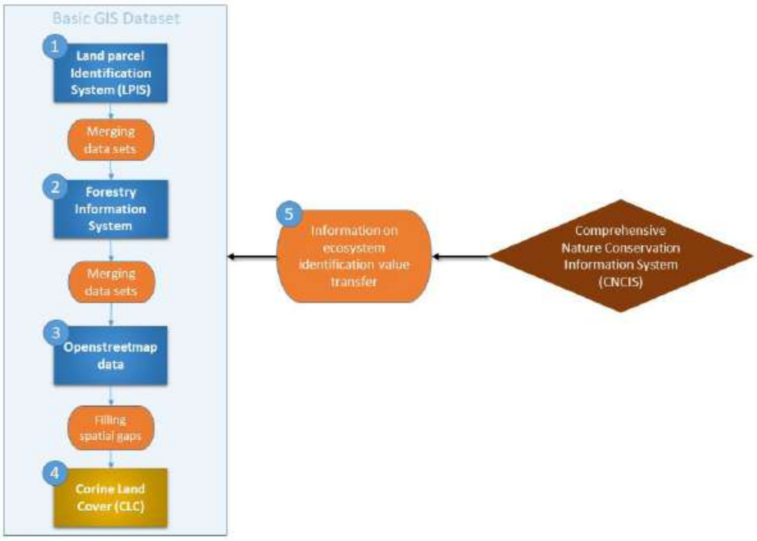

Fig. 1 Technical steps in the process of preparing an ecosystem map (source: Černecký et al. 2019)

1. The boundary of non-forest habitats was defined on the basis of LPIS system data (NPPC-VÚPOP 2018a). LPIS is a spatial information system that is the primary source of data on agricultural land use. It contains mainly attributes related to crops, but the main added value of the map is the exact spatial boundary of agricultural land mapped at a scale of 1: 5 000.
2. Published data from the National Forest Center were used as data on the spatial distribution of forest ecosystems and added to the collected data (NFC 2017). The Forest Geographic Information System is a database covering 96% of Slovak forests (with the exception of military forests and areas not defined as forest stand) with attributes defining age, tree composition, habitat identification, etc. The level of accuracy is a scale of 1:10 000.
3. Watercourses, road and rail infrastructure and elements of urban vegetation have been included in the map in order to highlight details and capture small but important basic ecological and artificial elements based on data from the Openstreetmap source (Geofabrik 2015).
4. Corine Land Cover (CLC 2012) was used as a basis for the remaining gaps in the ecosystem map where more accurate spatial data did not exist.
5. Selected attributes on habitats as a basis for the identification of ecosystems were taken from nature conservation databases. Data on the ongoing national monitoring of habitats of European importance on permanent monitoring plots were used, from which the necessary information on habitats and their quality was obtained (KIMS SNC SR, 2017). These attributes are mainly related to the assessment of the favorable status of habitats. National habitat categories have been transferred to the EUNIS habitat category (Annex 1)

All layers and components were combined into one unit and created a coherent polygon map of Slovakia. Layer overlap problems have been solved by prioritizing more accurate data sets. Undesirable properties - very small (less than 10 m2) and very thin polygons (width less than 10 m) were solved by incorporating them into larger adjacent polygons (mainly through the "eliminate" function). Fig. 2 shows the accuracy of the boundaries of the ecosystem map.

Fig. 2 Demonstration of the accuracy of the ecosystem boundaries in the process of preparing an ecosystem map (source: Černecký et al. 2019)

The accuracy of the final data set is conditioned by the spatial accuracy, specifically the input data. LPIS data were used for 45.5%, data for forest ecosystems for 34.9%, CLC data for 19.4% and Openstreetmap data for 0.2% of the area of Slovakia. Based on these data, 80% of the total area of Slovakia in the final map of ecosystems is prepared at a scale of 1: 5,000 - 1: 10, 000. For LPIS data, the minimum accuracy is defined on the basis of Art. 70 of EU guideline no. 1306/2013 at a scale of 1: 5,000. Horizontal absolute accuracy is expressed as RMSE (Root Mean Square Error) at 1.25 m (5000 x 0.25 mm = 1.25 m) or CE95 equivalent (standard error at 95% confidence interval) values. For CLC, the overall confidence rate is 85% (CLC 2012). For forest habitats, the accuracy of mapping is determined on the basis of a nationally defined standard at a scale of 1: 10,000.

In order to check the accuracy of the final data set (polygon map of ecosystems in Slovakia), a compact area with an area of 1,169 hectares was randomly selected, for which mapping of habitats / ecosystems was carried out directly in the field in 2017 - 2018 (Fig. 3). The mapping method was modified by the national standard habitat mapping method (Stanová & Valachovič 2002). The analysis of ecosystem overlap (EUNIS lvl 3) of the selected area of the final data set with ecosystems identified by field mapping (Tab. 3) shows 87.7% accuracy and 93.45% agreement of the polygon boundaries of the resulting ecosystem map (20 meter buffer was used).

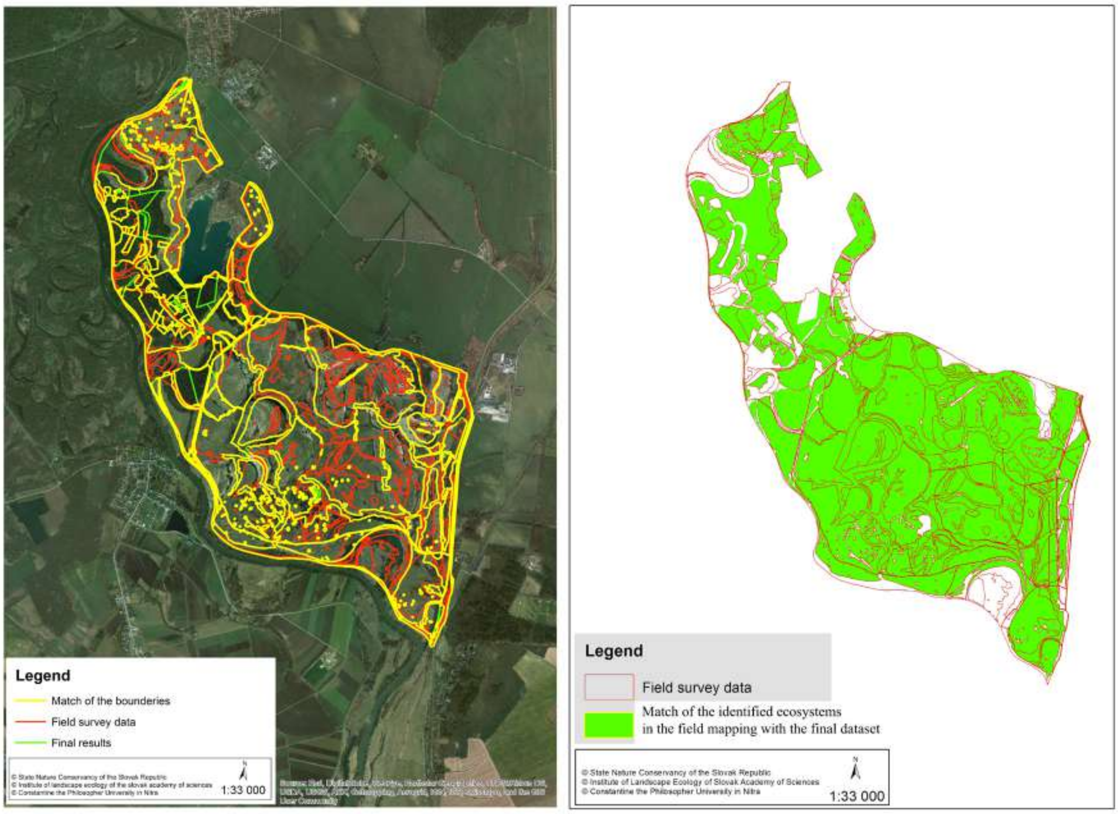

Fig. 3 Overlay of polygons of identified ecosystems from field mapping with final data set (source: Černecký et al. 2019)

Tab. 3 Overlay data from field mapping (study area) with final data set (source: Černecký et al. 2019)

Ecosystem	Studied area (m2)	Overlay area (m2)	% overlay
C1.3	252 133,53	231 961,27	92,00
C3.2	2 603 490,25	2 519 549,92	96,78
E2.2	42 810,03	0.00	0,00
E3.4	6 095 352,07	6 069 002,35	99,57
E5.4	68 997,90	58 389,14	84,62
G1.1	890 866,05	0.00	0,00
G1.2	1 737 336,63	1 371 504,91	78,94
Total	11 690 986,47	10 250 407,58	87,68

To reduce errors in the resulting data set, the ecosystem classification has been modified based on other attributes from the data set to reflect as much as possible the actual ecosystem occurring at the local level (e.g. based on the composition and representation of species in the ecosystem). If some habitats could not be identified on the basis of available data, they were classified into lower, less accurate levels of EUNIS categorization. The data processing uses the most accurate currently available agricultural data (LPIS) and spatial parts of forest ecosystems, which have been refined on the basis of LPIS data and cleared off areas where forest boundaries have encroached on agricultural land. In this way, it is guaranteed that forest areas never encroach on non-forest areas with spatial data (Fig. 4).

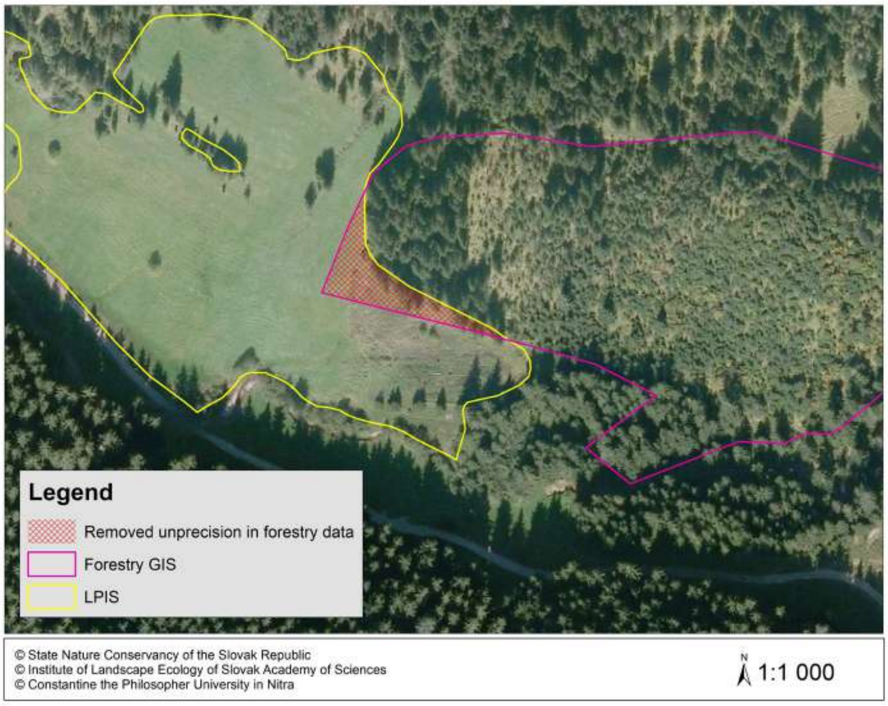

Fig. 4 Removing an inappropriate forest boundary (source: Černecký et al. 2019)

ArcGIS version 10.1 was used for all spatial analyses. Standard geoprocessing tools and functions were used in the analyses, such as *intersect, union, erase, merge, dissolve.* Some line elements were solved through the *buffer* function (watercourses). The most common *summary statistics* functions were used for summaries. The calculation of values was performed using the *field calculator* functions. Various data were used in the preparation, which required a transformation of the projection. The resulting projection is set to *S-JTSK Krovak east north.*

2.3 Assignment of ecosystem services to individual ecosystems and determination of the level of their provision

The capacity of the country (potential supply) and the actual flow of the ES create the so-called **ES supply**, which is based on potentials and additional inputs. These inputs are related to the economy and represent social, human, financial and productive investment assets. (Burkhard et al. 2014).

For a successful ES assessment, it is necessary to clearly identify which ES are provided by each ecosystem. It is also necessary to express differences in the amount of potential of ecosystems for the provision of the ES, and its supply. For this purpose, matrix evaluation and definitions according to Burkhard et al. (2012, 2014) were used:

Evaluation of the potential for providing ES (Potential, Capacity)

The potential is assessed as an optimal and maximalist variant of ES provision under ideal conditions and provided that all ecosystems are in a favorable condition and provide the ES in full measure and quality.

The ES potential is the hypothetical maximum yield from selected ES.

Evaluation of ES stock / production (Supply)

ES production refers to the capacity of a specific area that provides a specific set of ecosystem goods and services over a period of time. In this case, the stock refers to the creation of a real set of natural resources and services - the used part of the capacity. The production in this work takes into account the assessment of the quality of ecosystems and thus differs from the potential.

The expression of the potential value of Slovak ecosystems for the provision of services with the assignment of relevant ES (Fig. 5) was carried out according to the Burkhard matrix of potential ES ("ecosystem service potential matrix"). For the purposes of this assessment, the matrix has been modified and elaborated in more detail - for all habitats in the EUNIS categorization (see Chapter 3.1) - and each habitat is assigned a potential index value on a scale of 1 to 5 (low to very high contribution) according to the contribution of a particular ES. Services and ecosystems that do not produce the ES have zero value (0). This is not an absolute zero, but a fact that the ecosystems in question do not produce a significant amount of ES and are therefore insignificant from an evaluation point of view.

When evaluating **the supply of Slovak ecosystems** for the provision of ES (current production, Supply), the qualitative parameter of ecosystems was taken into account in comparison with the potential capacity, because only non-degraded ecosystems are able to provide services in full measure. This is a flexible modification of the matrix in Fig. 5, in which the ecosystem quality values are determined for each polygon and the final value of the index is subsequently adjusted on this basis. If the given ecosystem is degraded, the values deteriorate, and if the ecosystem is without degradation, the values in the matrix remain the same (more in Chapter 2.5).

Fig. 5 Modified Potential Matrix (Burkhard 2014) from EUNIS level 1 categories to express the potential capacity of Slovak ecosystems for ES provision elaborated into more precise habitat categories in EUNIS

Habitats - EUNIS	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 domestic	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
C1.14-Submerged carpets of stoneworts in oligotrophic waterbodies	1	2	0	5	2	3	0	3	0	3	5	0	1	0	0	0	0	0	4	5	4	0	5	0	1	5	4	4	2	3	3
C1.2-Permanent mesotrophic lakes, ponds and pools	1	2	0	5	2	3	0	3	0	3	5	0	1	0	0	0	0	0	4	5	4	0	5	0	1	5	4	4	2	3	3
C1.3-Permanent eutrophic lakes, ponds and pools	1	2	0	5	2	3	0	3	0	3	5	0	1	0	0	0	0	0	4	5	4	0	5	0	1	5	4	4	2	3	3
C1.45-Peatmoss and bladderwort communities of dystrophic waterbodies	1	2	0	5	2	3	0	3	0	3	5	0	1	0	0	0	0	0	4	5	4	0	5	0	1	5	4	4	2	3	3
C1-Surface standing waters	1	2	0	5	2	3	0	3	0	3	5	0	1	0	0	0	0	0	4	5	4	0	5	0	1	5	4	4	2	3	3
C2.121-Petrifying springs with tufa or travertine formations	2	2	0	3	2	4	1	4	1	2	3	0	0	4	2	0	0	0	0	0	1	0	0	0	0	1	2	3	0	2	2
C2-Surface running waters	0	1	0	3	3	3	0	3	0	3	5	0	2	0	0	0	0	0	3	0	4	0	5	0	3	4	4	4	2	3	3
C3.26, D5.21 Reed canary-grass ([Phalaris]) beds, Beds of large [Carex] species	2	2	0	3	2	4	1	4	1	2	3	0	0	4	2	0	0	0	0	0	1	0	0	0	0	1	2	3	0	2	2
C3.4-Species-poor beds of low-growing water-fringing or amphibious vegetation	1	3	1	1	0	1	0	1	1	2	2	5	1	2	0	4	0	0	0	0	1	3	0	0	1	1	1	2	0	3	0
C3.53-Euro-Siberian annual river mud communities	2	2	0	3	2	4	1	4	1	2	3	0	0	4	2	0	0	0	0	0	1	0	0	0	0	1	2	3	0	2	2
C3.55221-Carpatho-Alpine small-reed river gravel communities	2	2	0	3	2	4	1	4	1	2	3	0	0	4	2	0	0	0	0	0	1	0	0	0	0	1	2	3	0	2	2
C3-Littoral zone of inland surface waterbodies	1	2	0	5	2	3	0	3	0	3	5	0	1	0	0	0	0	0	4	5	4	0	5	0	1	5	4	4	2	3	3
D1.11-Active, relatively undamaged raised bogs	5	4	0	4	4	4	2	3	2	3	4	0	2	0	0	0	0	0	0	0	1	2	1	0	0	3	2	3	0	2	4
D1.12-Damaged, inactive bogs	5	4	0	4	4	4	2	3	2	3	4	0	2	0	0	0	0	0	0	0	1	2	1	0	0	3	2	3	0	2	4
D1-Raised and blanket bogs	5	4	0	4	4	4	2	3	2	3	4	0	2	0	0	0	0	0	0	0	1	2	1	0	0	3	2	3	0	2	4

D2.2, D2.3 Poor fens and soft-water spring mires, Transition mires and quaking bogs	2	2	0	3	2	4	1	4	1	2	3	0	0	4	2	0	0	0	0	0	1	0	0	0	0	1	2	3	0	2	2
D4.1-Rich fens, including eutrophic tall-herb fens and calcareous flushes and soaks	2	2	0	3	2	4	1	4	1	2	3	0	0	4	2	0	0	0	0	0	1	0	0	0	0	1	2	3	0	2	2
D5.24-Fen beds of great fen sedge ([Cladium])	2	2	0	3	2	4	1	4	1	2	3	0	0	4	2	0	0	0	0	0	1	0	0	0	0	1	2	3	0	2	2
D6.14-Swards of Carpathian travertine concretions	2	2	0	3	2	4	1	4	1	2	3	0	0	4	2	0	0	0	0	0	1	0	0	0	0	1	2	3	0	2	2
E1.11-Euro-Siberian rock debris swards	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E1.12-Euro-Siberian pioneer calcareous sand swards	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E1.2211, E1.2932 Pre-Noric sub-Pannonic steppes, Circum-Pannonic siliceous pale fescue grasslands	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E1.231-Sub-Pannonic meadow-steppes	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E1.291-Calci-orophile pale fescue grasslands	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E1.2C-Pannonic loess steppic grassland	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E1.2F2-Pannonic open sand steppes	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E1-Dry grasslands	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E2.1-Permanent mesotrophic pastures and aftermath-grazed meadows	2	1	0	1	0	1	1	1	0	2	4	0	1	5	5	0	0	0	0	0	2	0	0	0	5	2	2	2	0	3	1
E2.22-Sub-Atlantic lowland hay meadows	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E2.31, E4.51 Alpic mountain hay meadows, Subalpine yellow oatgrass hay meadows	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E2.6-Agriculturally-improved, re-seeded and heavily fertilised grassland, including sports fields and grass lawns	2	2	2	2	2	2	2	1	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	1	0	2	1
E3.41-Atlantic and sub-Atlantic humid meadows	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E3.43-Subcontinental riverine meadows	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E3.51-Purple moorgrass ([Molinia]) meadows and related communities	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E3-Seasonally wet and wet grasslands	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E4.11-Boreo-alpine acidocline snow-patch grassland and herb habitats	0	1	0	1	1	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	2	1	1	3	0	2	1
E4.12-Boreo-alpine calcicline snow-patch grassland and herb habitats	0	1	0	1	1	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	2	1	1	3	0	2	1
E4.3171-Western Carpathian mat-grass swards	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E4.34-Alpigenous acidophilous grassland	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E4.4-Calcareous alpine and subalpine grassland	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E4-Alpine and subalpine grasslands	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E5.41-Screens or veils of perennial tall herbs lining watercourses	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E5.4-Moist or wet tall-herb and fern fringes and meadows	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E5.5514 Carpathian tall herb communities	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E5.5-Subalpine moist or wet tall-herb and fern stands	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E5-Woodland fringes and clearings and tall forb stands	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
E6.2-Continental inland salt steppes	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3

E-Grasslands and lands dominated by forbs, mosses or lichens	5	2	0	1	3	4	5	1	1	1	2	0	1	2	3	0	0	0	0	0	5	1	0	0	2	3	4	5	1	3	3
F2.24-Alpigenic high mountain crowberry - heather heaths	3	4	0	2	3	3	2	2	2	2	3	0	1	1	1	0	0	2	0	0	2	1	0	0	0	4	4	5	1	2	4
F2.32-Subalpine and oro-boreal willow brush	3	4	0	2	3	3	2	2	2	2	3	0	1	1	1	0	0	2	0	0	2	1	0	0	0	4	4	5	1	2	4
F2.33-Subalpine mixed brushes	3	4	0	2	3	3	2	2	2	2	3	0	1	1	1	0	0	2	0	0	2	1	0	0	0	4	4	5	1	2	4
F2.461-Carpathian subal-pine mountain pine scrub	3	4	0	2	3	3	2	2	2	2	3	0	1	1	1	0	0	2	0	0	2	1	0	0	0	4	4	5	1	2	4
F3.16-Common juniper scrub	3	4	0	2	3	3	2	2	2	2	3	0	1	1	1	0	0	2	0	0	2	1	0	0	0	4	4	5	1	2	4
F3.24-Subcontinental and continental deciduous thickets	3	4	0	2	3	3	2	2	2	2	3	0	1	1	1	0	0	2	0	0	2	1	0	0	0	4	4	5	1	2	4
F4.2-Dry heaths	3	4	0	2	3	3	2	2	2	2	3	0	1	1	1	0	0	2	0	0	2	1	0	0	0	4	4	5	1	2	4
F9.111-Pre-Alpine willow-tamarisk brush	3	4	0	2	3	3	2	2	2	2	3	0	1	1	1	0	0	2	0	0	2	1	0	0	0	4	4	5	1	2	4
FB.4-Vineyards	1	1	1	1	0	1	1	0	1	1	1	4	1	0	0	0	0	1	0	0	0	0	0	0	0	3	2	3	0	5	0
FB-Shrub plantations	1	1	1	1	0	1	1	0	1	1	1	4	1	0	0	0	0	1	0	0	0	0	0	0	0	3	2	3	0	5	0
G1.111-Middle European white willow forests	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.121-Montane grey alder galleries	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.21-Riverine ash - alder woodland, wet at high but not at low water	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.22-Mixed oak - elm - ash woodland of great rivers	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.4-Broadleaved swamp woodland not on acid peat	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.51-Sphagnum birch woods	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.61-Medio-European acidophilous beech forests	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.63-Medio-European neutrophile beech forests	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.65-Medio-European subalpine beech woods	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.66-Medio-European limestone beech forests	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.737-Eastern sub-Mediterranean white oak woods	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.76-Balkano-Anatolian thermophilous oak forests	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.7A1-Euro-Siberian steppe oak woods	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.81-Atlantic pedunculate oak - birch woods	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.87-Medio-European acidophilous oak forests	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.A16-Sub-continental oak - hornbeam forests	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.A41-Medio-European ravine forests	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G1.D-Fruit and nut tree orchards	2	2	2	2	1	2	2	2	5	3	2	4	1	0	0	0	2	2	0	0	0	2	0	0	0	3	2	2	0	4	1
G2-Broadleaved evergreen woodland	2	2	2	2	1	2	2	2	5	3	2	4	1	0	0	0	2	2	0	0	0	2	0	0	0	3	2	2	0	4	1
G3.1B-Alpine and Carpathian subalpine spruce forests	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	4
G3.1C-Inner range montane spruce forests	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	4
G3.1-Fir and spruce woodland	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	4
G3.25-Carpathian larch and Arolla forests	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	4
G3.442-Carpathian relict calcicolous Scots pine forests	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	4
G3.4-Scots pine woodland south of the taiga	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	4
G3.E-Nemoral bog conifer woodland	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	4
G3-Coniferous woodland	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	4
G4-Mixed deciduous and coniferous woodland	5	5	5	3	5	5	5	4	4	5	5	0	1	1	0	2	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5
G-Woodland, forest and other wooded land	5	5	5	3	5	5	5	4	4	4	4	0	1	1	0	1	5	5	0	0	5	3	0	0	0	5	5	5	3	4	5

H2.31-Alpine siliceous screes	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	3	3	2	2	1
H2.32-Medio-European upland siliceous screes	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	3	3	2	2	1
H2.44-Carpathian calcareous screes	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	3	3	2	2	1
H2.61-Peri-Alpine thermophilous screes	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	3	3	2	2	1
H2-Screes	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	3	3	2	2	1
H3.11-Middle European montane siliceous cliffs	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	3	3	2	2	1
H3.25, H3.42 Alpine and sub-mediterranean chasmophyte communities, Northern wet inland cliffs	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	3	3	2	2	1
H3.62-Sparsely vegetated weathered rock and outcrop habitats	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	3	3	2	2	1
H5-Miscellaneous inland habitats with very sparse or no vegetation	1	2	0	5	2	3	0	3	0	3	5	0	1	0	0	0	0	0	4	5	4	0	5	0	1	5	4	4	2	3	3
I1-Arable land and market gardens	1	2	1	2	0	1	0	1	1	2	2	5	5	5	0	5	0	0	0	0	1	3	0	0	2	1	1	2	0	3	0
I2.2/P-85.2 Small-scale ornamental and domestic garden areas/city parks	2	2	2	2	2	2	2	1	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	1	0	2	1
J1.6-Urban and suburban construction and demolition sites	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	2	0
J1.7-High density temporary residential units	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	3	2	2	1	0
J1-Buildings of cities, towns and villages	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	3	2	2	1	0
J2.1-Scattered residential buildings	0	0	0	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	3	2	2	2	2	0
J2-Low density buildings	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0
J3-Extractive industrial sites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3	0	0	2	0	1	0
J4.2-Road networks	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
J4.3-Rail networks	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
J4.4-Airport runways and aprons	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J4.5-Hard-surfaced areas of ports	0	0	0	0	0	0	3	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	1	0
J4-Transport networks and other constructed hard-surfaced areas	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
J6-Waste deposits	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X07-Intensively-farmed crops interspersed with strips of natural and/or semi-natural vegetation	1	2	1	1	0	1	1	1	2	3	2	4	2	2	1	4	0	1	0	0	1	2	0	0	1	2	2	2	0	3	0
X09-Pasture woods (with a tree layer overlying pasture)	2	1	0	1	0	1	1	1	0	2	4	0	1	5	5	0	0	0	0	0	2	0	0	0	5	2	2	2	0	3	1
X10-Mosaic landscapes with a woodland element (bocages)	2	1	0	1	0	1	1	1	0	2	4	0	1	5	5	0	0	0	0	0	2	0	0	0	5	2	2	2	0	3	1
X25-Domestic gardens of villages and urban peripheries	0	0	0	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	3	2	2	2	2	0

2.4 Qualitative assessment of ES

In assessing the ES provided, the relationship between the quality and quantity of ES provided and the state of the ecosystems themselves is demonstrated. Maes (2012) demonstrated **a clear relationship between habitat status and ES provision as such**, and stated that habitats in better condition have a higher ability to provide ES in higher quality and quantity, while demonstrating that ecosystem restoration has a positive impact on habitat status.

On the basis of reporting under Art. 17 of the Habitats Directive submitted by the Member States, it can be noted that as regards terrestrial ecosystems in the European Union (EU), the biggest issue for all groups of birds, species and habitats is the agriculture and man-made changes in natural conditions. As far as agriculture is concerned - the biggest problem is a change in cultivation practices, excessive or insufficient grazing of cattle, including the abandonment of grazing systems, or non-grazing. In connection with changes in natural conditions, these are changes in hydrological conditions and changes in conditions of the water bodies (their functioning) caused by man, fragmentation of habitats and abstraction of water from groundwater. This statement is in line with the assessment under the Water Framework Directive, in which agriculture and hydromorphology have been identified as the main threats affecting water bodies (State of Nature 2015).

In Slovakia, detailed monitoring of the state of habitats and species of European importance at more than 10,000 permanent monitoring sites - TML - was recently performed in 2013-2015 (Šefferová Stanová et al. 2015, Janák et al. 2015). The results of the monitoring, in which a total of more than 300 experts were involved, were used for those ecosystems at the local level where TMLs are located and their **favorable condition** is evaluated. The condition in the field was assessed according to the methodology of monitoring habitats and species of European importance (Saxa et al. 2015). Data from monitoring also serve as a basis for generalized evaluation within the report according to Art. 17 of the Habitats Directive. The condition was evaluated in three categories, favorable (Fabourable - FV), unsatisfactory (Unfavourable - U1) and bad (Bad - U2). The resulting status was then assigned to those ecosystems at the local level where the monitoring of the status of habitats and species of European importance was performed and the data were related to individual polygons in the ecosystem map.

In the remaining part of the ecosystems, where detailed field monitoring was not performed, the assessment was performed on the basis of the processing of additional data and analyses listed below. In forest habitats, the quality and quantity of ES provision are mostly influenced by the age of the stand and interventions in the form of deforestation, and in non-forest areas it is, on the contrary, overgrowth and secondary succession.
In order to take into account the above-mentioned impacts and threats, an analysis of the overlap of the map of ecosystems with deforestation and growth of forest, excluding forest woody vegetation was prepared on the basis of data from Hansen et al. (2013). The analysis was performed on forest and non-forest ecosystems separately. Hansen et al. (2013) processed in detail satellite images from the territory of Slovakia from the years 2000 - 2015 and identified the places of increase and decrease of trees / bushes with a specified accuracy per raster unit of 25 m. Basically, any significant decrease / increase is identified and captured, even in the case of a relatively small area of change in the increase / decrease of trees. Based on the mentioned data, the data on the increase and decrease of the tree layer were recalculated and incorporated into the attributes of the layer of the ecosystem map and were taken into account as another parameter for evaluation, which affects the value of ES provision. The data presented in the analysis mentioned are in different values of increase or decrease, but the difference had to be obvious. Nevertheless, it is not possible to deduce the quantity of increase / decrease of wood mass. It is only an areal expression of the change based on analyses performed using satellite images in which changes in stands were identified, but not the quantity of loss itself; which for evaluation purposes was not even necessary. **For forest habitats**, the basic quality index for ES provision was determined **on the basis of the intervention in the stand and the age of the stand** as follows:

- Deforestation over 50% of the stand area in the years 2000 - 2015 = U2
- Deforestation between 10 - 50% of the stand area in the years 2000 - 2015 = U1
- Deforestation below 10% of the stand area or no intervention in the years 2000 - 2015 = FV

The age of the stand was taken into account as follows:

- calamity = U2
- 0-49 year = U2
- 50-99 years = U1
- 100 and more years = FV

For selected ES in forest ecosystems, the fact of the presence of **forest roads**, which may have an impact on the potential to provide regulation of natural disasters and erosion, was also taken into account.

In the case of **non-forest habitats**, specifically group E - grass-herbaceous habitats in the EUNIS categorization, mainly permanent grasslands - meadows and pastures - were qualitatively assessed. The biggest identified threat, as deducted from monitoring and reporting according to Art. 17 of the Habitats Directive is **gradual overgrowth and secondary succession**. In case the results of direct field monitoring were not available, the following approach was taken into account:

- In the years 2000 - 2015: 100 - 50% of the overgrown area = U2
- In the years 2000 – 2015: 50- 10 % of the overgrown area = U1

In the years 2000 – 2015: 10 – 0 % of the overgrown area = FV

For the remaining ecosystems (this is only a minority of the total set of ecosystems, e.g. some aquatic ecosystems) for which no local assessment was available, assessment data for the reporting under Article 17 of the Habitats Directive for the period 2007-2012 (Černecký et al 2014) were used, which assesses the status of habitats at the level of the biogeographical region and contains various qualitative data that are usable in ES assessment, eventhough not at the local level, but only at the national level.

For **aquatic habitats**, the evaluation from the monitoring of habitats of European importance at the local level was used (Šefferová Stanová et al. 2015), especially data from the Water Framework Directive reporting were processed. Specifically, ecological status of waters in the years 2009-2012, where from data for the assessment of the quality of individual aquatic ecosystems was transferred. Spatial identification was an issue, as the spatial representation of waters was highly inaccurate in the Water Framework Directive reporting. Therefore, more precise watercourse boundaries had to be identified in the ecosystem map and subsequently assigned the assessment attributes from the Water Framework Reporting. Attributes on the overall ecological status of waters by streams and reservoirs were used on a scale of 1 - 5 (1 very good status - 5 poor status) and subsequently converted to a three-point scale for uniformity of ecosystem status assessment as follows: 1 and 2 - favorable status (FV), 3 - unfavorable inadequate condition (U1), 4 and 5 - unfavorable bad condition (U2).

Another parameter prepared was the average **slope.** It was processed on the basis of the digital terrain model (DTM) of Slovakia (GISAT 2007). A slope raster (Fig. 6) was created from the raster base in ArcGIS using the *slope* function (Fig. 6), then it was converted into a vector form and the data were converted as an attribute (average slope of a given polygon) into an ecosystem map. Slope plays an important role in the ES, such as erosion control, natural disaster control and more.

Soil fertility is an important factor influencing mainly provision ES focused on the cultivation of crops, biomass, livestock feed, etc. To differentiate the potential and supply of these ES, we took into account the processed digital map of soil fertility (Lieskovský 2017). Based on the fertility percentage of the soil, the individual polygons "I0 - arable land" in the ecosystem map were classified into three categories:

0-33,33 – less fertile soil – U2
33,33 – 66,66 – average fertile soil – U1
66,66 – 100 – highly fertile soil - FV

Based on the above categories, the supply ES values for each polygon were adjusted. In case there was an average fertile soil in the given polygon, the value was reduced by one point. If there was a less fertile soil in the given polygon, then the value of the ES provisioning index was reduced by 2 points for the individual evaluation.

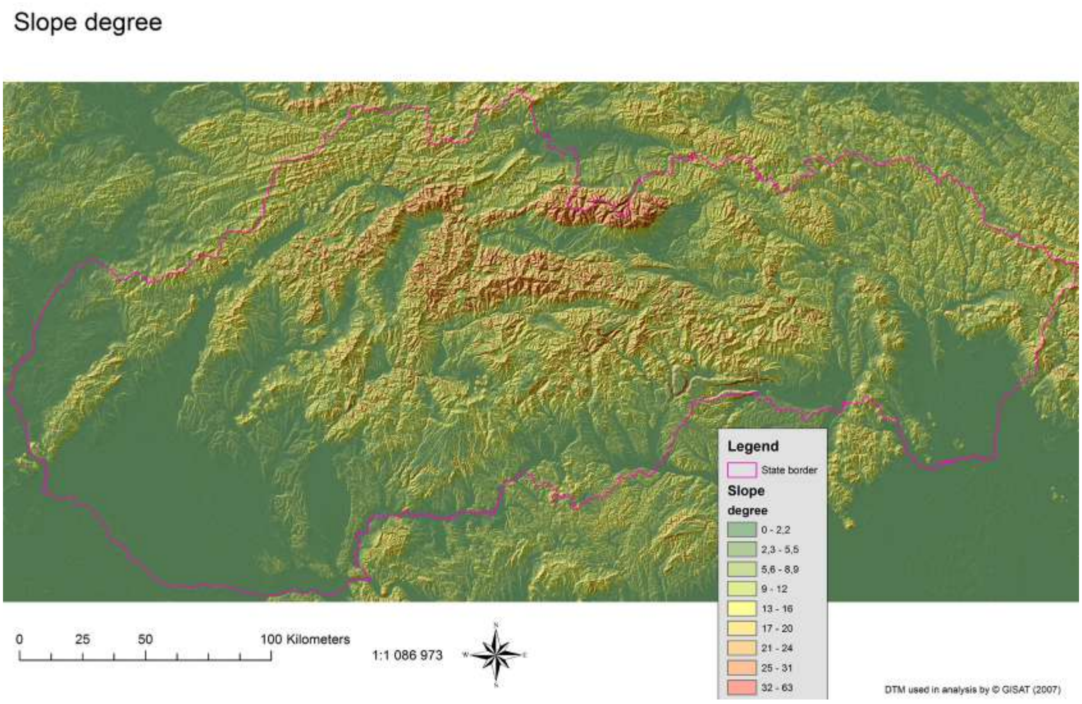

Fig. 6 Produced slope map in Slovakia based on DTM

Summary of the indexing method (Tab. 4): The qualitative assessment for all categories of ecosystems was reflected in the basic geodatabase of the ecosystem map and served as a basis for refining the assessment of the ES themselves. If the quality rating was set in the FV category, the basic index remained unchanged. If the value was U1, then one index point was deducted and if the final rating was U2, then two index points were deducted. The result could not go into negative in order to avoid misinterpretation of the data.

Tab. 4 Overview of qualitative parameters and their effect on the final evaluation of the ES

Basic ecosystems	Basic quality parameters for ES evaluation	Retaining the original index value (FV)	Subtraction of one index point (U1)	Subtraction of two index points (U2)
Non-forest habitats	Secondary succession	0-10 %	10-50 %	Above 50 %
Forest habitats	Interventions in the stands	0-10 %	10-50 %	Above 50 %
	Age of the satnds	100 years and older	50 – 100 years	Up to 50 years
Aquatic habitats	Ecological status of waters	Level 1 and 2	Level 3	Level 4 and 5
Arable land	Soil fertility	66,66 – 100 %	33,33 – 66,66 %	0-33,33 %
Habitats on permanent monitoring sites	Assessment of favorable state at the monitoring site	Favourable	Unfavourable	Bad
Other habitats for which no other data existed	Assessment of the favorable state at the level of the bioregion in the reporting according to Art. 17 of the Habitats Directive	Favourable	Unfavourable	Bad

2.5 Valuation procedure for individual ecosystem services (Quantitative assessment of ES)

Based on a comprehensive nationwide map of ecosystems and the subsequent assignment of relevant ES and their potential and production on a scale of 0 to 5, it is possible to assign values expressed in EUR/ha/year to each ecosystem. According to the area of individual ecosystems, it is possible to recalculate unambiguously for each polygon the **monetary value** of individual ES, as well as to determine the total value of ES (for all ecosystems together). Most ES have been valued using the ***value transfer*** method (Liu et al. 2010, Wilson & Hoehn 2006). The transfer of values is a procedure that uses the findings of existing studies (from other territories) and applies them in a new context.

As part of the project "TD010066 Integrated Assessment of Ecosystem Services in the Czech Republic", the Czech Republic has developed a comprehensive database that contains a total of 121 data on the economic value of the ES and published an overview of basic values (Frélichová et al. 2014). The meta-analysis of data performed in the Czech Republic on the ES value was the collection of all relevant published data, especially in the European environment (more than 90%) and thus provides a relatively comprehensive picture of **average values provided by the ES on a global scale expressed in EUR / ha / year.** It should be noted that at the time of preparation of the documents, no other comprehensive and appropriate valuation of individual ES obtained by a uniform approach existed, and it is for this reason that these values were used. The work of Czech experts was published in 2014 and it is therefore necessary to always take into account the fact of inflation in the range of 3-5% for each subsequent year in addition to the resulting amounts. Thus, the average values expressed in EUR/ha of area are based on the robust basis of the collected data (Tab. 5) and these were used as a basis for the economic evaluation of the ES in Slovakia.

Tab. 5 Overview of used economic values of ecosystem services (EUR/hectares/year) (source: Frélichová et al. 2014 own processing)

Category of the service	Ecosystem service	Average value (EUR/ha/year)
Supply	Biomass production	421,39
	Fish production	107,54
	Game production	9,91
	Non-forest products	57,23
	Timber production	6912,09
	Water production	32,43
Regulatory	Air quality regulation	266,33
	Climate regulation	4015,78
	Disaster regulation	8456,19
	Erosion regulation	5766,57
	Nutrient regulation	200,10
	Pest control	7,31
	Pollination	1378,76
	Water outflow regulation	1373,14
	Water quality regulation	1210,67
Cultural	Aesthetic value	5971,94
	Recreation	2190,52

The average values in EUR (Frélichová et al. 2014), which were used in the evaluation, corresponded to the level, in our case on a scale / value, of **"3" as the average value of the service provided to the given ecosystem.** Average values in EUR were increased by 1/3 for one index point in case of ES provision to given ecosystems at level "4" and "5" and decreased by 1/3 for one index point at level "1" and "2". Ecosystems that provide the ES to a significant extent with an index above the level "3" had the values increased by 1/3 in the case of index "4" and by up to 2/3 of the average value per hectare in the case of index value "5". Conversely, in case of ecosystems that provide a given ES in value "2", these values have been reduced by 1/3 and in the case of index value "1" by 2/3.

For services related to plant, animal provision (crops) and fiber - fiber (wood only), the national market price was used for the valuation of services, as these data were not presented in the work of Frélichová et al. (2014). Market prices are a simple and direct way of evaluating goods and services according to currently valid price lists.

The following calculation was used to calculate crop production in EUR/ha:

current production and sales of agricultural production in EUR / ha of agricultural land - crop production = 391.75, - EUR

The following calculation was used to calculate livestock production in EUR/ha:

current production and sales of agricultural production in EUR/ha of agricultural land - animal production = 472,36, - EUR

The following calculation was used to calculate the fiber production in EUR/ha:

50.40 EUR (price list Lesy SR in 2018) * 241 m3 (average number per 1 ha based on forestry statistics) = 12,050 EUR / ha

The following calculation was used to calculate firewood production in EUR/ha:

50.40 EUR (price list price Lesy SR in 2018) * 241 m3 (average number per 1 ha based on forestry statistics) = 12,050 EUR / ha

The amounts were again adjusted for the value of the index, increased or decreased by 1/3 for each index point different from the average value of index 3, which was 100%, and thus at 3 the average values just given were used.

A modified production matrix (Burkhard et al. 2014) with assigned values in EUR / ha, which combines the average ES values according to Frélichova et al. (2014) is given in Annex 2 and Annex 3.

Based on the above conversions of average amounts to indices, it was possible to calculate the maximum unit value of a given ES in financial terms. This value represents the average price per hectare increased by 2/3 according to the rules mentioned above and is the maximum value that the ES can reach for an index of 5.

Individual **values in EUR** for polygons were always related on the basis of acreage through the following recalculation:

*((maximum unit value of the given ES in EUR/5) * ES index in the given polygon for potential or supply)) * area in ha = total ES value in EUR for the given polygon/year for potential or supply*

2.6 Summary assessment of individual services

Within the summary assessment, absolute and relative values were determined for 2 indicators - potential and supply; and their comparison was made in tabular and graphical form (Chapter 3). Each major group of ecosystems had the average values of the index determined independently of each other, and the summary average index was calculated on the basis of a weighted average according to the acreage of the individual ecosystems. Monetary values were calculated for all ecosystems together and also for the categories - potential and supply. Subsequently, the results for the ES groups, namely regulatory, provisioning and cultural, were evaluated. During this evaluation, summary maps of all ES in a given category were prepared in such a way that the values of the indices were again averaged and as a result gave the value of the given ES group. Monetary values were calculated for regulatory, provisioning and cultural services, for each group separately. The results were again divided into categories for potential, supply and balance in tabular and graphical form. Summary evaluation for all services was not performed because the so-called "trade-off" effect would play an important role, especially in case of summarizing regulatory and cultural ES vs. provisioning services. Only the total monetary value of all ES together was calculated without taking into account the "trade-off" effect.

3 Results

3.1 Classification of ecosystems in Slovakia and their representation

The resulting map of ecosystems in Slovakia represents a complex spatial geodatabase with identified ecosystems for the entire territory of the state. The map of Slovakia's ecosystems contains **1,033,905 unique polygons,** with an average size of 4.9 hectares. Examples from the map of ecosystems according to the regions of Slovakia are shown in Fig. 7. The smallest polygon has a size of 0.00001 hectare and the largest 2,839 hectares - it is a large continuous body of water with one type of ecosystem (water dam). The size of polygons depends on the type of ecosystems. The most accurate data available were used to define the boundaries of individual ecosystems and landscape features. By combining a number of data sources, it was possible to examine the extent to which Slovak ecosystems can be assigned to different levels of EUNIS habitat classification (Tab. 6). **Most of the map (more than 600,000 polygons) can be distinguished at EUNIS level 4 (45 different habitat types) and higher.**

Tab. 6 Number of different habitat types at different levels of EUNIS (source: Černecký et al. 2019)

Classification of habitat (EUNIS)	Number of types of ecosystems	Area (km²)	% from the area of Slovakia
1	2	35.01	0.07
2	20	18,132.20	36.98
3	30	7,648.28	15.6
4	45	18,619.83	37.97
5	13	4,161.59	8.49
6	3	417.78	0.85
7	1	20.93	0.04
Spolu	114	49,035.62	100

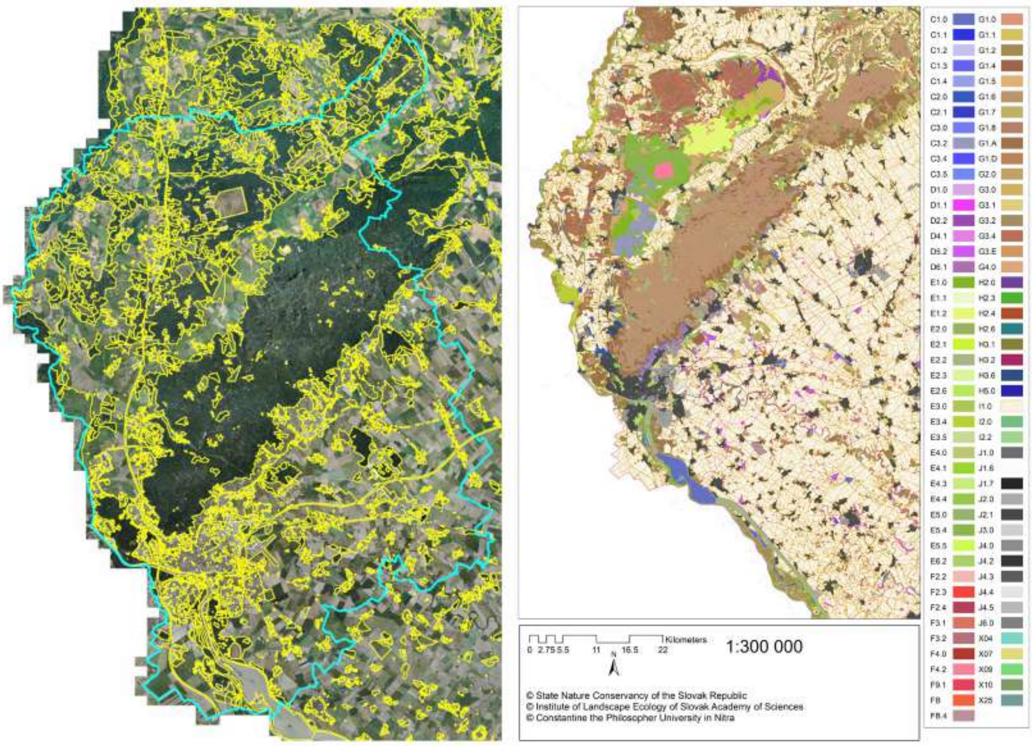

Fig. 7 Map of ecosystems of the Bratislava region – EUNIS level 3 – codes of habitats in annex 1 (source: Černecký et al. 2019)

The final map of Slovakia's ecosystems contains different levels of EUNIS ecosystems classifica tion and their accuracy. The map in Fig. 7 is figured at EUNIS level 3, supplemented by EUNIS level 2 in places where it was not possible to obtain more detailed data on habitat identification, thus filling in the blanks in the final map. The map is available online at http://maps.sopsr.sk/wms-ekosystemy?request=getCapabilities.

EUNIS level 1 – an overview

The largest ecosystem in Slovakia, from the EUNIS 1 classification point of view, are **Woodland, forest and other wooded land** with a total area of 1,853,076.26 hectares (all "G" categories of the EUNIS) and a share of **38 % of the total area of Slovakia**. A large part of the territory of Slovakia is covered by non-forest habitats with an area of 1,222,864.80 hectares ("C, D, E, F, H" of the EUNIS category). Regularly or recently cultivated agricultural, horticultural and domestic habitats (including gardens, vineyards, etc.) occupy 1,402,798.33 hectares of Slovakia ("I" category EUNIS). Habitat complexes ("X" category EUNIS) cover 112,427.74 hectares of Slovakia. The area of Constructed, industrial and other artificial habitats takes up 303,102 hectares ("J" category EUNIS). The rarer Mires, bogs and fens cover only 0.43% of Slovakia. An overview of all habitat categories at the EUNIS 1 level, including their frequency, area and percentage from the territory of Slovakia is shown in Tab. 7.

Tab. 7 Overview of habitat categories at EUNIS 1 level including their frequency, area and percentage from the territory of Slovakia (source: Černecký et al. 2019)

EUNIS level 1 classification	Number of polygons	Area (hectares)	% from the area of Slovakia
C – Inland surface waters	12,601	68,262.75	1.39
D – Mires, bogs and fens	2,110	20,955.13	0.43
E – Grasslands and lands dominated by forbs, mosses or lichens	137,671	1,031,933.78	21.06
F – Heathland, scrub and tundra	5,889	101,565.17	2.07
G – Woodland, forest and other wooded land	787,208	1,853,076.26	37.82
H – Inland unvegetated or sparsely vegetated habitats	388	5,931.97	0.12
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	58,088	1,402,798.03	28.63
J – Constructed, industrial and other artificial habitats	3,970	303,102.41	6.19
X – Habitat complexes	25,980	112,435.44	2.29
Overall	1,033,905	4,900,060.94	100

EUNIS level 4 – an overview

From the point of view of individual EUNIS levels with an accuracy similar to the Catalogue of Habitats of Slovakia (Stanová et al. 2002), the most suitable level is 4. At this level of classification**, the most widespread** type of forest **ecosystems is the Medio-European neutrophil beech forests** (G1.63) and the most widespread type of non-forest habitats is the **Sub-Atlantic lowland hay meadows** (E2.22). **The rarest** types of ecosystems are Fen beds of great fen sedge (Cladium) (D5.24) - a total of 6 polygons, Submerged carpets of stonewort in oligotrophic waterbodies - a total of 12 polygons and Damaged, inactive bogs - 14 polygons. Other rare habitats related to sands, peatlands, mountain and xerothermic habitats have also been identified. Several rocky habitats have been identified with a relatively small representation and small area, however, there there is rather a lack of data in this case, as t the rocky habitats have not been sufficiently mapped to date and other data sources do not contain information on this type of ecosystem.

3.2 The quality of ecosystems and the relationship to the provision of ecosystem services

The quality of ecosystems and their relationship to the quality of ES provision is evident. The methodological procedure for assessing the quality of ecosystems is described in Chapter 2.4. The results are important in order to refine the ES assessment and to distinguish between potential capacity of ecosystems to provide ES and the actual ES stocks. The current trend is rather negative in terms of the quality of ecosystems, there is a uniformization of land management, the extinction or transformation of ecosystems into degraded areas in many places takes place constantly. Constant processes of secondary succession, low age of stands, intensive interventions in forest stands, calamities, degradation of arable land fertility, deterioration of habitats and species living in Slovakia, unfavourable ecological status of waters - these are all factors that significantly affect the quality of ES for man himself in a negative sense.

Non-forest habitats undergo changes over time. An increase in twoody species and shrubbery on an area of 68,809.70 ha has been identified in ecosystems that are not part of the forest land from 2000 to 2015, based on the analysis using data from Hansen et al. (2013). In the same period, however, there was a loss of trees and shrubbery in non-forest habitats on an area of 149,504.95 ha. It should be noted that although secondary succession has declined, these are mostly larger areas that are uniformly managed and areas important for biodiversity conservation remain under secondary succession pressure. As an example, peatlands and moors are very important in terms of providing ES such as global climate regulation, local climate regulation, regulation of water regime and many others, however, an interest in their management is insufficient and they gradually overgrow in many places and subsequently disappear.

Forest habitats (EUNIS "G") show an increase in woody species on an area of 45,882.02 ha and a decrease in the area of 190,612.53 ha during the time period 2000 - 2015. In terms of areal expression it is evident that the increase during the mentioned period was significantly less than the area loss of woody species. An important role in these values were also played by calamities, which significantly contributed to the loss of the area continuously covered with woody species. In any case, in areas where older trees are missing, the quality of ES provided is also fundamentally affected and these facts must be taken into account in ES assessment.

The results of analysis described in Chapter 2.6 can be summarized in the statement that the **quality of 40% of Slovakia's ecosystems is favourable (FV), 21% unfavourable - inadequate (U1) and 39% unfavourable - bad (U2)** as seen in Fig. 8. In this case, it is a comprehensive analysis, which included data from field monitoring, as well as the data mentioned above, based on which the quality was determined for all ecosystems in Slovakia - **each of the 1,033,905 polygons has a determined individual quality.**

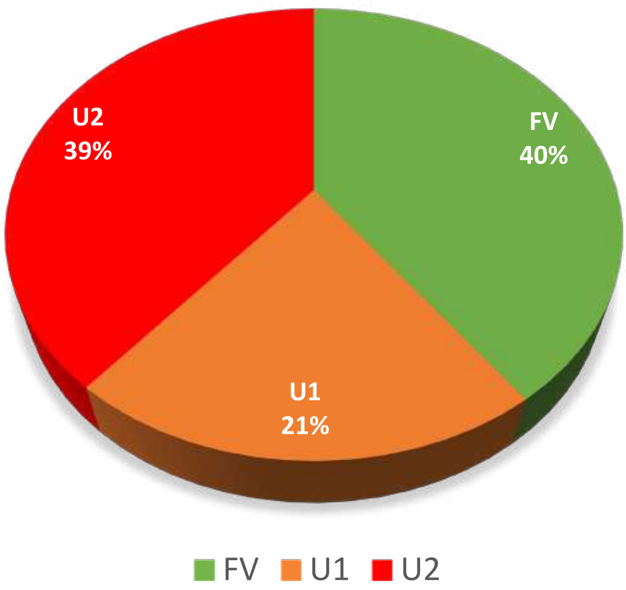

Fig. 8 Quality of Slovakia ecosystems

In terms of spatial distribution**, the worst quality of ecosystems is accumulated in the west and east of southern Slovakia,** it is mainly built-up areas and arable land (Fig. 9). The rest of Slovakia represents differently distributed types of ecosystems in different condition and thus provide different ES quality. There are significant interventions in forest ecosystems, calamitous areas are evident, in the case of non-forest habitats these are grassland-herb habitats that overgrow, in the case of aquatic ecosystems many parts of watercourses are degraded. All these factors significantly affect the quality of ES provided in a negative way, especially when it comes to regulatory and cultural ES. Arable land is defined separately because it is a heavily altered ecosystem and, in terms of regulatory and cultural ES provision, it is a category that is not as important as those ecosystems that are more natural and more linked to the biodiversity factor. Nevertheless, as a result, the quality of arable land was taken into account in the form specified in the methodological part, i.e. especially with regard to soil fertility.

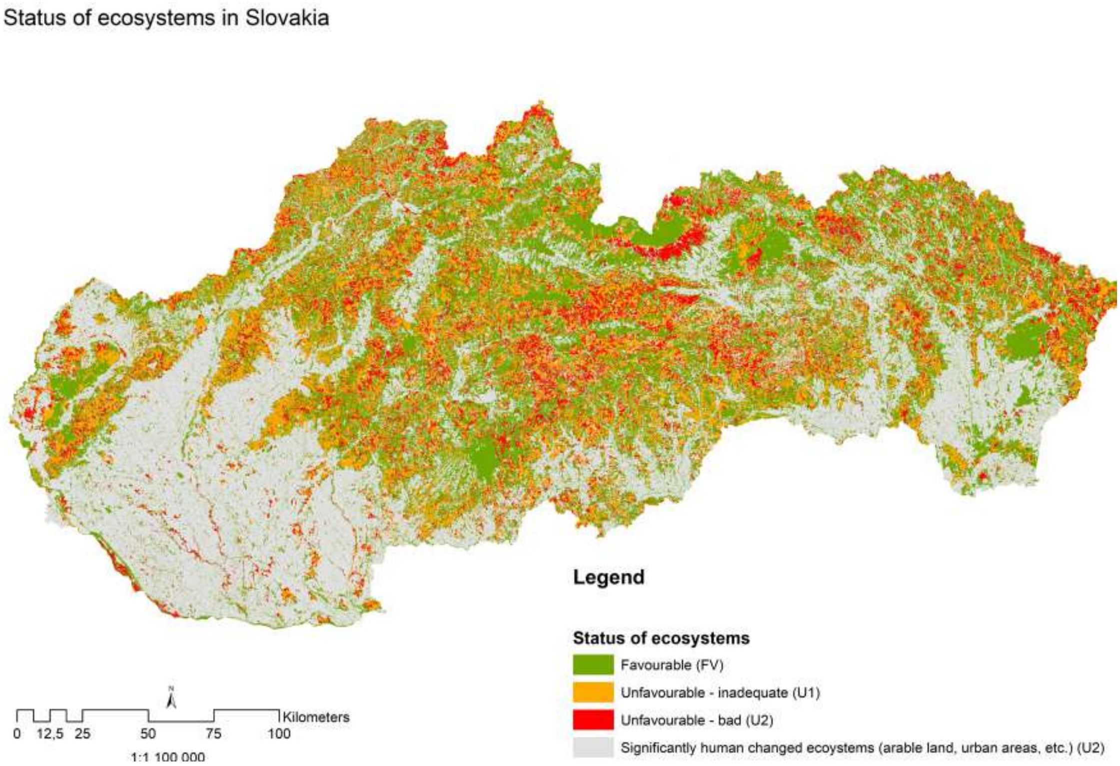

Fig. 9 Map of current qualitative status of Slovak ecosystem

3.3 Ecosystem services assessment

3.3.1 Regulatory ecosystem services

3.3.1.1 Global climate regulation

Global climate regulation is an important ES, in which plants, algae, soil and sediments play the greatest role as well as their ability to absorb carbon dioxide through the sequestration process. Unlike local climate regulation, this ES is also provided by local ecosystems, but it is only important to talk about it at the regional or national level. This is so because the synergies at the national level are stronger than regulation at the local level, where the locality is directly dependent on its immediate environment and thus, at the national level, the importance of global climate regulation grows. Global climate regulation helps mitigate the effects of climate change.

Natural forest ecosystems and wetland ecosystems maintain suitable atmospheric conditions for life on Earth and regulate the climate at a global level (Maes et al. 2015). The European Biodiversity Information System (IPBES 2018) identifies global climate regulation as one of the most important ES at global and European level.

Thus, the ongoing natural processes (carbon sequestration, maintenance of suitable atmospheric conditions, etc.) are irreplaceable in maintaining a stable climate at national and international level. Evaluation of ES global climate regulation is a necessary basis for setting sustainable land use. By evaluating global climate regulation, we get a comprehensive picture of the extent to which the Slovakia contributes to mitigating the impact of climate change from a global perspective.

Results of the evaluation of global climate regulation service

The total monetary value of the potential for provision of global climate regulation in Slovakia is approximately 21,835,942,003 EUR per year (Tab. 8). The service index value of potential would be 3.25 index point (on a scale of 1-5) if, ideally, all ecosystems were in a favourable state. The supply index is set at 2.83, which is 0.42 points less than the potential. After taking into account the quality of ecosystems, the monetary value of supply of global climate regulation service is reduced to 19,474,174,936 EUR per year, which means that due to the degradation of some ecosystems, Slovaks lose 2 billion EUR per year in this one service specifically. In terms of potential for provision of this service**, forest and non-forest ecosystems** are important (green colours in Tab. 8). In terms of area -quality ratio, the most important habitats are **G1.63 Medio-European neutrophile beech forests** and **E2.22 Sub-Atlantic lowland hay meadows**. In terms of the quality of the provision of global climate regulation, **peatlands** are very important, but their area is very small in order to fundamentally affect the overall values at the national level, however, the need for their protection is all the greater. In total, **90 habitats** contribute to the potential provision of global climate regulation service (with an index higher than 1) **on an area of 4,668,753.1 ha/46,687.531 km^{2}.**

Tab. 8 Indexes and values of potential and supply in relation to the ES provision of global climate regulation divided according to the EUNIS 1 level

GLOBAL CLIMATE REGULATION	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	0.27	104,625,459	0.25	96,152,855
D – Mires, bogs and fens	2.13	62,659,500	2.00	60,686,115
E – Grasslands and lands dominated by forbs, mosses or lichens	4.71	6,500,372,369	4.66	6,446,978,293
F – Heathland, scrub and tundra	1.78	197,137,790	1.74	195,282,596
G – Woodland, forest and other wooded land	4.99	12,876,396,746	3.92	10,580,324,938
H – Inland unvegetated or sparsely vegetated habitats	0	155	0	155
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	1.03	1,866,192,149	1.03	1,866,192,149
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	1.08	228,557,834	1.08	228,557,834
Total: Weighted average over ecosystem area/Total value in EUR	3.25	21,835,942,003	2.83	19,474,174,936

In the map of the supply of global climate regulation (Fig. 11) it is evident, that in contrast to the potential in Fig. 10, there are many more polygons with an average provision value, because the supply map also takes into account the qualitative assessment of ecosystems. In order to restore ecosystems and improve the quality of ES, it would be necessary to improve the ecological status of watercourses, reduce the size and intensity of forest interventions, increase the age of trees (e.g. by increasing harvest time) and fundamentally protect peatlands and wetlands where they are already protected and try to revitalize wetlands in places where they had perished, as their size is extremely small in relation to other ecosystems.

The resulting assessment maps for individual ES can be used at national and regional level, to a limited extent in local spatial planning (would require a refinement).

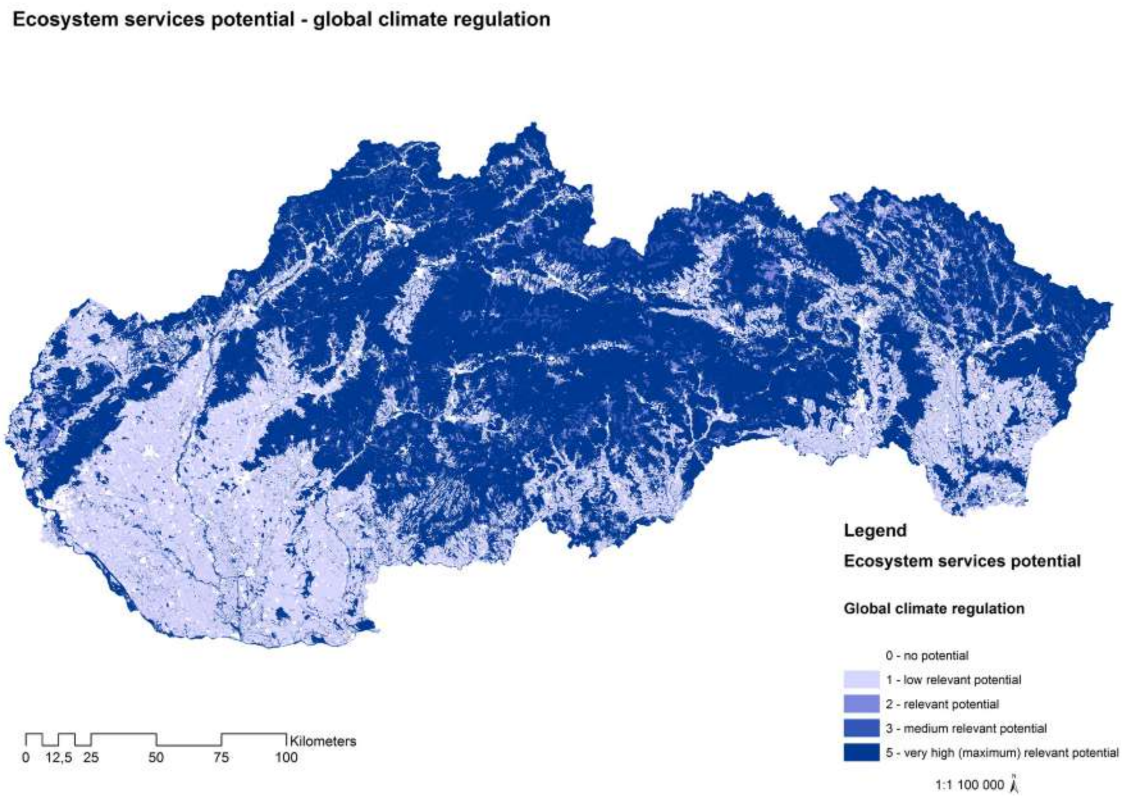

Fig. 10 Map of potential for provision ES global climate regulation

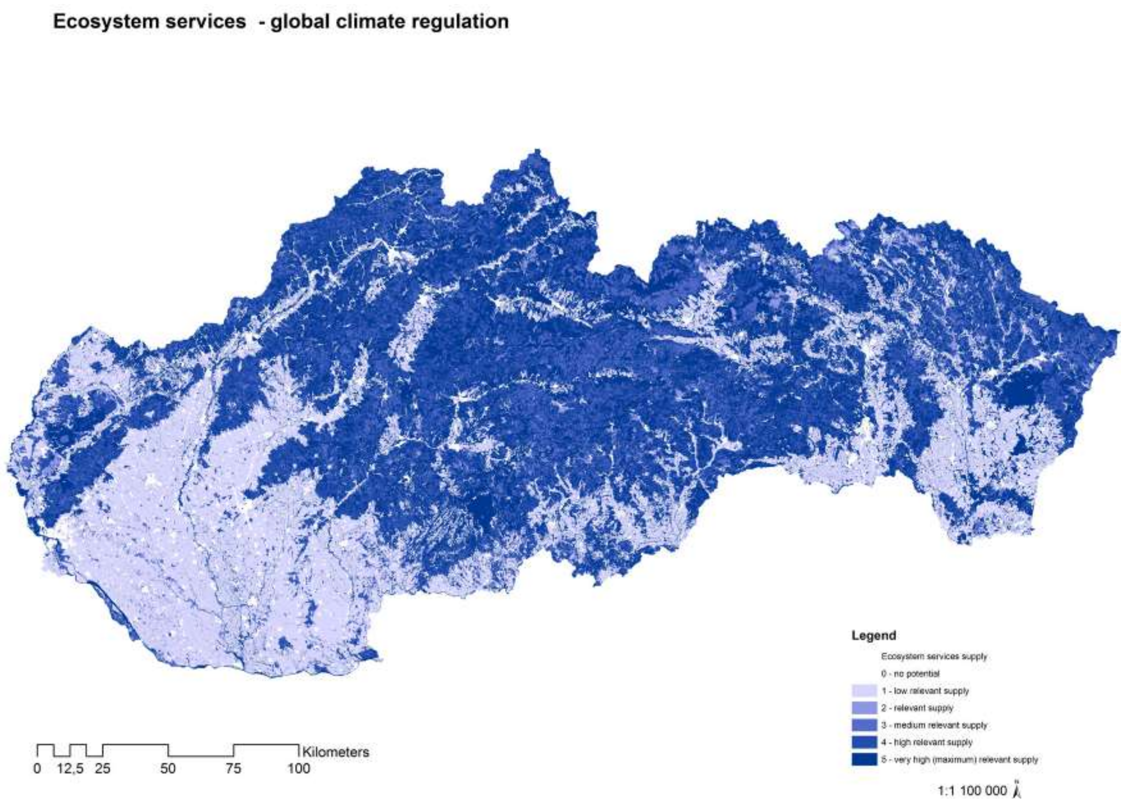

Fig. 11 Map of supply of ES global climate regulation in relation to the conservation status of ecosystems

3.3.1.2 Local climate regulation

Regulation of micro- and meso-climatic conditions is an important part of ecological balance of the landscape at the local level. From a local perspective, it is important that, in addition to the national benefits of global climate regulation, lower-level environmental regulation processes work sufficiently, especially in individual populations, cities and municipalities. In this respect, the biggest role is played by ecosystems that are in the immediate vicinity of towns and villages where people live a large part of their lives. It should be noted that ES local climate regulation is provided mainly by forest and non-forest ecosystemt. Potentially, also an agricultural land can provide this service, however, at a lower intensity.

In cities and their surroundings, woody vegetation or urban forests provide shade during hot summer days and cool down the environment with evapotranspiration, thus bringing benefits in terms of saved energy costs or reduced ozone production (Burkhard & Maes 2017). Local climate regulation can be summarized as the ability of ecosystems to regulate temperature, evapotranspiration, shadow, incident sunlight, wind, precipitation, imissions, dust and noise at the local level (Mederly, Černecký et al. 2019).

Results of the evaluation of local climate regulation service

The highest total value of the index for local climate regulation service is at the level of its potential - 2.97. The total monetary value of the potential of ecosystems to provide local climate regulation service is 19,918,428,632 EUR per year (Tab. 9). When comparing the economic value of the potential and the supply, the condition of individual ecosystems was revealed in the difference of 0.8 index point, which represents an annual loss of 2.7 billion EUR due to degraded ecosystems.

In terms of quality, the best habitats that provide ES local climate regulation are **G3.442 Carpathian relict calcicolous Scots pine forests**, but only on an area of 1,789 ha. Unequivocally stated, the habitat G3.442 is reasonably protected in many places, but from a national point of view it has only a local occurrence. In terms of quantity, the most important habitats are **G1.63 Medio-European neutrophile beech forests**, which are basically one of the most common forest habitats occurring in Slovakia, but also the most important for maintaining the quantity of this ES. From among the non-forest habitats, the most important are **E2.22 Sub-Atlantic lowland hay meadows.** From the overall point of view of the potential, local climate regulation service is provided by **93 different habitats in Slovakia on an area of 4,689,830.687 ha/46,898.31 km², although in many places to a very small extent.** The service is not provided at all (or only to a very limited extent) by 21 habitats in total on an area of 310,230 ha.

Tab. 9 Indexes and values of potential and supply in relation to the ES provision of local climate regulation divided according to the EUNIS 1 level

LOCAL CLIMATE REGULATION	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	1.18	163,585,598	1.07	145,707,303
D – Mires, bogs and fens	2.09	60,473,273	1.94	58,308,046
E – Grasslands and lands dominated by forbs, mosses or lichens	1.91	2,643,346,151	1.86	2,589,855,677
F – Heathland, scrub and tundra	2.17	230,990,155	2.13	229,096,065
G – Woodland, forest and other wooded land	4.99	12,876,396,746	3.92	10,580,313,989
H – Inland unvegetated or sparsely vegetated habitats	0.01	310	0.01	310
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	2	3,725,511,752	2	3,725,511,752
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	1.83	218,124,647	1.83	218,124,647
Total: Weighted average over ecosystem area/Total value in EUR	2.97	19,918,428,632	2.56	17,546,917,790

By comparing the potential and supply maps in Fig. 12 and Fig. 13, forest ecosystems clearly dominate, especially in terms of quantity.

The central part of Slovakia has the largest share of provision from the geographical point of view, the western part and the southern part of eastern Slovakia have larger areas of arable land and built-up areas, so they do not provide ES to such a high extent. In these parts of Slovakia, watercourses and overall aquatic ecosystems are important within the existing ecosystems. Among forest ecosystems, the localities of Malé Karpaty muntains and Slanské vrchy mountains are of key importance for these parts of Slovakia due to the more coherent provision of this ES on a large scale.

It is important that ES local climate regulation is taken into account in spatial planning, as the protection of individual inhabited parts of Slovakia from weather extremes depends on it and creates suitable climatic conditions for life. The results clearly show that the highest demand for this service is in larger cities and towns.

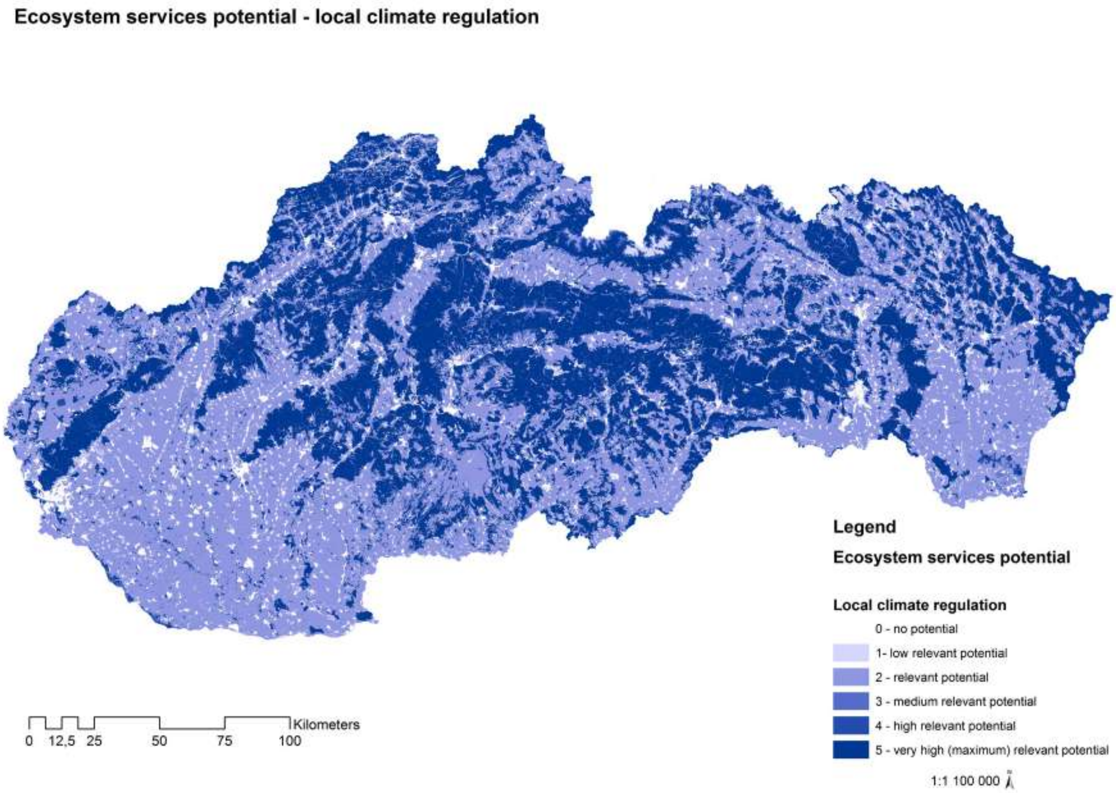

Fig. 12 Map of potential for provision ES local climate regulation

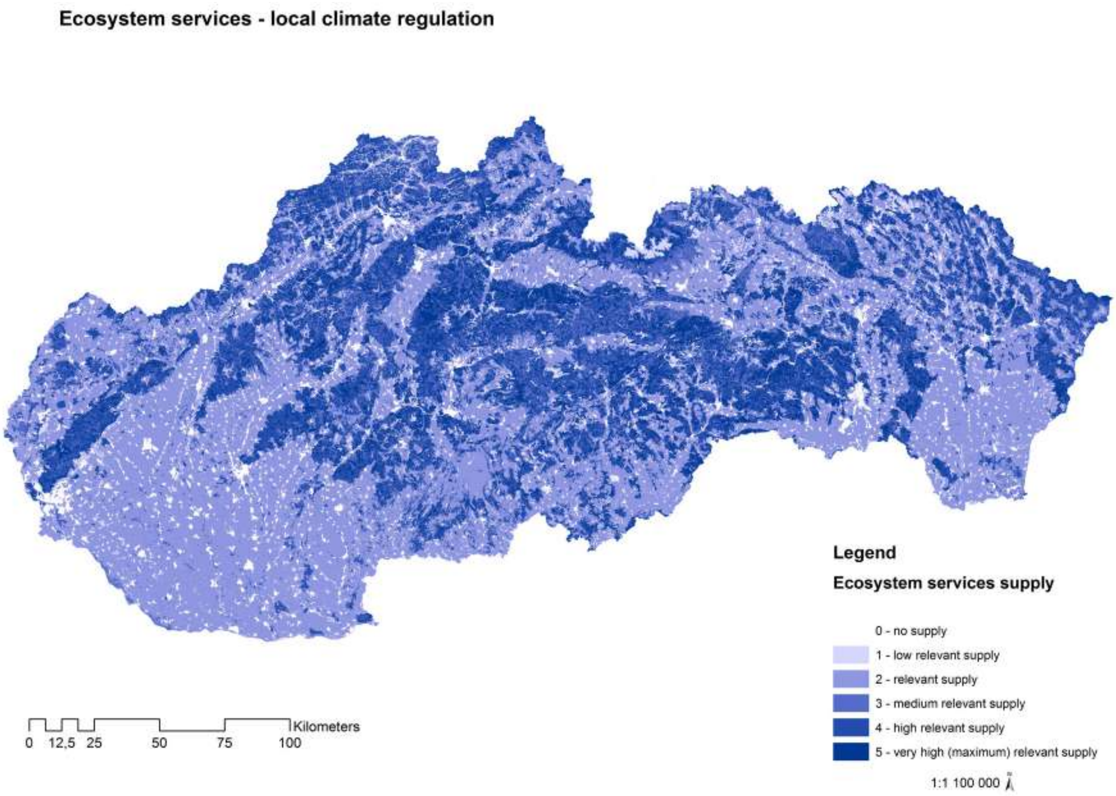

Fig. 13 Map of supply of ES local climate regulation in relation to the quality of ecosystems

3.3.1.3 Air quality regulation

Air quality regulation is an important ES provided by ecosystems in terms of human well-being and, above all, the health of the human population. Ecosystems and the processes that are linked to them ensure the production of oxygen, but also the mitigation and absorption of harmful substances in the air and thus provide an irreplaceable service for people in the form of cleaner and higher quality air. The number of respiratory diseases and premature deaths caused by poor air quality is constantly growing, and it is all the more necessary to emphasize the role of ecosystems, which have long served us in favour of mitigating the impact of air pollution. Their function is irreplaceable and the value of the service is quite morally and also economically valued, e.g. also through emission allowances and trading. It can be stated that the trading of emission allowances is simply a payment for preclusion of the provision of this ES. In addition, the funds thus obtained have no direct link to the creation/improvement of the quality of the ecosystem and are revenue of the state budget, which uses these funds for various purposes. Nevertheless, the connection of this topic with the ecosystems is very sporadic, in most cases ecosystems are not even mentioned.

The exchange of trace elements and particles between ecosystems and the atmosphere means that ecosystems can be a source of air pollutants (or their precursors), but can also have a positive effect on air quality through the capture, storage and disposal of pollutants such as air pollutants e.g. industrial emissions - sulphur compounds (Fowler et al. 2019, Preston et al. 2017). Deposition of atmospheric pollutants in soil and vegetation can significantly reduce their concentration in the air (Fowler et al. 2019) and thus reduce adverse effects on human health and other ES (RoTAP 2012). In summary, ES air quality regulation is a regulatory service that affects atmospheric concentrations of air pollutants and their storage in the landscape and water (Mederly, Černecký et al. 2019).

Results of the evaluation of air quality regulation service

From the national point of view, the calculated potential value of air quality regulation service is at the level of the index 2.22 and supply at the level of 1.81 (Tab. 10). This results in a loss in the index of 0.41 points due to the degradation of ecosystems in Slovakia, which in financial terms represents an annual loss of 152 million EUR. The highest value of the average index is achieved by forest ecosystems, up to 4.99 index point and they also contribute the most to the overall economic value of potential for provision of air quality regulation by 989,566,021 EUR per year.

In terms of the quality of provision of local climate regulation, habitat **G3.442 Carpathian relict calcicolous Scots pine forests** is important, but is only a local and takes up only a small area (353 localities). A similar case is the habitat **G1.A41 Medio-European ravine forests**, which occurs more frequently (13 936 localities). Since both are often difficult to access and interventions in them are not as frequent as in other stands, the results confirm that the quality of ES provision is higher compared to other forest habitats. **Orchards** (G1.D Fruit and nut tree orchards), **urban parks and their vegetation** (I2.2/P85.2 Small-scale ornamental and domestic garden areas/city parks) can be mentioned from toher types of habitats producing this ES in higher quality.

Tab. 10 Indexes and values of potential and supply in relation to the ES provision of air quality regulation divided according to the EUNIS 1 level

LOCAL CLIMATE REGULATION	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	0.02	222,273	0.02	210,134
D – Mires, bogs and fens	0	0	0	0
E – Grasslands and lands dominated by forbs, mosses or lichens	0	680,009	0	678,179
F – Heathland, scrub and tundra	0.61	6,338,943	0.61	6,336,364
G – Woodland, forest and other wooded land	4.99	853,966,922	3.92	701,689,948
H – Inland unvegetated or sparsely vegetated habitats	0	0	0	0
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	1.03	123,766,485	1.03	123,766,485
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	0.86	4,591,389	0.86	4,591,389
Total: Weighted average over ecosystem area/Total value in EUR	2.22	989,566,021	1.81	837,272,500

In terms of quality, it is necessary to state that **forest habitats clearly dominate** in provision of air quality regulation service. However, **arable land** provides this ES in the highest level in terms of quantity (on the largest area), but only with an index 1, which is relatively insignificant. The second largest habitat that provides the air quality service is **G1.63 Medio-European neutrophile beech forests** with an area of 1,015,599 ha and with the 3.9 value of supply of quality index, which is clearly **the most important habitat in Slovakia** in case of air quality regulation service. In total, air quality regulation service is provided (potential) by **36 different habitats on an area of 3,474,108.975 ha / 34,741.89 km²**.

Looking at the distribution of Slovakia´s habitats that provide air quality regulation service (Fig. 14) it is evident that in terms of the quantity, **arable land** (with a very low index) dominates, while in terms of quality **forest ecosystems** are more important. The calculated value of potential provision of this service is approximately 7 times higher in forests compared to the arable land (Tab. 10). The provision of air quality regulation service is evenly distributed throughout Slovakia (Fig. 15), the best are areas with a higher density of forest ecosystems. The western part of Slovakia provides this service in lower quality, built-up areas are also very poor and limited by city parks and other urban vegetation, in many places insufficiently and thus its inhabitants suffer from a lack of this service (air pollution), which causes people significant health risks and problems.

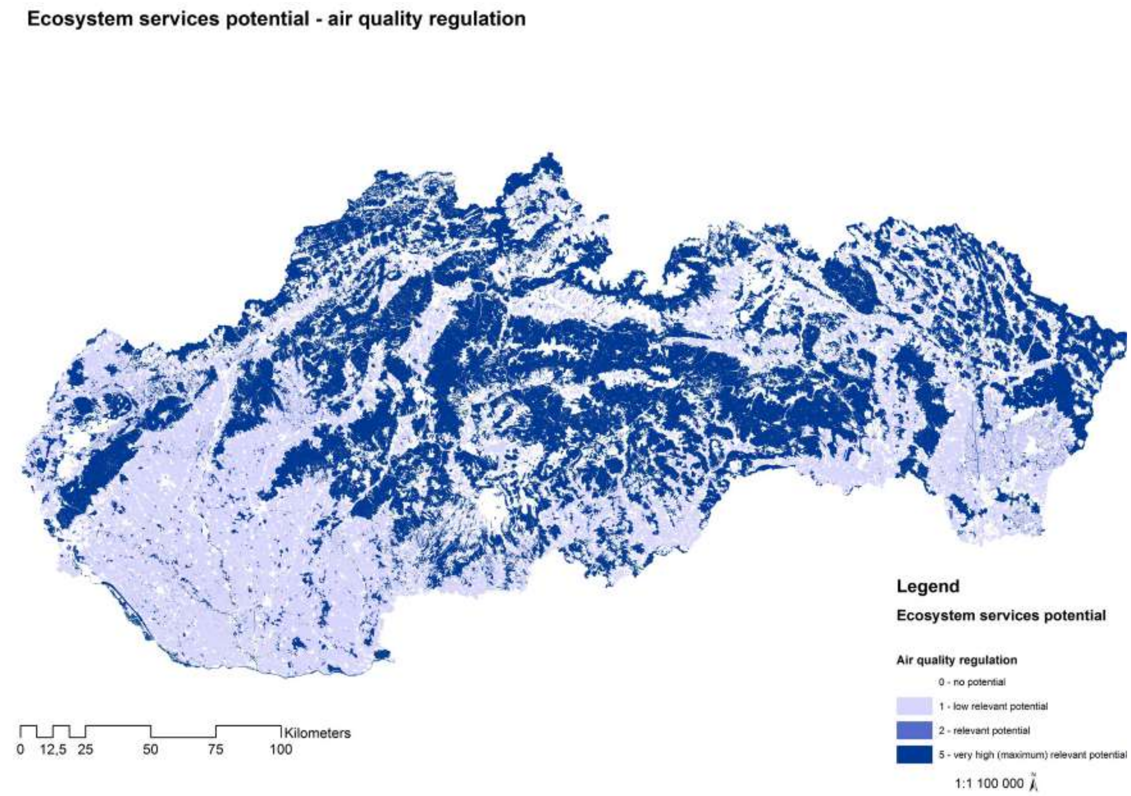

Fig. 14 Map of potential for provision ES air quality regulation

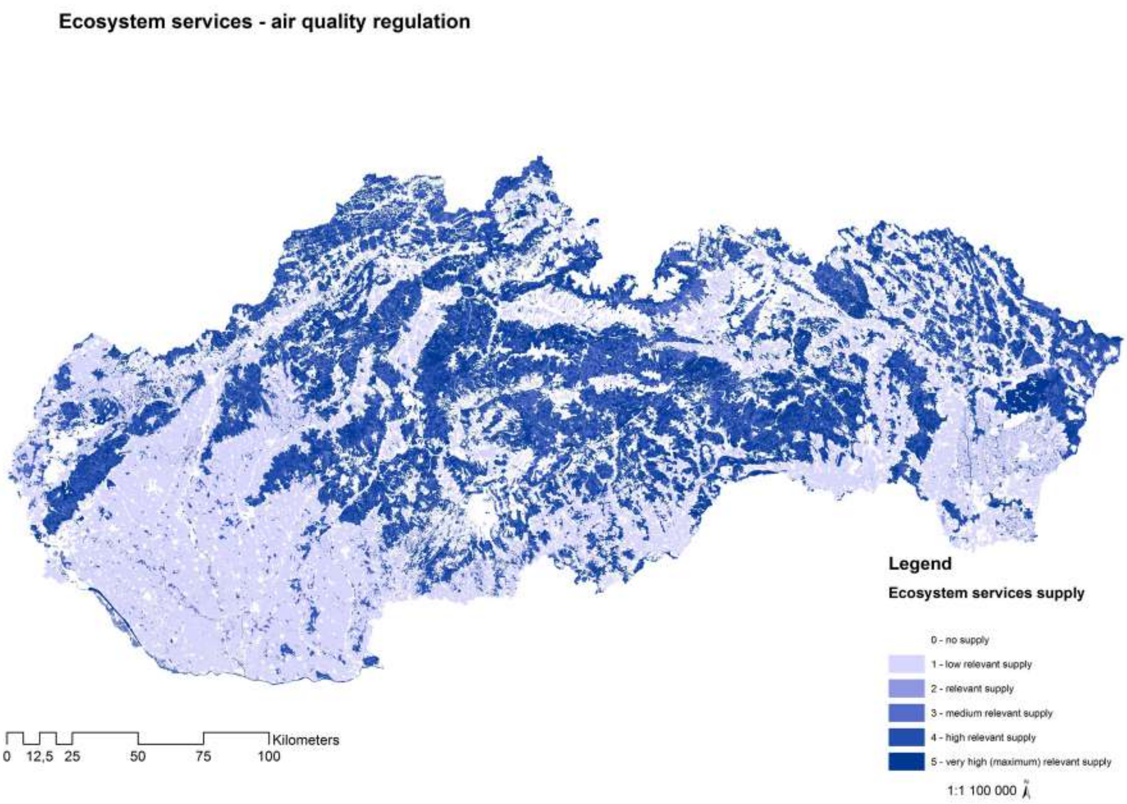

Fig. 15 Map of supply of ES air quality regulation in relation to the conservation status of ecosystems

3.3.1.4 Water flow regulation

Regulation of water flows in nature is a basic prerequisite for the right functioning of ecosystems as such. All ecosystems/habitats are dependent on water. Even xerothermic habitat needs the supply of water at a right time in order to survive and provide ES from which humans subsequently benefit. Disruption of the water cycle in nature often leads to extreme phenomena such as excessive rainfall closely linked to floods. The opposite extreme is drought, which threatens people directly and indirectly through e.g. degradation of food resources, but also ecosystems themselves, which subsequently does not provide services in full rate and thus again adversely affects humans. Ecosystems and their favourable condition are essential to ensure the proper functioning of the water cycle. It is necessary to be aware of the importance of protection of natural as well as semi-natural ecosystems/habitats and ensuring their favourable condition. On the other hand, not only rare habitats, but also man-modified or man-made, as well as large-scale habitats are important for provision of this service (as many others ES produced for human consumption), even if in lower quality of provision than natural and non-degraded habitats.

Water pollution, over-consumption and artificial treatment of natural water bodies are among the main threats to freshwater pollution in Europe (EEA 2012). According to Burkhard & Maes (2017), ideally, the country should naturally retain and store sufficient water for its needs, thereby limiting surface runoff. Forests, grassland and wetlands are high-capacity ecosystems for the regulation of water flows. In cities, where the water flows are not properly regulated by ecosystems, there is a much higher risk of extreme fluctuations, which can lead to floods or, conversely, to a lack of water (drinking or service). Water flow in the country can be affected by the following natural processes that contribute to water accumulation and thus prevent surface runoff: vegetation capture, deposition in surface aquatic ecosystems, infiltration and retention in soil, infiltration into groundwater.

Results of evaluation of water flow regulation service

The total value of potential for provision water flow regulation service and regulation of runoff conditions by Slovakia´s ecosystems is set at 2.02 index point. The provision of this ES, after taking into account the condition of ecosystems, is 1.61 (supply quality index value). The potential value calculated in monetary units (shown in Tab. 11) is 4,662,959,248 EUR per year. After taking into account the quality of individual ecosystems, supply of this ES is reduced to 3,852,879,612 EUR per year. This means that the economic value of provision of water flow regulation service is reduced by 810 million EUR per year due to the degradation of ecosystems.

In terms of quality, the most important, in comparison with the previous regulatory services, are **inland surface waters, mires, peat bogs and fens**. In particular, the highest quality habitats that provide water flow regulation service are **C1 Surface standing waters**, **C1.2 Permanent mesotrophic lakes, ponds and pools, C1.3 Permanent eutrophic lakes, ponds and pools followed by other aquatic habitats.** In terms of the largest area of provision of this service, **forest ecosystems** are very significant**, less arable land**. From among the forest habitats, the G1.63 Medio-European neutrophile beech forests participate in the provision of water flow regulation service on the largest area and in the highest quality, namely on area of 1,015,599.37 ha. G1.A16 Sub-continental oak - hornbeam forests on the area of 261, 088.22 ha, G1.61. Medio-European acidophilous Fagus forests on the area of 162,544.91 ha. From the overall view of the potential, this service is provided by **93 different habitats in Slovakia on the area of 4,592,333.32 ha/45,923.33 km^2.** But again, it is necessary to recall that some habitats provide the service only to a very limited extent and low quality. In case of areal expression it is necessary to take into account especially those habitats that provide the service at the level of at least 2-3 index points, which is basically a much smaller area.

Tab. 11 Indexes and values of potential and supply in relation to the ES provision of water flow regulation divided according to the EUNIS 1 level

WATER FLOW REGULATION	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	3.02	111,780,190	2.9	105,384,334
D – Mires, bogs and fens	3.04	29,521,918	2.9	28,781,548
E – Grasslands and lands dominated by forbs, mosses or lichens	1	481,453,272	0.96	464,271,769
F – Heathland, scrub and tundra	1.39	55,833,229	1.35	55,185,570
G – Woodland, forest and other wooded land	3	2,659,570,003	1.93	1,874,455,754
H – Inland unvegetated or sparsely vegetated habitats	0.01	265	0.01	265
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	2	1,273,888,039	2	1,273,888,039
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	0.97	50,912,332	0.97	50,912,332
Total: Weighted average over ecosystem area/Total value in EUR	2.02	4,662,959,248	1.61	3,852,879,612

In the map view in Fig. 16 it is evident that the water flow regulation service is generally provided by ecosystems **in a lower quality than other regulatory services**. At the highest quality is this service provided only by large water bodies, but in Slovakia does not exist many original natural lakes. However, in terms of quantity, these water bodies do not play an important role either, other aquatic ecosystems and forest ecosystems are much more important. In this example, it is also possible to demonstrate that on the one hand man-made large water structures help to regulate the water regime in the regional point of view, but on the second hand from the national point of view they are not significant and forest ecosystems are more significant.

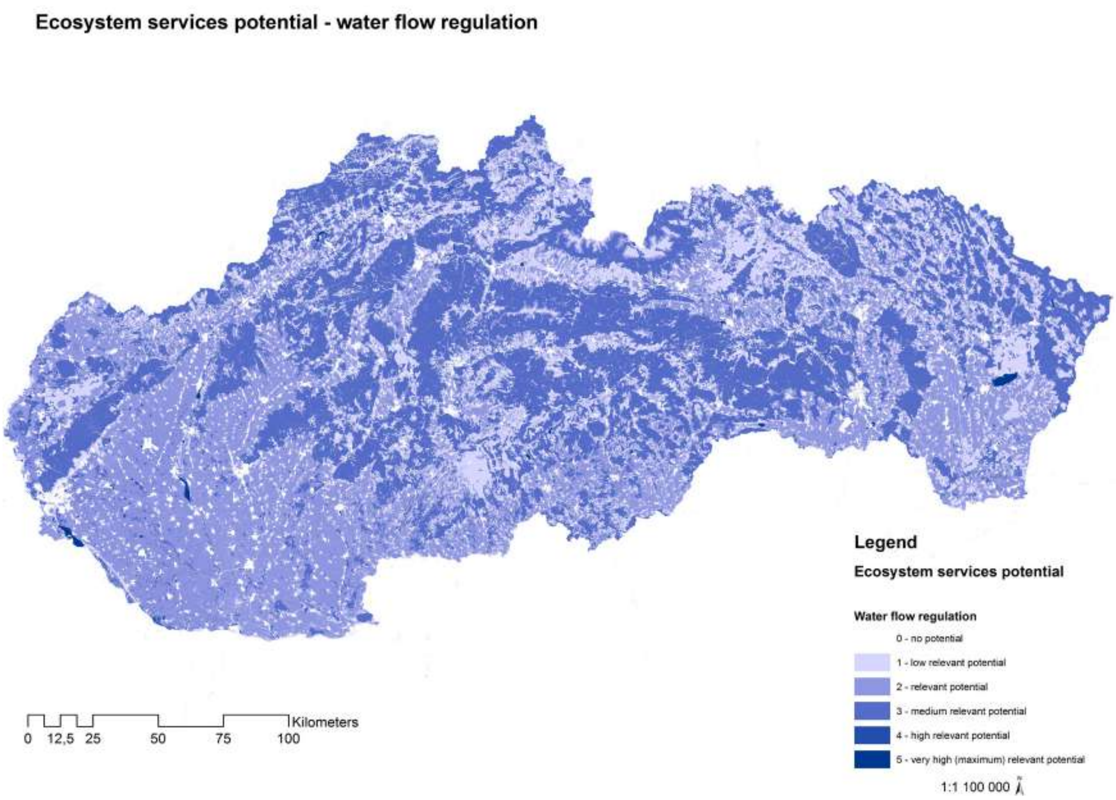

Fig. 16 Map of potential for provision ES water flow regulation

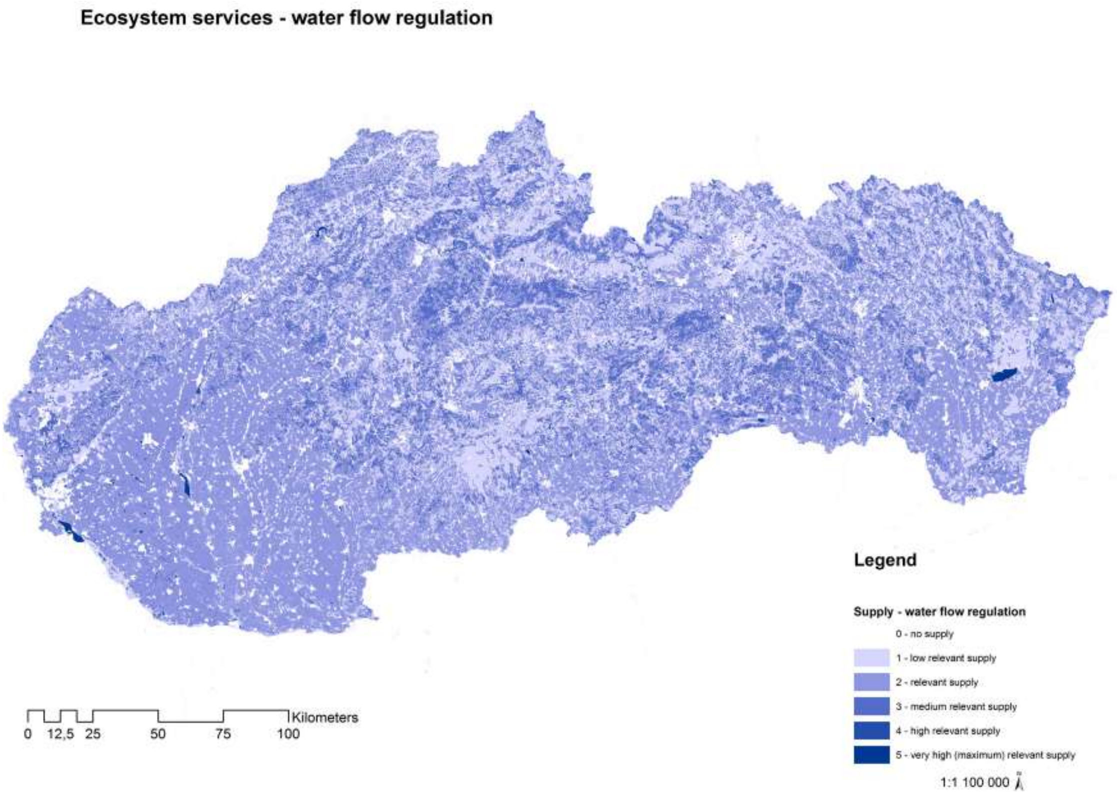

Fig. 17 Map of supply of ES water flow regulation in relation to the quality of ecosystems

In terms of the map display of supply of water flow regulation service (Fig. 17) it is necessary to draw attention to the fact that its supply is distributed evenly throughout Slovakia and in a similar quality, but overall with a low average index. Compared to the map of potential, it is evident that forests have a higher potential, but due to their condition they reach average values, comparable with agricultural land in many places. In view of the above, there is a high potential for the improvement of quality in every group of ecosystems in Slovakia, the widespread ones, but also the rarer and smaller ones.

3.3.1.5 Water purification

The water purification ecosystem service is important in terms of water resources, especially near areas of pollution and built-up areas where the highest concentration of pollutants occurs. The self-cleaning ability of water is an important factor in which several ecosystems are involved.

Freshwater ecosystems are able to maintain a sufficient quality of drinking water for drinking and other purposes associated with daily human activities. Freshwater plants, as well as entire aquatic ecosystems capture, decompose, process and transform pollutants, toxins and heavy metals present in water. Water purification is thus one of the key service associated with the water cycle (Grizzetti et al. 2019). La Notte & Maes et al. (2017) estimated the annual value of capacity and flow of water purification service for sustainable use in Europe at 458.86 billion EUR per year. Some wetland ecosystems can reduce nitrogen concentrations by more than 80% (MEA 2005). The water purification service can be measured by the amount of pollutants removed and it is variable - from fast-flowing streams to stagnant lakes that have a higher capacity (more time) to remove nitrogen but a lower capacity to clean organic pollutants (Burkhard & Maes 2017).

Results of evaluation of the water purification service

Given the conditions of Slovakia, it can be stated that a significant part of ecosystems produces this service on a large scale, which increases human well-being. The index of potential is 2.52 and the index of supply is 2.13 – there is a difference in 0.39 points due to degraded ecosystems. From the financial point of view, the potential provision (Tab. 12), is calculated up to 5,097,555,129 EUR per year. The monetary value of supply of water purification service is 4,383,970,274 EUR per year. As a result, Slovakia looses 713 million EUR per year in the supply of water purification service due to ecosystem degradation.

In terms of quantity and quality, the most important ecosystems for provision of water purification are forest habitats, followed by **grasslands**. In terms of quality (potential index value 4), preserved stands with valuable and protected habitat types such as **D1.11 Active, relatively undamaged raised bogs** and **D1.12 Damaged, inactive bogs** are also important, but with an area of only 1,580.26 ha. In terms of quantity and thus overall, the most important are forest and non-forest habitats such as G1.63 Medio-European neutrophile beech forests or permanent grasslands, which are, however, crucial for the proper functioning of the ecosystem and the provision of this service. Water purification (potential) through ecosystems is provided in different quality on an area **of 3,004,518 ha/30,045.18 km² by 94 different ecosystems.**

Tab. 12 Indexes and values of potential and supply in relation to the ES provision of water purification divided according to the EUNIS 1 level

WATER PURIFICATION	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index avergae	Value in EUR	Index avergae	Value in EUR
C – Inland surface waters	2.81	59,863,594	2.69	54,279,633
D – Mires, bogs and fens	2.09	18,231,332	1.94	17,578,565
E – Grasslands and lands dominated by forbs, mosses or lichens	2.72	1,122,077,694	2.68	1,107,515,264
F – Heathland, scrub and tundra	1.17	30,617,181	1.13	30,057,882
G – Woodland, forest and other wooded land	4.99	3,862,299,479	3.92	3,170,085,443
H – Inland unvegetated or sparsely vegetated habitats	1	2,393,930	0.99	2,381,568
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	0.07	2,071,918	0.07	2,071,918
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	0	0	0	0
Total: Weighted average over ecosystem area/Total value in EUR	2.55	5,097,555,129	2.13	4,383,970,274

The map´s distribution in Fig. 18 shows that the part covered by forest and grassland habitats in the central part of Slovakia has the highest potential for provision of water purification service (dark blue colour). Agricultural areas and built-up areas do not produce this service at all or only to a very low extent (white polygons in the map). Looking at the map of supply of water purification service (Fig. 19) it is evident that, compared to the potential, anthropogenic interventions in ecosystems slightly reduce the provision of this ES. Nevertheless, forest habitats are still the most important source of water purification processes.

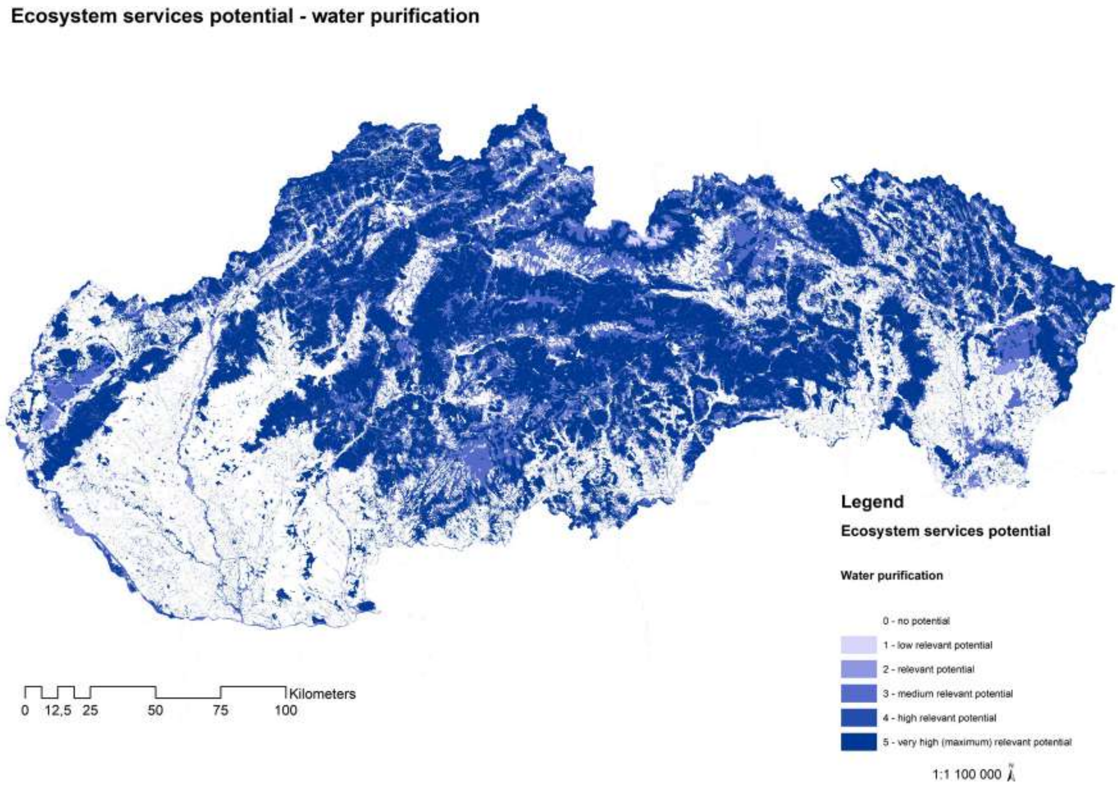

Fig. 18 Map of potential for provision ES water purification

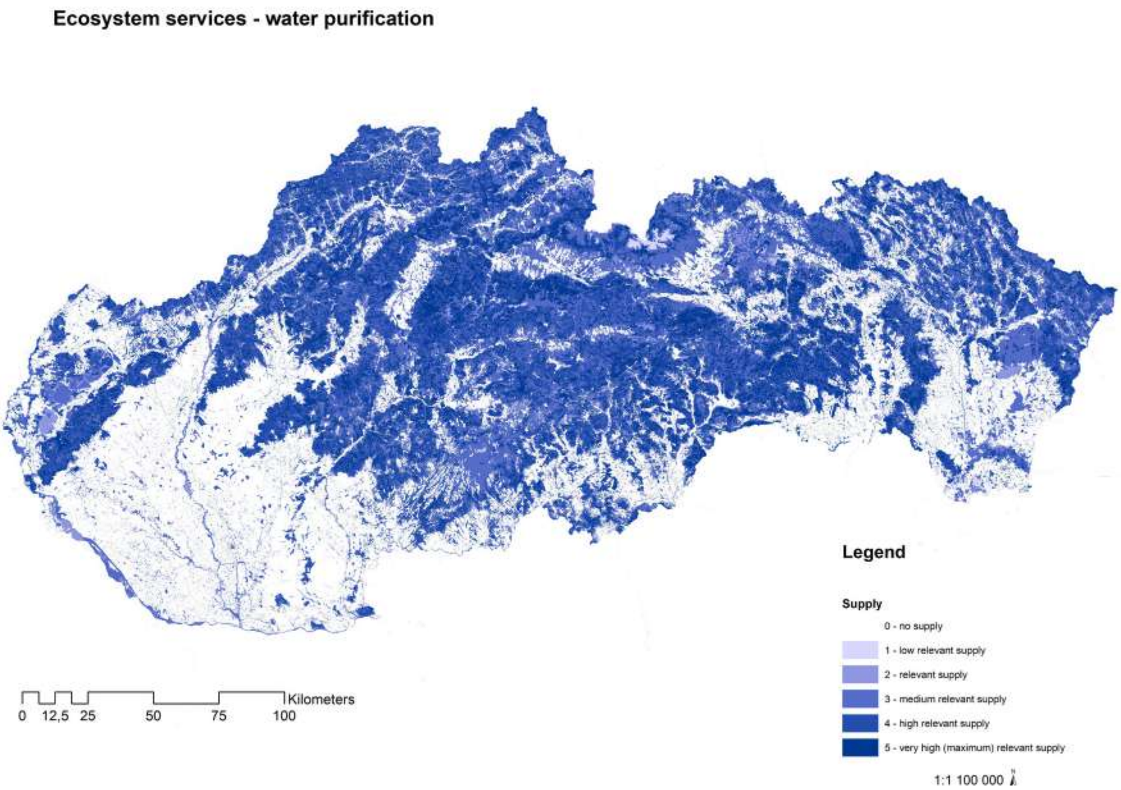

Fig. 19 Map of supply of ES water purification in relation to the quality of ecosystems

3.3.1.6 Nutrient regulation

The cycles of key nutrients, especially those such as phosphorus, nitrogen, sulphur and carbon, have changed significantly through human activities and over the last two centuries, with both positive and negative impacts on a range of ecosystems and their services. Humans benefit from the processes carried out by ecosystems by regulating the right chemical composition to maintain a balanced ecosystem, to maintain biodiversity of the area, to produce crops and fertilizers, e.g. dying forests and wood from which new plants, including trees, benefit (Hassan 2005).

For example, in terrestrial ecosystems the nutrients may be best concentrated in the living biomass (forest ecosystem), in humus or soil organic matter (peat ecosystems). Nitrogen (N) cycles altered by human activities have brought benefits to health and human well-being, but its excess has caused the degradation of many ecosystems and the quality of air and water (Compton 2011).

Nutrient regulation requires the involvement of a large number of different organisms from different functional groups and can therefore be considered as a good example of "functional biodiversity" or "functional ecosystem". On the contrary, dysfunctions in the nutrient cycle lead to disruption of ecosystem and thus to a reduction in the quality or quantity of services provided to humans, e.g. eutrophication of water bodies.

Results of evaluation of nutrient regulation service

The index of potential provision is set at 3.08 (Tab. 13) which in monetary units represents 1,027,362,697 EUR per year, the supply has an index of 2.67 and a monetary value presents 909,152,912 EUR per year. The important ecosystems for the potential provision, as well as supply of nutrient regulation service are the widespread habitats - **forest habitats** followed by **grassland**s. From among the forest habitats, on the area of 1,015,599.37 ha, these are **G1.63 Medio-European neutrophile beech forests** as the largest contributors of provision of nutrient regulation service, as well as **E2.22 Sub-Atlantic lowland hay meadows** on the area of 283,534.48 ha. Wetlands and aquatic ecosystems can be significant at the local level. From the overall point of view, the nutrient regulation service is potentially provided by **93 different habitats in Slovakia on an area of 4,689,830.687 ha/46,898.3 km²**, out of which up to 63 habitat types with an index of potential of 4 to 5.

Tab. 13 Indexes and values of potential and supply in relation to the ES provision of nutrient regulation divided according to the EUNIS 1 level

NUTRIENT REGULATION	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	3.08	15,107,608	2.96	14,175,572
D – Mires, bogs and fens	4	5,590,828	3.85	5,482,939
E – Grasslands and lands dominated by forbs, mosses or lichens	3.72	254,822,372	3.67	252,157,027
F – Heathland, scrub and tundra	1.78	9,823,061	1.74	9,728,682
G – Woodland, forest and other wooded land	4.99	641,610,274	3.92	527,200,139
H – Inland unvegetated or sparsely vegetated habitats	0.01	23	0.01	23
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	1.03	92,989,373	1.03	92,989,373
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	0.97	7,419,158	0.97	7,419,158
Total: Weighted average over ecosystem area/Total value in EUR	3.08	1,027,362,697	2.67	909,152,913

Based on the Fig. 20 it is evident that as with most regulatory services, forest ecosystems in e.g. mountains of Malé Karpaty, Veľká Fatra, Malá Fatra, Nízke Tatry, Kremnické vrchy, Štiavnické vrchy, Veporské vrchy, Muránska Planina, Volovské vrchy, Slanské vrchy, Čergov, etc., dominate in the potential provision of nutrient regulation service. These are the largest continuous natural ecosystems in Slovakia. On the contrary, built-up areas do not provide this ES at all and the agricultural land only with an index value of 1.03.

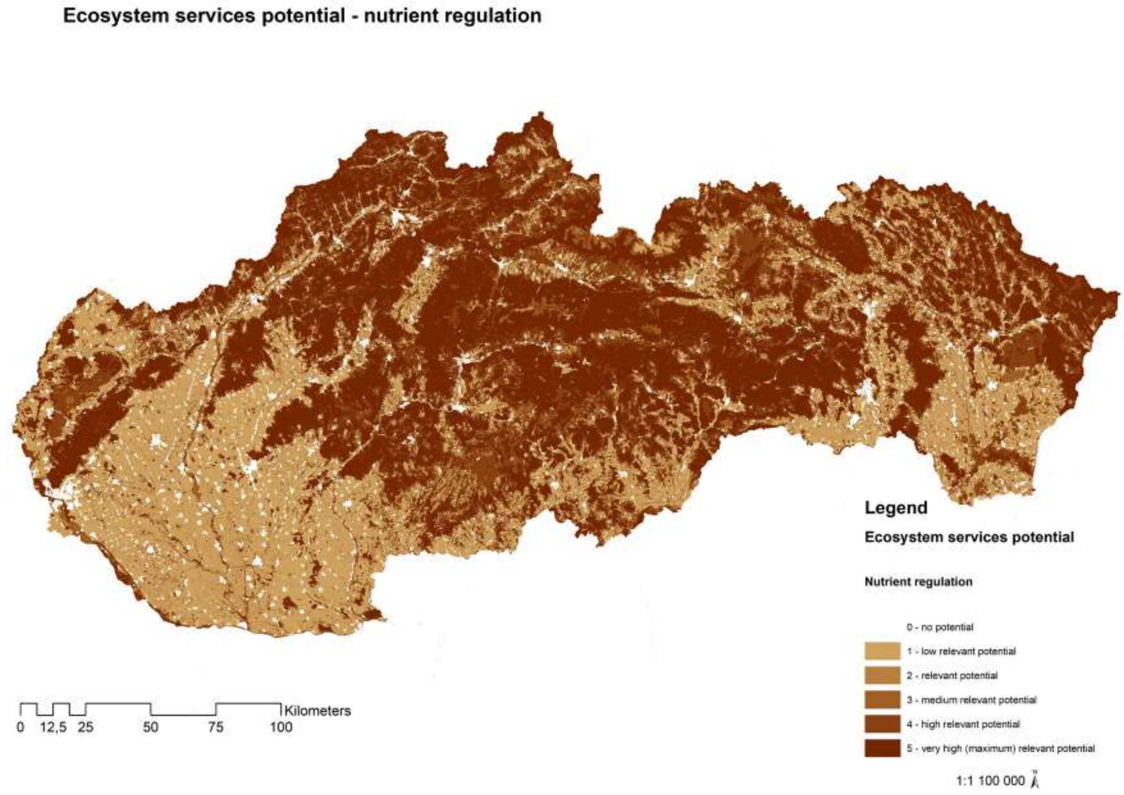

Fig. 20 Map of potential for provision ES nutrient regulation

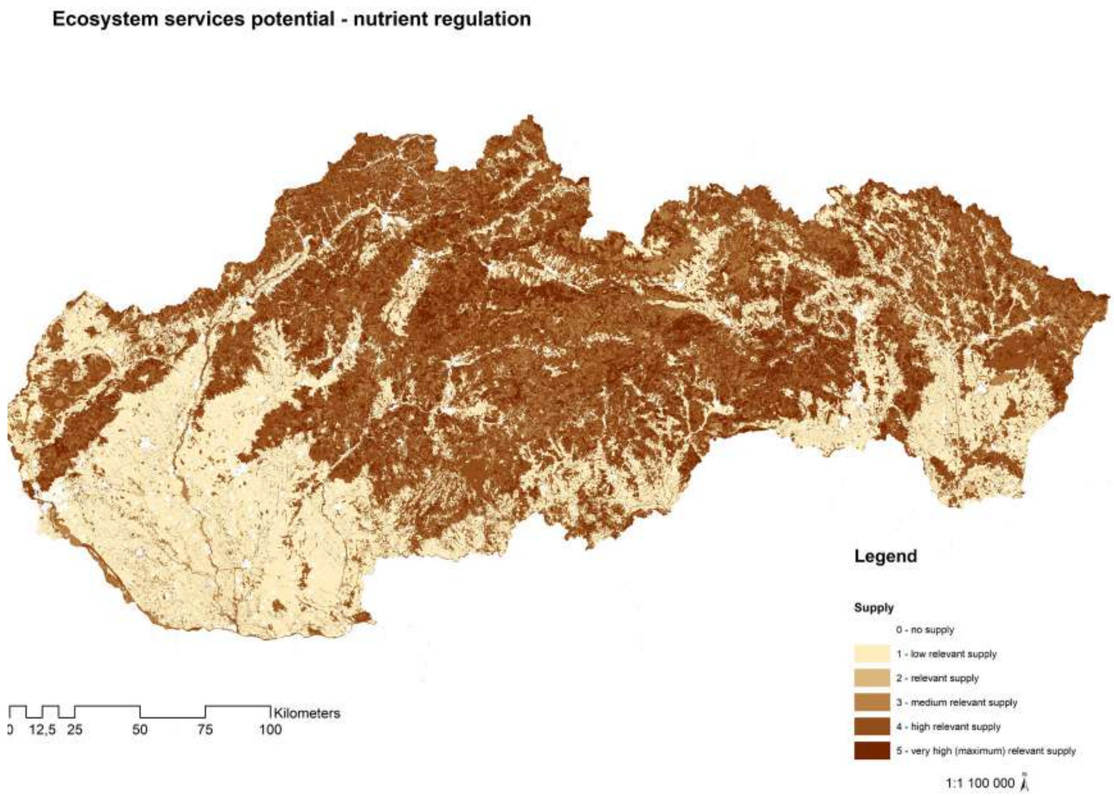

Fig. 21 Map of supply of ES nutrient regulation in relation to the quality of ecosystems

Looking at the map of nutrient regulation service supply (Fig. 21) it is clear that this ES has decreased due to ecosystem degradation. The degree of provision representing an index value of 5 in potential has decreased significantly, as seen in the map of supply of nutrient regulation service. At the same time it can be stated that protected areas play an important role in the preservation of ecosystems and also in the production of this ES, as well as of others. A significant part of the Pannonian biogeographical region does not provide nutrient regulation service to a somewhat significant extent. It consists mainly of agricultural areas where the supply index only reaches values close to 1, which is very low.

3.3.1.7 Erosion regulation

In terms of maintaining the quality of soils that are capable of producing the biomass, the erosion regulation service is an essential regulation service necessary for human well-being. Erosion is most pronounced in degraded ecosystems, especially in parts from which the biomass itself has been removed (or disturbed) e.g. agricultural land or forest stands. Due to the influence of wind, water and other natural factors, the fertile part of the soil is subsequently degraded and the landslides are threatened on the slopes, which can endanger inhabited areas and cause great damage to human health and property. In principle, these may not only be massive landslides, but also falling rocks on roads or near inhabited parts. Properly functioning ecosystems, in favourable condition, provide the most effective protection against erosion and landslides.

Soil erosion is one of the most serious environmental problems in the world today, as it poses a serious threat to agriculture, natural resources and the environment. Soil erosion is a natural process, but attention is focused on the so-called "accelerated erosion", which is caused by human activity or disturbing the natural rate of erosion. Accelerated erosion is a serious problem worldwide and it is difficult to assess its economic and environmental impact due to its extent, size, speed and the complex of processes that accompany it (Markov & Nedkov 2016).

Results of evaluation of erosion regulation service

Slovakia´s potential for the provision of erosion regulation service is on the scale of 0 to 5 in the rating of 3.01 index value, but after taking into account the quality of ecosystems, the provision decreases to 2.59 (supply index value). In terms of monetary evaluation, this is a highly valued service, where the potential provision reaches the value of 28,868,921,246 EUR per year and erosion regulation service supply (after taking into account the state of ecosystem degradation) is 25,478,733,317 EUR per year (Tab. 14). It means that due to the degradation of ecosystems, Slovakia loses 3,390,187,929 EUR per year.

As with other regulatory services, forest and grassland ecosystems are also valuable in terms of provision of erosion regulation services. In terms of quality, the best providers of this service are the habitats of **E4.34 Alpigenous acidophilous grassland, E3.41 Atlantic and sub-Atlantic humid meadows** as well as other grasslands. Surprisingly, forest habitats do not appear in the best quality of provision of this ES. In terms of acreage, however, forest habitats clearly dominate again through the **G1.63 Medio-European neutrophile beech forests** on an area of 1,015,599 ha in the index value of 3.9 and non-forest habitats through the **E2.22 Sub-Atlantic lowland hay meadows** on an area of 283,534 ha, but in a higher quality, specifically at an index value of 4.9. In total, **101 habitats** in the EUNIS categories (with an index higher than 0) and an **area of 3,564,632.539 ha/35,646.33 km^2** contribute to the potential provision of erosion regulation service. **However, it is necessary to take into account the fact that index up to level 2 is relatively low and thus the quality of provision of this ES is present on a much smaller scale.** 52 forest and grassland habitats reach the index value of potential at level 5.

Tab. 14 Indexes and values of potential and supply in relation to the ES provision of erosion regulation divided according to the EUNIS 1 level

EROSION REGULATION	**POTENTIAL**		**SUPPLY**	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	0.11	51,361,171	0.09	40,718,503
D – Mires, bogs and fens	1.04	43,419,110	0.91	40,585,374
E – Grasslands and lands dominated by forbs, mosses or lichens	4.62	9,117,483,208	4.57	9,040,672,126
F – Heathland, scrub and tundra	1.39	234,474,090	1.35	231,754,221
G – Woodland, forest and other wooded land	4.99	18,490,207,681	3.92	15,193,085,990
H – Inland unvegetated or sparsely vegetated habitats	1.99	22,804,315	1.99	22,745,432
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	0.07	9,868,818	0.07	9,868,818
J – Constructed, industrial and other artificial habitats	1.06	683,195,374	1.06	683,195,374
X – Habitat complexes	1	216,107,480	1	216,107,480
Total: Weighted average over ecosystem area/Total value in EUR	3.01	28,868,921,246	2.59	25,478,733,317

The high potential provision of the erosion regulation service is also confirmed in the map in Fig. 22. The majority of Slovakia, with the exception of intensively used agricultural areas in the Podunajská nížina lowland and Východoslovenská nížina lowland, in the Košická kotlina basin and Juhoslovenská kotlina basins, is shown in deep green and represents an index value of 4 to 5 from the modified Burkhard matrix of potential.

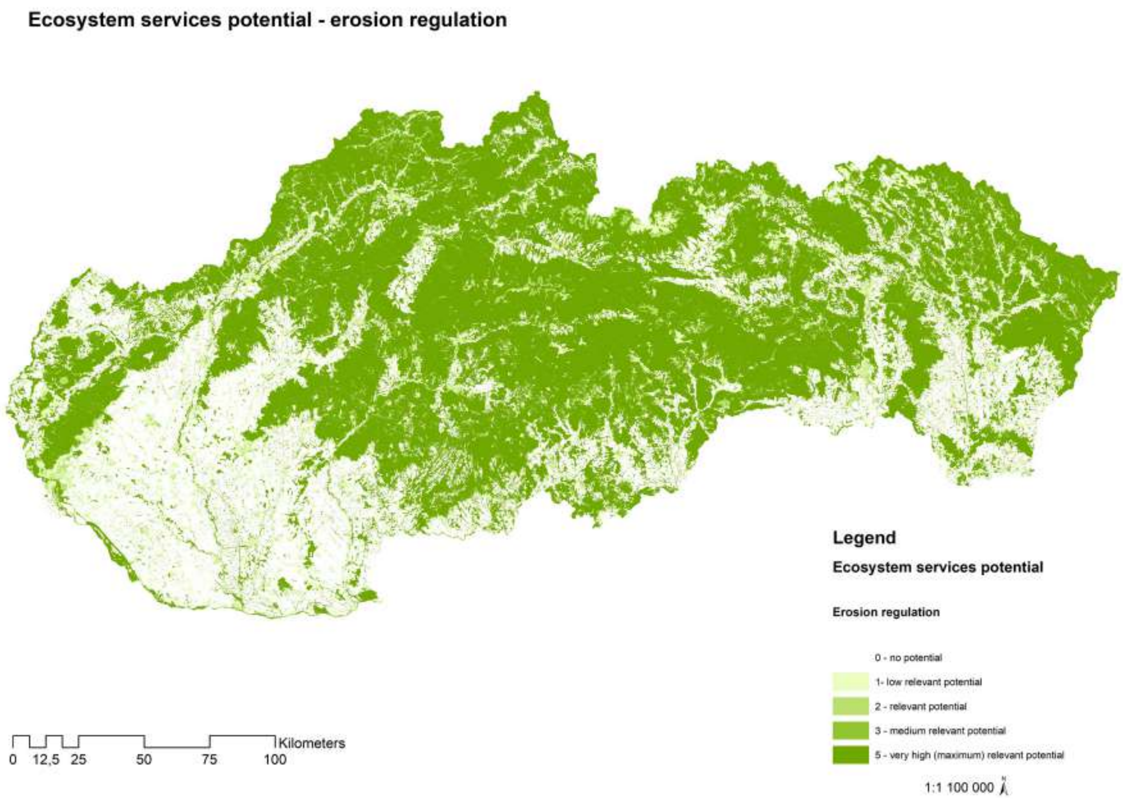

Fig. 22 Map of potential for provision ES erosion regulation

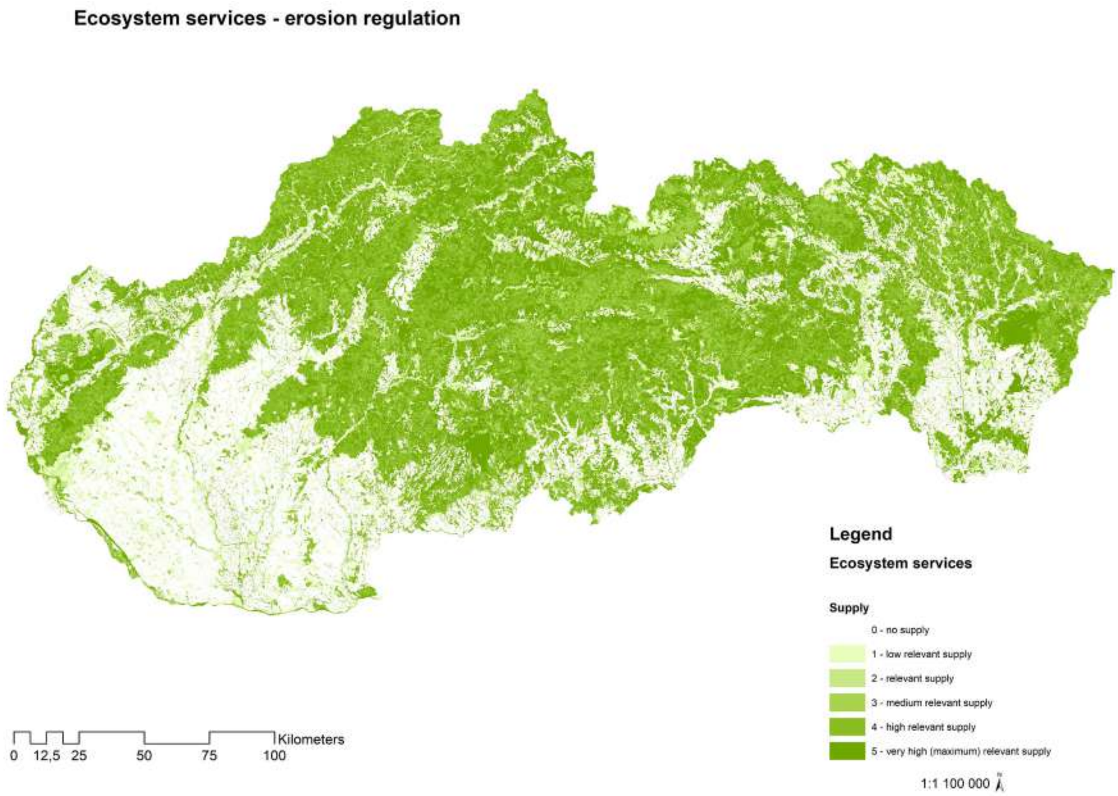

Fig. 23 Map of supply of ES erosion regulation in relation to the quality of ecosystems

After analysing the supply of erosion regulation service (Fig. 23) it can be said that the degradation of ecosystems in Slovakia has a slightly negative impact on the provision of this service, but from a national perspective, its supply is sufficient. However, this ES is missing in certain localities of Slovakia, often in places where it is very much needed, and its lack causes a threat to human health and property or excessive erosion on agricultural land, which subsequently degrades fertility. The risk of landslides increases in combination with other natural disasters such as earthquakes or a sudden high drop in precipitation causing local floods and soil disturbance and consequently a risk of landslides.

Insufficient supply at the local level is mainly in intensively cultivated fields in western and eastern Slovakia. Paradoxically, these are areas with the most fertile soils, but their protection against erosion is minimal in these parts of Slovakia. The original habitats that would provide the erosion regulation service at the local level in the mentioned areas of Slovakia are clearly under-represented. If the situation does not improve in the future for example through the restoration of natural habitats, partial mosaic afforestation or the improvement of degraded habitats, the intensively farmed agricultural land faces a similar scenario as many examples from abroad where due to erosion and the complete loss of the fertile part of the land, it was no longer possible to manage the fields.

3.3.1.8 Flood control

Floods are considered to be a natural hazard occurring in the biosphere that can damage humans and ecological systems. Annual economic losses caused by floods are constantly increasing on the basis of socio-economic factors, and flood activity is escalating due to the higher frequency and extent of heavy rainfall as a result of climate change. As a result of these negative developments, flood control is becoming increasingly important (de Guenni et al. 2005, Stürck et al. 2014). Flood control is one of the critical ecosystem services defined in the Millennium Ecosystem Assessment (MEA 2005), because an ecosystem in good condition has the ability to mitigate floods and reduce flood risks caused by large rainfall (Stürck et al. 2014).

Gradual climate change also brings with it a greater risk of extreme weather, including sudden floods in those parts of Slovakia where large watercourses may not even occur. Due to heavy rain, in which a high amount of precipitation falls in a short time in combination with a high slope, removal of woody vegetation, or improperly built field and forest roads there is a risk of floods with consequent damage to property and in some cases to human life. Ecosystems play a major role in this regard, as they ensure the retention of water in the landscape through biomass and the soil, protect us from floods and make a significant contribution to mitigating the effects of natural disasters, and can even prevent them altogether. In degraded ecosystems, these processes do not work fully, just as they do not work in man-altered habitats. Wetland habitats and forest habitats, which best ensure the water retention function in the country, are key to ensuring the flood regulation service. Wetlands have a high natural, cultural and economic value. They allow the existence of a large number of native species of plants and animals, many of which are rare. In Slovakia, wetlands cover approximately 0.5% of its acreage. Their conservation and restoration not only increases natural values, but also contributes to capturing flood waters, improving water quality, ensuring the replenishment of groundwater reserves or balancing flows in streams. However, their threat is growing, as the area and quality continue to decline. This is mainly due to intensive or insufficient agricultural practices, land reclamation, eutrophication, land fragmentation, changes in water regime, etc. Significant impacts on watercourses and coastal habitats are their man-made regulations, straightening and deepening, the absence of native riparian vegetation, pollution, flushing from agricultural areas and the infiltration of non-native species. All these threats and factors degrade the ecosystems themselves, which subsequently only partially and to a limited extent fulfill the function of this flood regulation service.

Results of the evaluation of the flood control service

The index of the potential provision of flood control service is 2.11 and the monetary value after conversion to the area of habitats is set at 29,967,149,379 EUR per year (Tab. 15). After taking into account the degradation of ecosystems, the supply of the flood control service is set at 1.69 index point and a monetary valuation on 24,978,449,231 EUR per year. As a result of the degradation of ecosystems in Slovakia, 5 billion EUR is lost annually.

Tab. 15 Indexes and values of potential and supply in relation to the ES provision of natural hazard regulation divided according to the EUNIS 1 level

FLOOD CONTROL	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	3.08	638,444,795	2.96	599,057,132
D – Mires, bogs and fens	3.96	231,663,776	3.81	227,104,371
E – Grasslands and lands dominated by forbs, mosses or lichens	1.00	2,954,127,542	0.96	2,848,319,070
F – Heathland, scrub and tundra	0.78	142,568,512	0.74	138,661,959
G – Woodland, forest and other wooded land	3.99	21,746,352,925	2.92	16,911,401,217
H – Inland unvegetated or sparsely vegetated habitats	1.01	16,721,285	1.00	16,634,938
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	1.00	3,922,478,265	1.00	3,922,478,265
J – Constructed, industrial and other artificial habitats	0	1,259,994	0	1,259,994
X – Habitat complexes	0.97	313,532,286	0.97	313,532,286
Total: Weighted average over ecosystem area/Total value in EUR	2.11	29,967,149,379	1.69	24,978,449,231

The contribution of individual habitat types to flood control service is evident, with the highest potential provision of **forest ecosystems** with 3.99 index value, followed by **wetland ecosystems** with 3.96 index value. However, taking into account the degradation of ecosystems, **wetlands** clearly dominate in the quality of supply of flood control service with 3.81 index value compared to forest habitats, which value of supply of this ES is set at 2.92. Among wetlands, the best habitats for potential provision of this service are **D5.24 Fen beds of great fen sedge** - Cladium - **a very rare habitat** and **D4.1 Rich fens, including eutrophic tall-herb fens and calcareous flushes and soaks**, but also other wetland habitats provide relatively high quality of this ES. In terms of area and also quality, **the most important habitat in Slovakia is G1.63 Medio-European neutrophile beech forests.** In total, **100 habitats** (in the EUNIS classification with an index value of potential of 1 to 4) contribute to the potential provision of the flood control service **on an area of 4,624,507.75 ha/46,245 km^2. However, it is on a much smaller total area if we consider the quality with index 3 and higher.**

Potential provision of flood control service is, as with most regulatory services, tied to mountains with continuous forests, as they cover approximately 40 % of Slovakia (dark green colours on the map in Fig. 24 represent the highest values of this ES potential). Wetland ecosystems and surface aquatic ecosystems are small and difficult to identify from a national map, but they contribute significantly to the provision of this service. Lowlands in the southwest and southeast of Slovakia and the ecosystems identified in them, with a predominance of arable land, have a much lower level of potential provision of flood regulation service.

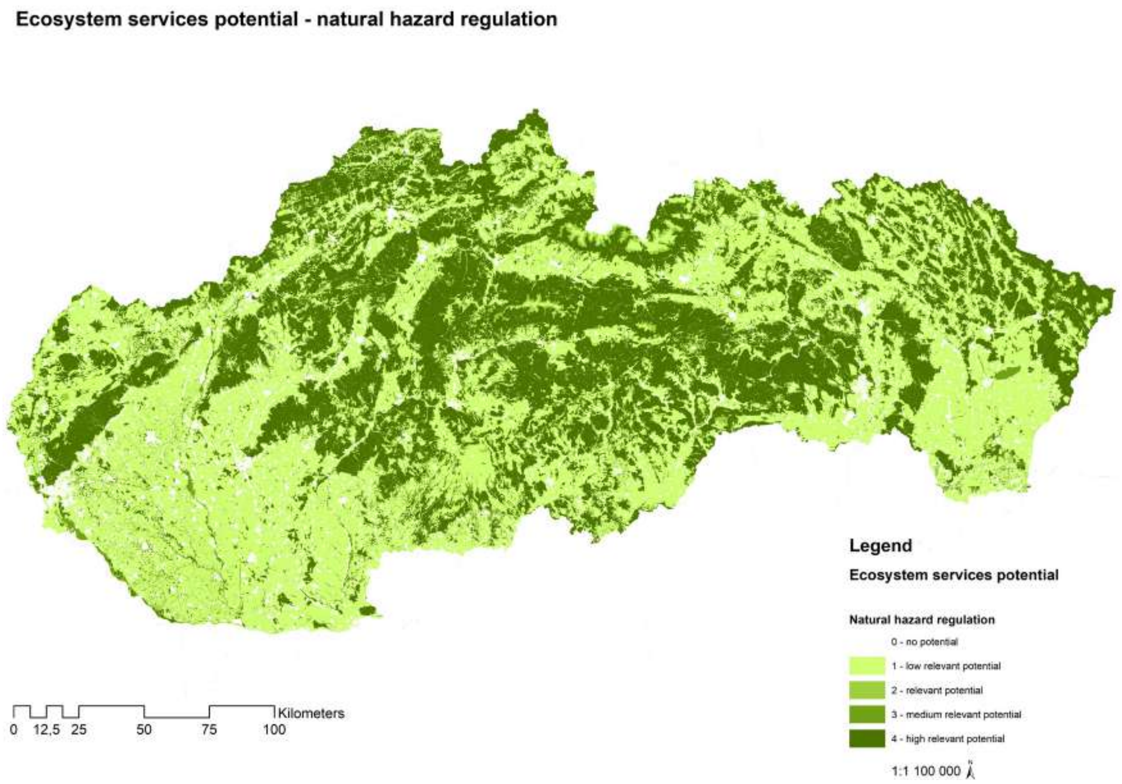

Fig. 24 Map of potential for provision ES natural hazard regulation

Fig. 25 shows a decrease in the index values, based on which it can be seen that the supply of the flood control service is significantly reduced. In the case of forest ecosystems, the decrease in supply compared to potential is up to 1.07 index point. This decline is due to degradation and artificial interventions in ecosystems. Cities and built-up areas contribute negligibly to the supply of the flood control service.

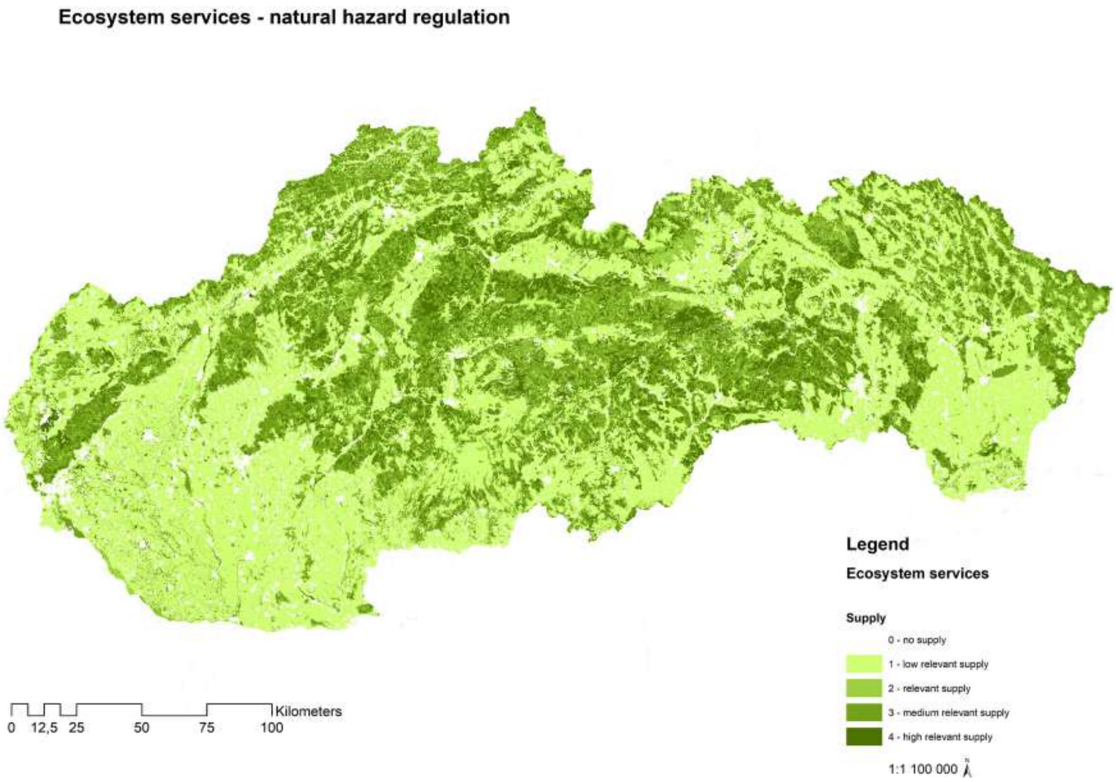

Fig. 25 Map of supply of ES natural hazard regulation in relation to the quality of ecosystems

The high index of supply in military districts is interesting. The areas covered by military districts represent, in most cases, a different types of habitats in a favourable condition, as there has been no intensive agricultural and forestry activity in them.

3.3.1.9 Pollination

Pollination of plants with bees as well as other insect species is an important ecosystem service that has an impact on the conservation of biodiversity and on the fertility, quality and stability of crop production (Kizeková et al. 2016). Based on a global pollination assessment prepared by experts from the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES), it is estimated that around 75 % of globally important crops, including fruit and seed production, depend on pollination and are also important for more than 80 % of wild plants of the temperate zone (Potts et al. 2016). Many of the crops, such as some fruits, nuts, oilseeds, cereals and vegetables, would not be able to produce any yield without pollination by insects. The most important pollinators in the temperate zone are *Hymenoptera*.

Results of the evaluation of the pollination service

From the point of view of the quality of the provision of the pollination service, **forest and shrub habitats** are especially important, but also G1.D - Fruit and nut tree **orchards**, which have an index value of potential up to 4.9. In terms of quantity, very significant habitats are **G1.63 Medio-European neutrophile beech forests** as well as **G1.A16 Sub-continental oak - hornbeam forests**, and from non-forest habitats it is **E2.22 Sub-Atlantic lowland hay meadows** which cover a relatively large area in term of pollination service provision.

Tab. 16 Indexes and values of potential and supply and in relation to the ES provision of pollination divided according to the EUNIS 1 level

POLLINATION	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	0.13	13,430,889	0.11	10,823,437
D – Mires, bogs and fens	1.04	10,381,292	0.91	9,703,760
E – Grasslands and lands dominated by forbs, mosses or lichens	0.91	427,650,899	0.87	412,213,080
F – Heathland, scrub and tundra	1.39	56,061,580	1.35	55,411,273
G – Woodland, forest and other wooded land	4.00	3,612,798,190	2.93	2,824,472,910
H – Inland unvegetated or sparsely vegetated habitats	0	0	0	0
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	1.03	640,728,843	1.03	640,728,843
J – Constructed, industrial and other artificial habitats	0.83	88,588,689	0.83	88,588,689
X – Habitat complexes	1.74	48,088,139	1.74	48,088,139
Total: Weighted average over ecosystem area/Total value in EUR	2.13	4,897,728,521	1.71	4,090,030,131

The total value of the potential for provision of pollination service in Slovakia is approximately 4,897,728,521 EUR per year. **82 habitats** in the EUNIS classification (with an index of potential higher than 0) **on the area of 4,663,880.806 ha/46,638.8 km^2** participate on the potential provision of pollination service nationwide. The index value of potential (in case that all ecosystems are in favourable conservation status) has a value of 2.13 (on a scale of 1-5). The supply index of pollination service is set at 1.71, which is 0.42 points less than the potential (Tab. 16). After taking into account the degradation of ecosystems, the monetary value of this service's supply is set at 4,090,030,131 EUR per year. **The index values of the potential and the supply are the lowest values among all other regulatory services and draw attention to the necessary need to care more about the issue of pollination in Slovakia,** which concerns not only the conditions of ecosystems, but mainly agricultural practises and their related negative modifications and human inputs in these ecosystems (arable land, wetlands, built-up areas and cities, grasslands and others ecosystems presented in Tab. 16). The difference in the total economic value between potential and supply is approximately 800 million EUR as shown in Tab. 16.

In the map of supply of pollination service (Fig. 27) it is evident that compared to the average potential provision (Fig. 26) there are more habitats that have a relatively high potential of this ES, however, areas with very low potential of this ES are still predominant, especially on an arable land. The most favourable situation in terms of supply of pollination service is especially in northern and central Slovakia with a high proportion of forests and grasslands. The deficit of this service is to some extent compensated mainly by beekeepers. In regions where there is insufficient supply of pollination service, it is necessary to increase the proportion of semi-natural ecosystems that provide suitable habitats for pollinators, as well as to create suitable conditions to support beekeepers and eliminate factors that cause bee deaths or declines.

Ecosystem services potential - pollination

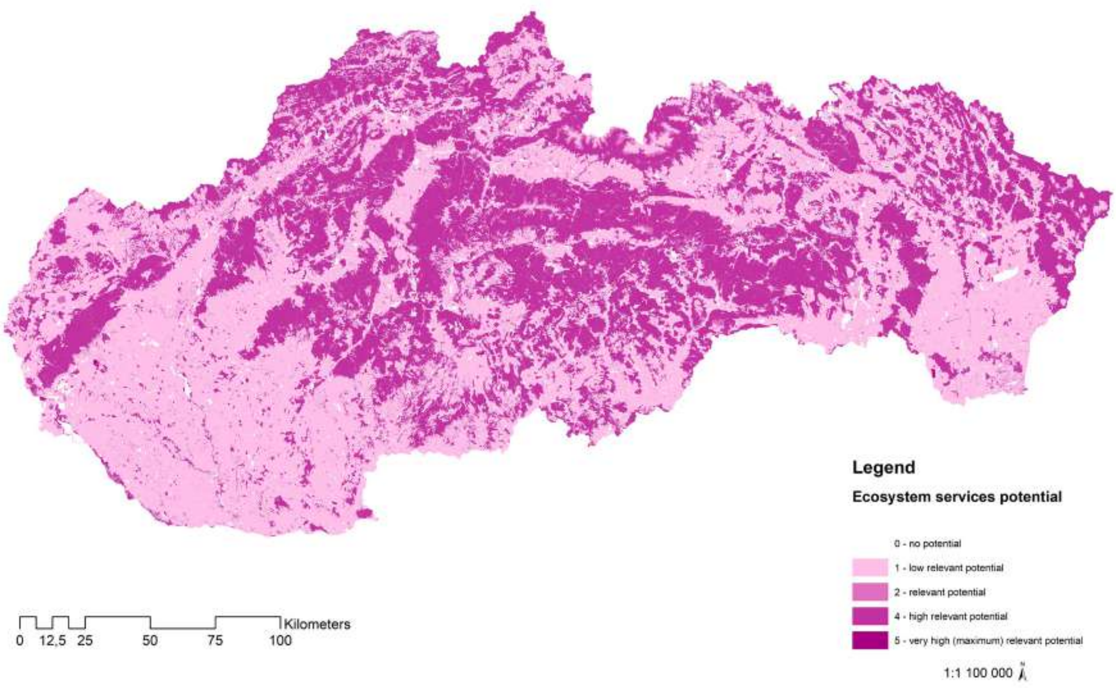

Fig. 26 Map of potential for provision ES pollination

Ecosystem services - pollination

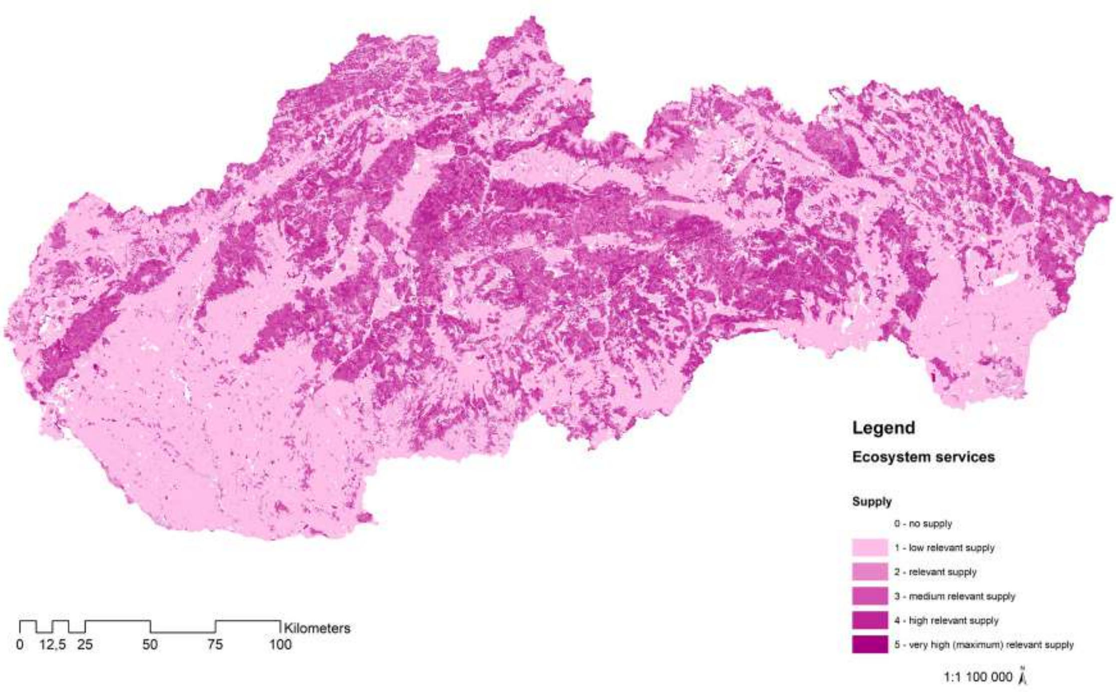

Fig. 27 Map of supply of ES pollination in relation to the quality of ecosystems

3.3.1.10 Pest and disease control

The structure of the landscape influences local diversity and ecosystem processes, including the influence of species and habitats among themselves, characterized by different dynamics. Species can bind themselves to certain communities, but also can move between different communities, both natural and anthropogenically changed (Tscharntke et al. 2005). Natural and semi-natural habitats fulfill a compensatory function – they reduce the negative consequences of human activity on the landscape and its components. In particular, habitats of extensively used grasslands or places left for self-development within arable land can serve as habitats for reproduction of plants and animals, for migration or spread in the landscape (dispersal of seeds by insects, birds and other animals), as habitats for pollinators, as places for rest, food, shelter, and thus also contribute to the regulation of pests and diseases (biological control of pests and diseases of livestock and plants, reduction of vectors, diseases of human pathogens), etc. This service has a very important role to play in the current context of globalization and is likely to increase in the future. The spread of human pathogens is greatly influenced by the structure of the landscape, the ecosystems in it and their quality. When caring for natural habitats, their appropriate distribution in the country has a significant impact on reducing the spread of human pathogens. To some extent, the link between the degradation of ecosystems and the rate of spread of diseases in the human population is important. Global pandemics (e.g. COVID-19) may reflect a lack of care for ecosystems, their gradual degradation and misallocation of the landscape, and this factor may play a role. It is possible that ecosystems and services, which they provide, play one of the most significant roles in the reduction of the spread of pathogens, diseases and thus bring an irreplaceable function for human survival and therefore need to be given adequate attention, which has obviously been greatly underestimated and even overlooked. For humans, it should be a question of life and death to "repair" damages that were done to ecosystems and through revitalization and restoration provide better protection for people from further spreading of human pathogens. The basis for these necessary changes in Slovakia exists and is listed below. It should be emphasized that since humanity has not faced a pandemic for the last 50 years to the extent it is facing today in connection with COVID-19, the evaluation of this service has been clearly underestimated (average only 7 EUR per hectare). It means that providing the relationship between a healthy ecosystem and the rate of spread of similar viruses is confirmed (similar types of viruses may and will emerge in the future), people die, the national economy quantifies daily losses in millions of EUR. Therefore it is clear that the current average monetary values of pest and disease control service are underestimated and probably should increase in the near future. Therefore, the data in this work should be taken as they were perceived before the outbreak of the COVID-19 pandemic, and if the link between the role of a healthy ecosystem and its effect on slowing the spread of similar diseases is confirmed, these values should be increased accordingly in the future as a reflection of these new realities.

Results of the evaluation of the pest and diseases control

Natural and semi-natural habitats in the neighbourhood of agroecosystems or other anthropogenic areas are particularly important for the potential provision of the pest and disease control service. The total monetary value of the potential of this service in Slovakia is **30,707,850 EUR per year** (Tab. 17). After taking into account the quality of ecosystems and their supply of pest and disease control service is set at 26,395,943 EUR per year, which means that **due to the unfavourable condition** of some ecosystems, **the total monetary value decreases by 4 million EUR per year**. The index values of potential is evaluated at 2.52 (on a scale of 1-5). In the map of supply of pest and disease control service (Fig. 29) it is evident that compared to the potential (Fig. 28) there are many more areas with a reduced provision values. The service´s supply index is set at 2.1 (on a scale of 1-5), which is 0.42 points less than the potential.

In terms of area, but also quality of the provision of this service, forest habitats are dominated by **G1.63 Medio-European neutrophile beech forests** and **G1.A16 Sub-continental oak - hornbeam forests. An arable land** is significant too, but mainly in terms of quantity, the quality is relatively low (only 2 index points). A total of **100 different habitats** in the EUNIS categorization (potential index higher than 0) contribute to the potential provision of pest and disease control service. The mountain regions of central and northern Slovakia appear to be relatively balanced areas.

Tab. 17 Indexes and values of potential and supply in relation to the ES provision of pest and disease control divided according to the EUNIS 1 level

PEST AND DISEASE CONTROL	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	2.87	427,708	2.75	393,324
D – Mires, bogs and fens	2.04	106,072	1.90	102,132
E – Grasslands and lands dominated by forbs, mosses or lichens	1.09	2,847,589	1.05	2,755,911
F – Heathland, scrub and tundra	1.39	297,150	1.35	293,703
G – Woodland, forest and other wooded land	4.00	18,966,431	2.93	14,787,973
H – Inland unvegetated or sparsely vegetated habitats	0.01	1	0.01	1
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	2.00	6,779,760	2.00	6,779,760
J – Constructed, industrial and other artificial habitats	0.94	612,317	0.94	612,317
X – Habitat complexes	2.83	670,822	2.83	670,822
Total: Weighted average over ecosystem area/Total value in EUR	2.52	30,707,850	2.10	26,395,943

In order to increase the quality of provision of this service, it would be necessary to improve the quality of forest ecosystems, because a significant part of forest stands is threatened by calamities due to the poor health of trees. Similarly, within the agricultural landscape, it is necessary to support an increase of the area representation of semi-natural habitats that would fulfill the function of refuge and eliminate their threat to the spread of non-native invasive species. Efforts should be made for a better landscape-ecological structure and restoration of natural ecosystems throughout the whole territory of Slovakia.

In regions where there is an insufficient provision of this service, it is necessary to increase the area and quality of ecosystems that provide pest and disease control as well as realise the increase of functional biodiversity in agroecosystems. If adequate measures are implemented to support the provision of this service, it should have a positive impact on pollination service or other regulatory services.

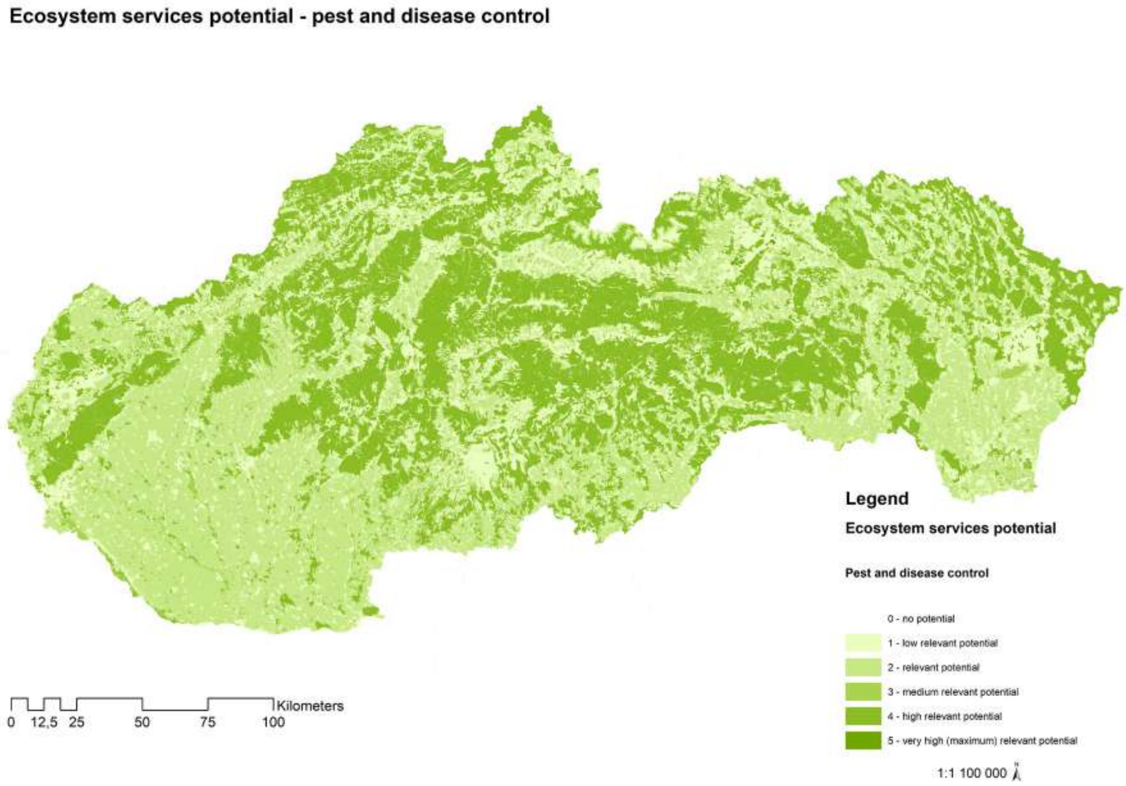

Fig. 28 Map of potential for provision ES pest and disease control

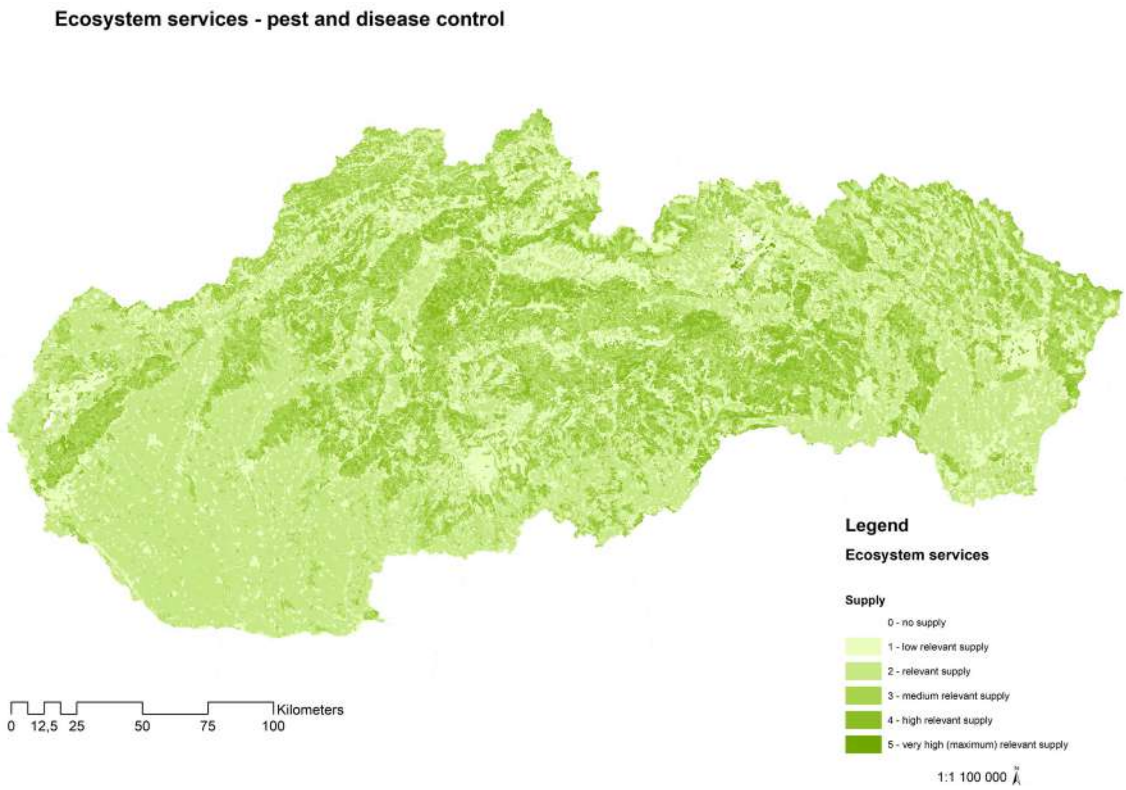

Fig. 29 Map of supply of ES pest and disease control in relation to the quality of ecosystems

At present, the damage caused by the SARS-COVID19 virus for Slovakia is estimated at billions of EUR. It is evident that if ecosystems were revitalized/restored in the future, their spatial structure improved, they will prevent the spread of similar viruses to a greater extent and thus bring significant savings to the state, fundamentally reduce current losses in the economy and especially on human lives. It can also be stated that if ecosystems in the current condition did not provide this service to the extent we assess it, the loss of human lives and economy would be many times greater than the current damage and losses, and therefore the conservation of ecosystems and their functions would should be a priority.

3.3.1.11 Regulation of waste

Ecosystem processes reduce concentrations of substances that are directly or indirectly dangerous to humans. However, capacity in ecosystems is limited and in many places the carrying capacity is exceeded (the example of ozone depletion and climate change are proof of this). Mankind produces a large number of different types of waste and harmful substances, which it stores in the environment. All the different types of water poisoning, soil contamination, environmental degradation due to landfills affect biota and are a failure of waste management and planning. The risk is that some contaminants cannot be turned into harmless material and remain in the environment permanently (Hassan 2005). Ecosystems play an important role in the treatment of waste and harmful substances introduced into the natural environment, but this ability to treat waste has certain limitations. For example, water systems "clean" an average of 80 %t of their global nitrogen impact, but this intrinsic self-cleaning capacity is reduced by the loss of wetlands worldwide. As the characteristics of waste, pollutants and the ecosystems receiving this waste and pollutants differ, the environment differs in their ability to absorb and manage the waste (Kumar et al. 2010). Increased quality of wetlands can improve the processing of harmful substances and save potential additional costs for their management (Costanza et al. 1997).

Results of the evaluation of regulation of waste service

The index value of the potential is currently set at 2.71 index point, the supply set at 2.29. Due to degradation, especially of forest ecosystems, the quality of regulation of waste service provision decreased by 0.42 index point (Tab. 18).

From the waste regulation service point of view, the most important ecosystems are clearly **aquatic habitats**, potential index value of which is 4.6. **Wetlands, peat bogs, moors** and **forest ecosystems** are also very significant. Quality-wise, the most important are **C2 Surface running waters vegetation, C1-Surface standing waters and C1.2 Permanent mesotrophic lakes, ponds and pools**. In terms of quantity, **I1 Arable land and market gardens, G1.63 Medio-European neutrophile beech forests** and **E2.22 Atlantic lowland hay meadows** are the most significant habitat types

Tab. 18 Indexes and values of potential and supply in relation to the ES provision of regulation of waste divided according to the EUNIS 1 level

REGULATION OF WASTE	POTENTIAL	SUPPLY
EUNIS level 1 classification	Index average	Index average
C – Inland surface waters	4.72	4.6
D – Mires, bogs and fens	3.04	2.9
E – Grasslands and lands dominated by forbs, mosses or lichens	2.18	2.13
F – Heathland, scrub and tundra	1.78	1.74
G – Woodland, forest and other wooded land	4.00	2.93
H – Inland unvegetated or sparsely vegetated habitats	0.01	0.01
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	2.00	2.00
J – Constructed, industrial and other artificial habitats	0.02	0.02
X – Habitat complexes	2.17	2.17
Total: Weighted average over ecosystem area	2.71	2.29

Fig. 30 and Fig. 31 show the visible contribution of river ecosystems (dark green colour), which form a network and ensure self-cleaning ability for the treatment of harmful substances and waste to the whole territory of Slovakia. The contribution of aquatic habitats is significant, of which the Danube River has the greatest weight, the reservoirs themselves have a rather local benefit and from a national quantity point of view it is essentially negligible. Forest ecosystems of the mountain and foothill areas of the Slovak Carpathians, which are quantitatively the most widespread in central Slovakia, have a high rate of potential provision of the regulation of waste service. Significant in terms of acreage, but qualitatively less important, are the large lowlands of the Pannonian biogeographical of Slovakia. The high potential of wetland habitats (index value of potential is up 3 to 4) is not visible in the national map display, as their area is only 20,955.13 ha/209.56 km^{2}.

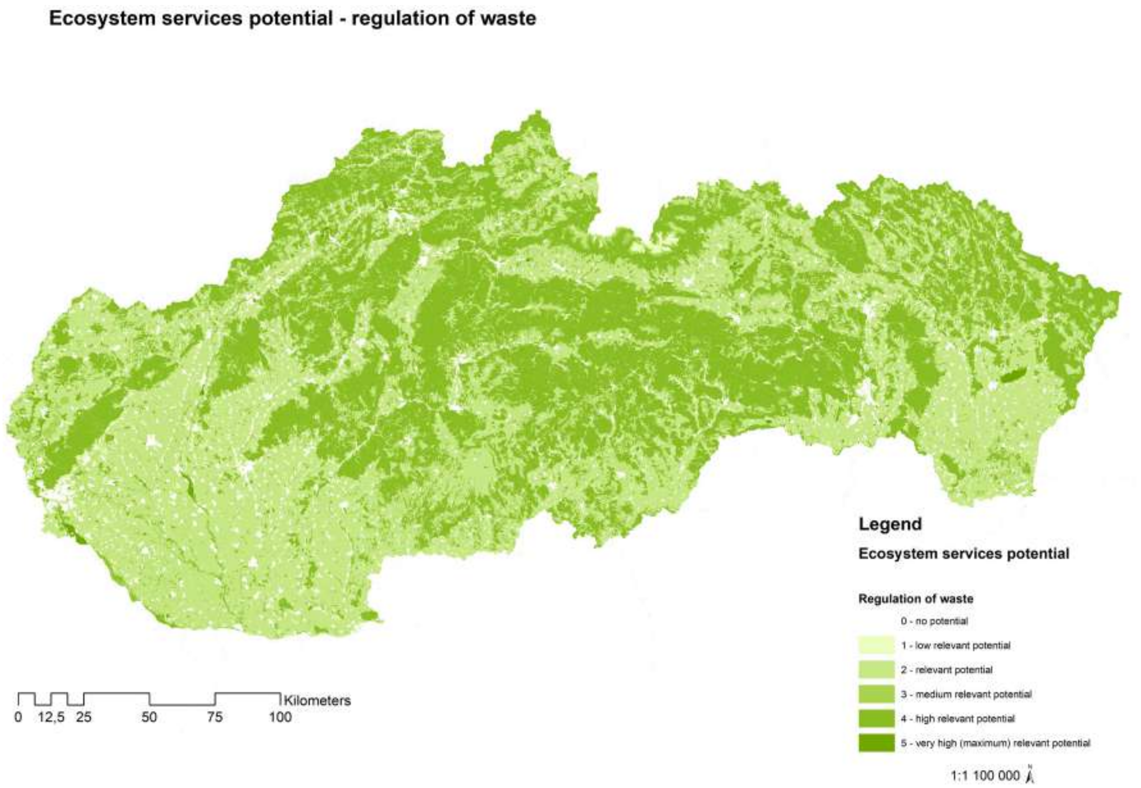

Fig. 30 Map of potential for provision ES regulation of waste

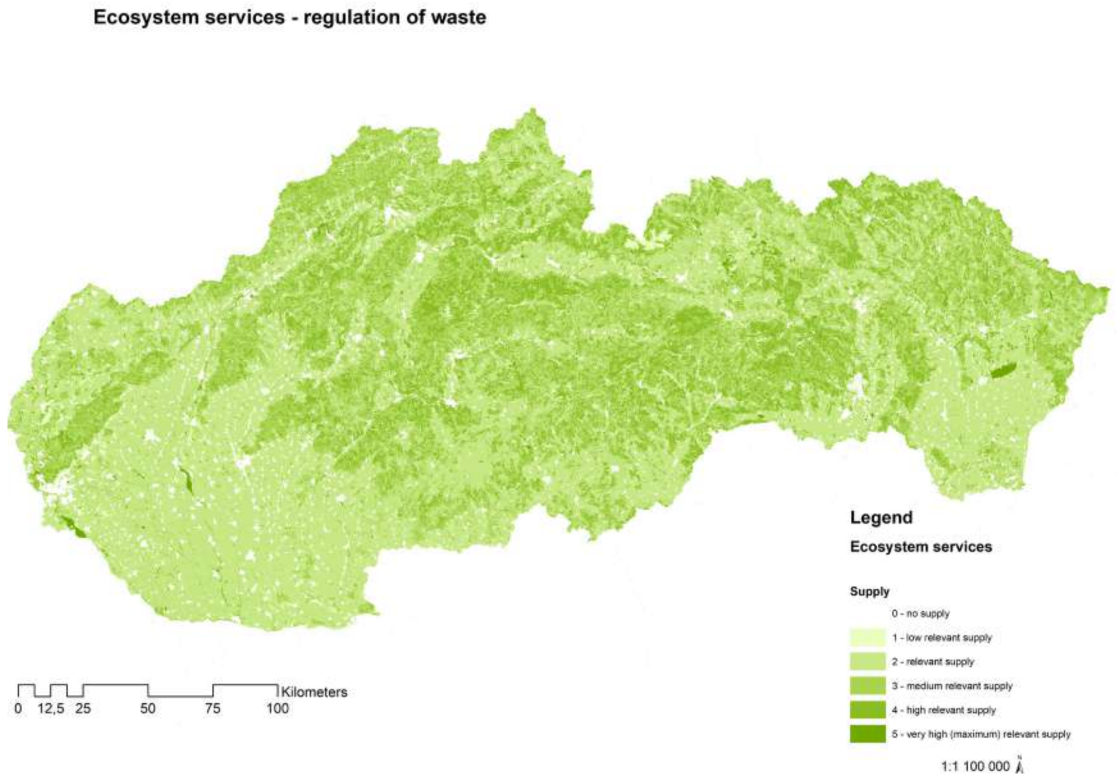

Fig. 31 Map of supply of ES regulation of waste in relation to the quality of ecosystems

3.3.2 Provisioning ecosystem services

3.3.2.1 Crops

Crop provision makes a significant contribution to human well-being. Agricultural ecosystems (agroecosystems) provide people with food, feed, bioenergy and medicines. Agroecosystems are highly dependent on ES provided by natural ecosystems (Power 2010). A better understanding of ecological processes and their economic benefits in agroecosystems can help improve the provision of ecosystem services by returning selective functional agricultural biodiversity to agriculture practise (Herridge et al. 2008). The combination of crops, the use of pest biocontrol in the cultivation of crops can save the initial investment in its cultivation.

On the one hand, the intensification of agricultural production brings higher production, but at the same time it poses a risk for individual ecosystems in terms of their transformation and gradual degradation. On the other hand, the rest of traditional farming methods in Slovakia are relatively beneficial in terms of nature and landscape protection, its landscape character. Crop production is concentrated mainly in the most fertile parts of Slovakia e.g., southwestern and southeastern part. However, lowlands also create an appropriate conditions for intensive agricultural production, which is negative in terms of degradation of native natural ecosystems and proportion of services which ecosystems provide. The original ecosystems of wetlands near arable land have been systematically ameliorated, and the landscape has been deforested over large areas. This has led to increased harvests and more efficient machine management in the short term, but in the long run it is vulnerable to the growing effects of climate change and, as a result, reduces the quality and quantity of regulatory ecosystem services provided.

Results of the evaluation of the crop provisioning service

From a national point of view, crop provision is limited to certain ecosystems, mainly **agroecosystems** (fields, gardens, orchards, vineyards), **habitat complexes** (e.g. landscape mosaics with forest elements, pasture forests), and also for this reason the resulting index value of potential is low - 1.57 index point (Tab. 19). Crop provision is provided by ecosystems in various qualities (with an index of potential higher than 0) on **an area of 1,757,268.253 ha/17,572.58 km²** and is provided by **9 different ecosystems** (of which an arable land represents an area of 1,389,009.37 ha).

Tab. 19 Indexes and values of potential and supply in relation to the ES provision of crops divided according to the EUNIS 1 level

CROPS	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	0.09	1,634,726	0.09	1,600,226
D – Mires, bogs and fens	0	0	0	0
E – Grasslands and lands dominated by forbs, mosses or lichens	0	0	0	0
F – Heathland, scrub and tundra	2.43	37,296,202	2.43	37,292,979
G – Woodland, forest and other wooded land	0.01	25,426,381	0.01	25,358,887
H – Inland unvegetated or sparsely vegetated habitats	0	0	0	0
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	4.84	906,898,105	4.06	769,810,069
J – Constructed, industrial and other artificial habitats	0.83	25,170,671	0.83	25,171,057
X – Habitat complexes	3.46	27,170,356	3.46	27,170,772
Total: Weighted average over ecosystem area/Total value in EUR	1.57	1,023,596,441	1.35	1,023,505,916

Map display of the potential provision of Slovakia´s ecosystems of crop provision service (Fig. 32) shows that the Pannonian biogeographical region has the highest potential of provision of this service, specifically arable land of lowlands Záhorská nížina, Podunajská nížina, Východoslovenská nížina, as well as basins Košická kotlina, Ipeľská kotlina and uplands Trnavská pahorkatina and Nitrianska pahorkatina. After taking into account the fertility of soils in Slovakia and condition of ecosystems in the map of supply (Fig. 33) it is clear that part of arable land meets the values of potential - these are areas in the foothills of western Slovakia (e.g. the foothills of Malé Karpaty), but also southern areas of central and eastern Slovakia.

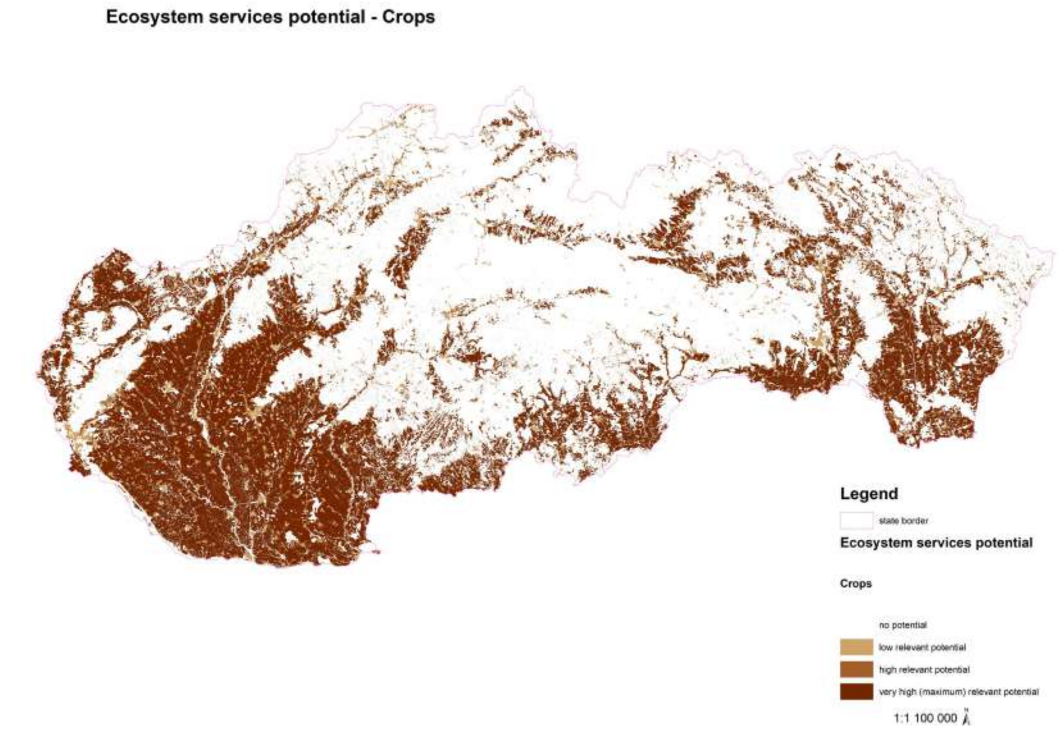

Fig. 32 Map of potential for provision ES crops

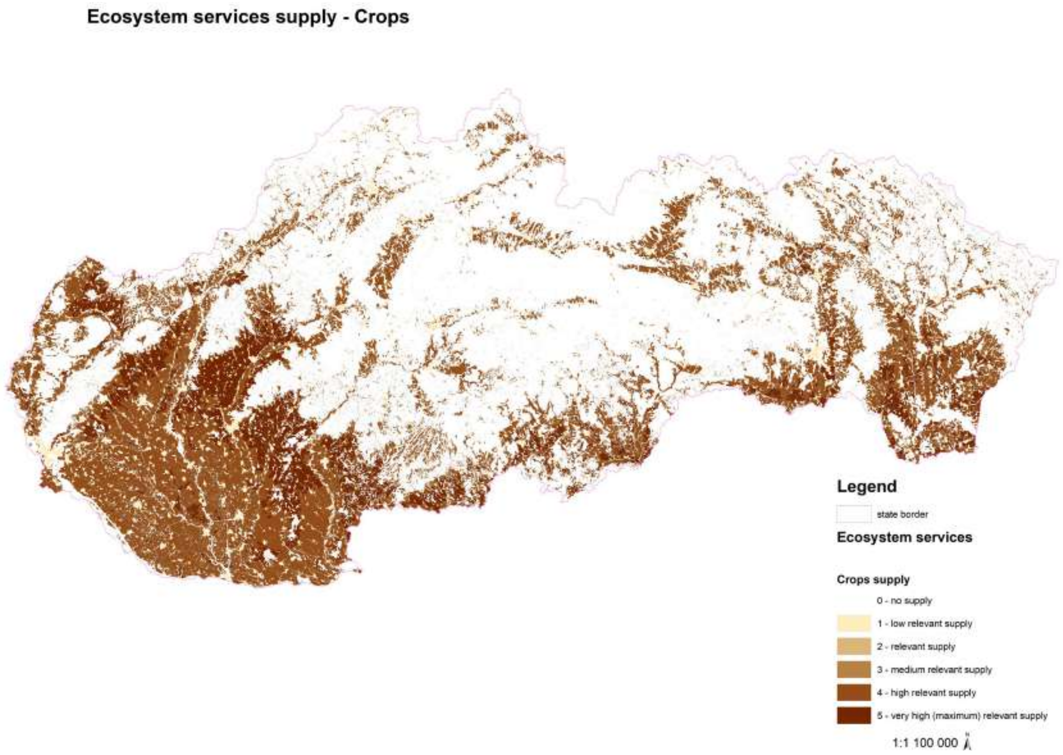

Fig. 33 Map of supply of ES crops in relation to the quality of ecosystems

3.3.2.2 Biomass for energy

Biomass provision is a renewable energy source. In order to mitigate climate change and increase energy security, the demand for renewable energy has been rising in recent years (McBride et al. 2011). Twenty percent of total energy production in the EU 2020 should come from renewable sources by 2020 (Gissi et al. 2016). Biomass is a product of individual ecosystems and Slovakia has a great potential in its provision and use. More than 90 % of the territory of Slovakia provides biomass in a certain quality and quantity. Mountain areas produce more dendromass, to which biomass of grasslands is added in the foothills. The lowlands are dominated by biomass of agricultural crops (Kanianska et al. 2010). However, it should be emphasized that excessive and reckless biomass uptake can gradually degrade individual ecosystems and thus lower an amount of this regulation service´s provision at the local level. Therefore, when using biomass, it is necessary to sensitively plan its use in such a way that other important ecosystem services are preserved in the given place. Biomass can be produced as the secondary product for example after logging in the form of branches and other wooded remains or after harvesting of crops in the form of stalks. Approximately 2 million tons of excess parts of plants (stalks) can be obtained annually from agriculture in Slovakia. Its further use in the form of biomass can cover the annual energy consumption of 300,000 households.

It means that it is possible to provide certain regulatory and provisioning ES at the same time. However, biomass can be used as a primary product of the ecosystem, and in such case there is a risk analysis needed in order to safeguard a balanced integrated approach. It is important to find out which areas have a great potential to provide biomass. A good example of sustainable use of biomass is a study concerning the village of Poniky near Banská Bystrica, which shows a way of long-term and efficient processing of biomass and at the same time preserving the original ecosystems, their quality and thus ensuring the provision of important regulatory and cultural ES (Polák et al. 2014).

Results of the evaluation of biomass for energy service

Although the potential of **agroecosystems** is relatively high, current stocks are only in the case of **forest ecosystems and peatlands**. Peatlands should be highly protected in view of their small size, as they provide to a much greater extent regulatory ES that far exceed the value of peat provision. The total monetary value of the potential of biomass for energy service, which counts on an ideal situation where all ecosystems and soils are in a favourable condition, is 1,441,242,765 EUR per year, but due to habitat degradation Slovakia loses about 180 million EUR per year (Tab. 20). The index of potential has a value of 2.06, the index which expressed the supply of this ES is 1.57 index point. A total of **80 different habitats** in the EUNIS classification (mainly with the index of potential of 1) contribute to the provision of biomass for energy service **on a total area of 4,583,596.604 ha/45,835.97 km^{2}.**

Tab. 20 Indexes and values of potential and supply in relation to the ES provision of biomass for energy divided according to the EUNIS 1 level

BIOMASS FOR ENERGY	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	1.73	8,198,185	1.64	7,273,167
D – Mires, bogs and fens	0.09	458,819	0.09	457,626
E – Grasslands and lands dominated by forbs, mosses or lichens	1.00	146,075,475	0.95	140,815,798
F – Heathland, scrub and tundra	1.00	13,581,926	0.97	13,421,736
G – Woodland, forest and other wooded land	1.00	274,336,904	0.33	96,972,213
H – Inland unvegetated or sparsely vegetated habitats	0	16	0	1
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	4.84	975,529,058	4.06	828,053,984
J – Constructed, industrial and other artificial habitats	0.01	173,694	0.01	173,694
X – Habitat complexes	1.83	22,888,688	1.83	22,888,688
Total: Weighted average over ecosystem area/Total value in EUR	2.06	1,441,242,765	1.57	1,257,531,997

The potential of the biomass for energy provision in Slovakia (Fig. 34) is slightly significant and most ecosystems are able to provide this ES to a limited extent. They are dominated by arable land in the southwestern and southeastern part of Slovakia, but important are also forest and non-forest ecosystems, which produce the biomass for energy service in a slightly smaller quantity.
After taking into account soil fertility and condition of ecosystems, the provision of this service is slightly different and it is produced to the maximum extent only by ecosystems on a smaller part of the most fertile arable lands in the Podunajská nížina lowland, Východoslovenská nížina lowland and Košická kotlina basin (Fig. 35). However, for the interpretation of this data it is necessary to remember that only a small part of the potential produced biomass can be used and a large part of the biomass remains unused or is used as another provisioning, regulatory or cultural service.

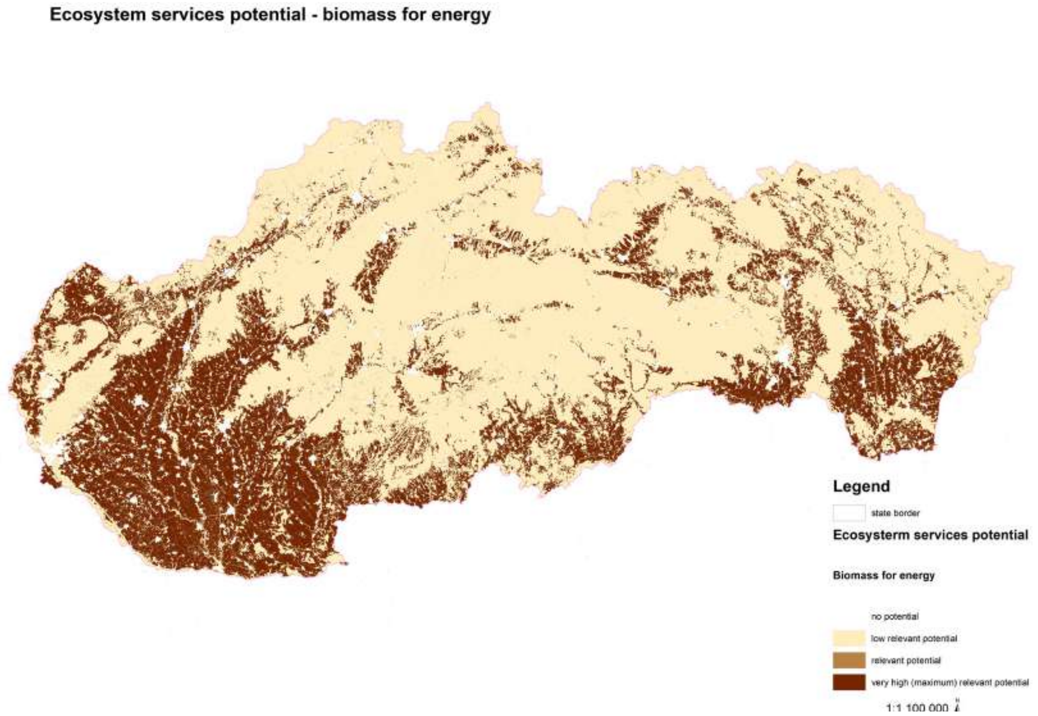

Fig. 34 Map of potential for provision ES biomass for energy

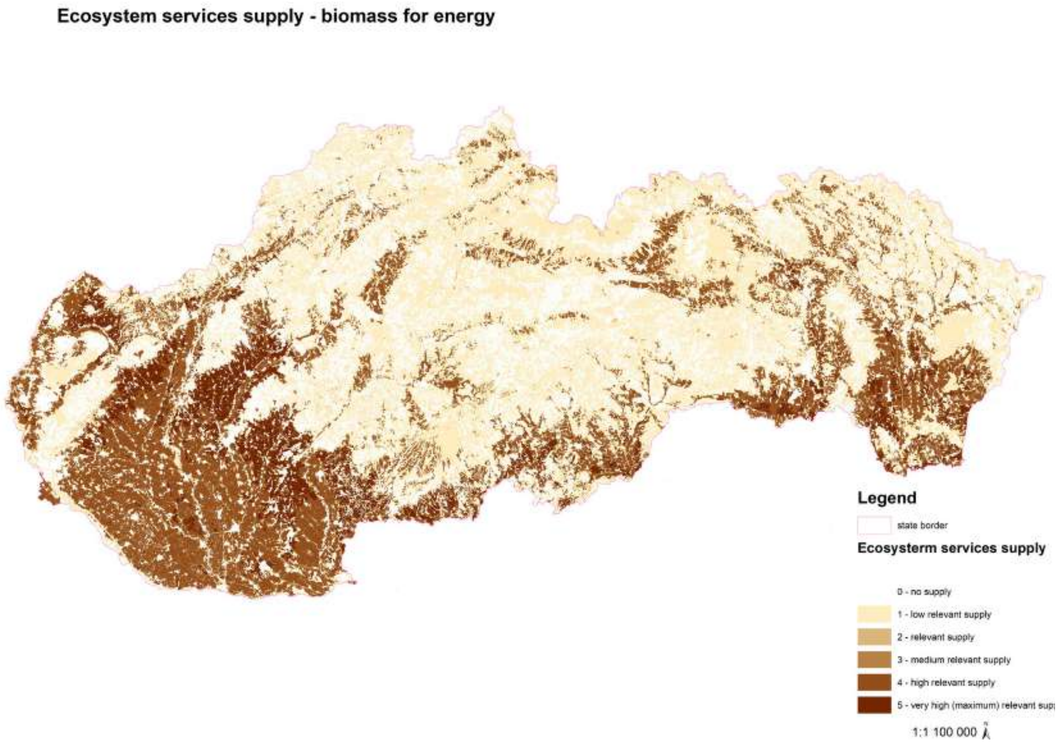

Fig. 35 Map of supply of ES biomass for energy in relation to the quality of ecosystems

3.3.2.3 Fodder (feed for cattle and other livestock)

The provision of fodder service in Slovakia has a similar value of the potential as the provision of crops or the provision of biomass for energy service, because of it is provided by essentially identical ecosystems. The base of fodder consists of fodder cultivated on an arable land, on permanent grasslands, further on areas where fodder is obtained as a by-product of plant production (stalk, etc.) and on non-agricultural areas, e.g. watercourse and reservoir's dams from where the fodder is obtained (Holúbek et al. 2007). The wildlife food base is mainly provided by various non-forest and forest ecosystems in Slovakia.

Results of the evaluation of the fodder service
Arable land is the most important ecosystem for the provision of the fodder service (Tab. 21). The potential´s index assessment confirms the highest potential of grassland habitats and a lower index value of the potential occurs in altered ecosystems (X Habitat Complexes), built-up areas and areas most affected by man. Due to the degradation of ecosystems, Slovakia loses 104 million EUR per year (as it can be seen in comparison of the potential and the supply in Tab. 21). The total index value of potential of fodder service is 2.32, the supply is set up to 1.83 index point. In economic terms, the total potential of Slovakia´s ecosystems to provide this service is 1,140,905,050 EUR per year (Tab. 21). Fodder provisioning through ecosystems is provided in various qualities on **an area of 4,467,647.11 ha/44,676.47 km^2 by 72 different ecosystems.**

Tab. 21 Indexes and values of potential and supply in relation to the ES provision of fodder divided according to the EUNIS 1 level

FODDER	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	0.49	866,944	0.46	13,698,312
D – Mires, bogs and fens	3.82	1,133,264	3.68	9,882,409
E – Grasslands and lands dominated by forbs, mosses or lichens	2.27	44,527,509	2.22	312,255,429
F – Heathland, scrub and tundra	0.90	287,389	0.36	3,157,275
G – Woodland, forest and other wooded land	1.00	110,236,147	0.33	83,861,474
H – Inland unvegetated or sparsely vegetated habitats	0	0	0	0
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	4.84	975,529,058	4.6	769,810,069
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	2.28	8,324,739	2.28	52,364,491
Total: Weighted average over ecosystem area/Total value in EUR	2.32	1,140,905,050	1.83	1,245,029,459

Ecosystem service fodder is provided mainly by fertile parts of Slovakia on an arable land (Fig. 36 and Fig.37), ecosystems of meadows and pastures are especially important. The fodder provisioning service is directly linked to livestock provision.

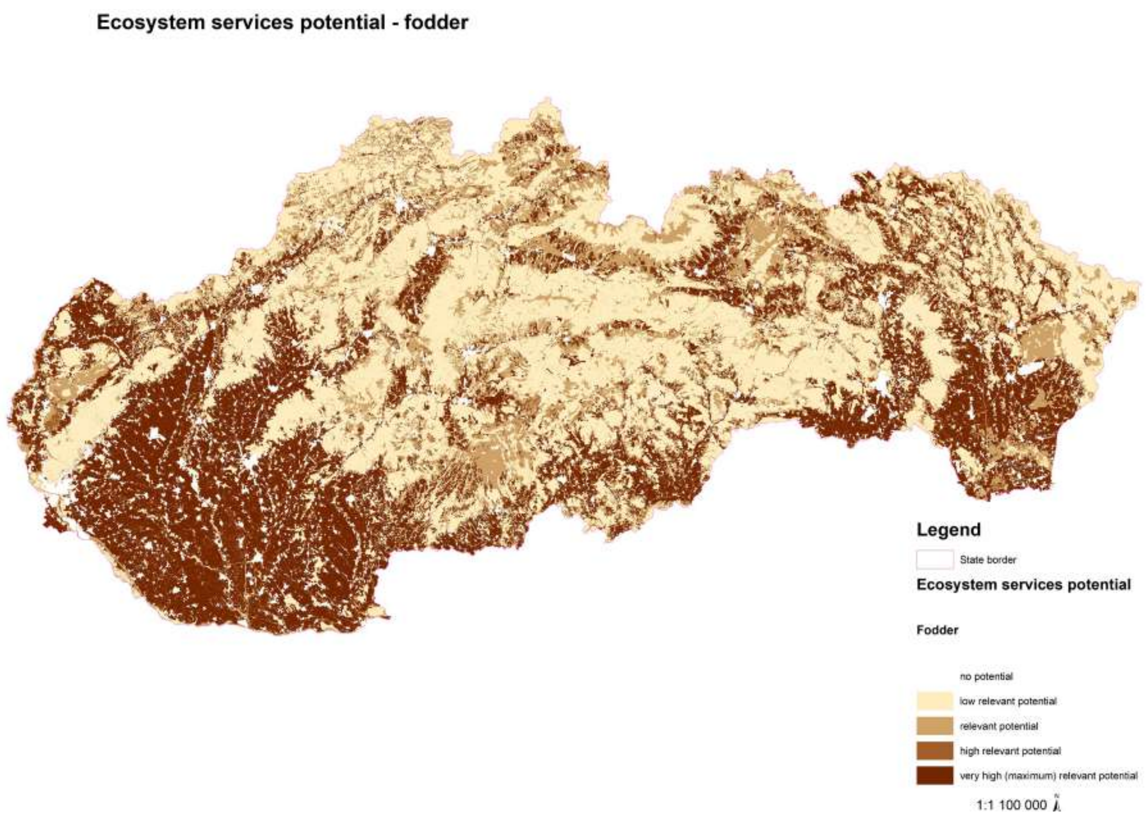

Fig. 36 Map of potential for provision ES fodder

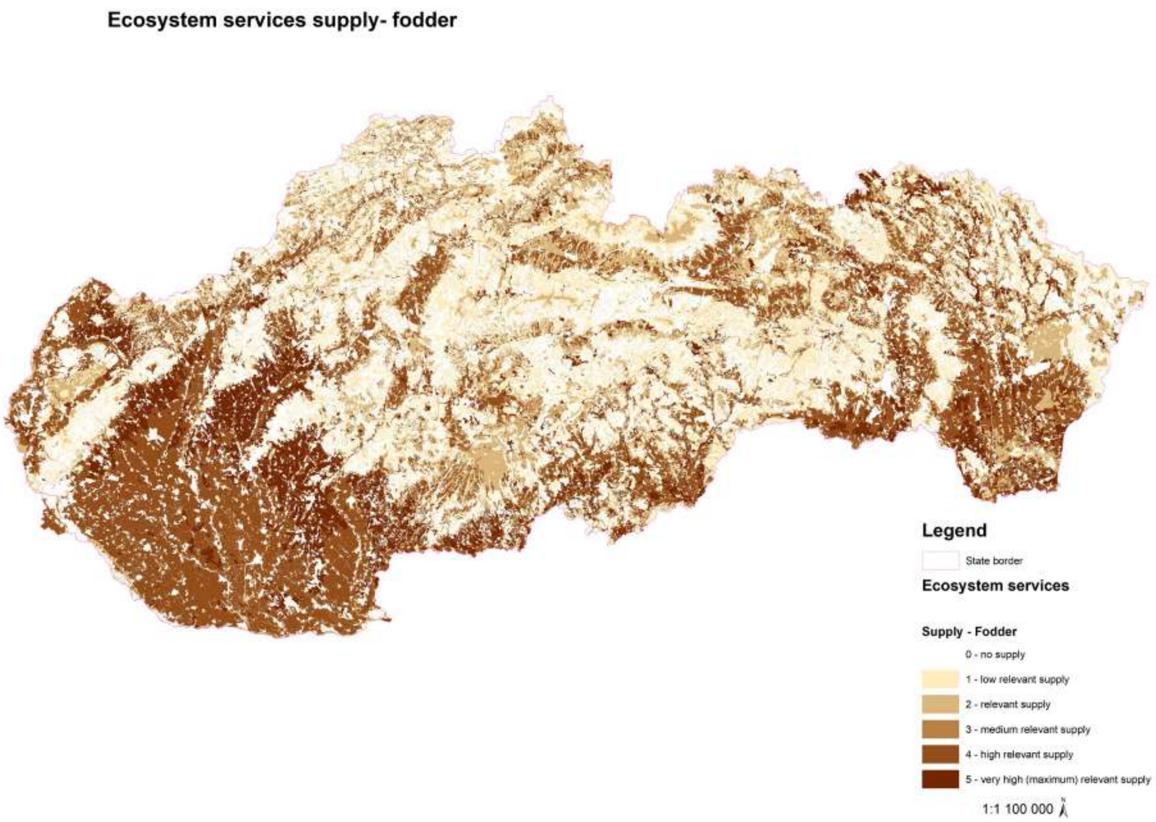

Fig. 37 Map of supply of ES fodder in relation to the quality of ecosystems

3.3.2.4 Livestock

The provision of domestic cattle in Slovakia is tied mainly to grassland habitats. Unlike the fodder service, the breeding domestic livestock is not fundamentally affected by arable land, on which, however, the feed for livestock itself is also partially cultivated. Grazing or mowing plays an important role as a maintenance management measure for the common, as well as rare ecosystem in Slovakia. At present, most cattle are bred in eastern Slovakia, sheep breeding dominates in the area of central Slovakia and pig breeding in western Slovakia (Horalová & Dráb 2018).

Results of the evaluation of domestic livestock provisioning service
Nationwide, **46 different habitats** contribute to the potential provision of the domestic livestock service **on an area of 1,201,971.34 ha/12,019.71 km².**

Tab. 22 Indexes and values of potential and supply in relation to the ES provision of livestock domestic divided according to the EUNIS 1 level

PRODUKCIA DOMÁCEHO DOBYTKA	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Value in EUR	Index average	Value in EUR	Index average
C – Inland surface waters	0.23	8,414,383 €	0.2	7,355,686 €
D – Mires, bogs and fens	1.91	6,084,622 €	1.77	5,831,197 €
E – Grasslands and lands dominated by forbs, mosses or lichens	3.17	528,777,181 €	3.13	522,466,624 €
F – Heathland, scrub and tundra	0.39	3,981,932 €	0.36	3,806,893 €
G – Woodland, forest and other wooded land	0	0€	0	0€
H – Inland unvegetated or sparsely vegetated habitats	0	0€	0	0€
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	0	0€	0	0€
J – Constructed, industrial and other artificial habitats	0	0€	0	0€
X – Habitat complexes	1.43	54,996,091 €	1.43	54,995,392 €
Total: Weighted average over ecosystem area/Total value in EUR	0.72	602,254,209 €	0.71	594,455,792 €

In terms of both potential and supply, it is necessary to emphasize the value of all **grassland habitats** that contribute to the provision of this ES with a relatively high index value (3.17 and 3.13) compared to other ecosystems (Tab. 22). In terms of the quality of habitats which provide domestic livestock service, it is important to mention **peatlands and moors**, with an index value of potential of 1.9, which are extremely valuable for this service. Habitat type **E2.1 Permanent mesotrophic pastures and aftermath-grazed meadows** and **E2.22 Sub-Atlantic lowland hay meadows** have the highest index value of potential among the EUNIS category E of habitat types, as well as habitats of landscape mosaic with forest elements and pasture forests among the EUNIS category X. From a national perspective, the index value of both potential and supply of domestic livestock service is very low, only 0.72 index point. The economic value of services provided by ecosystems in a favourable condition is 602,254,209 EUR per year. As this service provides mostly man-influenced ecosystems outside protected areas, the extent of their degradation is relatively difficult to measure.

DOMESTIC LIVESTOCK	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	0.23	8,414,383	0.2	7,355,686
D – Mires, bogs and fens	1.91	6,084,622	1.77	5,831,197
E – Grasslands and lands dominated by forbs, mosses or lichens	3.17	528,777,181	3.13	522,466,624
F – Heathland, scrub and tundra	0.39	3,981,932	0.36	3,806,893
G – Woodland, forest and other wooded land	0	0	0	0
H – Inland unvegetated or sparsely vegetated habitats	0	0	0	0
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	0	0	0	0
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	1.43	54,996,091	1.43	54,995,392
Total: Weighted average over ecosystem area/Total value in EUR	0.72	602,254,209	0.71	594,455,792

The breeding of domestic cattle does not fundamentally affect the grassland on which the fodder is grown. For this reason, the map view of Slovakia in Fig. 38 is not dominated by the agricultural areas of our largest lowlands and basins, but by the variously distributed lowland and foothill meadows and pastures. Especially the central and eastern part of Slovakia has the great potential for cattle breeding, which is also documented by historical aspects and developments. Herds of sheep and cattle were the most numerous here and the land was managed and farmed with their help in the past. Today, it is problematic to maintain these areas despite the efforts to maintain the many grassland ecosystems through subsidies, but these are not sufficient and the mentioned ecosystems further degrade. Comparing Fig. 38 and Fig. 39 it is evident that the quality area for the provision of domestic livestock service has decreased significantly.

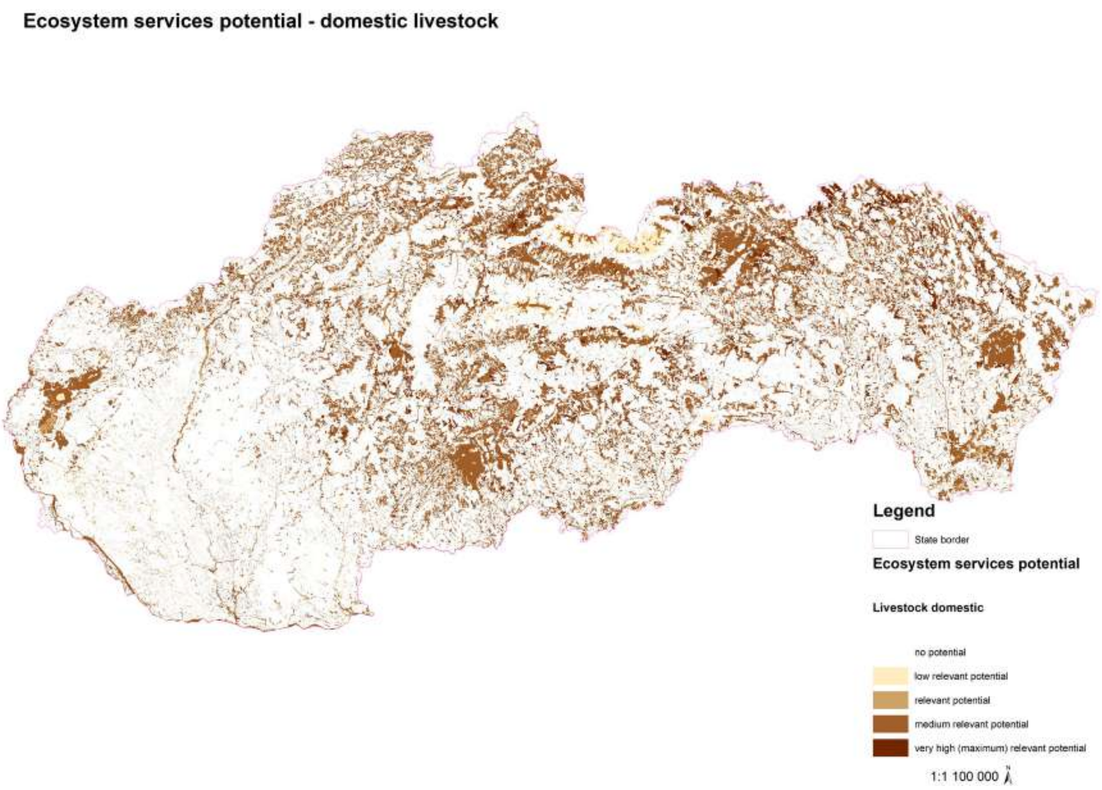

Fig. 38 Map of potential for provision ES livestock domestic

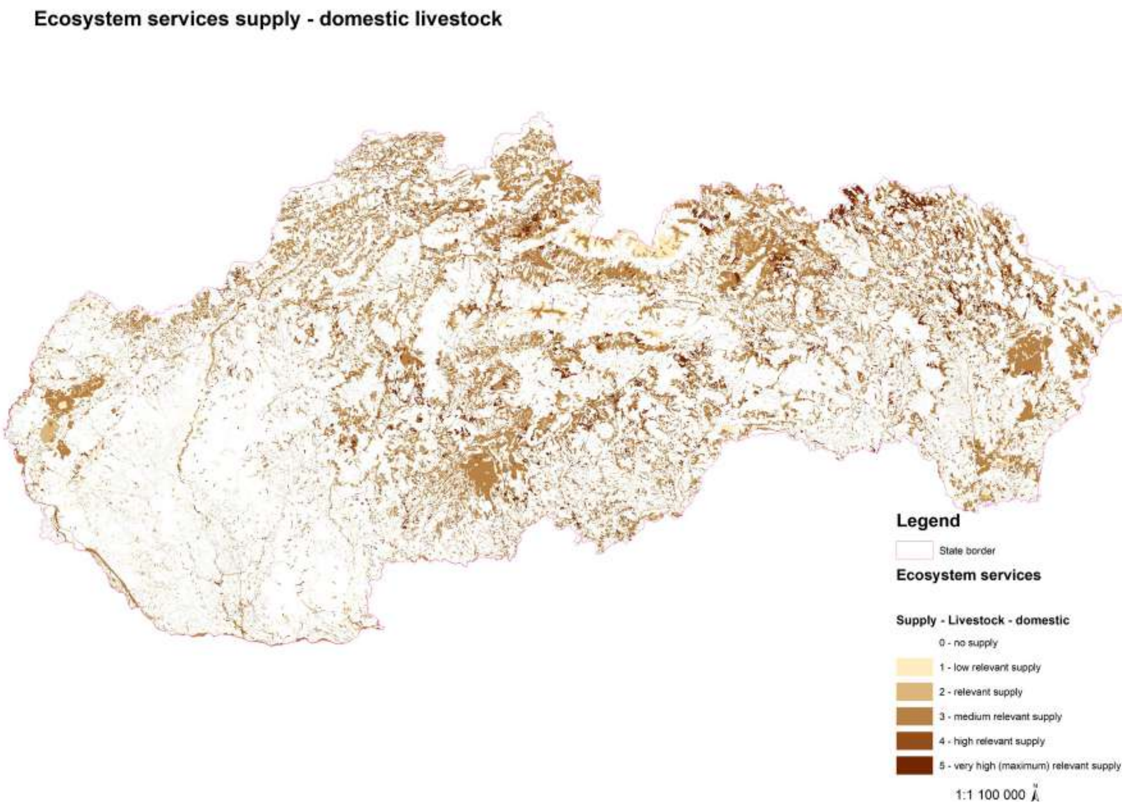

Fig. 39 Map of supply of ES livestock domestic in relation to the quality of ecosystems

3.3.2.5 Fibre

Natural fibres (not including provisioning services wood and firewood - these have separate categories and do not overlap with this ES) are an important ES provided by ecosystems to humans in the long term. The fibre provisioning service originates as a by-product in the manufacturing of other wooden-made products mainly. Natural fibres are divided into vegetable fibres (cotton, flax, hemp, jute, wood pulp and others) and animal fibres (wool). The value of some has lost some of its former significance over time and their provision is declining (e.g. sheep's wool), replaced by man-made fibres in the textile and clothing industry. However, some fibres still form an important part in the manufacture (wood fibre). Fibers are generally part of agricultural crops, so the largest share of its potential provision is represents by arable land.

Results of the evaluation of the fibres provisioning service

Before assessing the results it should be noted that the evaluation of the fibre provisioning service is based on the assumption that also crops that provide useful fibres can be grown on arable land, but in reality such crops are in Slovakia grown in very limited quantities only. **Agroecosystems** are represented by the highest value of an index of potential for provision of the fibre service - up to 4.84 index points. Arable land is followed by **habitat complexes and forest ecosystems.** A total of **29 habitats** with an area of **3,321,650.047 ha/33,116.5 km^2** contribute to the potential provision of this service. The resulting average index of potential is 1.84 and an index of supply is 1.37 (Tab. 23).

Tab. 23 Indexes and values of potential and supply in relation to the ES provision of fibre divided according to the EUNIS 1 level

FIBRE	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	0.07	40,226,968	0.07	39,165,000
D – Mires, bogs and fens	0	0	0	0
E – Grasslands and lands dominated by forbs, mosses or lichens	0	0	0	0
F – Heathland, scrub and tundra	0	0	0	0
G – Woodland, forest and other wooded land	1.00	7,738,758,708	0.33	5,207,808,994
H – Inland unvegetated or sparsely vegetated habitats	0	0	0	0
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	4.84	27,895,933,463	4.60	23,678,780,930
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	3.43	830,948,718	3.43	830,948,718
Total: Weighted average over ecosystem area/Total value in EUR	1.84	36,505,867,857	1.37	29,756,703,642

The total economic value of the potential of this service is 36,505,867,857 EUR per year (Tab. 23), but due to the degradation of ecosystems and lower soil fertility in certain localities, the value decreases by 6.8 billion EUR per year. This difference shows a high economic loss caused by the poor condition of ecosystems and the reduced soil fertility in Slovakia over time.

The map of ecosystems that have a high potential of provision of fibre service (Fig. 40) contains intensive agricultural areas in Poddunajská nížina lowland and Východoslovenská nížina lowland, in the west arable land of Záhorská nížina lowland, Myjavská pahorkatina upland, Trnavská pahorkayina upland and Nitrianska pahorkatina upland, in central Slovakia there are the basins Ipeľská kotlina, Lučenecká kotlina and Rimavská kotlina, in the east Slovakia Košická kotlina basin. In addition to an arable land ecosystems, forest ecosystems provide this service, too. After assessment of the quality of ecosystems, the map of the fibre supply (Fig. 41) shows a decrease in the areas which provide this service.

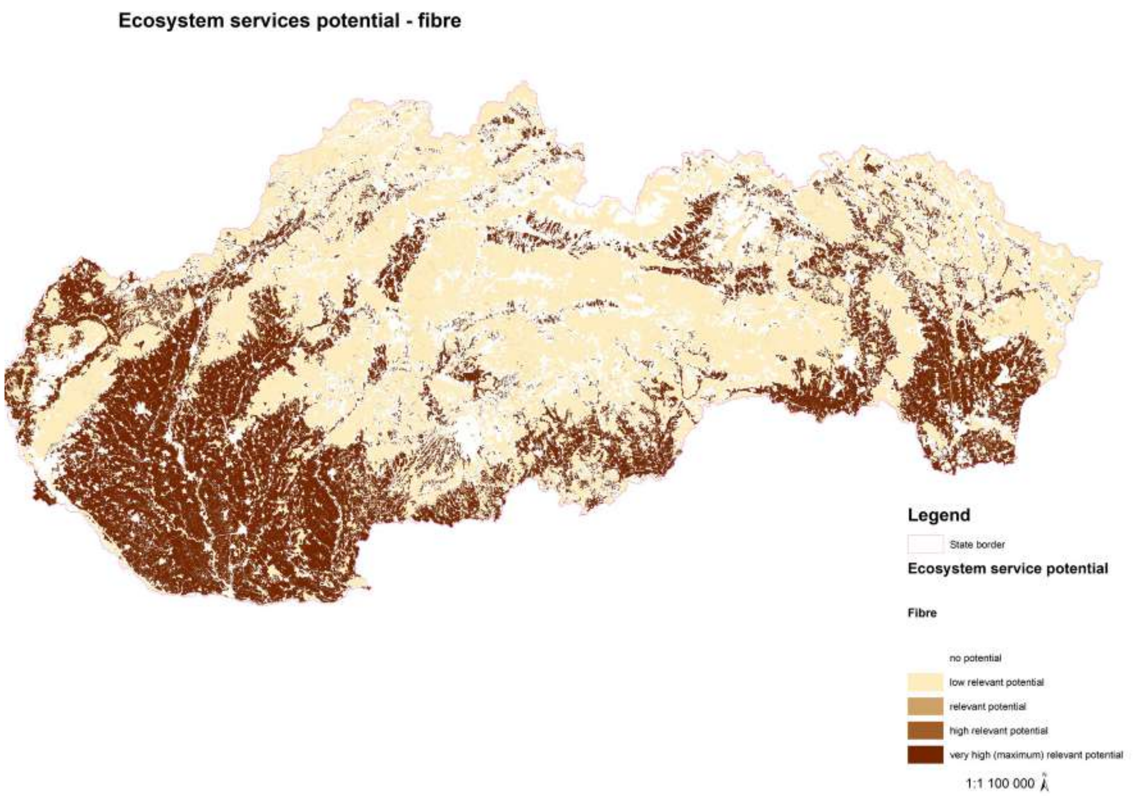

Fig. 40 Map of potential for provision ES fodder

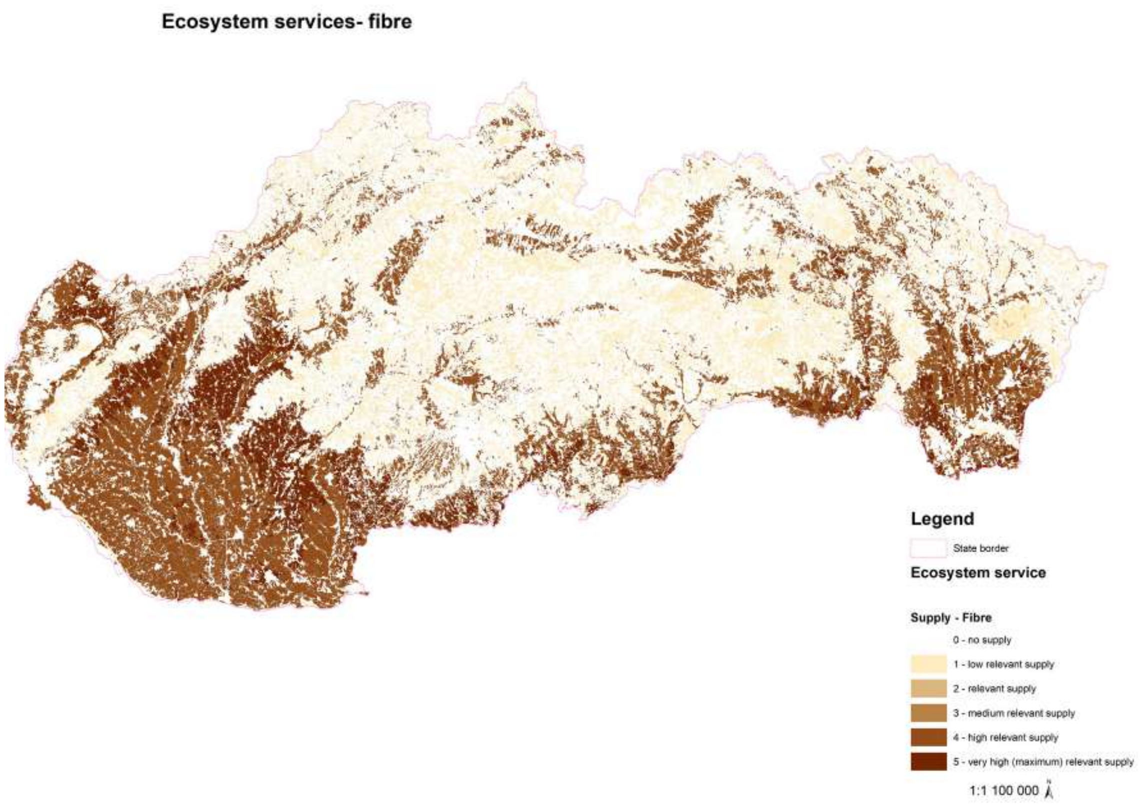

Fig. 41 Map of supply of ES fodder in relation to the quality of ecosystems

3.3.2.6 Timber

Wood is an important raw material in Slovakia, which, as one of the few products provided by forest ecosystems, is currently actually monetized and brings direct financial benefits or employment. The use of wood in various sectors of the economy and social life is also related to the country's traditions. These relate to the use of wood in construction, in the cultural use of paper products (Paluš 2013). Wood provision within the meaning of this assessment is wood that is suitable for further processing (e.g. cut-outs, boards, prisms) and does not include the production of firewood and pulp (separate assessments are processed for these ES and do not overlap).

Unlike the production of other crops, wood grows only very slowly and over a long period of time. Logging is a typical activity that uses one ES at the expense of several regulatory, production and cultural ES (trade-offs) and therefore it is necessary to set the right limits and spatial distribution of logging in a way as to preserve other necessary ES as much as possible and at the same time ensure a sufficient wood production. However, this planning process is demanding and often not set appropriately at the local level, or is the result of natural disasters, windstorms and calamities related to inappropriate tree species composition. In those cases, there is a temporary or permanent deterioration of ecosystems, which is reflected in the quality and quantity of the provision of most ES, in particular protection against natural disasters, erosion protection. It also affects other regulatory, provisioning and cultural ES.

Results of the evaluation of wood provisioning service

The results evaluate the provision of wood not only in places registered as forest stands within the registered forest land, but in all parts of Slovakia, where there is a more continuous forest stand outside the forest land fund (accurately recorded on a map). This brings a new knowledge into the national perspective.

The total potential for the provision of ES timber provision was calculated at 1.89 index point, which represents an important value of the index, if we take into account that the ES is mainly provided by only one group of ecosystems - **forests and forest stands**. In total, there are **28 different forest habitats** in EUNIS categorization on an area of **1,927,097.074 ha / 19,270.97 km^2** with an index for potential of up to 4.99, and these ecosystems cover a large part of Slovakia (potential map in Fig. 42). After assessing the quality of ecosystems, the total service provision is lower by 0.41 index point, which represents an annual loss of approximately 4 billion EUR out of the total economic value of the potential of 22,163,258,160 EUR per year (Tab. 24). The highest value of potential expressed in monetary units is in case of the habitat **G1.63 Medio-European neutrophile beech forests** - 11.7 billion EUR per year, then **G1 .A16 Sub-continental oak - hornbeam forests** approximately 3 billion EUR per year, **G1.61 Medio-European acidophilous beech forests** - 1.6 billion EUR per year and **G1.66 Medio-European limestone beech forests** - 1.6 billion EUR per year.

Tab. 24 Indexes and values of potential and supply in relation to the ES provision of timber divided according to the EUNIS 1 level

TIMBER	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	0	0	0	0
D – Mires, bogs and fens	0	0	0	0
E – Grasslands and lands dominated by forbs, mosses or lichens	0	0	0	0
F – Heathland, scrub and tundra	0	0	0	0
G – Woodland, forest and other wooded land	4.99	22,163,258,160	3.92	18,211,168,466
H – Inland unvegetated or sparsely vegetated habitats	0	0	0	0
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	0	0	0	0
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	0	0	0	0
Total: Weighted average over ecosystem area / Total value in EUR	1.89	22,163,258,160	1.48	18,211,168,466

The high potential of wood provision in the Slovak Republic is represented by the areas of dark brown colour in Fig. 42. They can be seen in western Slovakia along watercourses and in a detailed view as small or even larger areas distributed throughout Slovakia, originally overgrown by pastures or as newly formed forest. The potential has long been the largest in central Slovakia.

The main interventions in the existing forest ecosystems were taken into account in methodological approach and therefore the difference between the potential in Fig. 42 and wood supply in Fig. 43. is evident. The age of the forest ecosystem and previous interventions are decisive criteria in the quantity / quality of timber provision, the area is important in terms of quantity. In the evaluation, all these criteria were taken into account and thus provide a comprehensive picture of the current situation in the provision of this provisioning service. It is important to realize that forest ecosystems provide humans with several key regulatory ES (a total of 9 ES with an index for potential often greater than or equal to 3 on a scale of 1-5).

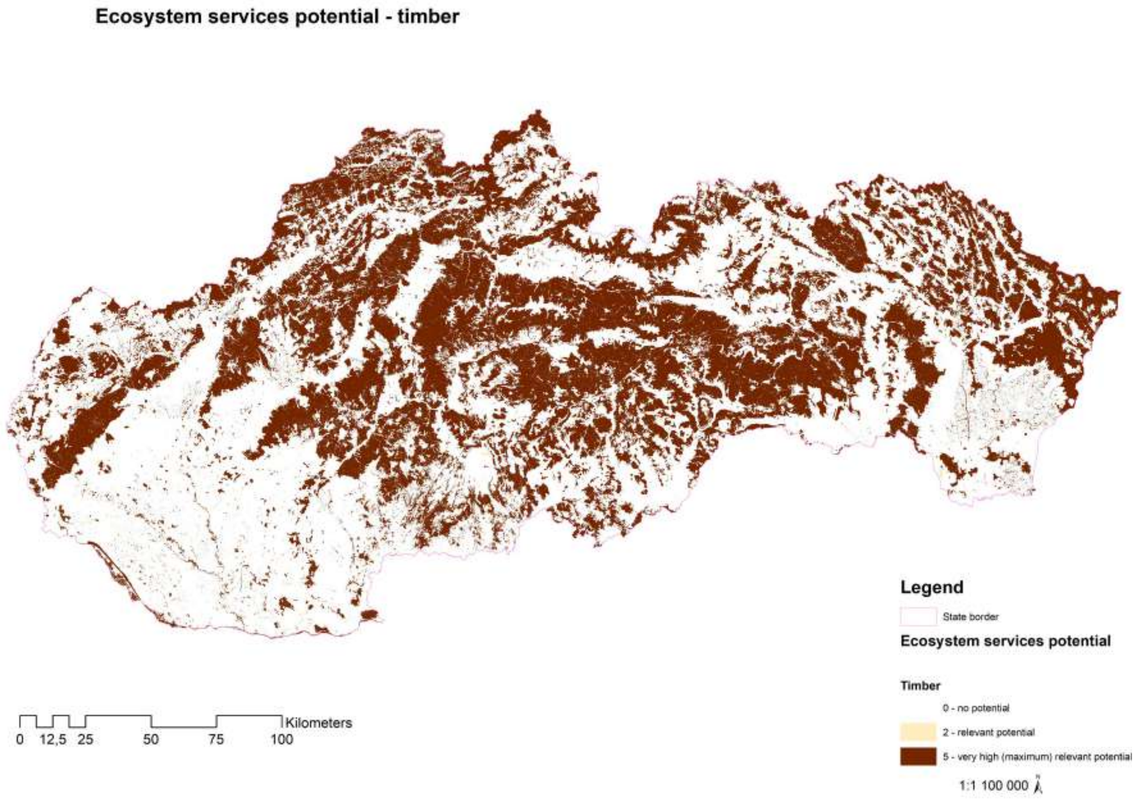

Fig. 42 Map of potential for provision ES timber

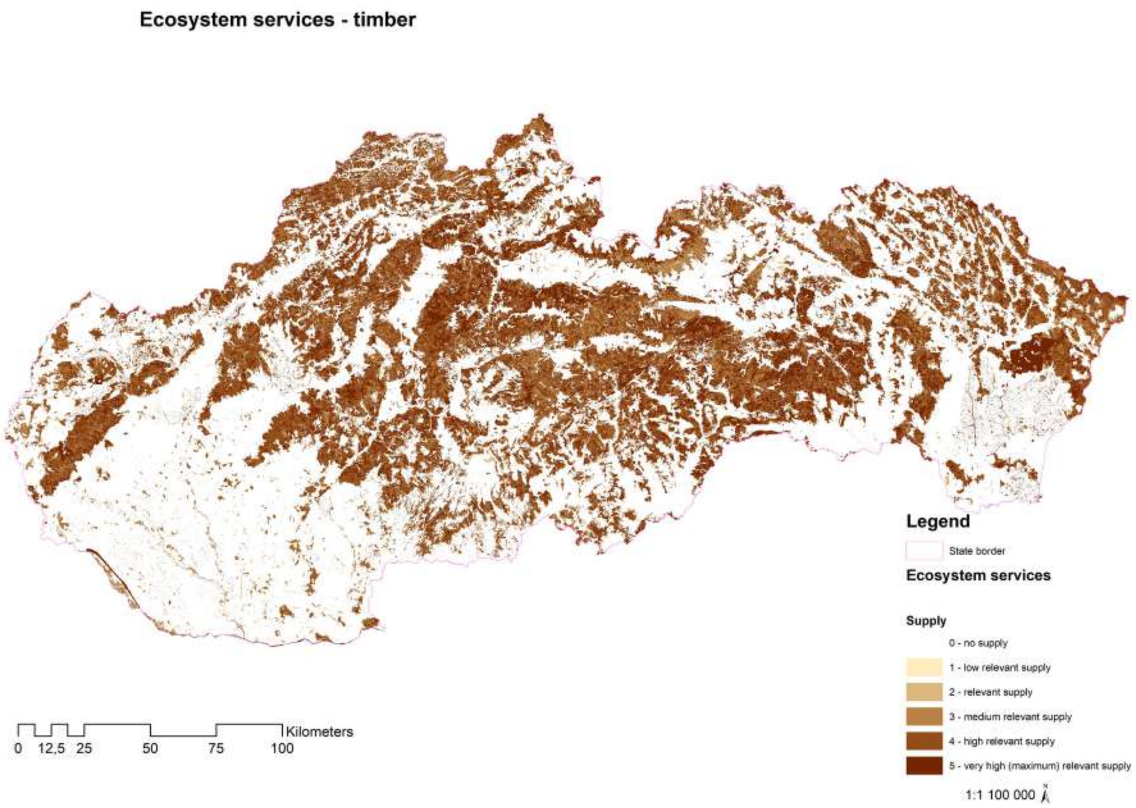

Fig. 43 Map of supply of ES fodder in relation to the quality of ecosystems

3.3.2.7 Wood Fuel

Firewood is a product of forest ecosystems, usually harvested in combination with the production of wood for timber production purposes. After harvesting of timber, a suitable wood mass from thicker branches remains, which can be used as fuel. Timber not suitable due to unsuitable tree trunks or types are also often used exclusively for firewood production purposes. Thus, it is raw wood, which is used for energy production in plants and households (Paluš 2013). The assessment of this ES is therefore not a duplicate assessment of ES timber production and ES fiber production, but it is a complementary ES, which does not overlap with these ES. It is therefore necessary to take into account the fact that this ES does not overlap with the ES assessing wood production, as this service assesses wood that can be used for products (boards, prisms, quality cut-outs, etc.), while this ES it is precisely the part of biomass that cannot be used for such a purpose, because it does not meet the necessary quality parameters.

Results of the evaluation of wood fuel provisioning service

The calculations included mainly **forest ecosystems**, but also **xerothermic and heathland ecosystems** or **habitat complexes** that participate in the provision of services with a value of 1.94 index point for potential (Tab. 25). A total of **39 habitats** (EUNIS) contribute to the potential provision of the ES on **an area of 2,075,509.174 ha / 20,755.09 km²**.

Tab. 25 Indexes and values of potential and supply in relation to the ES provision of wood fuel divided according to the EUNIS 1 level

WOOD FUEL	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	0	0	0	0
D – Mires, bogs and fens	0	0	0	0
E – Grasslands and lands dominated by forbs, mosses or lichens	0	0	0	0
F – Heathland, scrub and tundra	1.39	489,964,106	1.35	484,280,586
G – Woodland, forest and other wooded land	4.99	38,637,693,738	3.92	31,747,929,149
H – Inland unvegetated or sparsely vegetated habitats	0	0	0	0
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	0	0	0	0
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	0.86	207,737,179	0.86	207,737,179
Total: Weighted average over ecosystem area / Total value in EUR	1.94	39,335,395,023	1.53	32,439,946,914

The total monetary value of the ES firewood provision potential of forest ecosystems is higher than the prices used to calculate ES timber production due to the fact that in terms of biomass accessibility, there is more biomass in the ecosystems providing this ES that is not suitable for construction purposes in high quality, but on the contrary exceeds biomass, which is suitable for use as firewood and hence the overall higher value of this ES. Moreover, it is often a product that is produced in areas that are not forest land and it is here that wood quality is often particularly suitable for use as firewood. As a result of habitat degradation, Slovakia loses approximately EUR 6 billion per year out of a total of 39,335,395,023 EUR per year. The highest value of potential expressed in monetary units is in case of the habitat **G1.63 Medio-European neutrophile beech forests** 20.4 billion EUR per year, followed by **G1. A16 Sub-continental oak - hornbeam forests** with 5.2 billion EUR per year, **G1.61 Medio-European acidophilous beech forests** with 3.2 billion EUR per year and **G1.66 Medio-European limestone beech forests** 2.8 billion EURyear.

Map expression of the potential of firewood provisioning service in Fig. 44 shows its extensive provision by ecosystems within the Slovak Republic (also relatively high quality). It mainly concerns mountains and hilly areas, but also the edges of watercourses that line forest or shrub habitats or various ecotones between grass-herbaceous and forest ecosystems or agroecosystems. After taking into account the quality of ecosystems (on the supply map Fig. 45) there was a significant decrease in the provision of this ES.

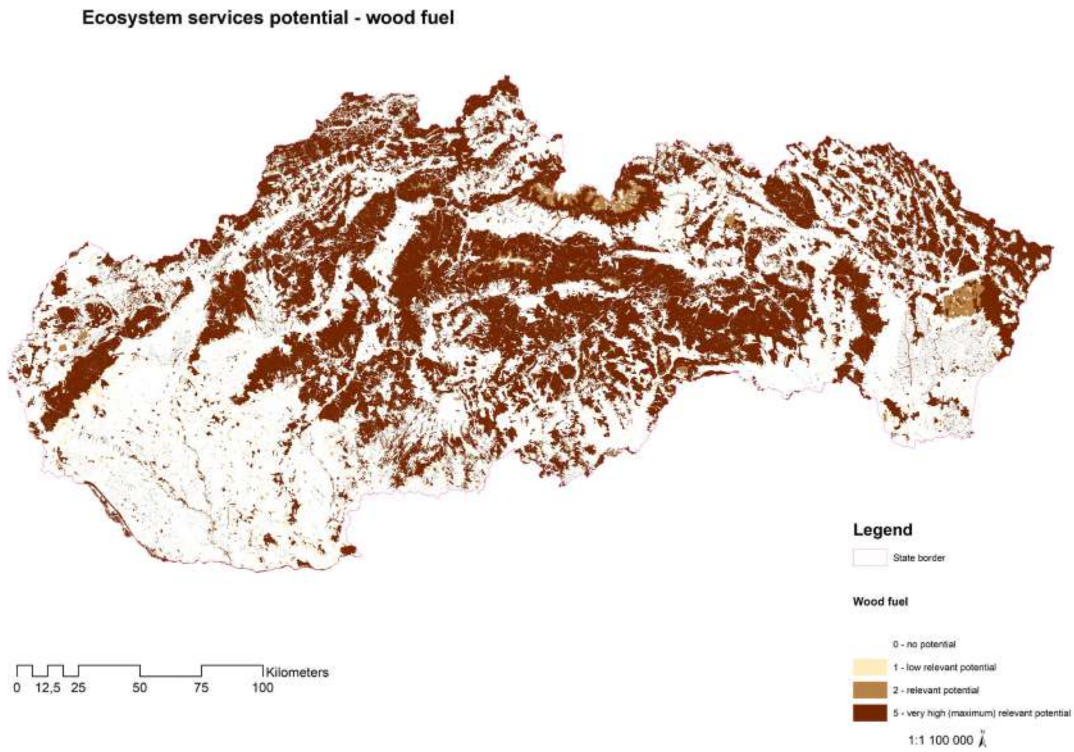

Fig. 44 Map of potential for provision ES wood fuel

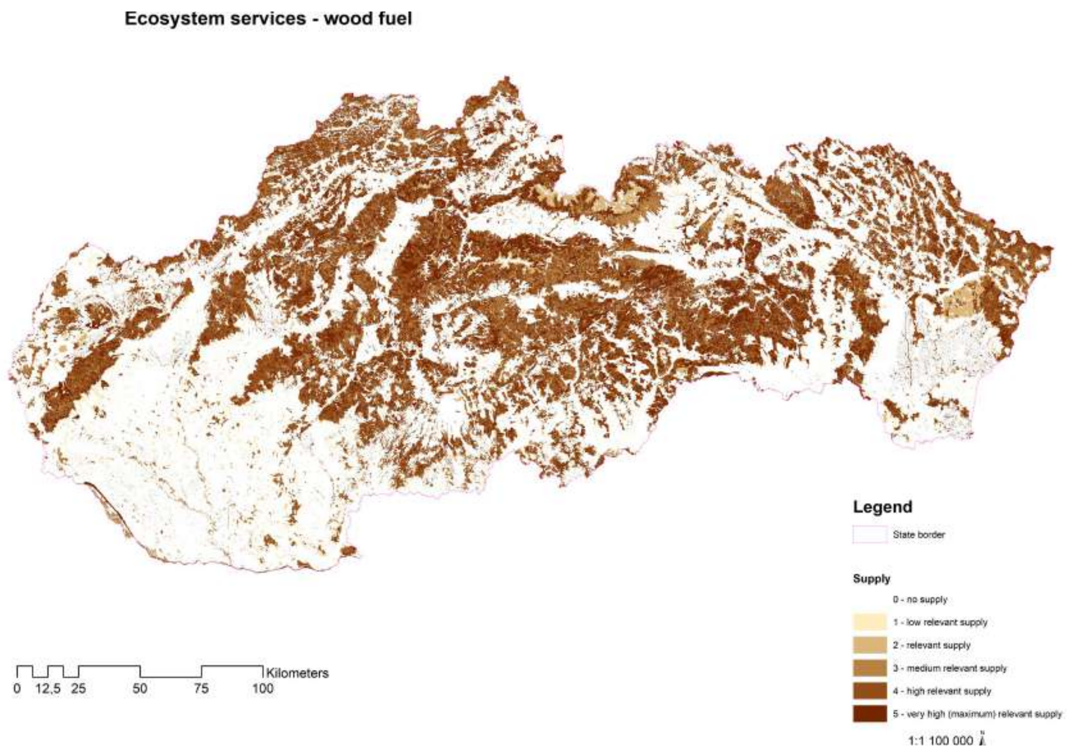

Fig. 45 Map of supply of ES wood fuel in relation to the quality of ecosystems

An inappropriate example of the use of this ES may be the felling of trees for combustion around roads and streams where they strengthen the slopes, and after their removal, erosion or felling of draws may occur in fields and pathways that are important ecotones for insects and other animals. Like other provisioning services, ES production of firewood is often used at the expense of more important regulatory services (microclimate regulation, air quality, erosion, natural disasters, etc.) and its long-term sustainable use needs to be achieved, especially by appropriate selection of sites for ES supply and sensitive and individual interventions in the forest stands.

3.3.2.8 Fish

When assessing ES fish production, it is necessary to take into account those species of fish that are normally consumed, for which there is a demand and enter the food market. In Slovakia, fishing has an important position in terms of organization and legislation. Fish farming, recreational and sport fishing are represented, but scientific interest in ichthyological surveys and the dissemination of knowledge about the ecology and ethology of all species of fish living in Slovakia also plays an important role. However, scientific interest in fish is not part of the assessment of this ES.

According to national law Act No. 216/2018 Coll. on fishing, Slovak waters are divided according to the species of fish that live in them into carp waters (watercourses in the lowland zone), trout waters (especially torrents, mountain streams and foothill streams, upper sections of rivers) and linden waters (foothill sections of streams, rivers and secondary trout zones under water reservoirs). In 2015, an extensive ichthyological monitoring took place in Slovakia, during which 522 localities were mapped. The results showed that only in about one third (34.7 %) of water bodies in Slovakia the state of ichthyocenoses meets the criteria set by the European Commission (in terms of Water Framework Directive). On the contrary, up to a third (33.7 %) of water bodies in Slovakia have the state of fish communities in poor or very poor condition (Kováč & Jakubčinová 2015).

Results of the evaluation of fish provisioning service

Slovakia has a relatively dense river network and the amount of stagnant waters, but their area is low compared to the area of the whole country and therefore the total potential index (weighted average) has a very low value of 0.04 index point. The monetary value of the potential is calculated on 4,994,591 EUR per year (Tab. 26). **C1.3 Permanent eutrophic lakes, ponds and pools** and **C1.2 Permanent mesotrophic lakes, ponds and pools** have the highest potential expressed in monetary units. **8 habitats** (with an index for potential 3 to 4) contribute to the provision of ES fish provision nationwide.

Tab. 26 Indexes and values of potential and supply in relation to the ES provision of fish divided according to the EUNIS 1 level

FISH	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	2.63	4,994,574	2.54	4,739,548
D – Mires, bogs and fens	0	0	0	0
E – Grasslands and lands dominated by forbs, mosses or lichens	0	0	0	0
F – Heathland, scrub and tundra	0	0	0	0
G – Woodland, forest and other wooded land	0	0	0	0
H – Inland unvegetated or sparsely vegetated habitats	0	0	0	0
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	0	0	0	0
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	0	0	0	0
Total: Weighted average over ecosystem area / Total value in EUR	0.04	4,994,574	0.04	4,739,548

Western Slovakia (Fig. 46), especially the Žitný ostrov island area, appears to be the most important area in terms of the potential for providing ES fish, mainly due to the large number of water bodies located in this part of the republic. Locally and qualitatively, large reservoirs such as the Orava Reservoir, Liptovská Mara or Zemplínska Šírava are important. To the east, the amount of potential resources provided by the ES is decreasing. Watercourses, resp. aquatic habitats are endangered mainly by human activity such as damming of rivers, regulation of river beds (straightening), construction of water canals, their use for transport, energy, agriculture, eutrophication, contamination and spread of invasive species. After taking into account the degree of degradation, aquatic ecosystems also contribute to a large extent to ES supply (Fig. 47).

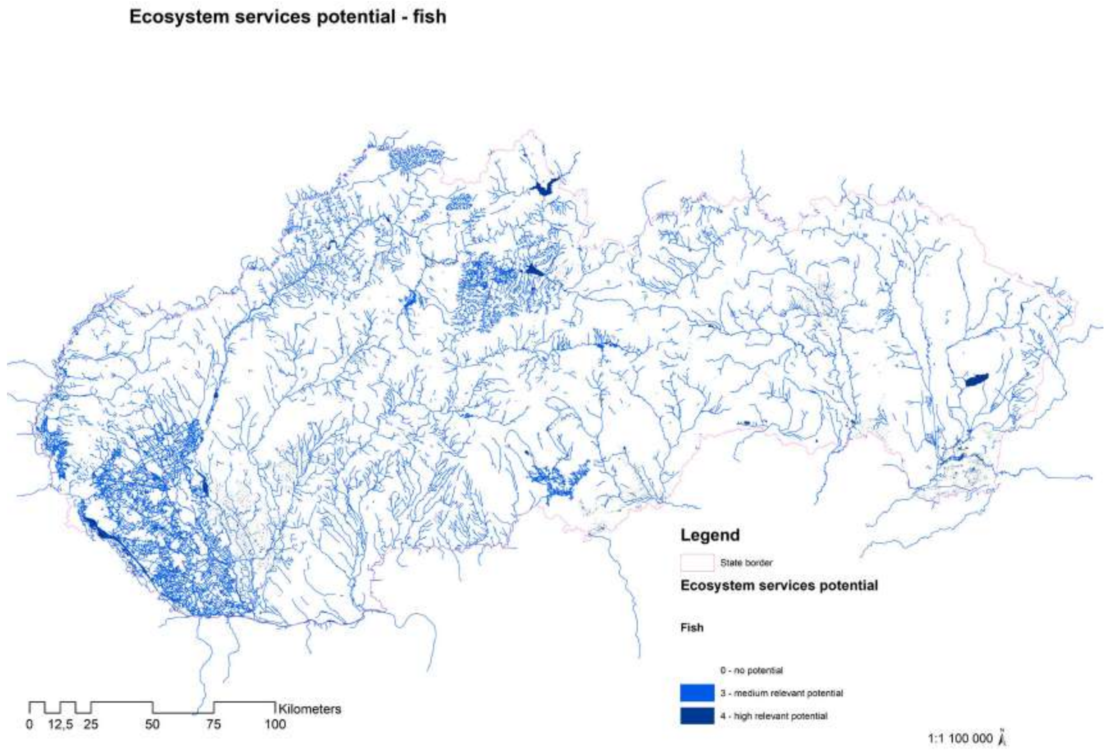

Fig. 46 Map of potential for provision ES fish

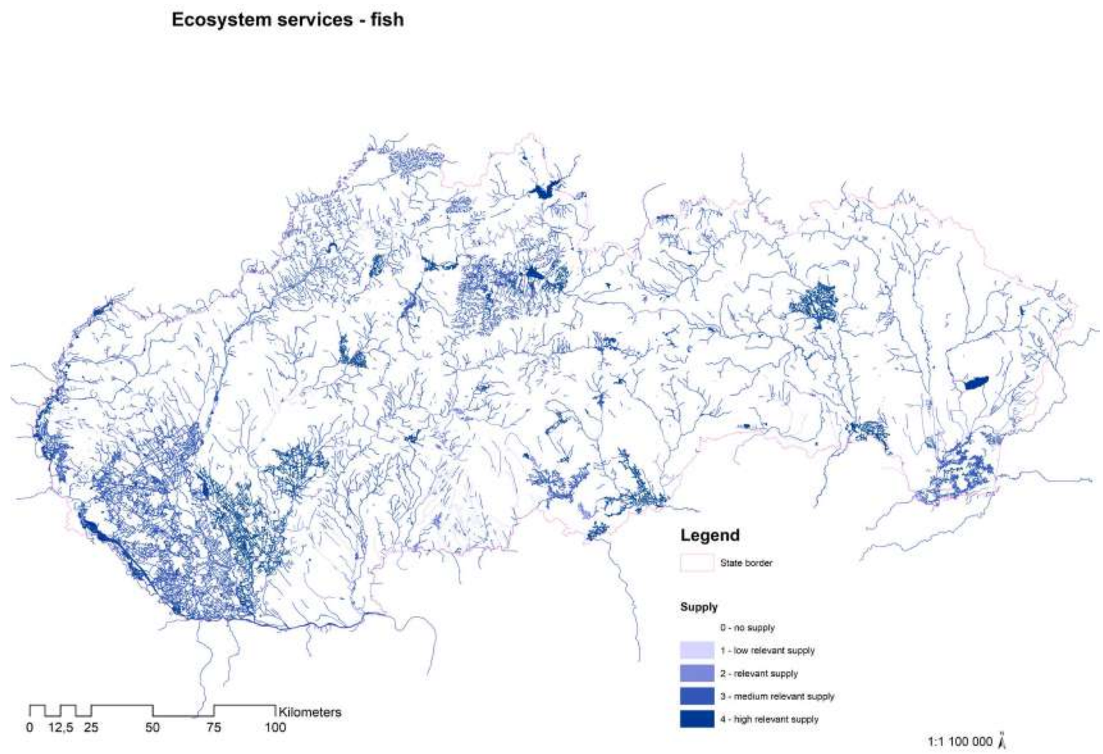

Fig. 47 Map of supply of ES fish in relation to the quality of ecosystems

3.3.2.9 Wild foods & resources

The collection of wild crops such as mushrooms, medicinal plants, various fruits and game hunting is an important provisioning ES that ecosystems can provide to humankind in the long run. Consumption of these products is not negligible and the number of people involved in the collection of forest fruits is relatively high, as well as the number of hunters. Collecting mushrooms and berries is not just a source of food in sense of nutritional and economic benefits for humans, it also includes cultural and traditional aspect. The collection of wild crops and herbs is associated with a stay in nature, which is a tradition of either urban or rural people. It supports the relationship with nature, forest fruits often serve as decorative materials used seasonally. Wild crops and wildlife are thus a source of cultural heritage, and some authors also define this service as cultural ES (King et al. 2015). For the purpose of this assessment, however, we focus purely on production aspect of this ES, cultural aspect is not taken into account. The use of this ES can be found in every country in the form of traditional national cuisine. Within the EU, 26 species of birds and 12 species of mammals are hunted and consumed (Schulp et al. 2014). In Slovakia, these are mainly hunting species of wild game: red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*) and pheasant (*Phasianus colchicus*). The breeding of game in the menagerie is also present, but this assessment deals mainly with game that is reared and supported by ecosystems and is its integral part.

Thanks to the varied natural plant richness in Slovakia, people keep a tradition of collecting medicinal, ubeneficial and aromatic plants. In times of poor crop production and war, people sought wild fruits as a source of food (e.g. acorns) and in the 17th century, during the 30-year war, people made flour out of wild pears (Zdycha et al. 2008). The glorious past of Slovak herbalism and oil making dates back to the 14th century, in the 18th century the well-known title "Zelinkár" (Fándly 1793) was published. Harvesting plants as a valuable resource for the treatment of various diseases is a combination of knowledge of nature and efforts to use it for the benefit of humanity (Macků & Mokrý 1957).

Results of the ES evaluation of wild foods & resources service

Almost all groups of ecosystems in Slovakia participate in the provision of ES wild crops. It should be noted that these are products that the ecosystem provides naturally, without human intervention, and it is therefore important to use them wisely in terms of sustainability, so as not to deplete them and thus degrade or destroy the ecosystem that provides them. The monetary value of ES according to Frélichová et al. (2014) is low - € 57.23/ha, the potential is 3.25 index points. For forest ecosystems, in Tab. 27 the decline in the average quality index is visible due to the degradation of ecosystems in certain places. The total potential economic value of ecosystems providing the ES is estimated at 308,866,499 EUR per year. The most important providers of this ES are **forests ecosystems, grassland and herb ecosystems and surface aquatic ecosystems.**

Tab. 27 Indexes and values of potential and supply in relation to the ES provision of wild foods & resources divided according to the EUNIS 1 level

WILD FOODS & RESOURCES	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	3.61	3,536,229	3.49	3,292,371
D – Mires, bogs and fens	1.00	399,740	0.87	371,689
E – Grasslands and lands dominated by forbs, mosses or lichens	4.71	92,570,393	4.66	91,806,655
F – Heathland, scrub and tundra	0.78	964,845	0.74	938,407
G – Woodland, forest and other wooded land	4.98	181,641,415	3.91	148,930,376
H – Inland unvegetated or sparsely vegetated habitats	0.01	9	0.01	9
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	0.97	26,496,743	0.97	26,496,743
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	1.08	3,257,126	1.08	3,257,126
Total: Weighted average over ecosystem area / Total value in EUR	3.25	308,866,499	2.83	275,093,375

The map of the potential for ES wild foods((Fig. 48) shows that practically the entire territory of the Slovak Republic participates in the provision of this service, with the exception of settlements where the provision is negligible. In central Slovakia, ecosystems (especially forests) of hills and mountains are represented, which participate in the provision of services of the highest quality and quantity. After taking into account the quality of ecosystems on the supply map (Fig. 49) the decrease of ecosystems for ES provision can be seen, but due to the high capacity of the area, this is not a significant difference.

This provisioning service is not as important for man and the economic economy of the country as the production of wood, crops or drinking water, but it is still a major contributor and deserves its appreciation.

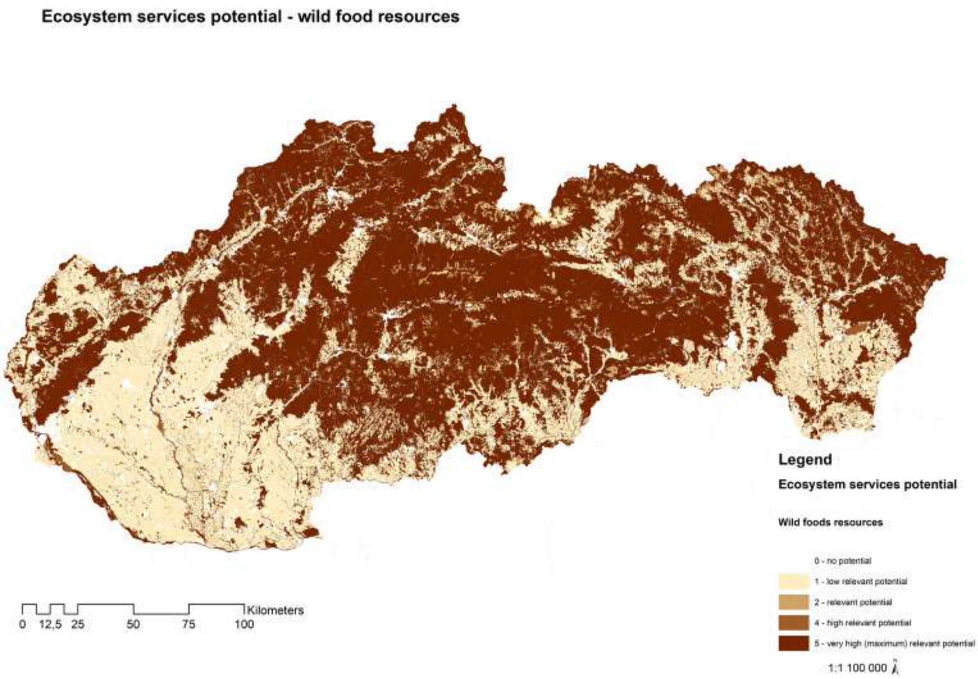

Fig. 48 Map of potential for provision ES wild foods & resources

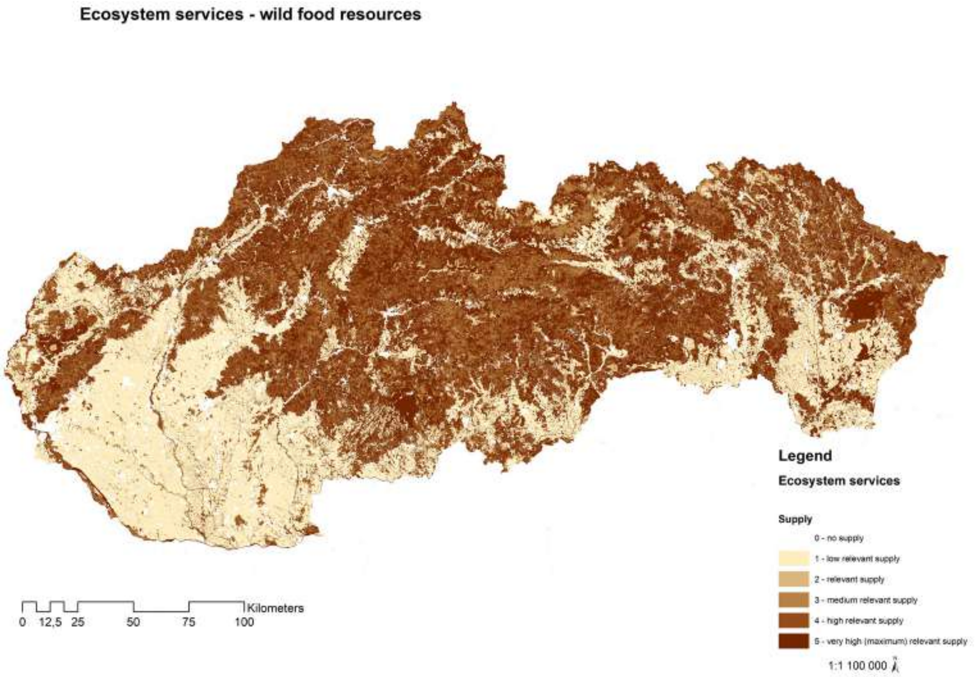

Fig. 49 Map of supply of ES wild foods & resources in relation to the quality of ecosystems

3.3.2.10 Freshwater

"*Water is not a commercial product like other products but rather a heritage that needs to be protected, defended and treated as such*" according to the Directive of the European Parliament and of the Council in the field of water management (Directive 2000/60/EC). The production of water (drinking and utility water) is the most important production of the ES, because man is directly and indirectly dependent on it. Man's daily needs and activities are closely linked to the provision of water, whether it is for direct consumption, domestic use or in all sectors of the economy and industry. Not only humans but also all ecosystems are dependent on water and its availability and quality can therefore be a limiting factor for the provision of all other provisioning, regulatory and cultural ES. Climate change, pollution of water resources, increasing water consumption in households and industry may threaten its supply from natural sources in the future. To preserve quality water resources, the European Commission has therefore decided to legislate and present the Water Framework Directive (2000). Based on the results of reports on the water balance of surface and groundwater (SHMÚ 2018a, SHMÚ, 2018b), it can be stated that in Slovakia approximately one third of watercourses / sources are in positive balance, one third are in tension and one third in passive (negative) balance. From the point of view of this service, those ecosystems that participate in the formation of surface water were taken into account and groundwater reserves and processes of groundwater creation were not evaluated due to the demanding and comprehensive definition of those ecosystems that participate in water generation. Therefore, it is necessary to take into account the fact that the assessment focuses only on the partial production of surface waters and not on groundwater.

Results of evaluation of ES freshwater provisioning service

Slovakia has a relatively large number of surface water resources in good quality, which is proved not only by the results of the balance assessment of water quality mentioned above, but also in terms of assessment of ecological status, most aquatic habitats are in favourable condition. Nevertheless, **the resulting index of ES water provision potential is very low** - only 0.06 index point (Tab. 28). This is a consequence of the **small area of surface water** resources - 68,262.75 ha, which is approximately **1.4 % of the area** of the Slovakia. In the overall assessment, the potential index is equal to the production index, and in monetary value this means only an insignificant difference. The total monetary value of the potential is 2,127,712 EUR per year.

Nationwide, **11 habitats** (7 aquatic, 3 habitats of peatlands and uplands - EUNIS) with an area of 40,672.2 ha participate in the provision of ES surface water production (with a quality index for potential higher than 0). There are other ecosystems in question that the Burkhard matrix does not list as potential producers, but it is certain that they are involved in water production to some extent. However, from the point of view of consistent evaluation, we take into account the data in the matrix primarily as published.

Tab. 28 Indexes and values of potential and supply in relation to the ES provision of freshwater divided according to the EUNIS 1 level

FRESHWATER	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	4.34	2,110,051	4.25	2,033,153
D – Mires, bogs and fens	0.04	17,655	0.04	17,604
E – Grasslands and lands dominated by forbs, mosses or lichens	0	0	0	0
F – Heathland, scrub and tundra	0	0	0	0
G – Woodland, forest and other wooded land	0	0	0	0
H – Inland bare or sparsely vegetated habitats	0	0	0	0
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	0	0	0	0
J – Constructed, industrial and other artificial habitats	0	0	0	0
X – Habitat complexes	0	0	0	0
Total: Weighted average over ecosystem area / Total value in EUR	0.06	2,127,706	0.06	2,050,757

A map comparison of potential (Fig. 50) and supply (Fig. 51) confirms the results above. Slovakia has a high potential in terms of quality surface water resources and after taking into account the quality of aquatic ecosystems, the provision of ES does not change significantly. Quantitatively, most water resources and bodies are located in western Slovakia and are declining to the east. At the same time, however, much more support must be given to water retention measures in the country through the protection of natural ecosystems, especially wetlands, but also forest and non-forest habitats.

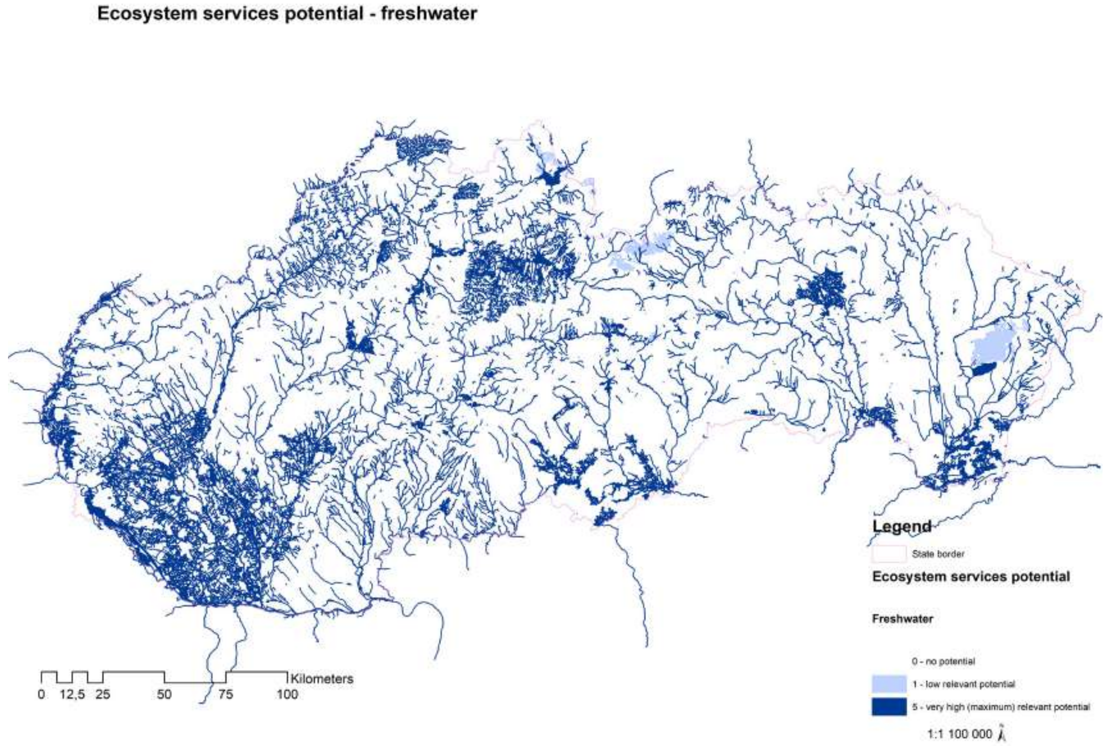

Fig. 50 Map of potential for provision ES freshwater

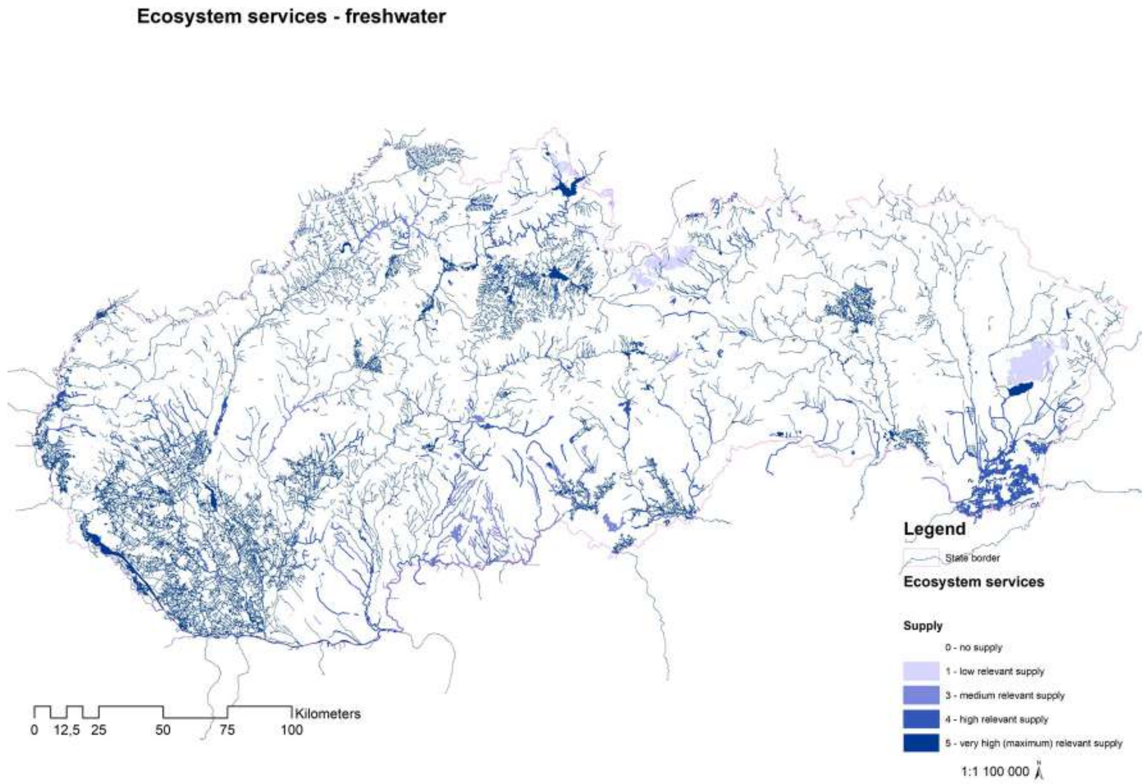

Fig. 51 Map of supply of ES freshwater in relation to the quality of ecosystems

3.3.3 Cultural ecosystem services

Cultural ES are services that provide people with intangible benefits from ecosystems through spiritual enrichment, cognitive development, reflection, and recreational and aesthetic experiences (MEA 2005). However, compared to provisioning and regulatory services, cultural ES have not yet been effectively integrated into ES evaluation methodologies. One of the reasons is that transdisciplinarity is needed to solve the problem, because cultural ES (including physical, intellectual, spiritual interactions with biota) must be analysed from several perspectives (i.e. ecological, social, behavioural). The second reason is the lack of data from larger evaluations, as mainly regional surveys are the main source of information on cultural ES (Paracchini 2014).

3.3.3.1 Recreation and tourism

Recreation and tourism are an important part of the economy, but in addition to the economic importance of this sector, they also contribute to improving the quality of life (Bratman et al. 2019), overall well-being and education. It is mainly the use of land for various recreational activities such as hiking, running, horseback riding, swimming and others that also bring direct economic benefits. In the future, the share of tourism in gross domestic product is expected to increase and especially nature-oriented tourism to grow (Mehmetoglu 2007). ES assessment, mapping and quantification is often problematic due to the dynamic relationship between humans and ecosystems over time. The economic benefits of recreation (Mayer & Woltering 2018) are, of course, only one way of measuring the importance of the ES. Factors that significantly affect the ES include in particular the attractiveness of the landscape, the occurrence of protected areas and water areas, the type of relief, the degree of naturalness, accessibility and socio-demographic variables of potential users. These are mainly the attributes of the environment, which influence, depending on the specific activities of visitors, the decision on the choice of destination (water quality, occurrence of target species, diversity of habitats but also infrastructure and cultural attractions, etc.). Land use, e.g. investment in infrastructure or logging can have a major impact on the number and quality of service users, the length of their stay and their recreational experience (see, for example, Czeszczewik et al. 2019).

In the specific context of ecotourism, certain positive results have been recorded in connection with the appropriate setting of forestry. For example, forest roads improve access to ecotourism areas and small natural features can increase visibility and be used as a resting place (for more information on the effects of forests on visitors' experiences, see Brunson (1996) and Mattson & Li (1994)). Simply said, ecotourists are motivated to experience a natural environment that is perceived as intact and generally untouched. Although some levels of environmental degradation may be overlooked or tolerated, a greatly degraded landscape will be uncomfortable for most visitors. "Clark suggests (1987), the most important question is not whether ecotourism should be integrated with other resource uses, but where, when and how this integration can be achieved. On the other hand, mass and concentrated tourism is putting pressure on ecosystems and gradually degrading them, thus at the same time worsening its ability to provide this ES with high quality. Therefore, it is essential that recreation and ecosystem tourism are balanced and do not exceed the carrying capacity of the area / ecosystem.

Results of the evaluation of recreation and tourism service

Compared to regulatory and provisioning ES, all ecosystem groups (according to EUNIS level 1 categorization) with a potential index higher than 1 participate in the provision of recreation and tourism services, even parts of urban areas (the index increases especially rural settlements) have the potential for provision 2, 51 index point (Tab. 29). The potential index is ideally 3.13 and the supply index is **2.72. Natural forest and non-forest ecosystems** have the highest potential in terms of acreage. **Wetland habitats** (category D in the sense of EUNIS) represent equally attractive localities for recreation and tourism, but their area is low - they occupy only 0.43% of the area from the territory of the Slovak Republic. The expression in monetary units is very similar to the index. The total economic potential for the provision of ES recreation and tourism in the Slovak Republic is estimated at 11,346,479,255 11 EUR per year, but due to the degradation of ecosystems in the Slovak Republic it loses 1.3 billion EUR annually.

Tab. 29 Indexes and values of potential and supply in relation to the ES provision of recreation and tourism divided according to the EUNIS 1 level

RECREATION AND TOURISM	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	3.63	151,581,290	3.52	142,244,463
D – Mires, bogs and fens	1.09	17,685,969	0.96	16,609,530
E – Grasslands and lands dominated by forbs, mosses or lichens	2.90	2,204,028,640	2.85	2 174,779,916
F – Heathland, scrub and tundra	3.39	230,274,512	3.35	229,241,328
G – Woodland, forest and other wooded land	4.99	7,059,339,311	3.92	5,806,875,957
H – Inland unvegetated or sparsely vegetated habitats	2.01	8,662,999	2.00	8,640,632
I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	1.07	1,019,841,762	1.07	1,019,841,762
J – Constructed, industrial and other artificial habitats	2.51	490,007,866	2.51	490,007,866
X – Habitat complexes	2.03	165,056,904	2.03	165,056,904
Total: Weighted average over ecosystem area / Total value in EUR	3.13	11,346,479,255	2.72	10,053,298,359

The maps of potential (Fig. 52) and supply (Fig. 53) complement the numerical evaluations in which forest ecosystems lead, followed by other non-forest and aquatic, while the lowest potential for ES provision is the ecosystems of agricultural land in the southwest and southeast of Slovakia (Fig. 52). For non-conflict land use, the system should be set so that the value of this ES does not decrease, especially in protected areas of Slovakia.

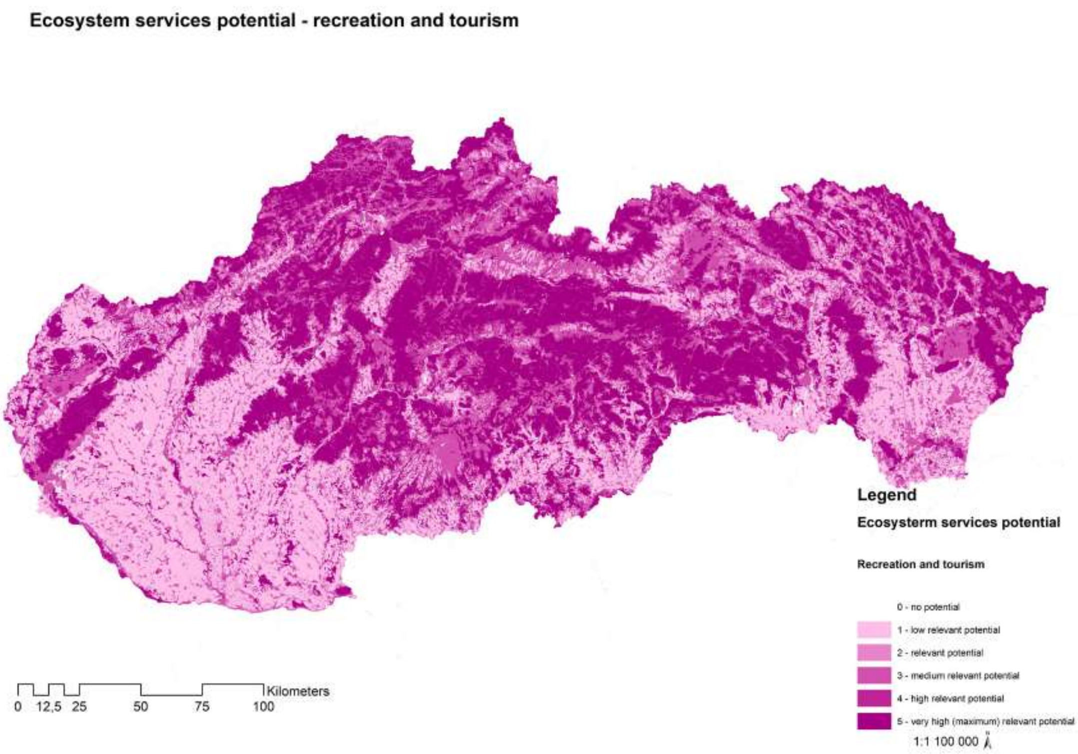

Fig. 52 Map of potential for provision ES recreation and tourism

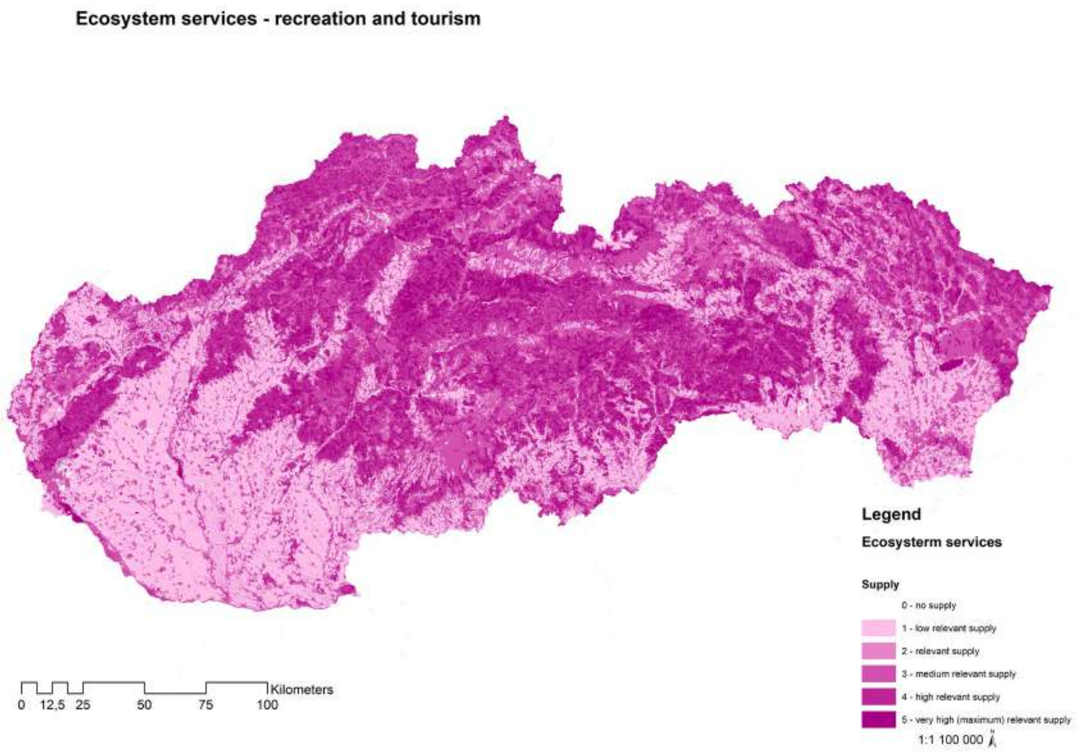

Fig. 53 Map of supply of ES recreation and tourism in relation to the quality of ecosystems

3.3.3.2 Landscape aesthetics and inspiration

Different approaches to the landscape imply the existence of different directions for perceiving and evaluating the landscape. Perception of the landscape is closely related to its aesthetics, because aesthetics is an essential part of our cultural landscape (Svobodová 2011). A certain landscape peculiarity, originality, uniqueness is an expression of the configuration resulting from the original structure of natural landscape types, the composition resulting from human artifacts and the arrangement of the current landscape structure (Supuka 2004). In general, the beneficiaries of this ES benefit sensitively perceive and evaluate different types of landscapes and landscape features. Perspectives on the positive perception of the landscape are individual according to the psychological and physiological characteristics of observers - e.g. the agricultural landscape is perceived more positively by older people than by younger people (Howley 2011).

Results of the evaluation of landscape character, aesthetics and spiritual inspiration services
It must be said that all ecosystems in Slovakia contribute to some extent to the provision of ES landscape character, aesthetics and spiritual inspiration, and therefore the total potential index has a value of 3.27 index points (Tab. 30) .

Tab. 30 Indexes and values of potential and supply in relation to the ES provision of landscape aesthetics and inspiration divided according to the EUNIS 1 level

LANSCAPE CHARACTER, AESTHETICS, SPIRITUAL INSPIRATION	POTENTIAL		SUPPLY	
EUNIS level 1 classification	Index average	Value in EUR	Index average	Value in EUR
C – Inland surface waters	3.72	422,214,889	3,6	394,398,566
D – Mires, bogs and fens	2.00	83,428,486	1.85	80,208,540
E – Grasslands and lands dominated by forbs, mosses or lichens	3.81	7,845,835,278	3.76	7,766,095,579
F – Heathland, scrub and tundra	2.78	485,649,087	2.74	482,832,354
G – Woodland, forest and other wooded land	4.99	19,148,709,524	3.92	15,734,165,641
H – Inland unvegetated or sparsely vegetated habitats	3.00	35,425,609	2.99	35,364,629

I – Regularly or recently cultivated agricultural, horticultural and domestic habitats	1.07	2,780,356,360	1.07	2,780,356,360
J – Constructed, industrial and other artificial habitats	1.68	952,474,563	1.68	952,474,563
X – Habitat complexes	2.00	447,607,666	2.00	447,607,666
Total: Weighted average over ecosystem area / Total value in EUR	3.27	32,201,701,462	2.85	28,673,503,897

The diversity of the landscape and its elements (ecotones, mixed forests, species-rich grassland meadows, natural aquatic ecosystems) is of great importance in the provision of the ES, while uniform ecosystems (monoculture fields, forests, permanent grasslands, etc.) provide low value. The total supply index is calculated at 2.85 index points. Landscape character, aesthetics and spiritual inspiration is the ES, on which people are not dependent, they use it more or less free of charge and it is not a tradable product, although it indirectly benefits from it, for example in tourism. The economic expression of the potential is evaluated at 32,201,701,462 EUR per year, after evaluating the quality of ecosystems the value decreased to 28,673,503,897 EUR per year. **Forest ecosystems** (4.99 index point), **grassland and herb ecosystems and aquatic ecosystems** have the highest potential and supply for ES provision in terms of quality and quantity.

Protected areas, which are designed for the conservation of specific natural and semi-natural ecosystems (habitats and species), play an important role in providing the ES with a landscape, aesthetics and spiritual inspiration. This statement is also supported by the assessment of the relationship between the ES landscape and the aesthetics and significance of the area in terms of nature protection (Mederly, Černecký et al. 2019), in which there was a clear positive correlation, in particular **the higher the degree of protection of the territory, the higher the lanscape capacity to provide ES**. Based on the map of evaluation of potential (Fig. 54) and supply (Fig. 55) it can be said that the most interesting areas for ES provision are mountain areas, namely Tatra and Fatra mountains, Slovenský raj, Slovenské rudohorie, Strážovské vrchy hills, Javorníky, Štiavnické vrchy hills, Malé Karpaty, large watercourses such as the Danube river, the Váh river, the Hron river. Lowlands and agricultural areas are less important.

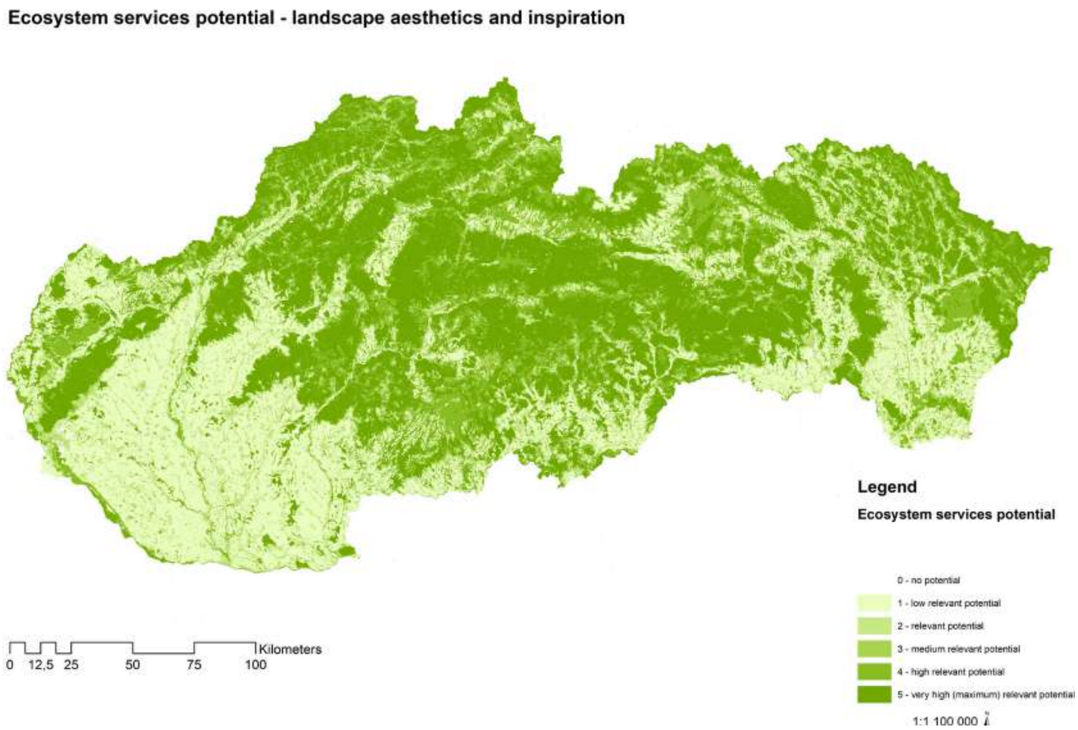

Fig. 54 Map of potential for provision ES landscape aesthetics and inspiration

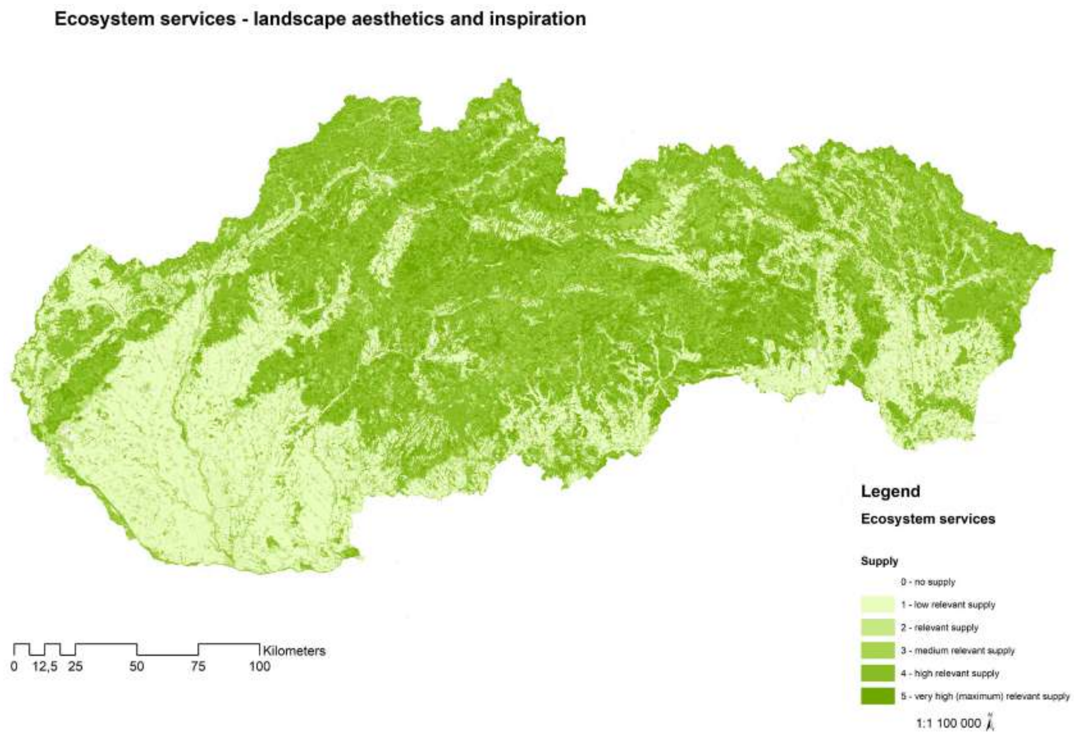

Fig. 55 Map of supply of ES landscape aesthetics and inspiration in relation to the quality of ecosystems

3.4 Overall assessment of the benefits of ecosystem services in Slovakia

3.4.1 Regulatory ecosystem services

A total of 11 regulatory ecosystem services were evaluated. The greatest potential of ecosystems, in terms of the assessment of the average index, has been calculated for the following ES:
- global climate regulation - 3.25 index point,
- regulation of nutrient circulation - 3.08 index point,
- erosion control – 3.01 index point,
- local climate regulation - 2.97 index point.

The above ES would be provided in the highest quality if all ecosystems were in favourable condition. After taking into account the degree of ecosystem degradation, the ES has the highest quality for following ES:
- global climate regulation - 2.83 index points,
- nutrient regulation - 2.67 index point,
- local climate regulation - 1.61 index point,
- erosion control - 1.58 index point.

Comparison of the average potential indexes is shown in Fig. 56 and the supply indexes in Fig. 57 for all regulatory ES.

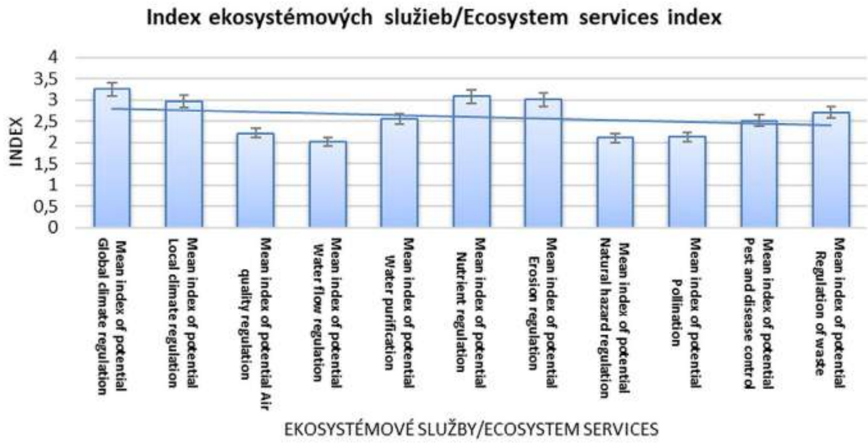

Fig. 56 Comparison of average potential index values of 11 regulatory ES

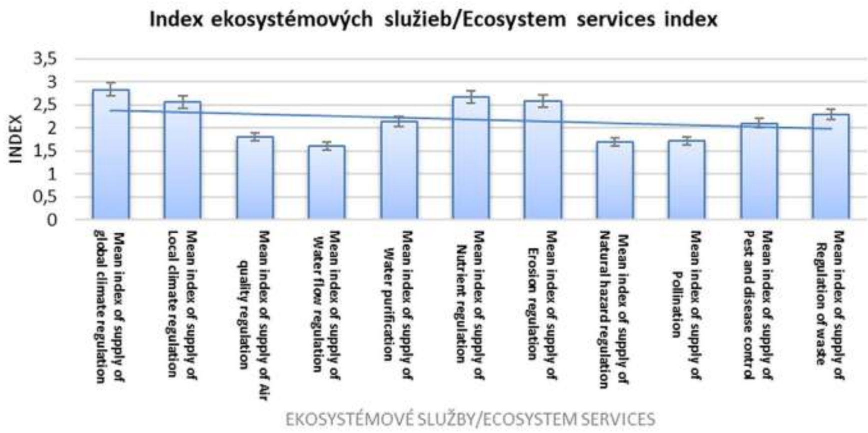

Fig. 57 Comparison of average supply index values of 11 regulatory ES

Fig. 58 and Fig. 59 show a different view of the comparison of average indexes of regulatory services.

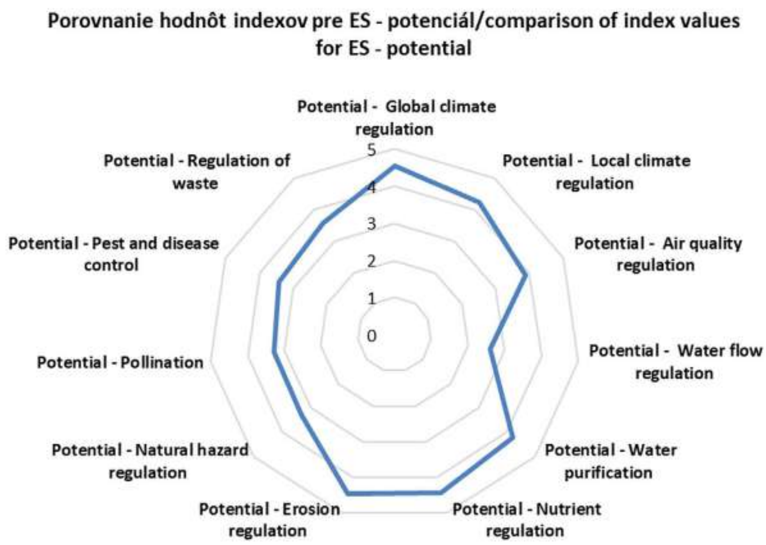

Fig. 58 Comparison of potential indexes values for 11 regulatory ES

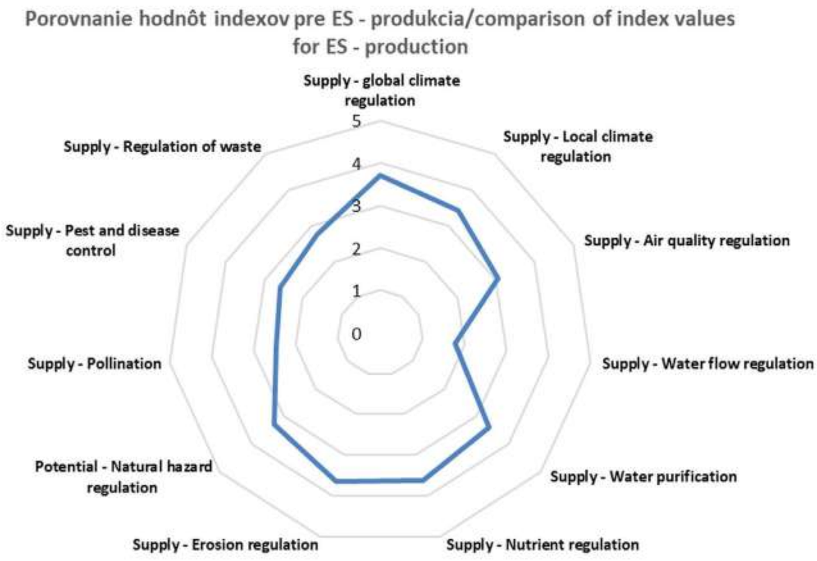

Fig. 59 Comparison of supply indexes values for 11 regulatory ES

In terms of quantity, **ES regulation of erosion control and regulation of water regime are provided on the largest scale.** Both mentioned ES are provided on an area of more than 30,000 km^2, which is approximately **⅔ the area of the Slovak Republic**. Air quality regulation has the smallest area of ecosystems providing regulatory ES (less than 20,000 km^2).

The map in Fig. 60 contains a summary of all evaluated regulatory ES given according to average values in individual polygons according to the potential index. When mapping the potential of the evaluated regulatory ES, it is evident that **forest ecosystems** dominate in terms of quality. In terms of quantity, the situation is more balanced and the results also include a relatively high area of non-forest ecosystems, especially **grasslands**. The lowest values of potential and supply are given for ecologically significantly altered ecosystems and in urban areas of the Slovak Republic.

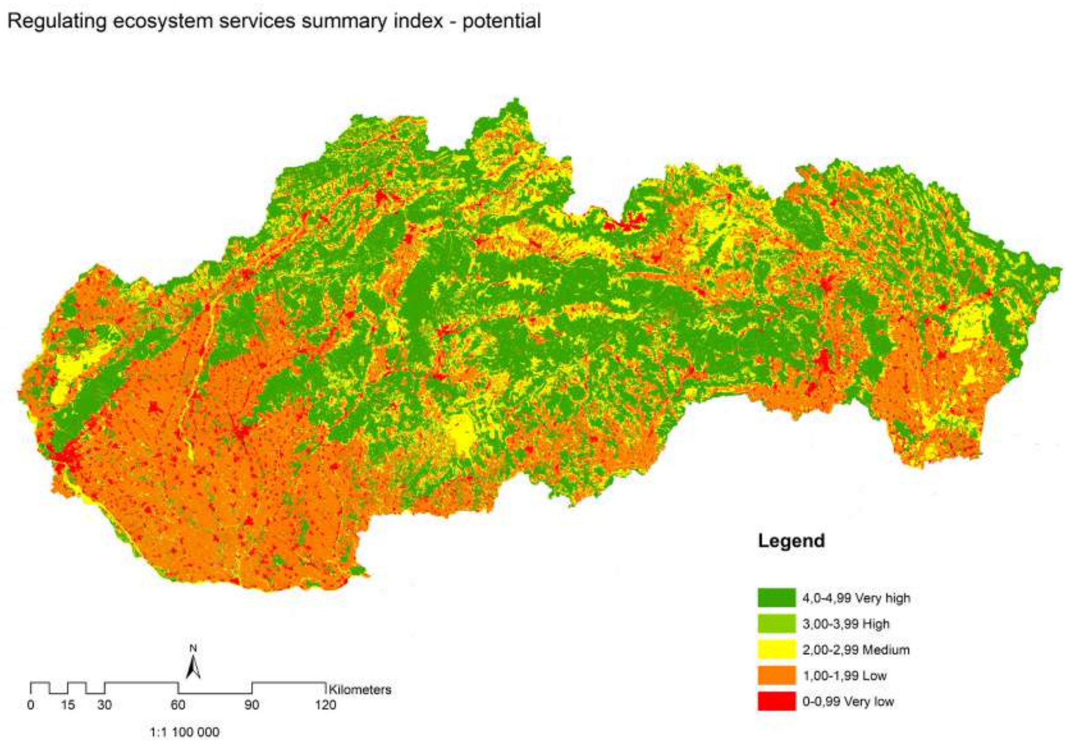

Fig. 60 Map of evaluation of the potential for 11 regulatory ES according to the average values of the index

The summary supply map in Fig. 61 shows the difference from the potential (Fig. 60). The degradation and lower quality of ecosystems is subsequently reflected in the quality provided by the ES and in the assessment index. The dark green areas (quality index 4 - 5) are much less present compared to the potential and more yellow areas (quality index 2 - 3.99).

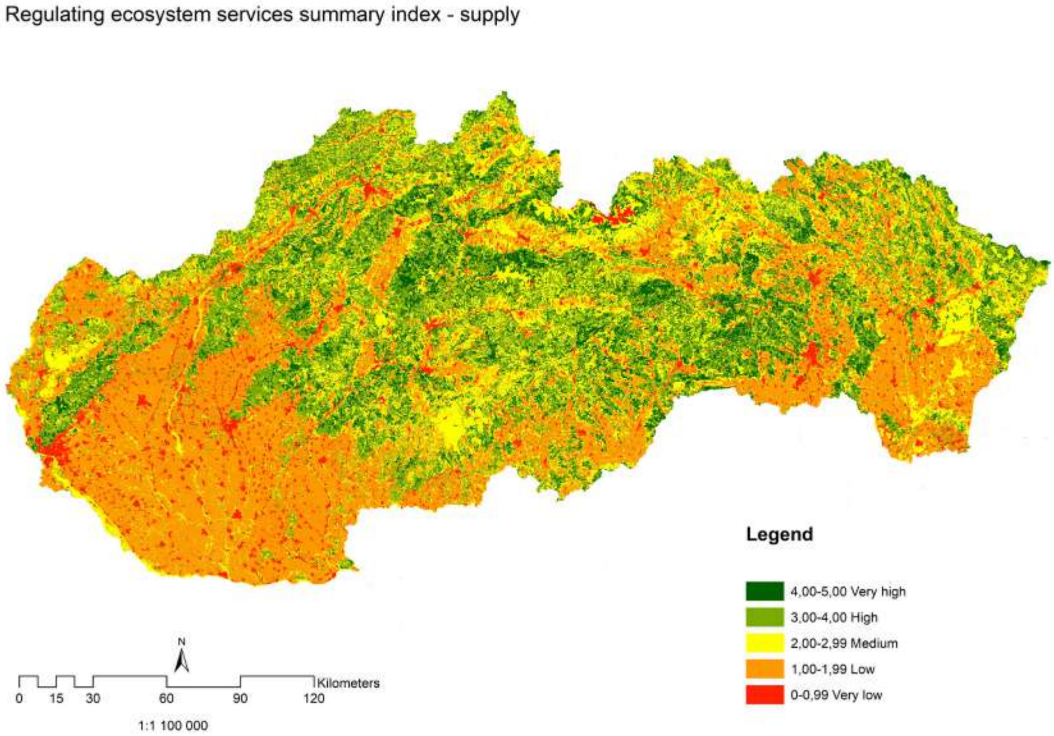

Fig. 61 Map of evaluation of the supply for 11 regulatory ES according to the average values of the index

In terms of quality, a significant difference compared to the potential is visible and the highest provision is maintained mainly by old and preserved parts of forest ecosystems, most often occurring in protected areas. Most of the remaining areas belong to the average. The most important habitats that produce regulatory ES in relatively good quality, but especially on a large area are Ls5.1 Beech and fir-beech flower forests (**G1.63 Medio-European neutrophile beech forests**), irreplaceable role is played mainly by older forests and primeval forests. Of the non-forest habitats, it is the Lk1 lowland and foothill meadows (**E2.22 Sub-Atlantic lowland hay meadows**). **Wetlands and peatlands** are important for the quality of regulatory ES provision, but their size is very small to have a significant impact on overall values at national level, however the need for their protection is all the greater.

In the case of regulatory ES, an important result is **the demonstration of the importance of relatively common forest and non-forest habitats** in the Slovak Republic (especially Ls5.1 and Lk1 habitats), which play a key and most important role in providing evaluated 11 regulatory ES. It is necessary to ensure adequate protection, sensitive management of these habitats and strive to keep them in the best possible condition. This principle is different from the nature conservation approach, which seeks to protect, in particular, rare and endangered habitats in which nature and its components are the main client, which is an adequate approach to the conservation of biodiversity. In principle, the current nature protection setting protects several supporting ES, but lacks systematic protection of regulatory ES. However, ecosystems providing regulatory ES need to be viewed from a different perspective, from a human perspective and needs. The use of regulatory ES is important for man and the preservation of his health, prosperity and favourable environment for life, and it is therefore necessary to protect and maintain the state of habitats that are close to man and his settlements, even though they are not in terms of frequency occurrence rarely. Protected areas make a significant contribution in this regard, especially those located in close proximity to towns and villages, but of course others more remote ecosystems that produce regulatory ES are not static but flow in the environment (air quality regulation, water regime regulation, etc.) Some factors currently complicate the maintenance of regulatory ES, e.g. climate change and its impact on forest ecosystems. As a result, many forest ecosystems are weakened and the effects of adverse environmental influences create large-scale calamities, which in the long run complicate the adequate provision of regulatory ES. In non-forest ecosystems, they are manifested by a change in species composition, the introduction of more thermophilic, non-native and invasive species - all of which affect to some extent the provision of regulatory ES itself.

3.4.2 Provisioning ecosystem services

For provisioning ES, 10 services were comprehensively evaluated. Most provisioning ES have long been part of the economy and market mechanism, especially the market for timber, firewood, drinking water, and biomass. When comparing the indices provided by the ES in terms of potential (Fig. 62) **provided by ecosystems, the following services dominate**:

- wild food and resources – 3.25 index point,
- fodder - 2.32 index point,
- biomass provision – 2.05 index point,
- timber provision - 1.9 index point,
- firewood provision -1.9 index point.

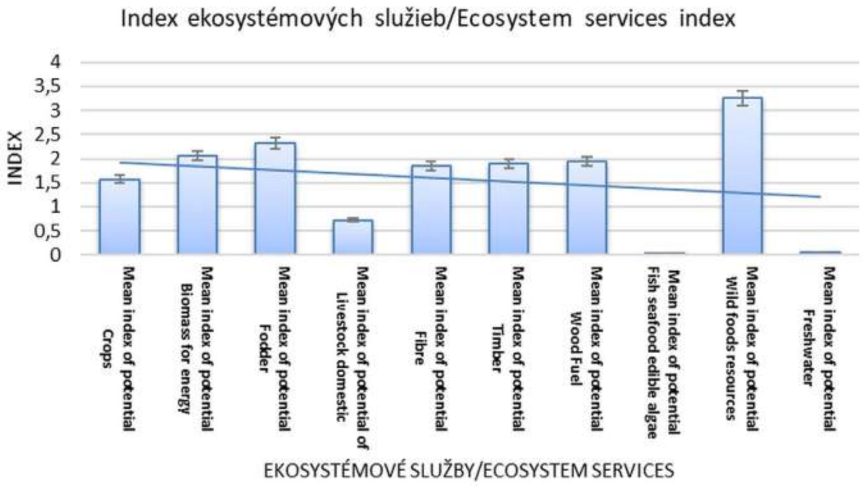

Fig. 62 Comparison of average potential index values of 10 provisioning ES

After taking into account the quality of ecosystems, the values of average supply indexes are reduced and the following services remain dominant (Fig. 63):

- wild food and resources - 2.83 index point,
- fodder – 1.8 index point,
- biomass provision - 1.57 index point,
- firewood provision -1.53 index point,
- timber provision 1.48 index point.

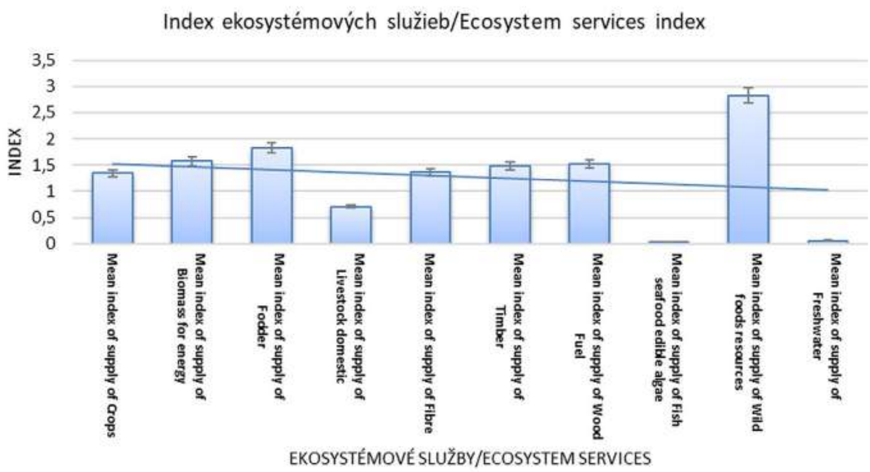

Fig. 63 Comparison of average supply index values of 10 provisioning ES

Fig. 64 and Fig. 65 show a different view of the comparison of average indices of provisioning services.

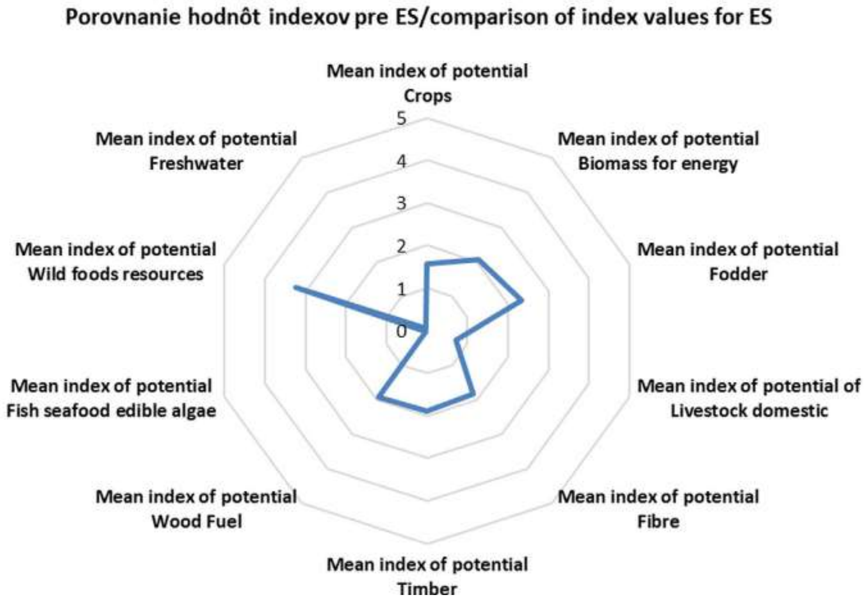

Fig. 64 Comparison of potential indexes values for 10 provisionig ES

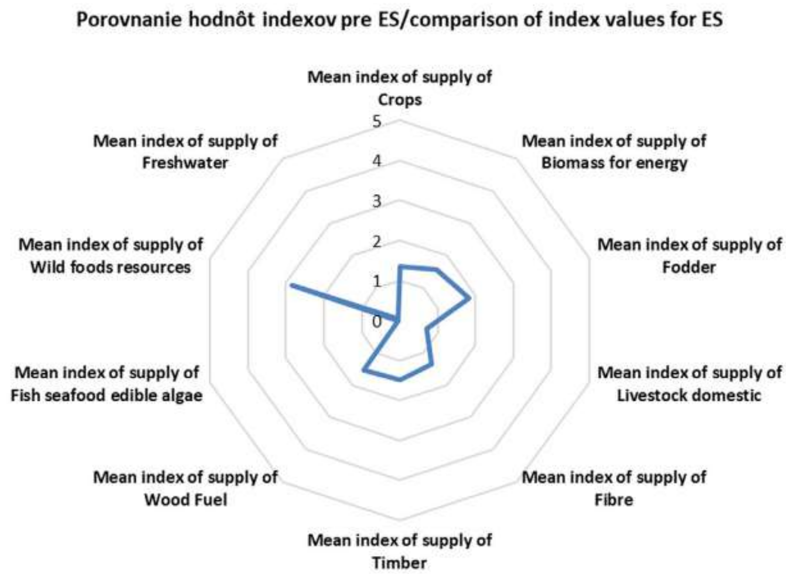

Fig. 65 Comparison of supply indexes values for 10 provisionig ES

A map representation of the total potential of ecosystems in Fig. 66 in comparison with the regulatory and cultural ES, captures the difference in the average values of the indices of services provided by individual ecosystems, which are significantly lower. This is mainly due to the fact that some production ES do not accumulate in one place. For example, in places where ES production of crops is provided, it is not possible to provide additional provisioning ES (in those places, in principle, only 1 or a few production ES are produced, with the exception of some ES provided by forest ecosystems). It is necessary to take into account the evaluation in the matrix itself, which does not achieve a high score for some production ES and thus the average total values for production ES at a given site do not reach values higher than 3 and also to some extent exclude some ecosystems from ES production, although in reality this may not be the case. In terms of current potential, it is evident that the lowest average values of supply ES are in urban areas and on degraded ecosystems and in areas of rock ecosystems, e.g. the highest areas of the Tatras. The highest values are achieved on **arable land, forest and grass-herb ecosystems.**

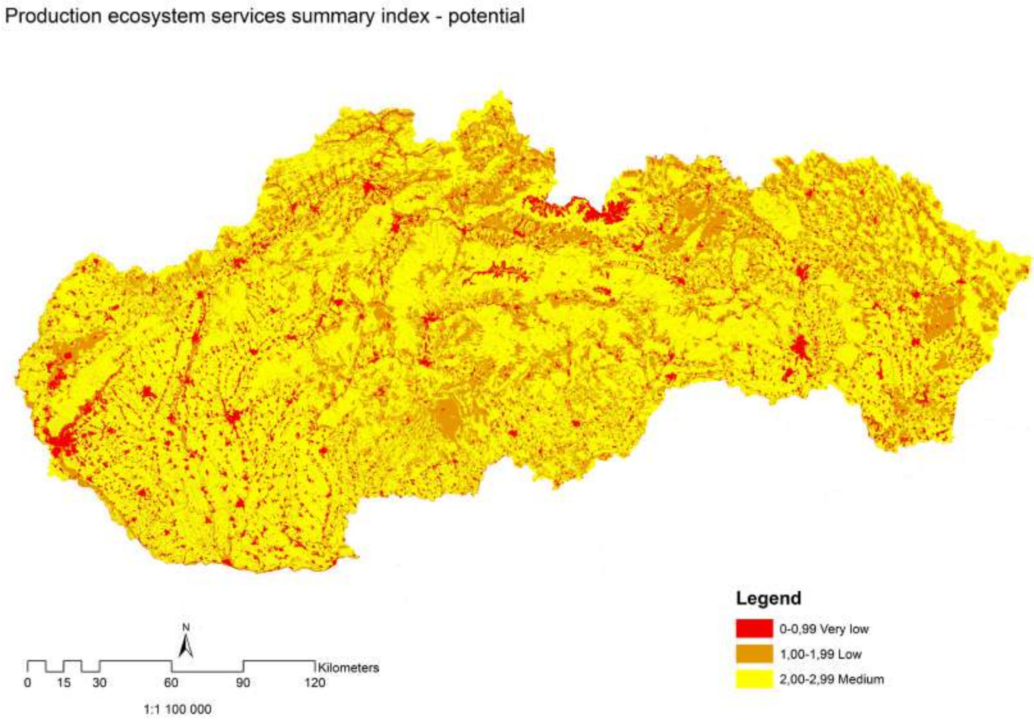

Fig. 66 Map of evaluation of the potential for 9 provisionig ES according to the average values of the index

After taking into account the degradation of ecosystems and fertility in the area of arable land (Fig. 67) the highest average values of provided provisioning ES reach the most fertile arable land. The remaining ecosystems provide only a relatively small average index of supply of provisioning ES, mostly only up to 2, which is a relatively low rating compared to regulatory ES. In the case of degraded ecosystems, areas of calamitous areas in forest ecosystems (High Tatras, Low Tatras, etc.) are also evident in the map display, which have a lower ability to provide provisioning ES compared to ecosystems in a favourable condition. The urban areas of Slovakia have the lowest ability to provide provisioning ES.

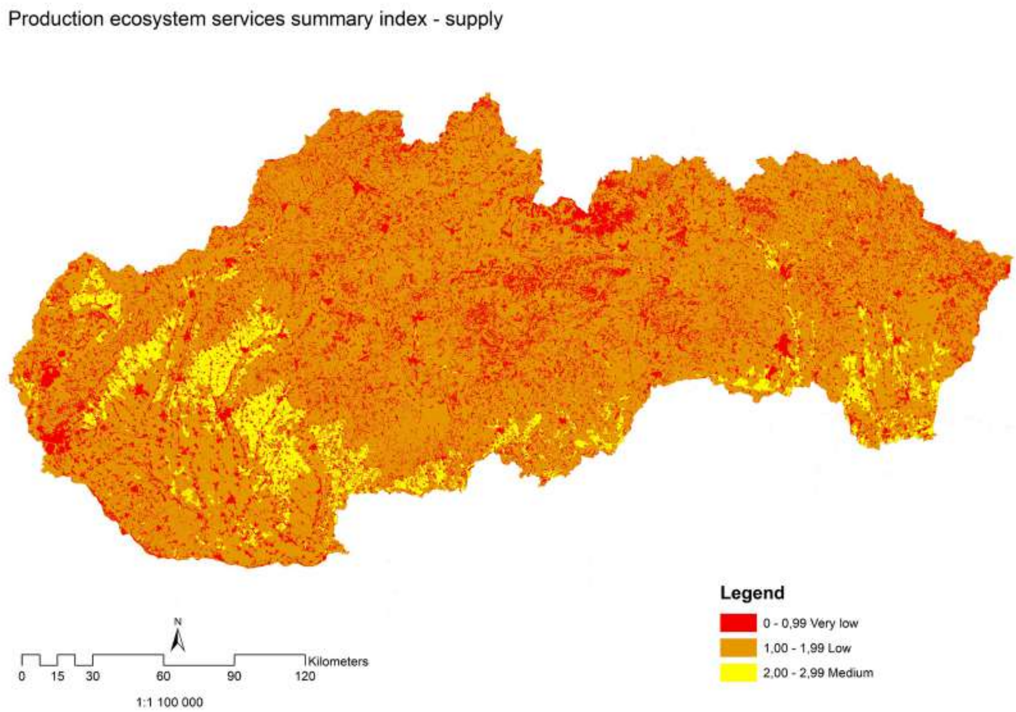

Fig. 67 Map of evaluation of the supply of 10 provisionig ES according to the average values of the index

The largest acreage in provisioning ES is in **the production of fodder and wild food and resources.** The smallest areas reach the services of fish production, and surface drinking water.

The most important ecosystems for provisioning ES based on quality and quantity assessments are **arable land**. In terms of quantity, it is the **G1.63 Medio-European neutrophile beech forests, G1.63 Medio-European neutrophile beech forests** which are important from the group of natural forest ecosystems and **E2.22 Sub-Atlantic lowland hay meadows, E2.22 Sub- Atlantic lowland hay meadows**, which are important from the group of natural non-forest ecosystems.

3.4.3 Cultural ecosystem services

In the case of cultural ESs, 2 ESs were comprehensively evaluated – recreation and tourism and landscape character, aesthetics and spiritual inspiration. From the index point of view (Fig. 68 and Fig. 69) it is evident that the Slovak Republic also has a high potential for the provision of cultural ESs. In the quality of provision, the ES landscape character prevails, aesthetics spiritual inspiration over ES recreation and tourism.

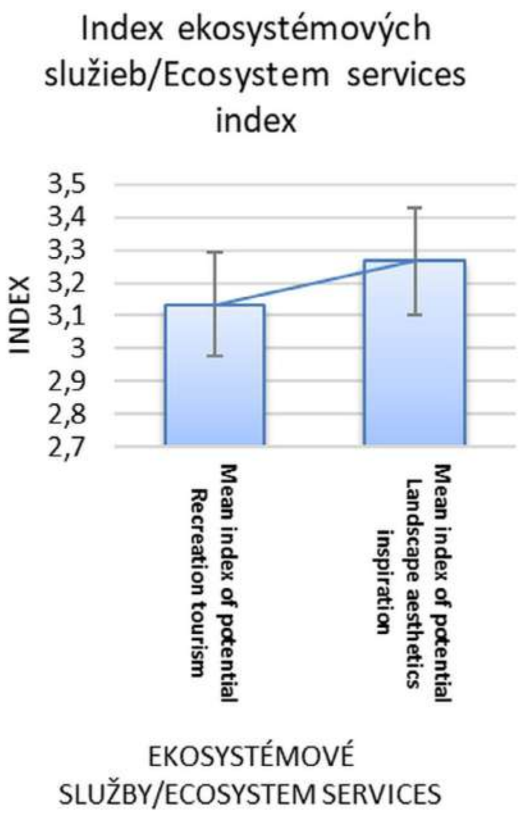

Fig. 68 Comparison of average potential indexes values for 2 cultural ES

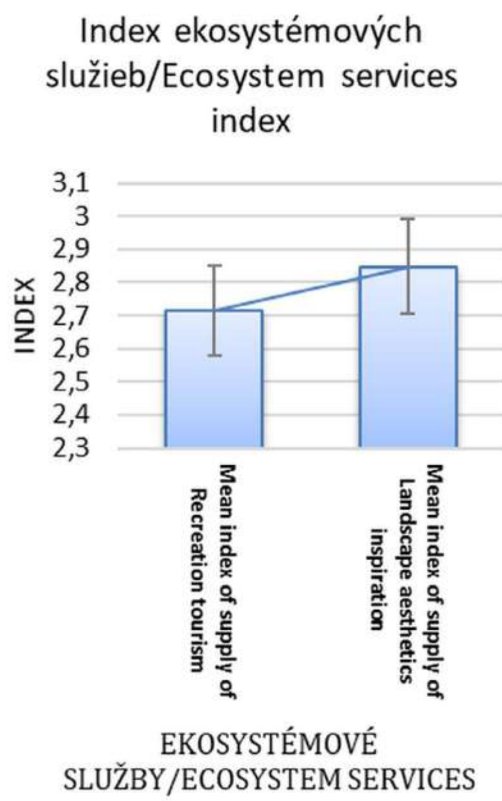

Fig. 69 Comparison of average supply indexes values for 2 cultural ES

The economic value calculated for the ES landscape character, aesthetics and spiritual inspiration is approximately three times higher than the value of ES recreation and tourism. ES landscape character, aesthetics and spiritual inspiration is almost € 30 billion / year, indicating a still high level of conservation of landscape, native and natural ecosystems, which are often the result of traditional farming practices in the past and still persist in some places.

Map evaluation of the potential for both cultural ES in Fig. 70 shows that **forest ecosystems**, the rural settlements areas and small scale arable land have the highest potential index. Similar to regulatory and cultural ES, commonly spread habitats in the Slovak Republic play an important role, mainly **G1.63 Medio-European neutrophile beech forests** and **E2.22 Sub-Atlantic lowland hay meadows**.

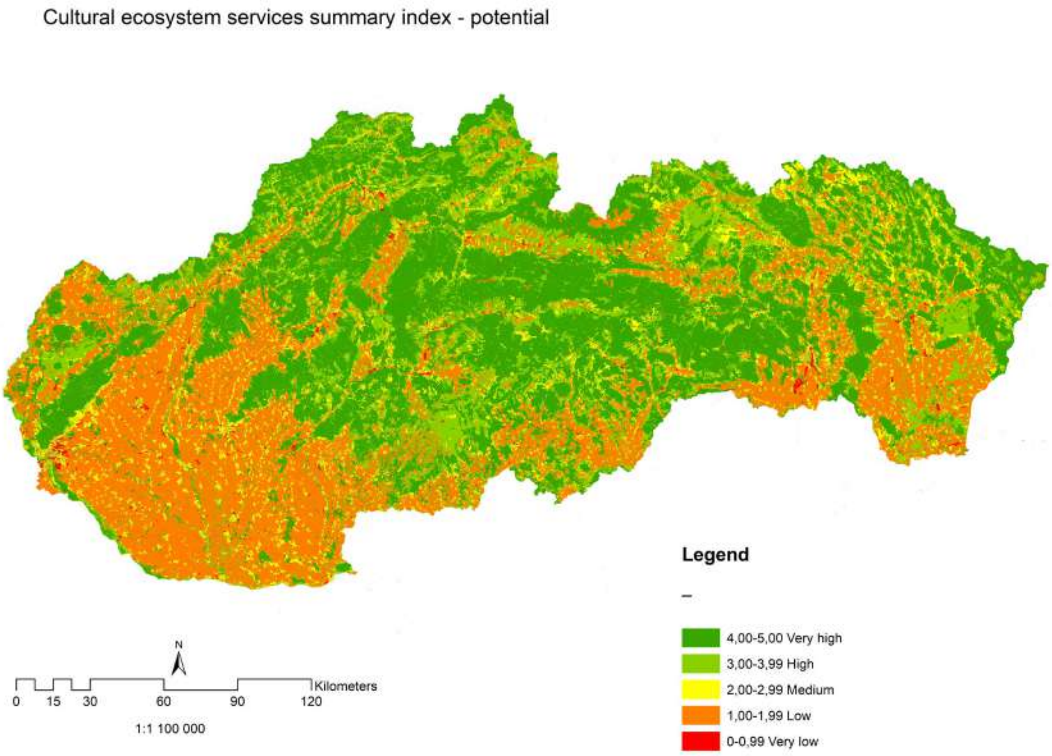

Fig. 70 Map of evaluation of the potential for 2 cultural ES according to the average values of the index

In the following supply map in Fig. 71, the state of degradation and interventions in ecosystems compared to the potential map is clearly visible. Both assessed cultural ESs are sensitive to interventions caused primarily by intense human activity. Degraded ecosystems or ecosystems under strong anthropogenic influence are not as touristicaly and aesthetically attractive as native and natural ecosystems or habitats.

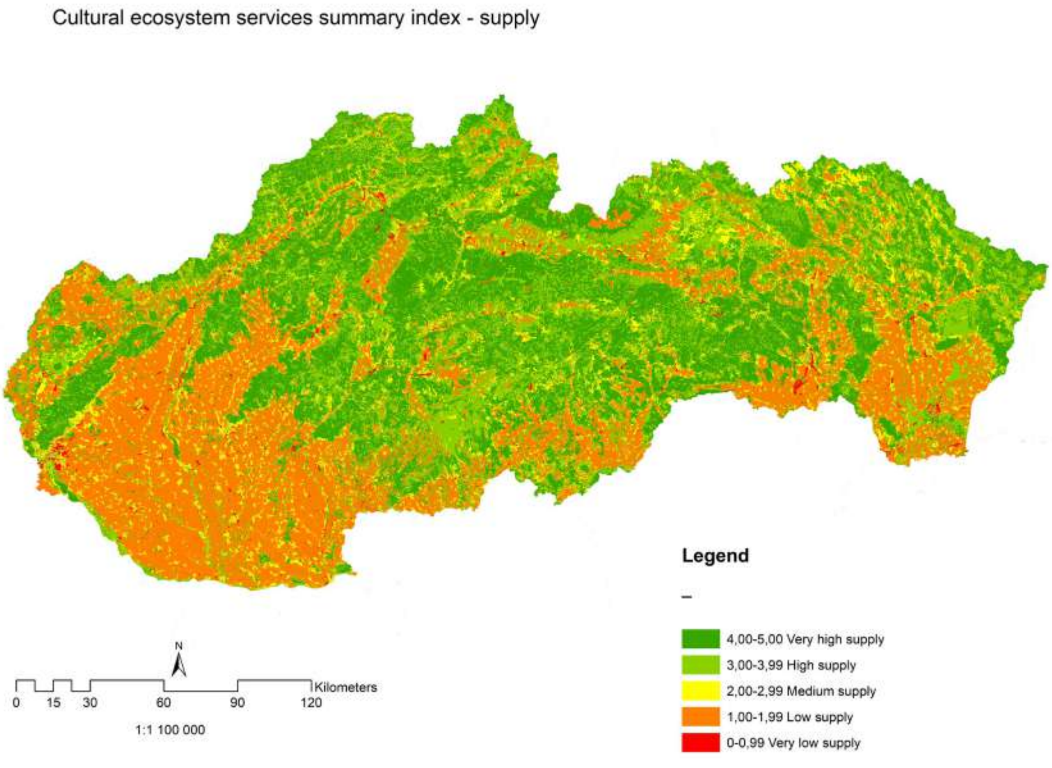

Fig. 71 Map of evaluation of the supply for 2 cultural ES according to the average values of the index

The best ecosystems for the provision of cultural ES are only those that show **a high degree of naturalness** and at the same time **a low value of intense anthropogenic influences**. In the case of forest ecosystems, these are old preserved forest stands, in the case of non-forest natural meadow communities, little affected by secondary succession. The spatial distribution is dominated by the central part of Slovakia at the expense of the western and eastern parts, in which the average index is significantly lower, mainly due to intensive agricultural activity.

In terms of quality in relation to the area, it is necessary to highlight the ES landscape character, aesthetics and spiritual inspiration, which came out in the evaluation with the best quality index 4 and is provided on an area of up to 1,589,000 ha / 15,890 km^2. It is very positive that **approximately 90% of the area of the Slovak Republic produces cultural ES**, but it is necessary to take into account that in many places the provision of this ES is only worth 1 index point, which is a relatively low provision of ES in general.

3.4.4 Summary evaluation of ES for the territory of Slovakia

The overall evaluation of all ES is quite problematic in all circumstances and for many different reasons. In principle, it is difficult to combine provisioning, regulatory and cultural services, which have their own specificities, and it is necessary to take into account the fact that drawing on some ES may prevent the production of other ES (trade-offs). From the point of view of correct interpretation, we therefore recommend to confront the summary results with the detailed results for individual ES. It should also be emphasized that, as in other studies and works, the selection of ES evaluated is not complete. The results should therefore always be taken as partial, as the full spectrum of all existing ES has not been evaluated. In the future, it is necessary to expect that, in particular, total monetary values will increase due to the addition of assessments of other ES. Therefore, it is important to interpret the resulting monetary values as the minimum prices calculated by the methodology in this work and always take the total value in relation to our chosen ES and not as the final price of ES. The resulting monetary values are expressed in scope and should be used as a guide only and will need to be refined in the future by specifying the methods for determining the basic price units on the acreage provided by the ES.

The summary evaluation for individual indexes shows that cultural and regulatory ES exceed the total index of provisioning ES (Tab. 31). When comparing at the regional level, regional differences can also be seen, which are mainly influenced by the representation of ecosystems in a given region. The regions of western Slovakia achieved lower overall average values of regulatory ES. It is interesting that all provisioning ES have similar average values throughout Slovakia, but after taking into account the area of regions, the index has a value of 1.27. Regulatory ES averaged 2.92 and cultural up to 3.52, although it should be noted that only 2 services were evaluated for cultural ES.

Tab. 31 Summary supply indexes values of assessed ES by 8 self-governing regions of Slovakia

Region	Area (m²)	Index - Regulatory ES summary	Index - Provisioning ES summary	Index - Cultural ES summary
Banská Bystrica region	9,453,109,000	3.03	1.26	3.66
Prešov region	8,994,707,000	3.09	1.27	3.71
Košice region	6,749,650,000	3.14	1.33	3.73
Žilina region	6,793,264,000	3.04	1.25	3.71
Nitra region	6,341,266,000	2.43	1.28	2.95
Trenčín region	4,499,161,000	2.94	1.26	3.58
Trnava region	4,147,714,000	2.51	1.25	3.02
Bratislava region	2,053,264,000	2.77	1.21	3.39
Total area and average index weighted over to the area of the region	49,032,135,000	2.92	1.27	3.52

For monetary values, it is interesting to look at the results divided by region in Tab. 32. Even in monetary terms, regulatory ES values have the highest aggregate value. Economic studies and articles evaluate, based on their approaches, the West as a richer part of Slovakia, led by the Bratislava Region and poorer Central and Eastern Slovakia. However, the Banská Bystrica, Prešov, Žilina, Košice and Nitra regions appear to be the richest in Slovakia, with a total value exceeding EUR 20 billion per year, due to the presence of ecosystems in their territory, which provide irreplaceable ES. It is obvious that economically "malnourished" regions produce a different type of value, which is not currently reflected in the economy.

Tab. 32 Summary monetary supply values of assessed ES by 8 self-governing regions of Slovakia

Region	Regulatory ES (billion EUR/year)	Provisioning ES (billion EUR/year)	Cultural ES (billion EUR/year)	Total (billion EUR/year)
Banská Bystrica region	18 – 21	14 – 16	7 – 8	39 – 45
Bratislava region	3 – 5	3 – 4	1 – 2	7 – 11
Košice region	11 – 14	10 – 12	4 – 5	25 – 31
Nitra region	7 – 9	11 – 12	3 – 4	21 – 25
Prešov region	16 – 19	11 – 13	6 – 7	33 – 39
Trenčín region	9 – 11	7 – 8	3 – 4	19 – 23
Trnava region	5 – 6	7 – 8	2 – 3	14 – 17
Žilina region	14 – 17	10 – 11	5 – 6	29 – 34
Total (billion EUR)	83 – 102	73 – 84	31 – 39	187 – 225

Comparison of the traditional GDP of any region of Slovakia (Tab. 33) with the monetary value provided by the ES in the same region (Tab. 32) brings interesting results - GDP is not higher than the economic value of the ES provided in the region. In making this finding, it is necessary to consider whether current traditional economic practices, without taking into account the ES as the basic pillars of healthy and sustainable living, are set correctly. Following the introduction of ecosystem accounting, these views and distributions may differ fundamentally from the current classical economic perception. In the traditional evaluation of GDP, the Bratislava region has long been the richest, but in the evaluation of the ES, this region is the poorest, even when calculating the value of traditional GDP and the value of the ES. These results fundamentally turn the angle of view of the wealth of the regions. Furthermore, they suggest that the regions of western Slovakia live to some extent from the regulatory and cultural ES, which are produced in other parts of the Slovak Republic and thus the regions of central and eastern Slovakia contribute to the values of people living in the western part of Slovakia.

Tab. 33 GDP by 8 self-governing regions of Slovakia in current prices (EUR) in 2017 (Source: ŠÚ SR, Statistical Yearbook of Slovak Regions)

Region	GDP (EUR)
Bratislava	23,727,000,000 €
Trnava	9,519,000,000 €
Trenčín	7,602,000,000 €
Nitra	9,273,000,000 €
Žilina	9,198,000,000 €
Banská Bystrica	7,486,000,000 €
Prešov	7,686,000,000 €
Košice	10,360,000,000 €

The total GDP in Slovakia, according to the Statistical Office of the Slovak Republic, is reported at EUR 84.9 billion in 2017 and EUR 88.6 billion in 2018. **The value of ES in Slovakia is at least EUR 187-225 billion per year, which is more than twice traditional GDP.** It is also necessary to say that **due to the degradation of ecosystems in Slovakia, the Slovak Republic loses about 20 billion EUR per year.** Theoretically, in the future, investment in ecosystems and their quality can be a very important economic element, because even from these results it is evident that e.g. with a significant investment in the restoration of ecosystems, these costs will have a very high return, which is always a very important factor in economic decision-making. From a fundamental point of view, it is crucial **to perceive natural wealth and the provision of the ES as an invaluable and inseparable part of human life,** since without functioning ES, human life on Earth could not even exist.

4 Discussion

4.1 Advantages and disadvantages of the approach used

The results of the work provide an overview at the national level of the potential and supply provided by the ES using the **ecosystem approach**. This approach takes into account many parameters, as the biotic component of the environment to some extent takes into account attributes such as geological composition, relief, the presence of the required chemical composition, the amount of water and many other parameters needed for a comprehensive ES assessment. In the ecosystem approach, it is therefore not necessary to deal with a wide range of diverse parameters, because the ecosystem itself and its quality is determined by these parameters and thus already reflects the factors that are otherwise assessed separately. Such an approach is suitable at the national level, where it is not necessary to determine local specifics.

The ecosystem map was prepared on the basis of ecosystem identification (Černecký et al. 2020). As part of the evaluation, an evaluation of the quality of ecosystems was also prepared, which was subsequently used in the results for individual ES. Ecosystems were assigned to potential indices and supply indices through a modified matrix, which already took into account the quality of ecosystems themselves. Monetary values were calculated on the basis of published data and recalculated on the basis of the quality of ecosystems, the total average values were determined taking into account the acreage of ecosystems. On the basis of the above documents, it was possible to prepare a **national evaluation** for selected ES.

The advantages of the used approach are connected with the use of background data, especially the map of ecosystems, which provides a comprehensive picture of the ecosystems of Slovakia and thus significantly helps to locate individual ecosystem services. The matrix approach, which was elaborated in more detail, enabled the assignment of potential indices to individual habitats and also determines their basic qualitative level. The definition of the quality of ecosystems has made it possible to distinguish the quality of individual ES provision in more detail and to introduce into the assessment an individual approach, where each site (polygon) has determined unique values of provision and ES values.

The disadvantage of the matrix approach is its schematicity - the basic setting of the matrix also reflects the overall evaluation. Opinions on individual values in the matrix may differ among experts, and there are also situations where some ecosystems may be unfairly underestimated or, on the contrary, overestimated in terms of the provision of some ES. With monetary values, a similar problem arises, with any financial expression creating a discussion and a difference of opinion. The effort to evaluate demand through a matrix was not completed despite the fact that most of the results were processed according to the matrices for demand, but in the end, in our opinion, did not have good informative value, or had only a partial value consumption is not reported at all. We therefore recommend using other more appropriate methods for assessing demand / consumption in the future.

The potential for ES provision in this work is based on **current land use**. Over time, there will be a change / transformation of ecosystems under the influence of anthropisation, changes in management and management, land use, the impact of degradation by natural and human activities, which will be reflected in repeated assessments over time. It will be possible to compare the results of future evaluations with the results in this work and thus evaluate the change in the quality and quantity of potential provided by regulatory and other ES.

4.2 Examples of alternative approaches to ES evaluation

In terms of the methods and approaches used, several diverse ES evaluation methodologies have been published, but there are still many areas that are not adequately defined. It is insufficient e.g. documenting and researching the positive link between soil biodiversity and regulatory and provisioning services (Bakker et al. 2019) or evaluating the use of some ES such as assimilation of pollutants in wetlands (Trimmer et al. 2019). The growing body of evidence on the positive impact of the natural environment on mental health points to the need to include models for ES assessment in this area as well (Bratman et al. 2019). Another interesting area is the spatial flows of the ES and their mutual relations on a local to global scale - e.g. from mountainous areas to lowlands (see Schripke et al. 2019).

Several authors deal specifically with e.g. **socio-economic analysis** of the ES in different types of habitats, e.g. pastures in Europe - Torralba et al. 2018, floodplain forests in the Czech Republic - Machar et al. 2018, mountain areas in Portugal - Carvalho-Santos et al. 2018, the integration of ecosystem values into cost-benefit analyzes (Kashi et al. 2018) or the impact of land use and development scenarios on the ES e.g. Indonesia and palm oil plantations - Sharma et al. 2018.

Mapping and assessment of the state of ecosystems and their services in Europe, including studies and assessment concepts, is analyzed by Nedkov et al. (2018). Also, the IUCN handbook (Neugarten et al. 2018) describes several tools for measuring, modeling and evaluating ES applied mainly in protected areas.

Several authors deal with the issue of evaluating the **significance of landscape character** and aesthetics, e.g. in the Netherlands (measuring the attractiveness of the landscape and identifying national hot spots - de Vries et al. 2013) or in Germany (assessing the aesthetic quality of the landscape using indicators of naturalness and uniqueness - Hermes et al. 2018). Bijker & Sijtsma (2017) emphasize in particular the importance of natural areas for the inhabitants of the urban environment. Daams et al. (2016) notes the effect of the perceived attractiveness of natural areas on the price of land. Davis et al. (2016) argue that not only the existing policy in the field of biodiversity protection but also the protection of the territory based on the psychological and emotional needs of the inhabitants is equally important. In their paper, Mayer & Woltering (2018) assesses the monetary value of **ES holiday homes** in German national parks using the Travel Cost Method.

One example of the evaluation of the **interaction of the ES and the protection of biodiversity** in protected areas with different management strategies is the work of Chung et al. (2018). In their contribution, they showed a positive correlation between the protection of biodiversity and nature-oriented tourism (cultural ES). Braat & Groot (2012) also report on the relationship between land use, biodiversity conservation and the ES. The study by Ratcliffe et al. (2017) focused on assessing the synergies between biodiversity and ES provision in Europe's forests. Although wood production is often in conflict with the protection of biodiversity, the authors point out that with proper management it is possible to maximize the ecosystem processes and thus the benefits for all. Felipe-Lucia et al. (2018) therefore proposes, in order to support more ES, to increase structural heterogeneity and to keep large and old trees, including gaps in the canopy. Ecosystem services provided by forest ecosystems may be affected by natural disturbances and land use changes (Fleischer et al. 2017).

The issue of the effectiveness of **payments for the ES** not only in the **level of protection of natural values**, but also the provision of socio-economic benefits is addressed by several authors (eg Börner et al., 2017, Ferraro et al. 2017, Jayachandran et al. 2017). Similar studies can be used to argue the need for investment in biodiversity conservation in order to protect natural values (Sánchez-Fernandéz et al. 2018). Hummel et al. discuss the issue of various ES definitions, classification methods, measurement methods and their use in protected area management. (2019). Wei et al. (2018), in turn, assesses the ES reserves declared for the protection of the giant panda and confirms that they are several times higher than the costs associated with their management. Specific evaluation and proposal of the method of valuing flag, resp. charismatic species, in the event of a fire, Molina et al. (2019). Dee et al. (2019) emphasizes that even rare species can, despite questioning assumptions, make a relatively significant contribution to the functioning of ecosystems and their services.

The concept of natural capital as an approach to nature based on financial valuation of localities and species has recently been the focus of current discussions on biodiversity protection. Anderson (2018) discusses not only the attractiveness but also the problem of this approach. ES economic evaluation is often criticized and the usefulness of individual methods needs to be seen in a broader context (Tinch et al. 2019). Ainscough et al. (2019) draws attention, for example, to the risk of using the ES assessment to support activities that are harmful to the environment or society. Vihervaara et al. (2019) describes the interconnection of different methodologies in ES mapping and evaluation, which helps to integrate information for decision-making processes with the aim of sustainable use and protection of the territory.

An alternative assessment of the state of ecosystems was used in a local study for the ES assessment of Bukk National Park in Hungary (Arany et al. 2018) and was based on a Luxembourg study by Becerra-Jurado et al. (2015), in which individual polygons are assigned a value based on the number of protected plant and animal species. In a polygon with 0 to 1 species, a value of 0 is assigned, a polygon with 2 to 7 species has a value of +1, a polygon with more than 8 species has a value of +2, and so on. The result, after reclassification, is a polygonal map of ecosystems with values of polygons 0-5, where the value 5 represents the areas with the most favorable state.

An alternative ES assessment is possible on the basis of a matrix prepared in Germany (Muller et al. 2018 draft). Based on the matrix concept for ES mapping according to Burkhard et al. (2014), a more complex matrix was developed in Germany (Fig. 72), which represents the potential for ES provision of different types of terrestrial, coastal and marine ecosystems. The types of ecosystems used in the attached version of the matrix were selected on the basis of the CLC resolution (levels) of Europe. The ES definitions have been summarized and adapted according to Kandzior et al. (2013). The index expression of potentials is generally rated between 0 (lowest potential) and 100 (highest potential).

Corine Code	CLC land type	Abiotic heterogeneity	Biodiversity	Biotic water flows	Metabolic efficiency	Exergy capture	Reduction of nutrient loss	Storage capacity	Crops (human nutrition)	Biomass for energy	Crops (fodder)	Livestock	Timber	Fibers	Wood fuel	Wild food	Fish and Seafood	Flotsam Organic	Ornamentals	Drinking water	Abiotic energy	Minerals	Groundwater recharge, water flow	Local climate regulation	Global climate regulation	Flood protection	Air quality regulation	Erosion regulation,wind	Erosion regulation, water	Nutrient regulation	Water purification	Pest and disease control	Pollination	Recreation and tourism	Landscape aesthetics + inspiration	Knowledge systems	Cultural heritage	Regional identity	Natural heritage
111	Continuous urban fabric	30	10	10	10	10	10	10	5	10	5	5	10	5	10	5	5	5	5	5	5	5	5	10	5	5	5	5	30	5	5	5	5	10	10	20	40	30	10
112	Discontinuous urban fabric	30	30	30	20	20	20	30	10	10	10	10	20	5	20	5	5	5	5	10	20	5	5	10	10	5	10	5	20	30	30	20	30	30	40	40	30	50	20
121	Industry and commerce	20	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	20	5	5	5	10	5	5	5	10	5	5	5	5	5	5	10	10	10	5
124	Airports	20	20	20	10	20	20	20	5	10	5	10	5	5	5	5	5	5	5	5	10	5	20	10	10	5	5	5	20	10	20	5	10	10	10	10	10	10	10
122	Road and railroad networks, traffic areas	20	20	20	20	20	20	20	5	10	5	10	10	10	10	10	5	5	5	5	10	5	10	10	10	10	10	10	10	10	10	10	10	60	40	20	50	40	10
131	Mineral extraction sites	20	10	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	20	5	10	90	20	5	5	5	5	5	5	5	5	5	5	10	10	30	30	30	10
132	Dump sites	20	10	5	5	5	5	30	5	10	5	5	5	5	5	5	5	5	5	5	10	5	10	5	20	5	5	5	5	5	5	5	5	5	5	10	5	5	5
133	Construction sites	10	10	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5
142	Sport and leisure facilities	30	30	30	20	30	30	30	10	10	10	5	20	5	20	5	5	5	5	5	5	5	20	20	20	5	10	10	10	20	30	30	20	40	20	10	30	20	30
141	Urban green	50	50	50	50	50	30	30	10	10	10	5	20	5	20	20	5	5	10	5	5	5	30	30	50	20	30	30	30	40	50	30	30	60	50	50	60	60	30
142	Camping and tourism sites	20	20	20	20	20	10	10	5	10	5	5	10	10	10	20	5	5	5	5	10	5	10	10	20	5	5	5	5	5	5	20	20	70	30	20	20	20	20
122	Institution for information transfer	10	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	60	20	90	40	30	30
211	Arable land non- irrigated, in general	50	30	50	30	90	10	40	90	90	90	5	5	10	5	10	5	5	20	5	50	5	50	40	40	20	20	30	30	30	10	30	30	40	50	40	50	50	30
211	Mass animal husbandry	5	5	5	5	5	5	5	5	20	5	90	5	5	5	5	5	5	5	5	50	5	5	5	5	5	5	5	5	5	5	5	5	5	5	10	5	10	5
222	Fruit trees and berries	60	50	50	50	70	30	70	80	10	10	40	10	5	40	50	5	5	5	5	20	5	30	30	30	10	30	30	30	50	40	50	90	50	50	60	50	50	40
231	Pastures	30	50	70	50	90	30	80	10	50	90	80	5	5	5	30	5	5	5	5	50	5	70	20	70	30	20	90	90	40	40	80	80	40	50	40	50	50	60
243	Hetero-geneous agricultural areas	60	60	60	40	80	30	60	70	50	70	50	30	20	30	50	5	5	10	30	20	5	50	40	50	10	30	50	50	50	30	40	70	60	50	50	50	50	60
311	Broad- leaved forest	60	70	90	70	90	90	90	5	10	5	10	90	10	90	90	5	5	10	20	5	5	90	90	90	20	90	90	90	90	90	80	70	80	80	70	70	80	80
312	Coniferous forest	50	50	70	50	90	90	90	5	10	5	5	90	10	90	90	5	5	10	20	5	5	90	90	90	20	90	90	90	80	90	70	40	70	70	70	60	80	50
313	Mixed forest	50	90	90	90	90	90	90	5	10	5	10	90	10	90	90	5	5	10	20	5	5	90	90	90	20	90	90	90	90	90	90	70	80	80	70	70	80	80
321	Natural grassland	50	90	60	90	70	90	80	10	10	10	40	5	10	5	60	5	5	10	20	20	5	80	20	70	30	20	80	80	50	50	90	60	50	60	50	60	50	90
322	Moors and heath-lands	60	80	70	70	60	90	90	10	10	10	10	10	10	10	70	5	5	10	5	5	5	80	90	90	20	20	20	30	70	70	70	70	60	70	50	50	70	90
324	Transitional woodlands	60	70	40	50	50	50	50	30	10	30	20	20	10	30	90	5	5	10	5	5	5	50	40	60	20	60	40	50	70	70	80	60	50	40	50	50	50	70
333	Sparesly vegetated areas	50	50	30	40	30	30	60	5	5	5	20	10	5	10	90	5	5	10	10	10	5	20	10	30	10	10	10	10	10	10	50	50	40	40	30	30	30	60
411	Inland marshes	50	50	70	40	70	30	90	10	10	10	10	10	20	5	30	5	5	10	30	10	5	50	70	60	80	10	20	30	70	70	50	50	60	60	50	50	50	80
412	Peat bogs	70	80	90	70	60	90	90	5	5	5	5	20	20	20	20	5	5	10	5	10	5	50	90	90	40	30	30	30	90	90	80	70	40	60	50	60	50	80
421	Salt marshes	50	60	70	50	50	50	80	10	10	10	40	5	10	5	10	5	5	10	5	10	5	10	50	30	90	10	20	50	70	70	50	60	70	70	60	70	70	80
511	Rivers, flowing waters	80	70	10	60	30	20	20	5	5	5	5	10	10	10	30	30	30	40	30	5	5	90	70	30	40	10	5	20	30	50	30	20	80	80	70	80	80	70
512	Lakes	50	70	10	70	40	40	80	5	5	5	5	10	30	5	30	30	30	30	30	5	10	90	70	40	40	10	5	20	30	50	30	30	80	70	70	80	80	70
512	Aqua-culture (pond)	40	40	30	30	50	40	60	10	10	10	10	10	30	10	10	90	30	5	5	5	5	10	10	30	20	10	5	5	30	10	30	20	20	40	30	40	30	20

Fig. 72 Alternative matrix ES assessment according Muller et al. (2018 draft)

4.3 Comparison of the results with the Catalogue of ES in Slovakia

The authors of the Catalogue of Ecosystem Services of Slovakia (Mederly, Černecký et al. 2019) evaluated the relative capacity of the Slovak country to provide 5 provisioning, 10 regulatory and 3 cultural ES on a scale of 0-100 (0 = lowest achieved capacity value and 100 = highest achieved capacity value for given by the ES). Background maps and calculations of the country's capacity for the provision of selected were realized in a raster shape with a pixel size of 25 m. The detail and usability of these documents is at the scale of 1:10 000 to 1: 25 000. The results for 18 ES, 3 ES groups and the total results were standardized in a 1x1 km network. To confront the results, summary maps of the potential for the provision of regulatory, provisioning and cultural ES and summary maps of the country's capacity were selected from the Catalogue of Ecosystem Services of Slovakia.

Tab. 34 shows a comparison of the classification of the evaluated ES of Slovakia between this work and the Catalogue of Ecosystem Services of Slovakia.

Tab. 34 Comparison of valuated ES in Slovakia with the Catalogue of Ecosystem Services in Slovakia

Classification of ES assessments in Slovakia	
ES Catalogue of Slovakia	**Value of ecosystems and their services in Slovakia**
Provisioning ecosystem services	
Biomass - agricultural crops (P1)	Crops
Biomass - wood and natural fibers (P2)	Timber
	Fiber
Drinking water (P3)	Freshwater
Utility water (P4)	
Wildlife / Natural crops (P5)	Fodder
	Wild foods & resources
	Production of fuel wood
	Biomass for energy
	Livestock production
	Fish, seafood & edible algae
Regulatory ecosystem services and supporting ecosystem functions	
Air quality regulation (R1)	Air quality regulation
Water purification (R2)	Water purification
Erosion and other natural hazards regulation (R3)	Erosion regulation
Regulation of runoff conditions and protection against floods (R4)	Natural hazard regulation
Regulation of local climatic conditions (R5)	Local climate regulation
Regulation of global climate / carbon retention (R6)	/ Global climate regulation
Promoting species and ecosystem diversity (R7)	
Support of life cycle processes and / Pollination (R 8)	Pollination
control of pests and diseases (9)	Pest and disease control

Classification of ES assessments in Slovakia	
ES Catalogue of Slovakia	**Value of ecosystems and their services in Slovakia**
control,and support the formation of the natural properties of the soil (R 10)	
	Nutrient regulation
	Regulation of waste and harmful substances
	Water flow regulation
Cultural ecosystem services	
Recreation and tourism - physical use of nature and landscape (C1)	Recreation and tourism
Landscape character and aesthetics - aesthetic values (C2)	Landscape character, aesthetics and spiritual inspiration
Natural and cultural heritage - intellectual and scientific values (C3)	

The maps in Fig. 60 (chapter 3.4.1) and Fig. 73 show very similar results of the evaluation of the potential / capacity of the country (ecosystems) of the Slovak Republic for the provision of regulatory ES. High values of potential are achieved by forest ecosystems of the Carpathian Mountains (especially middle) and foothill areas, agricultural areas of the Danube and East Slovakian lowlands have low potential / capacity and settlements and built-up areas have low to negligible potential. In the case of the ES Catalogue, several sources, GIS layers and data were used in the work. In this work, ecosystems and their quality were used as a basis for the overall assessment.

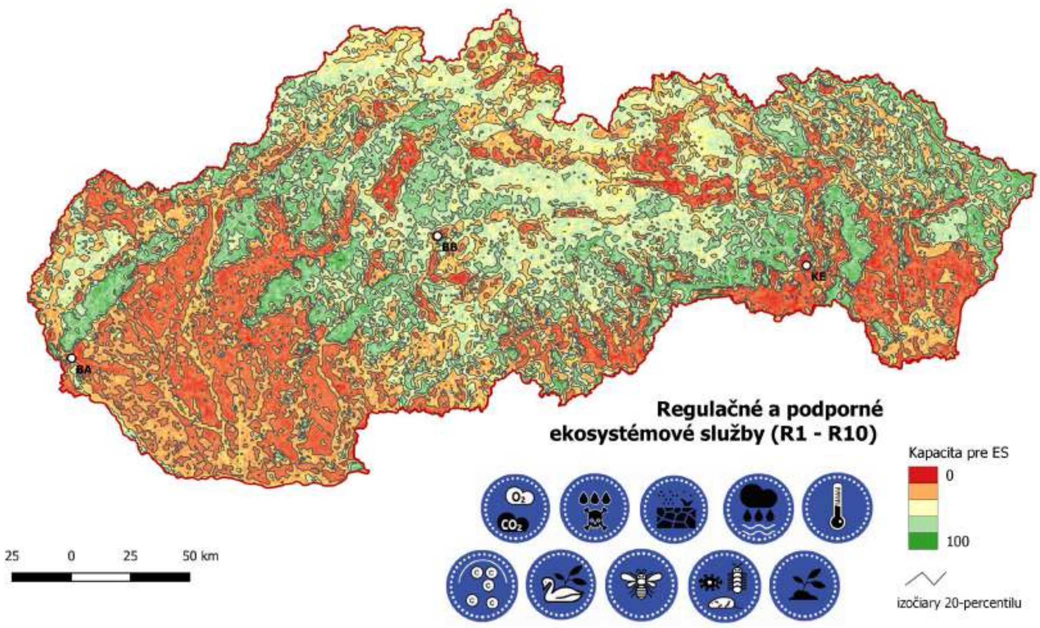

Fig. 73 The total capacity of the landscape to provide regulatory and supporting ES (source: Mederly, Černecký et al. 2019)

Comparison of map expression of capacity Fig. 74 and the potential of Fig. 66 (Chapter 3.4.2) countries for the provision of ES shows similar evaluations. The provisioning ESs is unevenly distributed throughout Slovakia, it is not primarily tied to mountains and foothills, as is the case with regulatory and cultural ES. Low to negligible provision of provisioning services have settlements and urban areas, the highest parts of the mountains such as. Tatras (red color on both maps). The lowlands, especially the Danube, but also the middle mountains, have a higher total supply of provisioning services.

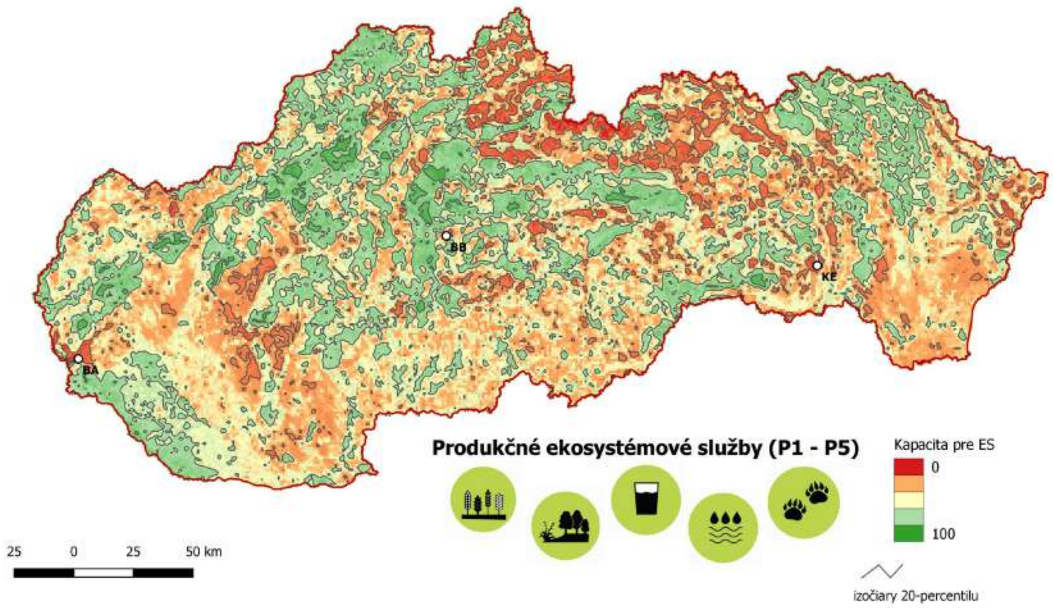

Fig. 74 The total capacity of the landscape to provide provisioning ES (source: Mederly, Černecký et al. 2019)

Provisioning ES only exceptionally reach the same high values as regulatory ES. Overall summary map evaluation of the potential of the country of the Slovak Republic Fig. 70 (chapter 3.4.3) for the provision of cultural ES is similar to the map evaluation of the country's capacity Fig. 75. The highest values are in the mountainous and foothill areas of the Carpathians and the lowest in the lowlands with agricultural land and urban areas. When comparing the capacity maps in the ES Catalogue and in this work, a considerable agreement is again evident and thus the ecosystem approach in this case can again be called as an umbrella / umbrella for a wider range of parameters.

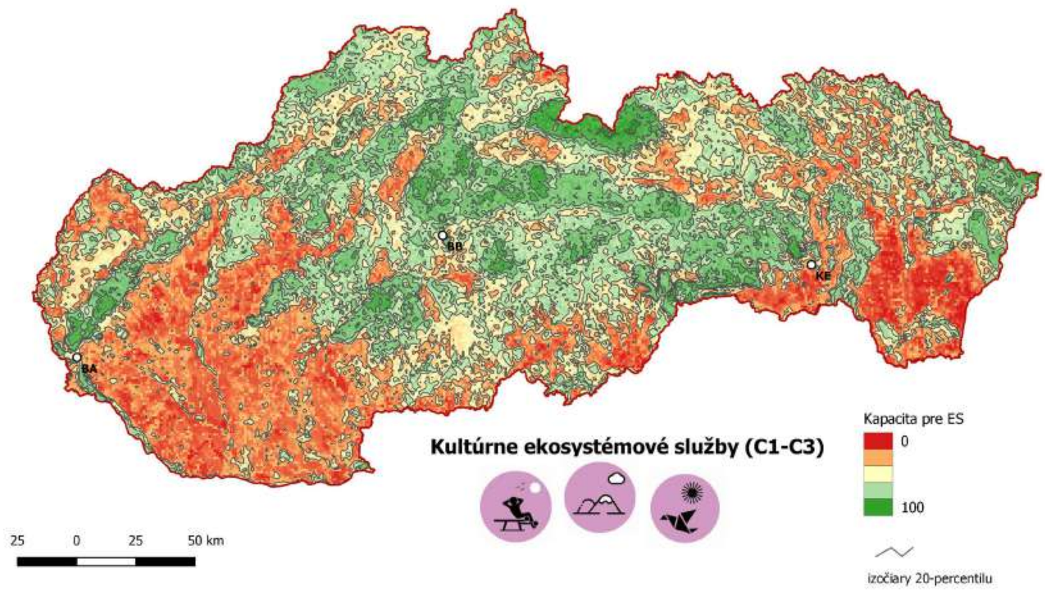

Fig. 75 The total capacity of the landscape to provide cultural ES (source: Mederly, Černecký et al. 2019)

A schematic comparison of the general resulting maps in the ES Catalogue of Slovakia (only potential) with the maps in this study revealed that they are very similar from a national simplified point of view. This fact may to some extent indicate that **ecosystems and the assessment of their quality** largely cover many other parameters, reflect a broader state of context and may be an **umbrella assessment.** Therefore, it can be stated that in the ES indicative evaluation it is not always necessary to deal with a wide range of parameters, but in a more general and comprehensive evaluation it seems sufficient to use e.g. ecosystem approach as a supporting approach. However, in a comprehensive and detailed assessment at the locality level, it is appropriate to take into account other parameters and documents, ideally verified by data collection directly in the area of interest.

4.4 Future challenges

The challenge for the future is to assess **the loss or increase of forest vegetation** using satellite data from the Copernicus program. In particular, multispectral satellite images of the Sentinel 2 satellite can be used for evaluation, and the radar data of the Sentinel 1 satellite can be used as a supplement (available at: https://scihub.copernicus.eu/) and free to download and use. Free software developed by the European Space Agency STEP (available at: http://step.esa.int/main/download/) can be used to process satellite images. STEP enables direct loading of Copernicus satellite images and provides tools for their processing as well as processing a large number of thematic analyzes (eg NDVI, FAPAR, WDVI, etc.). The frequency of making images for the whole territory is every 6 days. Sentinel 2 satellite images contain 13 spectral channels. The individual channels are photographed in different resolutions 10x10m, 20x20m and 60x60m. The R, G, B and near-infrared spectra are provided in a resolution of 10x10m and can be used for direct analysis of vegetation changes using the NDVI of a specific area. NDVI makes it possible to analyze information about the vegetation of a particular place by measuring the ratio of the reflection of near-infrared radiation and the absorption of the red spectrum of radiation used in photosynthesis. A loss of NDVI during the growing season in a particular area can mean a loss of vegetation (for example, felling of trees, plowing of grassland) or a significant deterioration in the health of vegetation. For unambiguous determination of forest loss, e.g. the radar data of the Sentinel 1 satellite, which measures changes in the height of the Earth's surface in the C-band frequency, can be used as a supplement by excavation. C-band radar waves penetrate the vegetation only partially and during the deforestation the change in height is clearly visible. Because the NDVI of grass and forest vegetation are different, it is possible to observe the gradual overgrowth of a specific area using time series of satellite images. Using NDVI, it is possible in combination with time series of satellite images to evaluate the beginning and end of the vegetation period in a particular area. A limiting factor in the use of multispectral satellite images is cloudiness. Multispectral imaging does not penetrate dense clouds, so it is necessary to combine multiple satellite images to remove cloud-covered areas.

As an alternative way of modelling **CO_2 sequestration,** it is possible to use the FAPAR index, which can be obtained from satellite data of the Copernicus program. The FAPAR index defines which part of the photosynthetically active spectrum of light is used by vegetation for photosynthesis. Since photosynthesis is the main factor of CO_2 sequestration, it is possible to model CO_2 sequestration in a specific area based on this index.

In addition to the ES Flood Control assessment, it would be possible to assess the wetting of the area by analyzing radar satellite images. Assessment of wetting of the area and soil could also be interesting for assessing the risk of natural fires. Data for the evaluation of landslide regulation could be obtained from the Dionýz Štúr State Geological Institute (ŠGÚDŠ).

As a supplement or alternative to the ES Crop Production assessment, Sentinel 2 satellite imagery time series can be used to analyze real land management. This analysis is quite often used in EU countries for agricultural payments and realistically shows the areas used for agricultural production in a given period of time. To determine what kind of farming is involved (what kind of crop is grown or whether TTP is mowed or grazed) it is necessary to perform a relatively comprehensive analysis of images and evaluation of vegetation indices.

As an alternative to the ES Wood Production assessment, a combination of NDVI and FAPAR indices could be used to identify tree / shrub vegetation based on NDVI and use the measured FAPAR index in the area to assess biomass growth similar to carbon sequestration assessment. Such an analysis could estimate the increase in wood mass. Logging can be identified directly by changing the NDVI at a specific location and confirmed in combination with Sentinel 1 images to analyze the change in vegetation height.

The advantage of the approach we use when using the map and geodatabase of ecosystems in Slovakia is that **its preparation is repeatable**. An identical map can be prepared in the same way in the future, which would make it possible to assess changes in ecosystems over time. In order for this data to be usable in practice, it is necessary to distinguish the source and quality of the underlying data - in particular whether they were obtained from detailed field mapping or derived from partial data that need to be verified by additional monitoring and mapping in the future. The use of an additional spatial data set such as ZB GIS (ZB GIS 2018) would improve the resulting ecosystem map. Data on small natural features, linear features and other detailed spatial data could be added. However, these data were not available at the time of preparing the map and geodatabase of ecosystems. The ecosystem map requires gradual verification in the field through verification of habitats by experts. Time-consuming and costly data collection in the field is a long-term process that brings many pitfalls. In the future, it is necessary to consider a more automated process based on the evaluation of satellite images. Data from various other areas and, if possible, with an appropriate spatial resolution are also important in the national evaluation, as a more comprehensive assessment of the ES evaluation can be prepared on the basis of a wider range of data from different sectors and areas.

The country's capacity (potential) to provide ES, but mainly the production of services by ecosystems, changes over time, so it is important to repeat the ES assessment process or to design a model that will take into account habitat changes in the future. As a starting point for such a model would be a retrospective mapping of ecosystems and evaluation of their services, e.g. since 1940 with the help of aerial photographs and various types of database data from the forestry, agriculture, water management, and other sectors. One of the sources may be a historical orthophotomap of Slovakia created by processing black and white aerial photographs from the period of the 40s and 50s, which was prepared by the Technical University in Zvolen (available at: mapy.tuzvo.sk). Other examples of usable data are a map of representative geoecosystems and maps of potential vegetation.

As it is important to objectively evaluate the **monetary value of the ES provided by ecosystems**, for most ES, market prices in Slovakia were not used, but **prices used in Frélichová et al. (2014)**, which were based on average ES valuation values from different countries. However, financial statements will always be a controversial topic and agreement between experts will be difficult and difficult to find. **An appropriate solution is to prepare new evaluation**, which would be an alternative to existing evaluations and seek consensus.
Data on the change in ecosystems, their condition, the newly built-up area (as well as other variables) need to be monitored over time and compared with the current assessment in order to assess changes in ES value in the future in case of additional ecosystem acreage for development or change, particularly state of ecosystems and its transformation into other types. It is no less important in the future to monitor the development of the road network and railway lines, which cause the fragmentation of individual ecosystems. At present, the problem of assessing the **demand for ecosystem services** is also unresolved. The consumption of individual ES is difficult to assess and it is a challenge for the future that this area will be relevantly evaluated. It is necessary to choose appropriate methods for the interpretation not only of what the ES territory of Slovakia provides and in what quality, but also for a comprehensive assessment of the extent to which the ES is consumed by people. These aspects of the availability and use of the ES must then be sufficiently expressed spatially through high-quality map and statistical outputs.

5 Conclusion

Comprehensive evaluation of the ES is a demanding process requiring a lot of effort, data collection, analytical and database work and processing of a lot of map data in a GIS environment. **The comprehensive assessment of the ES in the Slovak Republic contributes to the fulfilment of international requirements** for the assessment of the ES arising from various commitments, including the targets set for the protection of biodiversity by 2020.

In comparison with many ES evaluations abroad, this work sought to achieve a more spatially accurate assessment than in research based on Corine Land Cover or other generalized map materials. The prepared **map of ecosystems** sets aside individual landscape elements, thus providing a certain overview of habitats in Slovakia. Geodatabase / map data can be used mainly at the **national level**, to a limited extent at the regional and local level, on more precise scales, the basis requires refinement, ideally through field verification of data directly in the area of interest. However, the ecosystem map also provides **an excellent starting point for local assessment,** and subsequent refinement can achieve very detailed results. Based on the map of ecosystems and the prepared matrix of potential and supply, it is possible to assign to individual habitats of the ES, to define them spatially, but also qualitatively. An innovative approach was also used to take into account and develop the quality of ecosystems, in which a new methodological procedure was prepared for the use of data from **monitoring habitats of European importance** in combination with data from already processed data in the process of tree growth and loss in forest and non-forest ecosystems. With this approach, the current state of interventions and degradation of ecosystems was captured in the evaluation to a certain extent, and subsequently it was possible to individualize the subsequent qualitative evaluation of the ES in the given polygons.

It can be stated that each polygon (a total of 1,033,905) has its own individual evaluation and thus a **comprehensive geodatabase** is available, which **contains data on habitats, ecosystems, ecosystem services and their financial evaluation,** with certain limitations for anthropogenically significantly altered ecosystems, in which the individual evaluation is very demanding and basically requires a field survey. Such an approach ensures that it is currently possible to prepare habitats (with ideal verification in the field), ecosystems, the ES and their financial evaluation for the national level and large territorial units from a geodatabase with some precision, or to use these results as a starting point, as basis for further refinement. Another important fact is the possibility of repeating such a comprehensive evaluation, as the most important data used in the evaluation, including field data collection, are already being collected and will most likely continue to be collected. These databases are primarily used for purposes other than ES evaluation, but they were very suitable and usable for the evaluation carried out. It follows from the above that in the future it will be possible to repeat the same evaluation at any time, without increased demands for the collection of new detailed data.

Last but not least, it is necessary to emphasize the intent of a purely ecosystem approach, focusing on habitats and their contribution to ES provision, which is often neglected in ES evaluation studies. It is the ecosystem approach that is most important in terms of preserving and protecting the relevant ES, because without habitats there would be no ecosystems and without ecosystems there would be no ES, prosperity and a suitable environment for life on Earth. **The very name "ecosystem services" includes ecosystems and therefore the present study is primarily focused on ecosystems.**

The resulting work is also important in terms of setting the practical management of sites, because to some extent defined the spatial and qualitative state of ecosystems and the degree of their degradation. On the basis of the created geodatabase and other data, it is possible to set priorities for ecosystem restoration, quantify progress after the implementation of measures and approach measurably to achieve the goals set by international commitments for the revitalization of ecosystems as such. However, this process is very demanding, it depends on the cooperation of several ministries (especially agriculture and the environment). If the Slovak Republic wants to show obvious progress in the preservation and restoration of ecosystems, then the cooperation of foresters, conservationists and farmers is very important, especially in the field of regular land management and ecosystems for sustainable provision of all important ES in a balanced way.

6 Summary

World economic prosperity and the quality of life of the population are conditioned by the existence of natural capital – biodiversity and ecosystems that provide important goods and services to humans. Mapping ecosystem services (ES) is crucial to understand how ecosystems contribute to the quality of human life and to support the argumentation of multisectoral policies that have a major impact on natural resources and their use (Burkhard & Maes 2017). The expression of ES values in monetary units (Farley 2008) provides guidance on understanding the preferences of users (current generations) who use them, thus allowing better allocation of resources. According to Braat & Groot (2012), ES are off the market and are considered non-marketable public benefits. Maes (2012) has demonstrated a clear correlations between habitat status and the provision of ES – **habitats in better condition have a higher ability to provide ES in higher quality and quantity**. Therefore, ecosystem restoration is important and has a significant positive impact on habitat status. The publication "The Value of Ecosystems and their Services in Slovakia" contributes to the international requirements for ES assessment resulting from various commitments (i.e. CBD targets), including the objectives set out in the National Strategy "Updated National Biodiversity Conservation Strategy 2012-2020" and provides the basis for setting measurable conservation and recovery priorities of ecosystems in Slovakia.

The main objective of the publication is a comprehensive biophysical and monetary assessment of ecosystems and their services in Slovakia using an ecosystem approach based on the quality of ecosystems/habitats and their degradation rate. The first step for ES assessment was to create a **map and geodatabase of ecosystems in Slovakia** (Černecký et al. 2019) by linking the database data of the Land Parcel Identification System (LPIS), forestry (Forest Information System - LGIS), nature protection (Comprehensive Information and Monitoring System – KIMS), Open street map and more. **The ecosystem map contains 1 033 905 polygons** divided into EUNIS categorization at levels 1 to 7. Database and map outputs are developed at national level, but also to some extent partially applicable at the local level. The second step was to **evaluate the potential and supply of Slovak ecosystems to provide 11 regulatory, 10 provisioning and 2 cultural ES** by using modified **Burkhard potential matrixes**, which were reclassified based on quality of the ecosystem from monitoring data for species and habitats and other sources. The level of provision was evaluated on a scale of indexes 1 to 5 (low to very high contribution of ecosystems to the provision of a specific ES). The third, key step, was the assignment of **economic value to individual ecosystems in EUR/ha/year by the Value Transfer method according to prices in Frélichová et al. (2014).** Based on the area of the individual ecosystems/habitats the monetary value of the provided ES was calculated per each polygon and the total ES value for all ecosystems together were recalculated, too.

Most of the polygons (787 208) and thus the largest habitat of Slovakia, in terms of EUNIS 1 categorization, **are forests and other forested land** with a total area of 1,853,076.26 hectares and a share of 38% of the total area of Slovakia. At EUNIS level 4, the largest habitat is among forest **G1.63 Medio-European neutrophile beech forests** and among non-forests E2.22 Sub-Atlantic lowland hay meadows. The most precious types of ecosystems are D5.24 Fen beds of great fen sedge – Cladium – total of 6 polygons, C1.2 Permanent mesotrophic lakes, ponds and pools – total of 12 polygons and D1.12 Degraded, inactive bogs – total of 14 polygons.

Regulatory ES, which directly and indirectly improve human quality of life, have a positive impact on human health and improve their environment, can be classified as a key group of ES on the basis of several criteria. The most important regulatory ES (with the highest average index values) are Global climate regulation, Erosion regulation, Nutrient regulation, Local climate regulation and Water purification. On the largest area (more than 30 000 km^2) are provided ES Erosion regulation and ES Water flow regulation, which is approximately ⅔ area of Slovakia. **Forest ecosystems, which occur in the largest extent in Central Slovakia, have the highest potential for the provision of all regulatory ES in terms of both quality and quantity, while natural and semi-natural ones are of the highest importance.** The highest total economic value of the potential for regulatory ES provision was achieved by ES natural hazard regulation – EUR 29.9 billion/year, ES erosion regulation – EUR 28.9 billion, ES global climate regulation – EUR 21.8 billion/year and local climate regulation – 19.9 EUR billion/year.

In provisioning services the assessment is dominated by **provisioning services** provided by forest ecosystems (in terms of quality) followed by arable land (in terms of quantity). The highest average values of indexes for potential showed ES

Wild food & resources, ES Timber, ES Wood fuel. The varied and diverse landscape mosaic of Slovakia creates the high capacity and potential for the provision of **cultural ES**, in which dominate forest ecosystems (after taking into account both area and quality), xerophilous and scrub ecosystems, aquatic ecosystems and grassland ecosystems. The economic value of ES Landscape aesthetics and inspiration reaches almost 30 billion EUR/year.

From the point of view of quality of provision of several regulatory ES, peatbogs and some other minor important wetlands are of great importance, but their area is very low – only 1.4% of the area of the SR.

Overall, Slovakia's ecosystems and services can be summarized as having a relatively large number of areas with high quality ecosystems (40%) with relatively high ES provision. It is necessary to **open a discussion of various sectors, in particular agriculture, forestry and nature conservation**, with a view to unifying procedures for the use, conservation and restoration of the landscape of Slovakia, its ecosystems and habitats, which constitute transboundary benefits and are crucial for future generations.

7 References

Ainscough J., Lentsch A. V., Metzger M., Rounsevell M., Schröter M., Delbaere B., de Groot R. & Staes J. 2019. Navigating pluralism: Understanding perceptions of the ecosystem services concept. Ecosystem Services 36:100892. DOI: 10.1016/j.ecoser.2019.01.004. Accessed 16 January 2020.

Arany I., Kuslits B., Kállay T., Adem Esmail B., Geneletti D. 2018. Case Study Booklet: ES MAPPING AND ASSESSMENT FOR DEVELOPING PRO-BIODIVERSITY BUSINESSES IN THE BÜKK NATIONAL PARK, HUNGARY prepared for "WS 8 - Testing the final methods in policy- and decision-making (II): businesses and citizens" held in Eger, Hungary, 19-22 March 2018. ESMERALDA EC H2020 Grant Agreement no. 642007.

Anderson V. 2018. Debating Nature´s Value. The Concept of ´Natural Capital´. Cham: Palgrave Pivot. 126 pp. DOI: 10.1007/978-3-319-99244-0. Accessed 16 January 2020.

Bakker M. R., Brunner I., Ashwood F., Bjarnadottir B., Bolger T., Børja I., Carnol M., Cudlin P., Dalsgaard L., Erktan A., Godbold D., Kraigher H., Meier I. C., Merino-Martín L., Motiejūnaitė J., Mrak T., Oddsdóttir E. S., Ostonen I., Pennanen T. L., Püttsepp Ü., Suz L. M., Vanguelova E. I., Vesterdal L. and Soudzilovskaia N. A. 2019. Belowground Biodiversity Relates Positively to Ecosystem Services of European Forests. Frontiers in Forest Global Change 2:6. DOI: 10.3389/ffgc.2019.00006. Accessed 16 January 2020.

Barton D. N., Kelemen E., Dick J., Martin-Lopez B., Gómez-Baggethun E., Jacobs S., Hendriks C. M. A., Termansen M., García-Llorente M., Primmer E., Dunford R., Harrison P. A., Turkelboom F., Saarikoski H., van Dijk J., Rusch G. M., Palomo I., Yli-Pelkonen V. J., Carvalho L., Baró F., Langemeyer J., Tjalling van der Wal J., Mederly P. et al. 2018. (Dis) integrated valuation – Assessing the information gaps in ecosystem service appraisals for governance support. Ecosystem Services 29(C):529-541. DOI: 10.1016/j.ecoser.2017.10.021. Accessed 20 February 2020.

Becerra-Jurado G., Philipsen Ch., Kleeschulte S. 2015. Mapping and Assessing Ecosystems and their Services in Luxembourg – Assessment results. DOI: 10.13140/RG.2.1.4924.5841. Accessed 10 January 2020.

Bijker R. A. & Sijtsma F. J. 2017. A portfolio of natural places: Using a participatory GIS tool to compare the appreciation and use of green spaces inside and outside urban areas by urban residents. Landscape and Urban Planning 158:155–165. DOI: 10.1016/j.landurbplan.2016.10.004. Accessed 16 January 2020.

Börner J., Baylis K., Corbera E., Ezzine-de-Blas D., Honey-Rosés J., Persson U. M. & Wunder S. 2017. The effectiveness of payments for environmental services. World Development 96:359–374. DOI: 10.1016/j.worlddev.2017.03.020. Accessed 16 January 2020.

Boyd J. W. & Banzhaf H. S. 2005. Ecosystem services and government accountability: the need for a new way of judging Nature's value. Resources Summer:16–19.

Braat L. C. & de Groot R. 2012. The ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy. Ecosystem Services 1(1):4–15. DOI: 10.1016/j.ecoser.2012.07.011. Accessed 20 January 2020.

Bratman G. N., Anderson Ch. B., Berman M. G., Cochran B., de Vries S. at al. 2019. Nature and mental health: An ecosystem service perspective. Science Advances 5(7): eaax0903. DOI: 0.1126/sciadv.aax0903. Accessed 14 January 2020.

Brunson M. W. 1996. Human Dimensions in Silviculture. In: Ewert A. W. (eds). Natural Resource Management: The Human Dimension. Westview: 91–108.

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

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. DOI: 10.3097/LO.201434. Accessed 14 July 2019.

Burkhard B., Kroll F., Nedkov S. & Müller F. 2012. Mapping ecosystem service supply, demand and budgets. Ecological Indicators 21:17–29. DOI: 10.1016/j.ecolind.2011.06.019. Accessed 16 July 2019.

Burkhard B., Kroll F., Muller F. & Windhorst W. 2009. Landscapes' Capacities to Provide Ecosystem Services – a Concept for Land-Cover Based Assessments. Landscape Online 15:1–22. DOI:10.3097/ LO.200915. Accessed 16 July 2019.

Carvalho-Santos C., Monteiro A. T., Arenas-Castro S., Greifeneder F., Marcos B., Portela A. P. & Honrado J. P. 2018. Ecosystem services in protected mountain range of Portugal: Satellite-based products for state and trend analysis. Remote Sensing 10:1573. DOI: 10.3390/rs10101573. Accessed 10 January 2020.

CICES. 2018. Common International Classification of Ecosystem Services. Biodiversity Information system for Europe. http://biodiversity.europa.eu/maes/common-international-classification-of-ecosystem-services-cices-classification-version-4.3. Accessed 20 June 2019.

Clark R. N. 1987. Recreation Management: A Question of Integration. Western Wildlands Spring.

CLC. 2012. Corine land cover. Maps & Data. https://land.copernicus.eu/pan-european/corine-land-cover/clc-2012/view. Accessed 14 November 2019.

Comton J. E., Harrison J. A., Dennis R. L., Greaver T. L., Hill B. H., Jordan S. J., Walker H. & Campbell H. V. 2011. Ecosystem services altered by human changes in the nitrogen cycle: a new perspective for US decision making. Ecology Letters 14(8):804–815. DOI: 10.1111/j.1461-0248.2011.01631.x. Accessed 11 November 2019.

Costanza R., Daly H. 1992. Natural capital and sustainable development. Conservation Biology 6(1):37–46.

Czeszczewik D., Ginter A., Mikusiński G., Pawlowska A., Kaluza H., Smithers R. J. & Walankiewicz W. 2019. Birdwatching, logging and the local economy in the Bialowieza Forest, Poland. Biodiversity and Conservation 28(11):2967–2975. DOI: 10.1007/s10531-019-01808-6. Accessed 14 November 2019.

Černecký J. , Galvánková J., Považan R., Saxa A., Šeffer J., Šefferová V., Lasák R. & Janák R. 2014. Conservation status of habitats and species of Community interest for the period of 2007 – 2012 in the Slovak Republic. Banská Bystrica: SNC SR. 1626 pp. ISBN 978-80-89310-79-1.

Černecký J., Gajdoš P., Špulerová J., Halada Ľ., Mederly P., Ulrych L., Ďuricová V., Švajda J., Černecká Ľ., Andráš P., Rybanič R. 2019. Ecosystems in Slovakia. Journal of Maps 16(2): 28–35. DOI: 10.1080/17445647.2019.1689858. Accessed 2 December 2020.

Daams M. N., Sijtsma F. J. & van der Vlist A. J. 2016. The effect of natural space on nearby property prices: accounting for perceived attractiveness. Land Economics 92(3):389–410. DOI: 10.3368/le.92.3.389. Accessed 22 January 2020.

Davis N., Daams M., van Hinsberg A. & Sijtsma F. 2016. How deep is your love – Of nature? A psychological and spatial analysis of the depth of feelings towards Dutch nature areas. Applied Geography 77:38–48. DOI: 10.1016/j.apgeog.2016.09.012. Accessed 25 January 2020.

de Groot R., Brander L., van der Ploeg S., Costanza R., Bernard F., Braat L., Christie M., Crossman N., Ghermandi A., Hein L., Hussain S., Kumar P., McVittie A., Portela R., Rodriguez L. C., ten Brink P., van Beukering P., 2012. Global estimates of the value of ecosystems and their services in monetary units. Ecosystem Services 1(1):150–61. DOI: 10.1016/j.ecoser.2012.07.005. Accessed 2 February 2020.

de Groot R. S., Alkemade R., Braat L., Hein L. & Willemen L. 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7:260–272. DOI: 10.1016/j.ecocom.2009.10.006. Accessed 25 June 2019.

de Groot R. S., Wilson M. A. & Boumans R. M. J. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41:393–408.

de Guenni L. B., Cardoso M., Goldammer J., Hurtt G., Mata L. J., Ebi K., House J., Valdes J. & Norgaard R. 2005. Regulation of Natural Hazards: Floods and Fires In: Hassan et al. (eds) Ecosystems and Human Well-Being: Current State and Trends, 948 pp.

de Vries S., Buijs A. E., Langers F., Farjon H., van Hinsberg A. & Sijtsma F. J. 2013. Measuring the attractiveness of Dutch landscapes: Identifying national hotspots of highly valued places using Google Maps. Applied Geography 45:220–229. DOI: 10.1016/j.apgeog.2013.09.017. Accessed 15 February 2020.

Dee L. E., Cowles J., Isbell F., Pau S., Gaines S. D. & Reich P. B. 2019. When Do Ecosystem Services Depend on Rare Species? Trends in Ecology & Evolution 34(8):746–758. DOI: 10.1016/j.tree.2019.03.010. Accessed 15 February 2020.

EEA. 2018. EUNIS habitat classification. https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification#tab-european-data. Accessed 5 Januray 2020.

EEA. 2012. European Environment Agency. Climate change, impacts and vulnerability in Europe 2012. Copenhagen: EEA. 300 pp. https://www.eea.europa.eu/publications/climate-impacts-and-vulnerability-2012. Accessed 25 June 2019.

Európska komisia 2014. System of Environmental-Economic Accounting 2012, Experimental Ecosystem Accounting. New York: European Commission, United Nations. 198 pp.

Fándly J. 1793/1980. Malý zelinkár/Zelinkár. Martin: Osveta. 370 pp.

Farley J. 2008. The Role of princes in Conserving Critical Nature capital. Conservation Biology 22(6):1399-1408. DOI: 10.1111/j.1523-1739.2008.01090.x. Accessed 10 October 2019.

Felipe-Lucia M. R., Soliveres S., Penone C., Manning P., van der Plas F., Boch S., Prati D., Ammer Ch., Schall P., Gossner M. M., Bauhus J., Buscot F., Blaser S., Blüthgen N., de Frutos A., Ehbrecht M., Frank K., Goldmann K., Hänsel F., Jung K., Kahl T., Nauss T., Oelmann Y., Pena R., Polle A., Renner S., Schloter M., Schöning I., Schrumpf M., Schulze E. D., Solly E., Sorkau E., Stempfhuber B., Tschapka M., Weisser W. W., Wubet T., Fischer M., Allan E. 2018. Multiple forest attributes underpin the supply of multiple ecosystem services. Nature Communications 9:4839. DOI: 10.1038/s41467-018-07082-4. Accessed 4 February 2020.

Ferraro P. J. 2017. Are payments for ecosystem services benefiting the ecosystems and people? In: Kareiva P., Marvier M. & Silliman B. (eds.). Effective Conservation Science: Data Not Dogma. Oxford: Oxford University Press. 151 pp. DOI:10.1093/oso/9780198808978.003.0025. Accessed 4 February 2020.

Fleischer P., Pichler V., Fleischer P. Jr., Holko L., Máliš F., Gömöryová E., Cudlín P., Holeksa J., Michalová Z., Homolová Z., Škvarenina J., Střelcová K. & Hlaváč P. 2017. Forest ecosystem services affected by natural disturbances, climate and land-use changes in the Tatra Mountains. Climate Research 34:1–15. DOI: 10.3354/cr01461. Accessed 5 February 2020.

Fowler D., Pilegaard K., Sutton M. A., Ambus P., Raivonen M., Duyzer J., Simpson D., Fagerli H. et al. 2009. Atmospheric composition change: ecosystemsatmosphere interactions. Atmospheric Environment 43(33):5193–5267. DOI: 10.1016/j.atmosenv.2009.07.068. Accessed 19 July 2019.

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. DOI: 0.1016/j.ecoser.2014.03.001. Accessed 14 September 2019.

Geofabrik. 2015. Maps & Data – Openstreetmap. http://www.geofabrik.de/data/shapefiles.html. Accessed 20 October 2019.

GISAT. 2007. Digital terrain model (DTM). http://www.gisat.cz/content/cz/produkty/data-ke-stazeni. Accessed 10 June 2019.

Gissi E., Gaglio M. & Reho M. 2016. Sustainable energy potential from biomass through ecosystem services trade-off analysis: The case of the Province of Rovigo (Northern Italy). Ecosystem Services 18:1–19. DOI: 10.1016/j.ecoser.2016.01.004. Accessed 14 October 2019.

Grizzetti B., Lanzanova D., Liquete C., Reynaud A. & Cardoso A. C. 2016. Assessing water ecosystem services for water resource management. Environmental Science & Policy 61:194–203. DOI: 10.1016/j.envsci.2016.04.008. Accessed 16 July 2019.

Guerry A. D., Polasky S., Lubchenco J., Chaplin-Kramer R., Daily G. C., Griffin R., Ruckelshaus M., Bateman I. J., Duraiappah A., Elmqvist T., Feldman M. W. et al. 2015. Natural capital and ecosystem services informing decisions: from promise to practice. Proceedings of the National Academy of Science of the United States of America 112:7348–7355. DOI: 10.1073/pnas.1503751112. Accessed 18 July 2019.

Haines-Young R., Potschin R. 2018. Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure. 53 pp. https://cices.eu/content/uploads/sites/8/2018/01/Guidance-V51-01012018.pdf. Accessed 16 July 2019.

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. G. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342:850–853. DOI: 10.1126/science.1244693. Accesses 20 June 2019.

Hassan R. M., Scholes R. J. & Ash N. 2005. Ecosystems and Human Well-being: Current State and Trends, Volume 1: Findings of the Condition and Trends Working Group of the Millennium Ecosystem Assessment. Washington, Covelo, London: Island Press. 917 pp. https://www.millenniumassessment.org/documents/document.766.aspx.pdf. Accessed 13 August 2019.

Hermes J., Albert Ch. & von Haaren Ch. 2018. Assessing the aesthetic quality of landscapes in Germany. Ecosystem Services 31:296–307. DOI: 10.1016/j.ecoser.2018.02.015. Accessed 24 January 2020.

Herridge D. F., Peoples M. B. & Boddey R. M. 2008. Global inputs of biological nitrogen fixation in agricultural systems. Plant Soil 311:1–18. DOI: 10.1007/s11104-008-9668-3. Accessed 8 August 2019.

Holúbek R., Jančovič J., Gregorová H., Novák J., Ďurková E. & Vozár Ľ. 2007. Krmovinárstvo-manažment pestovania a využívania krmovín. Vysokoškolská učebnica. Nitra: SPU. 419 pp.

Horalová K., Dráb V. 2018. Živočíšna výroba, predaj výrobkov z prvovýroby a bilancia plodín. Bratislava: Štatistický úrad Slovenskej republiky. 35 pp.

Howley P. 2011. Landscape aesthetics: assessing the general publics' preferences towards rural landscapes. Ecolological Economics, 72(2011):161-169. DOI: 10.1016/j.ecolecon.2011.09.026. Accessed 22 November 2019.

Hummel Ch., Poursanidis D., Orenstein D., Elliott M., Adamescu M. C., Cazacu C., Ziv G., Chrysoulakis N., van der Meer J. & Hummel H. 2019. Protected area management: Fusion and confusion with the ecosystem services approach. Science of the Total Environment 651(2): 2432–2443. DOI: 10.1016/j.scitotenv.2018.10.033. Accessed 26 January 2020.

Chan K. M. A., Guerry D., Balvanera P., Klain S., Satterfield T., Basurto X., Bostrom A., Chuenpagdee R., Gould R., Halpern B. S., Hannahs N., Levine J., Norton B., Ruckelshaus M., Russell R., Tam J. & Woodside U. 2012. Where are Cultural and Social in Ecosystem Services? A Framework for Constructive Engagement. BioScience 62(8):744–756. DOI: 10.1525/bio.2012.62.8.7. Accessed 16 July 2019.

Chung M. G., Dietz T. & Liu J. 2018. Global relationships between biodiversity and nature-based tourism in protected areas. Ecosystem Services 34:11–23. DOI: 10.1016/j.ecoser.2018.09.004. Accessed 26 January 2020.

IPBES. 2018. Summary for policymakers of the regional assessment report on biodiversity and ecosystem services for Europe and Central Asia of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. https://www.ipbes.net/assessment-reports/eca. Accessed 19 July 2019.

Izakovičová Z., Bezák P., Mederly P. & Špulerová J. 2017. Uplatňovanie konceptu ekosystémových služieb v plánovacej a riadiacej praxi v Slovenskej republike – výsledky projektu OpenNESS na prípadovej štúdii Trnava. Životné prostredie 51(4):198-204. ISSN 0044-4863.

Janák M., Černecký J. & Saxa A. (eds.) 2015. Monitoring of animal species of Community interest in the Slovak Republic, Results and assessment in the period of 2013-2015. State nature conservancy of the Slovak Republic. Banská Bystrica: DAPHNE, SNC SR. 300 pp. ISBN 978-80-8184-022-7

Jayachandran S., de Laat J., Lambin E. F., Stanton C. Y., Audy R. & Thomas N. E. 2017. Cash for carbon: A randomized trial of payments for ecosystem services to reduce deforestation. Science 357 (6348):267–273. DOI: 10.1126/science.aan0568. Accessed 6 January 2020.

Kaiser G., Burkhard B., Römer H., Sangkaew S., Graterol R., Haitook T., Sterr H., Schwartz D. S. 2013. Mapping tsunami impacts on land cover and related ecosystem service supply in Phang Nga, Thailand. Natural Hazards and Earth System Sciences 13:3095-3111. DOI: 10.5194/nhess-13-3095-2013. Accessed 24 August 2019.

Kandziora M., Burkhard B. & Müller F. 2013. Interactions of ecosystem properties, ecosystem integrity and ecosystem service indicators – A theoretical matrix exercise. Ecological Indicators 28:54–78. DOI: 10.1016/j.ecolind.2012.09.006. Accessed 22 August 2019.

Kandziora M., Burkhard B. & Müller F. 2013. Mapping provisioning ecosystem services at the local scale using data of varying spatial and temporal resolution. Ecosystem Services 4:47–59. DOI: 10.1016/j.ecoser.2013.04.001. Accessed 24 February 2020.

Kanianska R., Kizeková M., Nováček J. & Zeman M. 2010. Využitie historických a súčasných mapových podkladov pre stanovanie produkčného potenciálu biomasy. Kartografické listy 18:76–86. https://gis.fns.uniba.sk/kartografickelisty/archiv/KL18/8.pdf. Accessed 20 October 2019.

Kashi B., Simpson D., Simón C., Higgins M., Manion N. & Bruner A. 2018. Integrating ecosystem values into cost-benefit analysis: Recommendations for USAID and practitioners. Washington, DC: U.S. Agency for International Development. 81 pp.

Kelemen E., Garciá-Llorente M., Pataki G., Martín-López B. & Gómez-Baggethun E. 2016. Non-monetary techniques for the valuation of ecosystem service. In: Potschin M. & Jax K. (eds.): OpenNESS Ecosystem Services Reference Book. EC FP7 Grant Agreement no. 308428. www.openness-project.eu/library/reference-book. Accessed 19 July 2019.

KIMS. SNC SR. 2017. Komplexný informačný systém ochrany prírody. www.biomonitoring.sk. Accessed 8 September 2019.

King E., Cavender-Bares J., Balvanera P., Mwampamba T., Polasky S. 2015. Trade-offs in ecosystem services and varying stakeholder preferences: evaluating conflicts, obstacles, and opportunities. Ecology and Society 20(3):25. DOI: 10.5751/ES-07822-200325. Accessed 18 November 2019.

Kizeková M., Čunderelík J., Dugátová Z., Makovníková J., Kanianska R., Jaďuďová J., Jančová J. & Pálka B. 2016. Agroekosystémové služby a súčasný stav trávnych porastov v Slovenskej republike. Banská Bystrica: UMB & NPPC VÚTPHP, Bratislava: NPPC VÚPOP. 118 pp. ISBN 978-80-89800-09-4.

Kováč M. & Plašianka D. 2003. Geologická stavba oblasti na styku Alpsko-karpatsko-panónskej sústavy a priľahlých svahov Českého masívu. Vysokoškoslká učebnica. Bratislava: Univerzita Komenského. 85 pp.

Kováč V., Jakubčinová K. 2015. Stručný prehľad súčasného stavu ichtyocenóz Slovenska. Rybomil 2(2):5–6. Bratislava: Slovenská ichtyologická spoločnosť.

Kroll F., Müller F., Haase D. & Fohrer N. 2012. Rural-urban gradient analysis of ecosystem services supply and demand dynamics. Land Use Policy 29:521–535. DOI: 10.1016/j.landusepol.2011.07.008. Accessed 2 August 2019.

Kumar P. (eds). 2010. The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. London: UNEP/Earthprint. 456 pp.

Kušíková A. 2013. Využiteľnosť environemntu a ekosystémové služby. Enviromagazín 18(3):4–6. http://www.enviromagazin.sk/enviro2013/enviro3/04_vyuzitelnost.pdf. Accessed 2 August 2019.

La Notte A., Maes J., Dalmazzone S., Crossman N., Grizzetti B. & Bidoglio G. 2017. Physical and monetary ecosystem service accounts for Europe: A case study for in-stream nitrogen retention. Ecosystem Services 23:18–29. DOI: 10.1016/j.ecoser.2016.11.002. Accessed 1 November 2019.

Lieskovský J., Rusňák T., Klimantová A., Izsóff M., Gašparovičová P. 2017. Appreciation of landscape aesthetic values in Slovakia assessed by social media photographs. Open Geosciences 9(1): 593–599. DOI: 10.1515/geo-2017-0044. Accessed 10 June 2019.

Liu S., Costanza R., Troy A., D'Aagostino J. D. & Mates W. 2010. Valuing New Jersey's ecosystem services and natural capital:a spatially explicit benefit transfer approach. Environmental Management 45:1271–1285. DOI: 10.1007/s00267-010-9483-5. Accessed 15 June 2019.

Macků J. & Mokrý J. 1957. Naše liečivé rastliny. Bratislava: SAV. 405 pp.

Maes J., Paracchini M. L., Zulian G., Dunbar M. B. & Alkemade R. 2012. Synergies and Trade-offs between Ecosystem Service Supply, Biodiversity, and Habitat Conservation Status in Europe. Biological Conservation 155:1–12. DOI: 10.1016/j.biocon.2012.06.016. Accessed 6 July 2019.

Maes J., Teller A., Erhard M., Liquete C., Braat L., Berry P., Egoh B., Puydarrieux P., Fiorina C., Santos F., Paracchini M. L., Keune H., Wittmer H., Hauck J., Fiala I., Verburg P. H., Condé S., Schägner J. P., San Miguel J., Estreguil C., Ostermann O., Barredo J. I., Pereira H. M., Stott A., Laporte V., Meiner A., Olah B., Royo Gelabert E., Spyropoulou R., Petersen J. E., Maguire C., Zal N., Achilleos E., Rubin A., Ledoux L., Brown C., Raes C., Jacobs S., Vandewalle M., Connor D. & Bidoglio G. 2013. Mapping and assessment of ecosystems and their services: an analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Publications office of the European Union. 60 pp.

Machar I., Kulhavý J., Seják J. & Pechanec V. 2018. Efektivita územní ochrany a monetární hodnota biotopů lužných lesů v České republice. Zprávy lesnického výzkumu 63 (3):206–213. ISSN 0322-9688.

Markov B. & Nedkov S. 2016. Mapping of erosion regulation ecosystem services. Paper presented at 6th International Conference on Cartography and GIS, Cartographic Association and University of Architectur. Albena, Bulgaria. June 2016.

Mattson L. & Li C. 1994. How Do Different Forest Management Practices Affect the Non-Timber Value of Forests? An Economic Analysis. Journal of Environmental Management 41:79–88.

Mayer M. & Woltering M. 2018. Assessing and valuing the recreational ecosystem services of Germany´s national parks using travel cost methods. Ecosystem Services 31:371–386. DOI: 10.1016/j.ecoser.2017.12.009. Accessed 22 January 2020.

McBride A. C., Dale V. H., Baskaran L. M., Downing M. E., Eaton L. M., Efroymson R. A., Garten Ch. T., Kline K. L., Jager H. I., Mulholland P. J., Parish E. S., Schweizer P. E. & Storey J. M. 2011. Indicators to support environmental sustainability of bioenergy systems. Ecological Indicators 11(5):1277–1289. DOI: 10.1016/j.ecolind.2011.01.010. Accessed 21 October 2019.

MEA. 2005. Millennium Ecosystem Assessment. Ecosystems and Human Well-Being: A Framework for Assessment. Report of the Conceptual Framework Working Group of the Millennium Ecosystem Assessment. Washington, DC: Island Press. 266 pp. http://pdf.wri.org/ecosystems_human_wellbeing.pdf. Accessed 8 July 2019.

Mederly P., Černecký J. et al. 2019. Katalóg ekosystémových služieb Slovenska. Banská Bystrica: ŠOP SR, UKF v Nitre, ÚKE SAV. 215 pp. http://www.sopsr.sk/natura/dokumenty/Katalog-ES.pdf. Accessed 24 February 2020.

Mehmetoglu M. 2007. Typologising nature-based tourists by activity – Theoretical and practical implications. Tourism Management 28(3):651–660. DOI: 10.1016/j.tourman.2006.02.006. Accessed 14 June 2019.

Molina J. R., Zamora R. & Silva F. R. 2019. The role of flagship species in the economic valuation of wildfire impacts: An application to two Mediterranean protected areas. Science of the Total Environment 675:520–530. DOI: 10.1016/j.scitotenv.2019.04.242. Accessed 24 February 2020.

Nedkov S., Zhiyanski M., Borisova B. & Bratanova-Doncheva S. 2018. Mapping and assessment of ecosystem condition and ecosystem services across different scales and domains in Europe. One Ecosystem 3:1–11. DOI: 10.3897/oneeco.3.e29288. Accessed 24 January 2020.

Nedkov S. & Burkhard B. 2012. Flood regulating ecosystem services – Mapping supply and demand, in the Etropole municipality, Bulgaria. Ecological Indicators 21:67–79. DOI: 10.1016/j.ecolind.2011.06.022. Accessed 5 June 2019.

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. 2018. Tools for measuring, modelling, and valuing ecosystem services: guidance for Key Biodiversity Areas, natural World Heritage Sites, and protected areas. Gland, Switzerland: IUCN. 70 pp. 978-2-8317-1917-7.

NFC (National Forest Centre). 2017. Geographic information system of the forest. http://gis.nlcsk.org/lgis/. Accessed 10 September 2019.

NPPC-VÚPOP. 2018a. Geografický informačný systém poľnohospodárskej pôdy. http://www.podnemapy.sk/lpis_verejnost/viewer.htm. Accessed 8 September 2019.

NPPC-VÚPOP. 2018b. Register pôdy LPIS (Land Register – Land Parcel Information System: http://www.podnemapy.sk/lpis_verejnost/viewer.htm. Accessed 8 September 2019.

Paluš H. 2013. Trh a obchod s drevom a výrobkami z dreva. Vysokoškolská učebnica. Zvolen: Technická univerzita vo Zvolene. 225 pp.

Paracchini M. L., Zulian G., Kopperoinen L., Maes J., Schägner J. P., Termansen M., Zandersen M., Marta Perez-Soba M., Scholefield P. A., Giovanni Bidoglio G. 2014. Mapping cultural ecosystem services: A framework to assess the potential for outdoor recreation across the EU. Ecological Indicators 45:371–385. DOI: 10.1016/j.ecolind.2014.04.018. Accessed 15 August 2019.

Polák P., Galvánek D., Černecký J., Černecká Ľ. & Kerestúr D. 2014. Analýza potenciálu biomasy v katastrálnom území Poniky na udržateľné energetické využívanie. Bratislava: Priatelia Zeme, CEPA. 84 pp.

Potts S. G., Imperatriz-Fonseca V., Ngo H. T., Aizen M. A., Biesmeijer J. C., Breeze T. D., Dicks L. V., Garibaldi L. A., Hill R., Settele J. & Vanbergen A. J. 2016. Safeguarding pollinators and their values to human well-being. Nature 540:220–229. https://www.nature.com/articles/nature20588. Accessed 16 Novomber 2019.

Power AG. 2010. Ecosystem services and agriculture: tradeoffs and synergies. Philosophical Transactions of the Royal Society B 365:2959–2971. DOI: /10.1098/rstb.2010.0143. Accessed 8 October 2019.

Preston SM & Raudsepp-Hearne C. 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.

Ratcliffe S., Wirth C., Jucker T., van der Plas F., Scherer-Lorenzen M., Verheyen K., Allan E., Benavides R., Bruelheide H., Ohse B., Paquette A., Ampoorter E., Bastias C. C., Bauhus J., Bonal D., Bouriaud O., Bussotti F., Carnol M., Castagneyrol B., Chećko E., Dawud S. M., Wandeler H., Domisch T., Finér L., Fischer M., Fotelli M., Gessler A., Granier A., Grossiord C., Guyot V., Haase J., Hättenschwiler S., Jactel H., Jaroszewicz B., Joly F. X., Kambach S., Kolb S., Koricheva J., Liebersgesell M., Milligan H., Müller S., Muys B., Nguyen D., Nock C., Pollastrini M., Purschke O., Radoglou K., Raulund-Rasmussen K., Roger F., Ruiz-Benito P., Seidl R., Selvi F., Seiferling I., Stenlid J., Valladares F., Vesterdal L. & Baeten L. 2017. Biodiversity and ecosystem functioning relations in European forests depend on environmental context. Ecology Letters 20(11):1414–1426. DOI: 10.1111/ele.12849. Accessed 2 February 2020.

Reid W. V., Mooney H. A., Cropper R. A., Capistrano D., Carpenter S. R., Chopra K., Dasgupta P., Dietz T., Duraiappah A. K., Hassan R., Kasperson R., Leemans R., May R. M., McMichael T., Pingali P., Samper C., Scholes R., Watson R. T., Zakri A. H., Shidong Z., Ash N. J., Bennet E., Kumar E., Lee M. J., Raudsepp-Hearne C., Simons H., Thonell J. & Zurek M. B. 2005. Millenium Ecosystem Assessment – Ekosystémy a lidský blahobyt. Praha: World Resource Institute, Centrum pro otázky životního prostředí. Univerzita Karlova v Prahe. 138 pp.

State of Nature 2015. Report from the Commission to the council and the European parliament The State of Nature in the European Union. Report on the status of and trends for habitat types and species covered by the Birds and Habitats Directives for the 2007-2012 period as required under Article 17 of the Habitats Directive and Article 12 of the Birds Directive. Brussel. 19 pp.

RoTAP. 2012. Review of Transboundary Air Pollution: Acidification, Eutrophication, Ground Level Ozone and Heavy Metals in the UK. Contract Report to the Department for Environment, Food and Rural Affairs. UK: Centre for Ecology and Hydrology. 292 pp. http:// www.rotap.ceh.ac.uk/files/RoTAP%20Summary%20report_0.pdf. Accessed 14 october 2019.

Sánchez-Fernández D., Abellán P., Aragón P., Varela S. & Cabeza M. 2018. Matches and mismatches between conservation investments and biodiversity values in the European Union. Conservation Biology 32(1):109–115. DOI: 10.1111/cobi.12977. Accessed 2 February 2020.

Santos-Martín F., García-Llorente M., Quintas-Soriano C., Zorrillas-Miras P., Martín-Lopez B. & Loureiro M. 2016. Spanish National Ecosystem Assessment: Socio-economicvaluation of ecosystem services in Spain. Synthesis of key findings. Madrid, Spain: Biodiversity Foundation of the Spanish Ministry of Agriculture, Food and Environment. 68 pp.

Saxa A., Černecký J., Galvánková J., Mútňanová M., Balážová A. & Gubková Mihaliková M. (eds.) 2015. Príručka metód monitoringu biotopov a druhov európskeho významu. Banská Bystrica: SNC SR. 148 pp. ISBN 978-80-8181-024-1

SEEA-EEA. 2014. System of Environmental-Economic Accounting 2012 – Experimental Ecosystem Accounting. New York: United nations. 198 pp. ISBN: https://seea.un.org/sites/seea.un.org/files/seea_eea_final_en_1.pdf. Accessed 14 July 2019.

Selecká V. 2017. Hodnotenie ekosystémových služieb v leso-poľnohospodárskej krajine mesta Hriňová. Nitra: Univertiza Konštantína Filozofa v Nitre. Dizertačná práca. 133 pp. https://opac.crzp.sk/?fn=docviewChild00029C18. Accessed 15 October 2019.

Seppelt R., Dormann F. C., Eppink E. V., Lautenbachand S. & Schmidt S. 2011. A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. Journal of Applied Ecology 48:3630–636. DOI: 10.1111/j.1365-2664.2010.01952.x. Accessed 15 October 2019.

Sharma S. K., Baral H., Laumonier Y., Okarda B., Purnomo H., Pacheco P. 2018. An Analysis of Multiple Ecosystem Services Under Future Oil Palm Expansion Scenarios in Central and West Kalimantan, Indonesia. Bogor, Indonesia: Center for International Forestry Research (CIFOR). 54 pp. ISBN 978-602-387-077-6.

SHMU. Vodohospodárska bilancia kvality podzemnej vody sr v roku 2017. 2018b. Slovenský hydrometeorologický ústav, Bratislava 2018a. http://www.shmu.sk/File/Hydrologia/Vodohospodarska_bilancia/VHB_kvalita_PzV/KvPzV_2017_VHB_text.pdf. Accessed 24 November 2019.

SHMU. Vodohospodárska bilancia kvality povrchovej vody sr v roku 2017. 2018a. Slovenský hydrometeorologický ústav, Bratislava 2018b. http://www.shmu.sk/File/Hydrologia/Vodohospodarska_bilancia/VHB_kvalita_PV/2017/KvPV_VHB2017_text-n.pdf. Accessed 13 November 2019.

Schirpke U., Tappeiner U. & Tasser E. 2019. A transnational perspective of global and regional ecosystem service flows from and to mountain regions. Scientific Reports 9:6678. DOI: 10.1038/s41598-019-43229-z. Accessed 17 January 2020.

Schröter M., Remme R. P. & Hein L. 2012. How and where to map supply and demand of ecosystem services for policy-relevant outcomes? Ecological Indicators 23:220–221. DOI: 10.1016/j.ecolind.2012.03.025. Accessed 4 September 2019.

Schulp C. J. E, Thuiller W. & Verburg P. H. 2014. Wild food in Europe: A synthesis of knowledge and data of terrestrial wild food as an ecosystem service. Ecological Economics 105:292–305. DOI: 10.1016/j.ecolecon.2014.06.018. Accessed 10 November 2019.

SNC SR. 2018. Komplexný informačný systém ochrany prírody – KIMS. (Comprehensive Nature Conservation Information System – CNCIS). Dostupné na internete: www.biomonitoring.sk

Stanová V. & Valachovič M. (eds.) 2002. Katalóg Biotopov Slovenska. Bratislava: DAPHNE. 225 pp.

STATdat. 2019. http://statdat.statistics.sk/cognosext/cgi-bin/cognos.cgi?b_action=xts.run&m=portal / cc.xts&gohome=. Accessed 15 December 2019.

Stürck J., Poortinga A. & Verburg P. 2014. Mapping ecosystem services: The supply and demand of flood regulation services in Europe. Ecological Indicators 38:198–211. DOI: 10.1016/j.ecolind.2013.11.010. Accessed 14 July 2019.

Supuka J., Feriancová Ľ., Schlampová T. & Jančura P. 2004. Krajinárska tvorba: Pre študentov SPU. Nitra: Slovenská poľnohospodárska univerzita. 256 pp. ISBN 80-8069-334-X.

Svobodova K., Vondrus J., Filova L., Besta M. 2011. The role of familiarity with the landscape in visual landscape preferences. Journal of Landscape Studies 4:11–24. https://www.researchgate.net/publication/268076976_The_Role_of_Familiarity_with_the_Landscape_in_Visual_Landscape_Preferences. Accessed 18 November 2019.

Šefferová Stanová V. & Galvánková J. (eds.) 2015. Monitoring of plants and habitats of Community interest in the Slovak Republic, Results and assessment in the period of 2013 – 2015. Banská Bystrica: DAPHNE, SNC SR. 300 pp. ISBN 978-80-8184-023-4.

TEEB. 2010. The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. Earthscan, London and Washington: TEEB. 422 pp.

Tinch R., Beauromont N., Sunderland T., Ozdemiroglu E. et al. 2019. Economic valuation of ecosystem goods and services: a review for decision makers. Journal of Environmental Economics and Policy 8(4):379–393. DOI: 10.1080/21606544.2019.1623083. Accessed 13 January 2020.

Torralba M., Fagerholm N., Hartel T., Moreno G. & Plieninger T. 2018. A social-ecological analysis of ecosystem services supply and trade-offs in European wood-pastures. Science Advances 4:1–13. DOI: 10.1126/sciadv.aar2176. Accessed 17 January 2020.

Trimmer J. T., Miller D. C. & Guest J. S. 2019. Resource recovery from sanitation to enhance ecosystem services. Nature Sustainability 2:681–690. DOI: 10.1038/s41893-019-0313-3. Accessed 13 January 2020.

Tscharntke T., Rand T. A. & Bianchi F. 2005. The landscape context of trophic interactions: insect spillover across the crop-noncrop interface. Annales Zoologici Fennici 42:421–432. https://edepot.wur.nl/39081. Accessed 20 November 2019.

Vihervaara P., Kumpula T., Ruokolainen A., Tanskanen A. & Burkhard B. 2012. Using detailed biotope data for Ecosystem service assessment in Natural protection areas. International Journal of Biodiversity Science, Ecosystem Services & Management 8(1-2):169–185. DOI: 10.1080/21513732.2012.686120. Accessed 18 July 2019.

Vihervaara P., Viinikka A., Brander L., Santos-Martín F., Poikolainen L. & Nedkov S. 2019. Methodological interlinkages for mapping ecosystem services – from data to analysis and decision-support. One Ecosystem 4: e26368. DOI: 10.3897/oneeco.4.e26368. Accessed 15 July 2019.

Vrbičanov G., Kaisová D., Močko M., Petrovič F., Mederly P. 2020. Mapping Cultural Ecosystem Services Enables Better Informed Nature Protection and Landscape Management. Sustainability 12:2138. DOI: 10.3390/su12052138. Accessed 1 March 2020.

Wei F., Costanza R., Dai Q., Stoeckl N., Gu X., Farber S., Nie Y., Kubiszewski I., Hu Y., Swaisgood R., Yang X., Bruford M., Chen Y., Voinov A., Qi D., Owen M., Yan L., Kenny D. C., Zhang Z., Hou R., Jiang S., Liu H., Zhan X., Zhang L., Yang B., Zhao L., Zheung X., Zhou W., Wen Y., Gao H. & Zhang W. 2018. The value of ecosystem services from Giant Panda reserves. Current Biology 28(13):2174–2180. DOI: 10.1016/j.cub.2018.05.046. Accessed 8 February 2020.

Wilson M. & Hoehn J. P. 2006. Valuing Environmental Goods and Services Using Benefit Transfer: The State-of-the Art and Science. Ecological Economics 60:335–342. DOI: 10.1016/j.ecolecon.2006.08.015. Accessed 15 June 2019.

ZB GIS. 2018. GKÚ. https://zbgis.skgeodesy.sk/mkzbgis/?bm=zbgis&z=8&c=19.53000,48.80000#!. Accecces 3 March 2020.

Zdycha P., Valtýni J., Kodrík M., Urgela J. & Ďurčík V. 2008. Dejiny lesníctva. Vysokoškolská učebnica. Zvolen: Technická univerzita vo Zvolene 134 pp.

Zhiyanski M., Nedkov S., Mondeshka M., Yarlovska N., Borissova B., Vassilev V., Bratanova-Doncheva S., Gocheva K. & Chipev N. 2017. Methodology for assessment and mapping of urban ecosystems condition and their services in Bulgaria. Part B. Bulgaria: Clorind. 82 pp. https://www.researchgate.net/publication/322313619_2_METHODOLOGY_FOR_ASSESSMENT_AND_MAPPING_OF_URBAN_ECOSYSTEMS_CONDITION_AND_THEIR_SERVICES_IN_BULGARIA_ISBN_978-619-7379-03-7. Accessed 24 July 2019.

8 Annexes

Annex 1 Conversion table of habitats according to the Habitat Catalog of Slovakia (Stanová & Valachovič 2002) and habitats NATURA 2000 to EUNIS categories

Annex 2 Basic average economic values of regulatory ES in EUR/ hectar/ year. Green lines indicate relevant ecosystems for Slovakia

Annex 3 Basic average economic values of provisioning and cultural ES in EUR / hectare / year. Green lines indicate relevant ecosystems for Slovakia

Annex 1. Conversion table of habitats according to the Habitat Catalog of Slovakia (Stanová & Valachovič 2002) and habitats NATURA 2000 to EUNIS categories

SK kód	NATURA 2000 kód	EUNIS	Názov biotopu (SK)
Sl1	1340	E6.2	Vnútrozemské slaniská a slané lúky
Sl2	1340	D6.14	Karpatské travertínové slaniská
Sl3	1530	E6.2	Panónske slané stepi a slaniská
Sl4		E6.2	Subhalínne travinné biotopy
Pi1	2340	E1.99	Vnútrozemské panónske pieskové duny
Pi2	6120	E1.12	Suchomilné travinnobylinné porasty na vápnitých pieskoch
Pi3		E1.91	Pionierske porasty na silikátových pôdach
Pi4	8230	H3.62	Pionierske spoločenstvá plytkých silikátových pôd
Pi5	6110	E1.11	Pionierske porasty zväzu Alysso-Sedion albi na plytkých karbonátových a bázických substrátoch
Vo1	3130	C1.2	Oligotrofné až mezotrofné stojaté vody s vegetáciou tried Littorelletea uniflorae a / alebo Isoëto-Nanojuncetea
Vo2	3150	C1.3	Prirodzené eutrofné a mezotrofné stojaté vody s vegetáciou plávajúcich a / alebo ponorených cievnatých rastlín typu Magnopotamion alebo Hydrocharition
Vo3	3160	C1.45	Prirodzené dystrofné stojaté vody
Vo4	3260	C2	Nížinné až horské vodné toky s vegetáciou zväzu Ranunculion fluitantis a Callitricho-Batrachion
Vo5	3140	C1.14	Oligotrofné až mezotrofné vody s bentickou vegetáciou chár
Vo6		C1	Mezo- až eutrofné poloprirodzené a umelé vodné nádrže so stojatou vodou s plávajúcou a / alebo ponorenou vegetáciou
Vo7		C1.341	Makrofytná vegetácia plytkých stojatých vôd (Ranunculion aquatilis)
Vo8		C3.24	Spoločenstvá bylín a šachorín eutrofných mokradí s kolísajúcou vodnou hladinou

Vo9		C3.431	Ruderalizované porasty v zamokrených depresiách na poliach a na obnažených dnách rybníkov
Br1		C2.6	Štrkové lavice bez vegetácie
Br2	3220	C3.55221	Horské vodné toky a bylinné porasty pozdĺž ich brehov
Br3	3230	F9.111	Horské vodné toky a ich drevinová vegetácia s myrikovkou nemeckou (Myricaria germanica)
Br4	3240	F9.111	Horské vodné toky a ich drevinová vegetácia s vŕbou sivou (Salix elaeagnos)
Br5	3270	C3.53	Rieky s bahnitými až piesočnatými brehmi s vegetáciou zväzov Chenopodion rubri p.p. a Bidention p.p.
Br6	6430	E5.5514	Brehové porasty deväťsilov
Br7	6430	E5.41	Bylinné lemové spoločenstvá nížinných riek
Br8		C3.11	Bylinné brehové porasty tečúcich vôd
Kr1	4030	F4.2	Vresoviská
Kr2	5130	F3.16	Porasty borievky obyčajnej
Kr3		F3.16	Sukcesné štádiá s borievkou obyčajnou
Kr4	4080	F2.32	Spoločenstvá subalpínskych krovín
Kr5	4080	F2.33	Nízke subalpínske kroviny
Kr6	40A0	F3.24	Xerotermné kroviny
Kr7		F3.1	Trnkové a lieskové kroviny
Kr8		F9.2	Vŕbové kroviny stojatých vôd
Kr9		F9.1	Vŕbové kroviny na zaplavovaných brehoch riek
Kr10	4070	F2.461	Kosodrevina
Kr11		F2.461	Vysadená kosodrevina
Al1	6150	E4.34	Alpínske travinnobylinné porasty na silikátovom podklade
Al2	6150	E4.11	Alpínske snehové výležiská na silikátovom podklade
Al3	6170	E4.4	Alpínske a subalpínske vápnomilné travinnobylinné porasty
Al4	6170	E4.12	Alpínske snehové výležiská na vápnitom podklade

Al5	6430	E5.5	Vysokobylinné spoločenstvá alpínskeho stupňa
Al6		E5.5	Vysokosteblové spoločenstvá horských nív na silikátovom pod-klade
Al7		E5.5	Vysokosteblové spoločenstvá vlhkých skalnatých žľabov na karbonátovom podklade
Al8		E5.5	Horské vysokosteblové spoločenstvá na suchších a teplejších svahoch
Al9	4060	F2.24	Vresoviská a spoločenstvá kríčkov v subalpínskom a alpínskom stupni
Tr1	6210	E1.231	Suchomilné travinnobylinné a krovinové porasty na vápnitom substráte
Tr1.1		E1.231	Suchomilné travinnobylinné a krovinové porasty na vápnitom substráte s významným výskytom druhov čeľade Orchidaceae
Tr2	6240	E1.2211, E1.2932	Subpanónske travinnobylinné porasty
Tr3	6250	E1.2C	Panónske travinnobylinné porasty na spraši
Tr4	6260	E1.2F2	Panónske travinnobylinné porasty na pieskoch
Tr5	6190	E1.291	Suché a dealpínske travinnobylinné porasty
Tr6		E5.21	Teplomilné lemy
Tr7		E5.22	Mezofilné lemy
Tr8	6230	E4.3171, E1.712	Kvetnaté vysokohorské a horské psicové porasty na silikátovom substráte
Lk1	6510	E2.22	Nížinné a podhorské kosné lúky
Lk2	6520	E2.31, E4.51	Horské kosné lúky
Lk3		E2.1	Mezofilné pasienky a spásané lúky
Lk4	6410	E3.51	Bezkolencové lúky
Lk5	6430	E5.4	Vysokobylinné spoločenstvá na vlhkých lúkach
Lk6		E3.41	Podmáčané lúky horských a podhorských oblastí
Lk7		E3.41	Psiarkové aluviálne lúky
Lk8	6440	E3.43	Aluviálne lúky zväzu Cnidion venosi
Lk9		E3.442	Zaplavované travinné spoločenstvá
Lk10		C3.26, D5.21	Vegetácia vysokých ostríc

Lk11		C3.21	Trstinové spoločenstvá mokradí (Phragmition)
Lk12		C3.2A	Trstinové spoločenstvá brakických a alkalických vôd
Ra1	7110	D1.11	Aktívne vrchoviská
Ra2	7120	D1.12	Degradované vrchoviská schopné prirodzenej obnovy
Ra3	7140	D2.2, D2.3	Prechodné rašeliniská a trasoviská
Ra4	7150	D2.3H	Depresie na rašelinných substrátoch s Rhynchospora alba
Ra5	7210	D5.24	Vápnité slatiny s maricou pílkatou a druhmi zväzu Caricion davallianae
Ra6	7230	D4.1	Slatiny s vysokým obsahom báz
Ra7		E3.46	Sukcesne zmenené slatiny
Pr1		C2.111	Prameniská horského a subalpínskeho stupňa na nevápencových horninách
Pr2		C2.111	Prameniská nížin a pahorkatín na nevápencových horninách
Pr3	7220	C2.121	Penovcové prameniská
Sk1	8210	H3.25, H3.42	Karbonátové skalné steny so štrbinovou vegetáciou
Sk2	8220	H3.11	Silikátové skalné steny so štrbinovou vegetáciou
Sk3	8110	H2.31	Silikátové sutiny v montánnom až alpínskom stupni
Sk4	8120	H2.44	Karbonátové sutiny v montánnom až alpínskom stupni
Sk5	8150	H2.32	Nespevnené silikátové sutiny v kolínnom stupni
Sk6	8160	H2.61	Nespevnené karbonátové skalné sutiny v montánnom až kolínnom stupni
Sk7		H2.32	Sekundárne sutinové a skalné biotopy
Sk8	8310	H1	Nesprístupnené jaskynné útvary
Ls1.1	91E0	G1.111	Vŕbovo-topoľové nížinné lužné lesy
Ls1.2	91F0	G1.22	Dubovo-brestovo-jaseňové nížinné lužné lesy
Ls1.3	91E0	G1.21	Jaseňovo-jelšové podhorské lužné lesy
Ls1.4	91E0	G1.121	Horské jelšové lužné lesy

Ls2.1		G1.A16	Dubovo-hrabové lesy karpatské
Ls2.2	91G0	G1.A16	Dubovo-hrabové lesy panónske
Ls2.3.1	9170	G1.A16	Dubovo-hrabové lesy lipové – časť A
Ls2.3.2		G1.A16	Dubovo-hrabové lesy lipové – časť B
Ls2.3.3	9410	G3.1C	Dubovo-hrabové lesy lipové – časť C
Ls3.1	91H0	G1.7374	Teplomilné submediteránne dubové lesy
Ls3.2	91I0	G1.7A1	Teplomilné ponticko-panónske dubové lesy na spraši a piesku
Ls3.3	91I0	G1.7A1	Dubové nátržníkové lesy
Ls3.4	91M0	G1.76	Dubovo-cerové lesy
Ls3.5.1		G1.87	Sucho a kyslomilné dubové lesy – časť A
Ls3.5.2	91I0	G1.7A1	Sucho a kyslomilné dubové lesy – časť B
Ls3.6	9190	G1.81	Vlhko a kyslomilné brezovo-dubové lesy
Ls4	9180	G1.A41	Lipovo-javorové sutinové lesy
Ls5.1	9130	G1.63	Bukové a jedľovo-bukové kvetnaté lesy
Ls5.2	9110	G1.61	Kyslomilné bukové lesy
Ls5.3	9140	G1.65	Javorovo-bukové horské lesy
Ls5.4	9150	G1.66	Vápnomilné bukové lesy
Ls6.1		G3.4	Kyslomilné borovicové a dubovo-borovicové lesy
Ls6.2	91Q0	G3.442	Reliktné vápnomilné borovicové a smrekovcové lesy
Ls6.3		G3.4	Lesostepné borovicové lesy
Ls6.4	91T0	G3.42112	Lišajníkové borovické lesy
Ls7.1	91D0	G1.51	Rašeliniskové brezové lesíky
Ls7.2	91D0	G3.E	Rašeliniskové borovicové lesy
Ls7.3	91D0	G3.E	Rašeliniskové smrekové lesy

Ls7.4	91D0	G1.4	Slatinné jelšové lesy
Ls8		G3.1	Jedľové a jedľovo-smrekové lesy
Ls9.1	9410	G3.1B	Smrekové lesy čučoriedkové
Ls9.2	9410	G3.1B	Smrekové lesy vysokobylinné
Ls9.3	9410	G3.1C	Podmáčané smrekové lesy
Ls9.4	9420	G3.25	Smrekovcovo-limbové lesy
Ls10	91N0	G1.7C7	Panónske topoľové lesy s borievkou
X1		G5.8	Rúbaniská s prevahou bylín a tráv
X2		G5.8	Rúbaniská s prevahou drevín
X3		N / A	Nitrofilná ruderálna vegetácia mimo sídiel
X4		N / A	Teplomilná ruderálna vegetácia mimo sídiel
X5		N / A	Úhory a extenzívne obhospodarované polia
X6		N / A	Úhory a burinová vegetácia na pieskoch
X7		N / A	Intenzívne obhospodarované polia
X8		E5.4	Porasty inváznych neofytov
X9		N / A	Porasty nepôvodných drevín
X10		C3.5	Porasty ruderalizovaných bahnitých brehov
OP		I1	Orná pôda
CHM		I1	Chmeľnice
VIN		FB.4	Vinohrady
ZAH		X25	Záhrady
SAD		G1.D	Sady
TTP		E	Trvalé trávne porasty
OST		X07	Ostatné plochy

PPF		X07	Poľnohospodársky pôdny fond – ostatné nezaradené komplexy poľnohospodárskych biotopov
X(ZPPP)		X07	Nevyužívaná pôda
Vo		C3	Litorálna zóna vnútrozemských vôd
Vo		C3.4	Druhovo chudobné korytá s nízko rastúcou alebo obojživelnou vegetáciou
Ra		D1	Vrchoviská a rašeliniská
Lk		E1	Xerotermné lúky
Lk		E2.6	Poľnohospodárstvom upravené, prisievané a silno hnojené lúky, vrátane športových areálov a upravených trávnikov
Lk		E3	Sezónne zamokrené a podmáčané lúkx
Lk		E4	Alpské a subalpínske lúky
Lk		E4.3171	Západokarpatské lúky s výrazným hustým rastom tráv
Lk		E5	Lesné prameniská a čistiny a vysoké porasty netypických tráv
Kr		FB	Krovinové plantáže
Ls		G	Lesné biotopy a iné typy lesných pozemkov
Ls		G1.737	Západné submediteránne dubové lesy
Ls		G2	Širokolisté stálozelené lesy
Ls		G3	Ihličnaté lesy
Ls		G4	Zmiešané lesy
Sk		H2	Sute
Sk		H5	Rôznorodé vnútrozemské biotopy s veľmi riedkou alebo žiadnou vegetáciou
X		I2.2 / P-85.2	Mestská zeleň a parky
X		J1	Budovy, zastavaná plocha
X		J1.6	Staveniská a demolačné plochy
X		J1.7	Husto zastavané dočasné obývané plochy
X		J2	Rozptýlené osídlenie

X		J2.1	Roztrúsené obytné budovy
X		J3	Dobývacie priestory a lomy
X		J4	Dopravná sieť
X		J4.2	Cesty
X		J4.3	Železnice
X		J4.4	Letiská
X		J4.5	Prístavy
X		J6	Skládky odpadov
X		X09	Pasienkové lesy
X		X10	Krajinná mozaika s lesnými prvkami

Annex 2. Basic average economic values of regulatory ES in EUR/ hectar/ year. Green lines indicate relevant ecosystems for Slovakia

Ecosystem	Global climate regulation / EUR	Local climate regulation / EUR	Air quality regulation / EUR	Water flow regulation / EUR	Water purification / EUR	Nutrient regulation / EUR	Erosion regulation / EUR	Natural hazard regulation / EUR	Pollination / EUR	Pest and disease control / EUR	Regulation of waste / EUR
Agriculture & natural vegetation	2677,19	4015,78	177,55	915,43	807,11	133,40	3844,38	2818,73	919,17	7,31	4,87
Agro-forestry areas	2677,19	2677,19	177,55	915,43	807,11	133,40	5766,57	2818,73	1378,76	7,31	7,31
Airport	0,00	0,00	0,00	0,00	0,00	0,00	1922,19	0,00	0,00	2,44	0,00
Annual and permanent crops	1338,59	2677,19	88,78	457,71	0,00	66,70	3844,38	2818,73	459,59	4,87	4,87
Bare rock	0,00	0,00	0,00	0,00	403,56	0,00	3844,38	2818,73	0,00	0,00	0,00
Beaches, dunes and sand plains	0,00	0,00	0,00	457,71	403,56	66,70	0,00	14093,65	0,00	2,44	2,44
Broad-leaved forest	6692,97	6692,97	443,88	1373,14	2017,78	333,50	9610,95	11274,92	1838,34	9,74	9,74
Burnt areas	0,00	1338,59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,44
Coastal lagoons	1338,59	1338,59	0,00	1830,86	807,11	200,10	0,00	11274,92	0,00	7,31	12,18
Complex cultivation	1338,59	2677,19	88,78	457,71	0,00	66,70	1922,19	2818,73	919,17	7,31	4,87
Coniferous forest	6692,97	6692,97	443,88	1373,14	2017,78	333,50	9610,95	11274,92	1838,34	9,74	9,74
Construction sites	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Continuous urban fabric	0,00	0,00	0,00	0,00	0,00	0,00	3844,38	0,00	0,00	2,44	0,00
Discontinuous urban fabric	0,00	0,00	0,00	0,00	0,00	0,00	1922,19	0,00	459,59	2,44	0,00
Dump sites	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,87
Estuaries	1338,59	0,00	0,00	1373,14	1210,67	200,10	0,00	8456,19	0,00	7,31	12,18
Fruit trees and berry plantation	2677,19	2677,19	177,55	915,43	403,56	133,40	3844,38	5637,46	2297,93	7,31	4,87
Glaciers and perpetual snow	4015,78	5354,38	0,00	2288,57	0,00	0,00	0,00	0,00	0,00	2,44	2,44
Green urban area	2677,19	2677,19	177,55	915,43	807,11	133,40	3844,38	2818,73	919,17	4,87	4,87
Industrial or commercial unit	0,00	0,00	0,00	0,00	0,00	0,00	3844,38	0,00	0,00	2,44	0,00
Inland marshes	2677,19	2677,19	0,00	1373,14	807,11	266,80	1922,19	11274,92	459,59	4,87	7,31

Intertidal flats	1338,59	1338,59	0,00	457,71	403,56	66,70	1922,19	14093,65	0,00	4,87	7,31
Mineral extraction site	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Mixed forest	6692,97	6692,97	443,88	1373,14	2017,78	333,50	9610,95	11274,92	1838,34	12,18	12,18
Moors and heathland	4015,78	5354,38	0,00	915,43	1210,67	200,10	3844,38	5637,46	919,17	4,87	7,31
Natural grassland	6692,97	2677,19	0,00	457,71	1210,67	266,80	9610,95	2818,73	459,59	2,44	4,87
Non-irrigated arable land	1338,59	2677,19	88,78	915,43	0,00	66,70	0,00	2818,73	459,59	4,87	4,87
Olive groves	1338,59	1338,59	88,78	457,71	403,56	66,70	1922,19	0,00	459,59	4,87	4,87
Pasture	2677,19	1338,59	0,00	457,71	0,00	66,70	1922,19	2818,73	0,00	4,87	9,74
Peatbogs	6692,97	5354,38	0,00	1830,86	1614,22	266,80	3844,38	8456,19	919,17	7,31	9,74
Permanently irrigated land	1338,59	4015,78	88,78	457,71	0,00	66,70	0,00	2818,73	459,59	4,87	4,87
Port area	0,00	0,00	0,00	0,00	0,00	0,00	5766,57	8456,19	0,00	2,44	0,00
Ricefields	0,00	2677,19	88,78	457,71	0,00	66,70	0,00	0,00	459,59	2,44	4,87
Road and rail networks and associated land	0,00	0,00	0,00	0,00	0,00	0,00	1922,19	0,00	0,00	0,00	0,00
Salines	0,00	4015,78	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,44	2,44
Salt marshes	1338,59	1338,59	0,00	457,71	403,56	133,40	1922,19	11274,92	459,59	4,87	4,87
Sclerophyllous vegetation	2677,19	2677,19	88,78	457,71	403,56	133,40	1922,19	2818,73	919,17	4,87	7,31
Sea and ocean	4015,78	4015,78	0,00	457,71	807,11	200,10	0,00	0,00	0,00	7,31	12,18
Sparsely vegetated areas	0,00	1338,59	0,00	457,71	403,56	66,70	1922,19	2818,73	0,00	2,44	2,44
Sport and leisure facilities	1338,59	1338,59	88,78	457,71	403,56	66,70	1922,19	0,00	0,00	2,44	2,44
Transitional woodland shrub	2677,19	2677,19	88,78	457,71	403,56	133,40	1922,19	2818,73	919,17	4,87	7,31
Vineyard	1338,59	1338,59	88,78	457,71	0,00	66,70	1922,19	0,00	459,59	2,44	2,44
Water bodies	1338,59	2677,19	0,00	2288,57	807,11	200,10	0,00	8456,19	0,00	7,31	12,18
Water courses	0,00	1338,59	0,00	1373,14	1210,67	200,10	0,00	8456,19	0,00	7,31	12,18

Annex. 3. Basic average economic values of regulatory ES in EUR/hectar/year. Green lines indicate relevant ecosystems for Slovakia

Ecosystem	Crops / EUR	Biomass for energy / EUR	Fodder / EUR	Livestock domestic / EUR	Fibre / EUR	Timber / EUR	Wood Fuel / EUR	Fish, seafood & edible algae / EUR	Wild foods & resources / EUR	Freshwater / EUR	Recreation & tourism / EUR	Landscape esthetics & nspiration / EUR
Agriculture & natural vegetation	391,75	421,39	280,93	314,91	1935,36	2304,03	2304,03	0,00	38,15	0,00	1460,35	3981,29
Agro-forestry areas	261,16	421,39	280,93	472,36	967,68	6912,09	6912,09	0,00	38,15	0,00	1460,35	3981,29
Airport	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Annual and permanent crops	522,33	280,93	561,86	157,45	2419,20	0,00	0,00	0,00	19,08	0,00	730,17	1990,65
Bare rock	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1460,35	5971,94
Beaches, dunes and sand plains	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	3650,87	7962,58
Broad-leaved forest	0,00	140,46	140,46	0,00	483,84	11520,15	11520,15	0,00	95,38	0,00	3650,87	9953,23
Burnt areas	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Coastal lagoons	0,00	140,46	0,00	0,00	0,00	0,00	0,00	143,38	76,30	0,00	2190,52	7962,58
Complex cultivation	522,33	280,93	280,93	157,45	1935,36	0,00	2304,03	0,00	19,08	0,00	1460,35	3981,29
Coniferous forest	0,00	140,46	140,46	0,00	483,84	11520,15	11520,15	0,00	95,38	0,00	3650,87	9953,23
Construction sites	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Continuous urban fabric	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2190,52	5971,94
Discontinuous urban fabric	130,58	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2190,52	3981,29
Dump sites	0,00	140,46	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Estuaries	0,00	280,93	0,00	0,00	0,00	0,00	0,00	143,38	76,30	0,00	2190,52	7962,58
Fruit trees and berry plantation	522,33	140,46	0,00	0,00	0,00	4608,06	4608,06	0,00	0,00	0,00	2190,52	3981,29
Glaciers and perpetual snow	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	54,05	3650,87	9953,23
Green urban area	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2190,52	5971,94
Industrial or commercial unit	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Inland marshes	0,00	0,00	561,86	314,91	0,00	0,00	0,00	0,00	19,08	0,00	730,17	3981,29

Intertidal flats	0,00	140,46	0,00	0,00	0,00	0,00	0,00	0,00	19,08	0,00	2920,70	3981,29
Mineral extraction site	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Mixed forest	0,00	140,46	140,46	0,00	967,68	11520,15	11520,15	0,00	95,38	0,00	3650,87	9953,23
Moors and heathland	0,00	140,46	140,46	157,45	0,00	0,00	4608,06	0,00	38,15	0,00	2920,70	7962,58
Natural grassland	0,00	140,46	280,93	472,36	0,00	0,00	0,00	0,00	95,38	0,00	2190,52	7962,58
Non-irrigated arable land	652,91	702,32	702,32	0,00	2419,20	0,00	0,00	0,00	19,08	0,00	730,17	1990,65
Olive groves	522,33	140,46	0,00	0,00	0,00	4608,06	4608,06	0,00	0,00	0,00	1460,35	3981,29
Pasture	0,00	140,46	702,32	787,27	0,00	0,00	0,00	0,00	38,15	0,00	1460,35	3981,29
Peatbogs	0,00	280,93	0,00	0,00	0,00	0,00	0,00	0,00	19,08	10,81	2190,52	3981,29
Permanently irrigated land	652,91	140,46	280,93	0,00	1935,36	0,00	0,00	0,00	19,08	0,00	730,17	1990,65
Port area	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	730,17	3981,29
Ricefields	652,91	140,46	280,93	0,00	0,00	0,00	0,00	0,00	0,00	0,00	730,17	1990,65
Road and rail networks and associated land	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Salines	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1460,35	3981,29
Salt marshes	0,00	0,00	280,93	314,91	0,00	0,00	0,00	0,00	19,08	0,00	2190,52	3981,29
Sclerophyllous vegetation	0,00	140,46	140,46	157,45	483,84	4608,06	4608,06	0,00	19,08	0,00	1460,35	5971,94
Sea and ocean	0,00	561,86	421,39	0,00	0,00	0,00	0,00	179,23	76,30	0,00	2920,70	9953,23
Sparsely vegetated areas	0,00	0,00	0,00	157,45	0,00	0,00	0,00	0,00	19,08	0,00	730,17	1990,65
Sport and leisure facilities	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	3650,87	1990,65
Transitional woodland shrub	0,00	280,93	140,46	157,45	483,84	2304,03	4608,06	0,00	19,08	0,00	1460,35	5971,94
Vineyard	522,33	140,46	0,00	0,00	0,00	0,00	2304,03	0,00	0,00	0,00	2190,52	3981,29
Water bodies	0,00	140,46	0,00	0,00	0,00	0,00	0,00	143,38	76,30	54,05	3650,87	7962,58
Water courses	0,00	280,93	0,00	0,00	0,00	0,00	0,00	107,54	76,30	54,05	2920,70	7962,58

The State Nature Conservancy of the Slovak Republic
Value of Ecosystems and Their Services in Slovakia
Banska Bystrica
2021 - 137 pages

ISBN 978-80-8184-094-4
EAN 9788081840944

The publication was created within the project "Monitoring of species and habitats of European importance in accordance with the Habitats Directive and the Birds Directive" (ITMS 310011P170), which is co-financed by the ESIF under the Operational Programme Quality of Environment.

OPERAČNÝ PROGRAM
KVALITA ŽIVOTNÉHO PROSTREDIA

EURÓPSKA ÚNIA
Európske štrukturálne
a investičné fondy

ŠTÁTNA
OCHRANA PRÍRODY
SLOVENSKEJ REPUBLIKY

ISBN: 978-80-8184-094-4

9 788081 840944