A multi-tiered approach to map and assess the natural heritage potential to provide ecosystem services at a national level

Stoyan Nedkov[‡], Mariyana Nikolova[‡], Hristina Prodanova[‡], Vanya Stoycheva[‡], Desislava Hristova[‡], Eugenia Sarafova[§]

‡ National Institute of Geophysics, Geodesy and Geography - Bulgarian Academy of Sciences, Sofia, Bulgaria
§ Sofia University "St. Kliment Ohridski", Sofia, Bulgaria

Corresponding author: Stoyan Nedkov (snedkov@abv.bg)

Academic editor: Ignacio Palomo

Abstract

Natural heritage (NH) possesses an outstanding universal value that can be described as “natural significance” at a national level. The ecosystems can be considered as the spatial units which represent the NH of the particular area in terms of their value to people. Recreation and tourism are amongst the important values which are strongly dependent on the NH and they have a certain impact on the ecosystems' condition and the quality of the services they provide. The efforts through the Mapping and Assessment of Ecosystems and thier Services (MAES) process led to the development of a multi-tiered approach that considers different methods at different levels of detail and complexity and can be applied according to specific needs, data and resource availability. In this paper, we propose the development of this methodology for the specific need for mapping and assessment of the NH as a source of ecosystem services (ES) for recreation and tourism. The conceptual scheme of the study demonstrates how the MAES framework can be adapted to the specific needs of the work and arrange the methods into three tiers according to the data availability and resources. The mapping and assessment procedure is based on an algorithm for spatial data analyses which enables the evaluation of the NH potential to provide 15 ecosystem services. The results show that the NH of Bulgaria is a valuable source of ES which are well presented in most parts of the country. The areas with very high potential form several clusters that correspond to the country's tourist regions. The proposed approach is applicable on the national scale and solves the problem of data availability limitations for various ES. The algorithm ensures the optimal quality of the results using the available data and resources. Instead of an expert-based assessment for all services which is easier, but less accurate, the proposed approach provides the means how to define more precise indicators, based on statistical data or models where possible. The study provides appropriate data for analyses of the methods’ performance at different tiers.

Keywords

ES indicators, recreation, tourism, modelling, spatial proxy, InVEST, ESTIMAP

Introduction

Natural heritage (NH) refers to the elements of biodiversity, including flora and fauna, ecosystems and geological structures which are an important part of each country's natural resources. According to the World Heritage Convention (UNESCO 1972), it includes natural features consisting of physical formations, geological features, physiographical formations, natural sites or precisely delineated natural areas of outstanding universal value from the point of view of science, conservation and natural beauty. The outstanding universal value at the national level can be described by the term “natural significance”. It refers to the importance of ecosystems, biodiversity and geodiversity for their existence value and incorporates both biotic and abiotic elements. Thus, the ecosystems can be considered as the spatial units which represent the NH of the particular area in terms of their value to people (Ihtimanski et al. 2020). Recreation and tourism are amongst the important values which are strongly dependent on the NH and they have a certain impact on the ecosystems' condition and the quality of the services they provide. New directions in natural heritage conservation acknowledge conflicting relationships between societies and their environments and seek to respond to impending global crises due to over-consumption of resources, climate change and biodiversity extinction (Mallarach and Verschuuren 2019). The ecosystem services (ES) concept provides an appropriate basis for assessment and mapping methods that enable linking the state of ecosystems with human well-being (Roche and Campagne 2017, Rendon et al. 2022). Thus, it can be used as a platform to find solutions related to the conflicts between conservation and the use of the NH, for instance, in cases such as the conflict between the eco-activists and local comunities about the winter tourism in Pirin Mountain in Bulgaria, which is recognised as a world heritage site.

The efforts to solve such problems have the potential to deliver sustainable benefits to people. However, regions for which conservation benefits both biodiversity (including NH) and ES cannot be identified unless ES can be quantified and valued and their areas of production mapped (Naidoo et al. 2008). The mapping and assessment of ES provided by NH for the needs of recreation and tourism can be related mainly to cultural services, such as outdoor recreation, cultural heritage and aesthetic experiences, but also some regulating services, such as maintenance of habitats and local climate regulation, as well as to some provisioning services, such as water supply and crop production (Nedkov et al. 2021b). The variety of services necessitates various data from different sources which usually differ in quality and spatial resolution. Furthermore, different methods have to be used which limits the compatibility of outcomes and calls for a more consistent, but flexible approach (Grêt-Regamey et al. 2015). The tiered approach provides a classification of available methods according to levels of detail and complexity with the aim of providing advice on method choice (Burkhard and Maes 2017). It could significantly complement it by its ability to make ES maps comparable across scales and support the mapping for various purposes (Directorate-General for Environment (European Commission) 2013), Grêt-Regamey et al. 2015). The efforts through the Mapping and Assessment of Ecosystems and their Services (MAES) process led to the development of a multi-tiered approach that considers different methods (biophysical, socio-cultural and economic) at different levels of detail and complexity and can be applied according to specific needs, data and resources availability (Weibel et al. 2018, Burkhard et al. 2018b). The ES matrix approach that links ecosystem types or other geospatial units with ES in an easy-to-apply look-up table is one possible solution. It allows the assessment of more ES than other approaches, notably by overcoming data availability limitations or the lack of proper proxies to quantitatively evaluate ES (Campagne et al. 2020).

The multi-tiered approach covers a variety of ES aspects, as well as a wide range of possible applications. Therefore, this approach should be tested for different objectives and in different case studies to be validated and further developed into a comprehensive ES mapping and assessment methodology. Every ecosystem assessment has to be relevant to a certain theme and address a broad range of questions pertaining to decision-making processes that occur at different levels of decision-making and across different actors in society (Burkhard et al. 2018a). The mapping and assessment of NH as a source of ES for recreation and tourism is a theme that has not been appropriately studied so far. However, recreation represents an important service that interests millions of people and has an important role in human well-being and health since it provides physical, aesthetic and cultural benefits and offers the opportunity to experience directly a relationship with nature (Norman et al. 2010, Zulian et al. 2013, Lankia et al. 2015). Therefore, the mapping and assessment of the NH as a source of ES for recreation and tourism at different levels of complexity and scales could be an important contribution to the development of the multi-tiered approach.

The ES matrix approach was proposed in a series of papers (Burkhard et al. 2009, Burkhard et al. 2012, Burkhard et al. 2014) and, since then, has been broadly used as a highly flexible way to assess and map ES. In a recent review, Campagne et al. (2020) identified a total of 109 studies applying the ES matrix and made a critical analysis of its applicability and usage for different purposes. The result of the review emphasises the ability of the approach to cover more ES with a mean of 15.6 different ES assessed compared to the mean of 7.9 found in a similar review (Hölting et al. 2019) on quantitative methods to assess landscape or ecosystem multifunctionality. Therefore, the ES matrix approach allows the assessment of more ES than other approaches, notably by overcoming data availability limitations or the lack of proper proxies to quantitatively evaluate ES. However, the approach is more often used at the local and regional levels than at the national level (Campagne et al. 2020). Another limitation, found in 27 of the reviewed studies, is that it is not clear how the data have been used and from where the final scores came. The multi-tiered approach complements quite well with the ES matrix assessment as it allows the selection of the appropriate application of a certain method for tackling a specific question at a given scale (Weibel et al. 2018). To better link the tier level to specific ES mapping and assessment methods, it is necessary to explore how a particular method fits into a specific purpose of the study and find its place in the whole framework designed during the MAES process (Burkhard et al. 2018b). Thus, the application of the multi-tiered approach will not only support communication of the ES concept, but will also reduce the tendency for selecting an unsuitable approach for solving complex problems linked to ES-based resource management (Weibel et al. 2018).

Recent studies in Bulgaria presented the NH as a spatial phenomenon conceptualised by the flows of benefits from ecosystems to people, contributing to human well-being (Nikolova et al. 2021c, Prodanova 2021, Semerdzhieva and Borisova 2021, Silvestriev et al. 2021). Various aspects of the sustainable use of the NH for recreation and tourism have been studied and the ES concept was proposed as a platform to integrate them into a mapping and assessment methodological framework (Nedkov et al. 2021b). These studies also explore the opportunities to solve specific challenges for the development of recreation and tourism and discuss important aspects related to climate change adaptation, integration of recreational activities in the forest legislation and optimisation of the regional tourism policy (Nikolova et al. 2021b, Nikolova et al. 2021a, Zhiyanski et al. 2021). However, the conceptualisation of NH at the ecosystem level in these studies is based mainly on theoretical assumptions and indicators drawn there rely too much on expert assessment. It is necessary to search for new indicators and methods which will ensure quantification at tiers 2 and 3 with higher accuracy. Especially, the use of freely available satellite data is a valuable source for deriving parameters for both ecosystem condition and services.

In this paper, we propose a multi-tiered approach for mapping and assessment of ES, based on the MAES framework which is focused on the services provided by the NH at a national level. The main aim of the paper is to provide a deep insight into the whole process from the selection of ES through the indicators' quantification by using particular datasets and the estimation of the final scores for ES assessment. More specifically, we aim at: i) revealing what is the ES provided by NH and what is their potential to support recreation and tourism; ii) demonstrating which methods and indicators are used and how they are utilised in the ES assessment framework; iii) explaining the process of ES indicators quantification at different tiers; iv) analysing the ES potential and data quality at different tiers.

Material and methods

Methodological background

The MAES methodological framework provides typology for ecosystems, a set of indicators for the assessment of ecosystem condition and mapping of ES (Directorate-General for Environment (European Commission) 2013). The core elements of the framework are: 1) mapping of ecosystems; 2) assessment of ecosystem condition; 3) mapping and assessment of ecosystem services. The main steps which cover the core activities of an operational framework are presented in the conceptual scheme developed through the ESMERALDA*[1] project (Burkhard et al. 2018a). Furthermore, within the project, a multi-tiered approach for ES mapping and assessment was developed. The approach considers different methods (biophysical, socio-cultural and economic) at different levels of detail and complexity and can be applied according to specific needs, data and resource availability (Burkhard et al. 2018b). However, every ecosystem assessment has to be relevant to a certain theme and address a broad range of questions pertaining to decision-making processes that occur at different levels of decision-making and across different actors of society (Burkhard et al. 2018a). The mapping and assessment of ES provided by the NH for the needs of recreation and tourism is a theme that could contribute to finding solutions to the problems related to the conflicts between conservation and the use of the NH. A conceptual framework for mapping and assessment of ES provided by the NH in Bulgaria for recreation and tourism was developed through several efforts within the framework of the Centre of Excellence "Heritage BG"*[2]. It is based on the assumption that the generation of NH for the needs of tourism can be presented as the linkages between the natural systems and tourism in the form of ES potential, flow and demand (Nedkov et al. 2021b). A set of indicators for mapping and assessment at a national level are proposed and the methods for their quantification are arranged following the multi-tiered approach. They allow the production of ES maps for the priority ES which can be used for planning purposes in sustainable tourism. ES maps quantify and visualise where and to what extent ecosystems contribute to human well-being (Burkhard and Maes 2017). To represent ES provided by NH in a spatial context, it is necessary to define where ES are generated and what is the potential of the ecosystems. To map the overall potential of an area, it is necessary to integrate the whole range of ES. The matrix approach enables normalising all ES values in a uniform score from 0 to 5 which makes possible the integration of the resulting GIS layers.

Study area and initial data

Study area and initial data

The multi-tiered approach, developed in this work, is designed for application at the national level. Therefore, the whole area of Bulgaria is selected as a case study. Due to the diverse climatic, geological, topographic and hydrological conditions, Bulgaria is amongst the richest countries in Europe in terms of biodiversity and geodiversity. The country accounts for about 2.5% of the total EU area, but in terms of species present on the territory, it hosts 26% of all European species, 70% of the protected bird species under the EU Birds Directive and 40% of the conservation habitats types (under Annex I, Council of the European Union 1992). Both biodiversity and geodiversity, as elements of NH, are major sources of recreation and tourism in the country (Ihtimanski et al. 2020). The country is divided into nine tourist regions (Fig. 1). Each of them has a city recognised as a centre of the region and priority tourism branches which make the specialisation of the region. For instance, the Rhodopes Region is specialised in mountain and religious tourism, while the Valley of the Roses is in health and cultural tourism (Nikolova et al. 2021b).

MAES implementation needs spatially-explicit datasets to address the key drivers, pressures and their different gradients and variations in space and time. Each ES is assessed by specific indicators which have to be supported with appropriate spatial data available at the national level corresponding to the whole territory of the country. The activities under MAES in Bulgaria led to the development of several datasets, but their use at the national level at this stage is hampered by two main problems. Firstly, the data for the nine ecosystem types are in separate datasets which do not fit topologically correctly if they are merged in a single GIS layer. Secondly, the mapping does not cover the Natura 2000 areas which is a significant gap that makes these data inappropriate for national scale mapping. Only for some services, which are assessed using municipality-based initial information, there are appropriate data that can be applied at the national level. For instance, the quantification of education and science service is based on a number of papers calculated per municipality (Assenova et al. 2018).

The lack of full coverage at the national scale data of some ES can be overcome using models and modelling approaches. For instance, the ESTIMAP model for recreation uses easily available data on land cover, protected areas, water bodies, transport network and topography (Ihtimanski et al. 2020). The various data sources used for ES modelling at tier 3 are presented in Table 1. Nevertheless, there are still some services that could not be quantified using available data at the national level. Expert-based assessment is the only possible option for these services. The matrix approach at tier 1 necessitates appropriate spatial units to be selected for the assessment. In this study, we use the map of ecosystem subtypes, based on CORINE land-cover (CLC) data correlated to the MAES ecosystems classification at the third level for Bulgaria (Hristova and Stoycheva 2021). It contains 27 ecosystem subtypes which can be delineated after the correlation with CLC classes.

A multi-tiered approach

The multi-tiered approach for mapping and assessment of ES provided by the NH at the national level is based on the MAES framework (Directorate-General for Environment (European Commission) 2013) and on the conceptual scheme for its implementation (Burkhard et al. 2018a). It consists of four main elements (Fig. 2) which are described in the following subsections.

Prioritization of ES

The prioritisation of ES provided by the NH aims to identify the ES and rank them according to their significance for recreation and tourism. It is based on the application of the ES prioritisation matrix (ESPM) (Suppl. material 1) and a five-step algorithm (selection of ES; definition of prioritisation criteria; building an ESPM; expert assessment; analyses and identification of priority ES) designed to differentiate ES into priority levels according to their significance to recreation and tourism (Nedkov et al. 2021a). The experts were asked to range the ES according to their significance for recreation and tourism using the 0 to 5 scale used in the ES matrix. The expert assessment of the ES was made by a group of 12 experts from the fields of landscape ecology, forestry, tourism, climatology and geoinformation science. The analyses include several statistical procedures divided into three stages: 1) calculation of primary indices such as minimum, maximum and standard deviation of the initial expert scores; 2) the services with the highest deviations were analysed and re-evaluated by the same expert after a discussion on the primary results; 3) calculation of final scores per ES. Thus, each ecosystem receives an individual score which represents its importance for recreation and tourism. The application of this approach allowed us to distinguish three groups of the importance of services: high, medium and low priority. The priority classes were defined by the statistical distribution of the scores using the equal intervals method. The first contains obligatory ES for each mapping and assessment activity from the national to the local level. The high-priority group contains 15 ES which are distributed as follows: four provisioning services; five regulating services; and seven cultural services. More details about the individual services are given in the next sections.

Selection of indicators and methods at the different tiers

The approach consists of three tiers and both the level of detail of input data and the complexity of the analysis (i.e. methods) increase from tier 1 to tier 3 (Directorate-General for Environment (European Commission) 2014). Ecosystem service quantifications need a variety of information and long-term time series and data quality, which very often are not available to the extent required, so usually only a small group of potentially representative variables can be used as indicators (Müller and Burkhard 2012). To assess ES provided by NH, we analysed all potential sources of data at the national level and the ecosystem parameters that can be represented by each of them. The data come from various sources with different qualities, scales and levels of detail (see Table 1). These necessitate defining the most appropriate methods for services with diverse data availability and at particular scales. The multi-tiered approach provides appropriate means to cope with the variety of data quality and to choose the appropriate method for each individual service. Following this approach, we allocated the services according to the data availability, level of detail and the methods used for ES quantification (see Table 2). At tier 1, we put the services with no uniform data at the national level, which were assessed by expert judgement. The services at tier 2 were provided with statistical data or biophysical parameters at the municipality level that could be interpolated using GIS spatial analyses at the national level. The services at tier 3 were selected for more detailed analyses by different modelling methods. There are three services that are assessed in two tiers (VIII, X and XII); therefore, the number of ES assessed at different tiers do not correspond to the overall number (15) of ES assessed. For the study, the Common International Classification of Ecosystem Services (CICES) V.5.1 (Haines-Young and Potschin 2018) was used for the ES assessment.

ES indicators' quantification

ES indicators' quantification at tier 1

The indicators at tier 1 compensate for the lack of uniform data at the national level in Bulgaria. They are derived from ecosystems' spatial database and expert judgement. An expert-based assessment was applied for mapping the potential of NH to supply ES for recreation and tourism and the mapping was performed through a widely-used matrix approach. Twelve experts participated in the expert-based assessment by filling individual matrices for the potential of the NH to provide ES (Prodanova and Varadzhakova 2022). The number of experts is the same as in the ESPM, but their profile was slightly different as two of them were replaced by other persons in this assessment. The ecosystem subtypes derived from the CLC land-cover data (Hristova and Stoycheva 2021) were used as spatial units in the left column of the matrix. Nine priority ecosystem services were placed in the first row of the matrix. They were chosen, based on the analyses of the data (Nedkov et al. 2021b) available for quantification of the indicators at tier 2 and 3. The selected nine services were those with less available data; hence, the expert-based assessment remained the only possible method for mapping at the national level at this stage of the study. The experts were asked to score the potential of the NH to provide ES at the ecosystem subtype level. The profile of the experts is from five different fields and more details are given in table 3 in Prodanova and Varadzhakova (2022).

ES indicators' quantification at tier 2

The indicators at tier 2 relied on statistical data or biophysical parameters used to derive more complex indicators that were combined to estimate ES at the national level using GIS spatial analyses. Two services, *animals reared to provide energy* and *science and education value*, were quantified in this way. The information for both services is aggregated at a municipality level and integrated into the spatial dataset using GIS techniques. The indicator for *animals reared to provide energy* is the number of equines per municipality and the data are provided by the Ministry of Agriculture and Forestry. The indicators for *science and education values* are the number of publications (for science value) and the number of centuries-old trees (for education value), both of them calculated at the municipality level (Assenova et al. 2018).

ES indicators' quantification at tier 3

According to the methodological framework, the indicators at tier 3 are selected for more detailed analyses by modelling biophysical processes (Nedkov et al. 2021b). The biophysical modelling methods include several groups of approaches that come from ecology or other earth sciences fields, such as hydrology, climatology, soil science etc. (Vihervaara et al. 2019). The integrated modelling frameworks, such as InVEST and ESTIMAP, are recently-developed tools designed specifically for ES modelling and mapping that can assess trade-offs and scenarios for multiple services. The modelling methods are applicable predominantly at a local level due to their high demand for quality data. However, some indicators for the assessment of NH can be supplied by data also at a national level (Nedkov et al. 2021b). For this study, we managed to ensure appropriate datasets for the quantification of six ES by modelling approaches.

The **water for drinking purposes** ES integrates two CICES 5.1 classes: *surface water for drinking purposes* and *groundwater for drinking purposes*. The quantification is based on data about water bodies (surface and groundwater) and water sources (mineral water springs) which were processed in GIS to generate spatial data layers. The spatial proxy model, in this case, includes spatial analyses of proximity and overlay arranged in a specific algorithm to generate the spatial distribution and calculate the potential of the NH elements to provide this service.

The **regulation of natural hazards** ES is quantified using the modelling approach developed for flood regulation (Nedkov and Burkhard 2012, Nedkov et al. 2015). The results from flood regulation ES assessment, based on hydrological modelling in several watersheds, were used as a proxy to define the potential of land-cover classes to provide this service. The scores are based on indicators, such as surface run-off, peak flow and soil infiltration derived from the output of the GIS-based AGWA (Automated Geospatial Watershed Assessment) modelling tool (Miller et al. 2007). These scores are normalised to the 0 to 5 assessment scale and transposed to the ecosystem subtypes at a national level.

The **maintaining population and habitats** ES is quantified using two indicators: the hemeroby index and protected areas. The hemeroby index is a proxy of the naturalness of the area. Hemeroby is used in ecological studies to express the degree of human influence on ecosystems, the higher degree representing more harmful human influence (Szilassi et al. 2017). In our case, a lower degree of the index indicates well-preserved naturalness; hence, a higher potential for maintaining population and habitats. The existence of protected areas indicates additional efforts for the preservation of natural habitats. The different categories of the protected areas ensure a different level of protection; hence, the different potential for the provision of this ES. The highest scores are given to strict nature reserves, followed by national parks, nature parks, NATURA 2000 zones and protected sites. The calculation of the ES score was made using spatial overlay and map algebra GIS tools. Two GIS layers corresponding to the above-mentioned indicators were generated. Each of them is in a raster format and contains the scores from the assessment. The map algebra tool allows calculating the average score for each raster cell. Thus, the resulting layer contains the average score, based on the assessment from the two indicators.

The **local climate regulation ES** is considered in CICES 5.1 as *the regulation of temperature and humidity, including ventilation and transpiration* which is performed by the mediation of ambient atmospheric conditions by virtue of the presence of plants that improves living condition for people. Here, we consider this ES following the understanding of Goldenberg et al. (2021) as the potential of ecosystems to mitigate the urban heat island effect and dampen increasing temperatures and extreme events from future climate change. The concept of Local Climate Zones (LCZ) (Stewart and Oke 2012) is designed to reflect urban heterogeneity by taking into account factors such as morphology, surface cover and land use. It has already been used in the mapping and assessment of urban ES by developing an integrated index of spatial structure which enables defining of vegetation cover in urban ecosystems and assessing their condition as a part of the assessment framework (Nedkov et al. 2017). In this study, we use the World Urban Database and Access Portal Tools (WUDAPT) which ensures the acquisition, storage and dissemination of data on cities worldwide (Ching et al. 2018). In the LCZ classification scheme, the European Local Climate Zone map consists of 100 m spatial resolution zones. The input dataset (Demuzere et al. 2019) is a result of research that created a database of urban areas suitable for climate studies by using the computing power of GIS and the experience of creating city-by-city Land-Cover Zones using the standard WUDAPT. The input dataset was cut with the polygon borders of Bulgaria in QGIS so that further spatial analysis and maps could be produced.

The **condition for recreation** in CICES 5.1 is split into two service classes according to the source of the service provision: *condition for recreation by biotic systems* and *condition for recreation by abiotic systems*. The ESTIMAP recreation model provides a framework for a spatially-explicit assessment of local outdoor recreation (Zulian et al. 2013, Paracchini et al. 2014) which is an appropriate tool to ensure the estimation of this service. The model is adapted for application at a national level in Bulgaria by Ihtimanski et al. (2020). They propose additional indicators such as elevation and specify the data for the others to be applicable at the national level. The recreation potential modelled in ESTIMAP can be easily divided between the biotic and abiotic sources. The hemeroby index and natural protection are a function of the biotic systems and can be used to assess the *condition for recreation by biotic systems* ES. The water component and elevation are functions of the abiotic systems and can be used to assess the *condition for recreation by abiotic systems ES*. Thus, the outputs of the ESTIMAP recreation model were split into two different spatial layers representing the above-mentioned ES.

Modelling through InVEST provides a rapid way to value selected ES, such as **aesthetic experiences**. The InVEST module "Visitation: Recreation and Tourism" was applied in recent regional studies assessing the recreational-tourist potential in Bulgaria (Prodanova 2020, Hristova 2020) and in North Macedonia (Prodanova et al. 2022). Such modelling in InVEST can be used as an authentic indicator for the aesthetic experiences of people visiting NH sites due to its results being based on geo-tagged photographs derived from Flickr*[3]. The obtained results practically show the degree of popularity and respectively of the tourist visits in the selected area. The evidence of the popularity are the uploaded photos on Flickr. For the purposes of the study, a polygon with the borders of Bulgaria was set in the dialogue box of the module with the time period of 2005-2017.

Mapping NH potential to provide ES

The 15 priority ES were assessed using different methods and spatial units, as well as a different number of indicators. First, the results from indicators' quantification for each ES were integrated into a single layer. All datasets were converted into 50 m raster layers to ensure the correct spatial overlay. Thus, 15 layers with 50 m resolution representing the priority ES were generated. However, the importance of the different ES for recreation and tourism is not equal. Therefore, the results from the prioritisation were used to define weighted indices that represent these differences. The values of the weighted indices are given in Table 3. The map of the overall ES potential of the NH to provide ES at the national level was generated using the ArcGIS map algebra tool which enabled us to apply weighted overlay of the 15 ES raster layers.

Results

Mapping of ES provided by NH at national level in Bulgaria

The application of the multi-tiered approach enabled us to develop a GIS database containing layers for each of the 15 priority services (Suppl. material 2), as well as integrated layers about the overall potential and the potential of the main ES (provisioning, regulating and cultural). The GIS layers were used to prepare maps of ES provided by the NH in Bulgaria at the national scale (Fig. 3A-C). The main results present the overall potential of ecosystems in the country (Fig. 3D) which is the most important output directed to various practitioners in the recreation and tourism activities. The map shows that the areas with very high potential are almost evenly distributed across the country. They are scattered in polygons of various sizes. However, several clusters with a concentration of polygons with very high potential areas could be outlined. The largest one is located in the south-western part of the country within the high mountain areas of Rila, Pirin and Western Rhodopes. The second one covers areas in Central Stara Planina (Balkan Mountain) and Sredna Gora Mountain. There are also three other clusters in the Stara Planina located in its western and eastern parts. Two clusters are formed in the low mountain and hilly areas of Eastern Rhodopes and Strandzha. The last one is located in the lowland-hilly area of the Eastern Danube plain. The areas with very high potential cover 9578 km^2 which is about 9% of the country.

The areas with high potential cover about 24% of the country (Table 4) and their distribution shows a similar pattern as the very high potential. They form compact areas in the Western Rhodopes and Central Stara Planina Mountain and more or less scattered areas in the other mountains. The areas with moderate and low potential are predominant covering together almost half the country. The areas with very low potential are located predominantly in the lowland areas in the northern and south-eastern parts of the country comprising about 15% of its area. In general, the results show that almost the whole country has some kind of ES potential provided by the NH and only 4% are assessed as with no potential.

The maps of provisioning, regulating and cultural services visualise quite different patterns of ES potential throughout the country. The overall potential of the provisioning services (Fig. 3A) is quite low compared to the other two groups of services. The areas with higher potential for the provisioning services are located in the northern and south-eastern parts of the country where the topography is predominantly flat and the agricultural ecosystems are widespread. Regulating services have just the opposite pattern with higher potential in the southern and central mountainous areas (Fig. 3 B). Cultural services have higher overall potential with slightly higher values in the mountains (Fig. 3C).

ES potential of the tourist regions

The ES assessment of the NH for recreation and tourism enabled also the estimation of the ES potential per tourist region. We recalculated the overall ES scores for each tourist region estimating an average ES score as well as the distribution of the 0-5 scores. The average scores show quite similar results for all regions with figures ranging from 2.45 to 3.08 (Fig. 4). Two predominantly mountainous regions (Rila and Pirin and the Rhodopes) have the highest scores which exceed 3.0. In the third place is the Valley of the Roses region which comprises both mountainous and lowland areas in the central part of the country. The two Black Sea coast regions are in the “middle of the table” compared to the other regions. The Danube and Trace regions that occupy the areas with lower potential have also lower average scores. However, the region with the lowest average score is The Balkan which covers mainly mountainous areas.

In contrast to the relatively uniform average scores, the distributions of the 0-5 scores amongst the regions show quite different patterns. Each region has specific distribution and only the first two (Rila and Pirin and the Rhodopes) show a similar pattern in the distribution diagram with high and very high potential covering more than half of the area, moderate and low potential covering the rest, while the areas with 0 and 1 score have limited extent. The Danube Region has predominantly low and very low potential as they cover more than 75% of the area. The North Black Sea coast has a similar pattern with a slightly higher share of the area with moderate potential. This is in contrast with the South Black Sea coast which has a significantly higher share of the areas with high and very high potential than the North Black Sea coast.

Analysis of the ES potential results at different tiers

The results for the ES potential were obtained using various methods at three different tiers. From the methodological point of view, it is important to compare the results at different tiers. There are only two ES assessed by methods at tier 2 which is not enough for appropriate conclusions. Therefore, the analyses were made only for tier 1 and tier 3. The mapping results (in the form of GIS layers) were re-arranged into two groups corresponding to these tiers. The layers were processed to recalculate the ES potential derived from the method at different tiers. At tier 1, the scores for the nine ES from the expert assessment were recalculated to estimate mean values for each ES. Then, the mean values were normalised to the 0 to 5 assessment scale. At tier 3, there were seven layers produced by the different modelling methods. They were processed using the same procedure which was performed for the integrated layer of the overall ES potential. Thus, we had two resulting layers representing the results about ES potential, calculated using the methods at tiers 1 and 2. These scores could not be treated as another way to define the potential of the NH to provide ES. They are just for analysing the results at different tiers and to obtain data for discussion about their advantages and disadvantages from the methodological point of view. This enabled us to generate maps of the ES potential derived from methods at tier 1 and tier 3, as well as the differences between them (Fig. 5).

The two maps of the ES potential show a similar pattern which correlates relatively well with the overall ES map presented in Fig. 3. However, the differences in the actual scores are pronounced between the two maps. The areas of lower ES potential in the map of tier 1 are assessed mainly as 2 (low potential), while in the map of tier 3, their scores are mainly 1 (very low potential). The areas with no potential (score 0) are better represented on the map of tier 3, while on the tier 1 map, they are limited to smaller patches. The areas with very high potential are larger on the tier 1 map, while on the tier 3 map, they are smaller and more fragmented. Furthermore, areas of very high potential can be found also in areas where the tier 1 map indicates lower potential. The distribution of the areas with different ES potential is given in Table 5. It shows that the results from the two tiers coincide well only for the areas of moderate ES. The areas of very low and high potential are significantly higher in the tier 3 results, while the areas of low and very high potential are higher in the tier 1 results.

The comparison between the results obtained by methods at tier 1 and tier 3 were analysed by overlay between the two layers. First, the scores at tier 3 were recalculated to negative values. Then, an overlay procedure by a simple adding operation between the two layers was applied. Thus, in the areas where the scores are equal, the resulting value would be 0, in the areas where the tier 1 score exceeds the tier 2 score, the result will be a positive value between 1 and 5 depending on the excess value, in the areas with a higher score for tier 3, the result would be a negative value with the same gradient. The result of this procedure was a new layer presenting the differences in the scores between tier 1 and tier 3 (Fig. 5). The results show that, in 91% of the area, the scores are equal or differ by one unit (Fig. 6). The areas with excess higher than two units are negligible (below 1%). In general, the scores at tier 1 are higher as the areas where they exceed by one unit cover 42% percent of the studied area. The coincidence between the two scores is found for 36% of the area. The areas with an excess of tier 3 scores are located mainly in the mountains, while the tier 1 excess is mainly in the lowlands (Fig. 5).

Spatial data quality analysis at different tiers

Data availability and accuracy of the resulting ES maps are amongst the most important issues in the application of the tiered approach (Grêt-Regamey et al. 2015). The accuracy of the maps strongly depends on spatial resolution and the quality of both initial and intermediate data sources. Intermediate data sources in our study are the data layers generated as the result of different spatial analyses during the indicators' quantification stage of the study (see Fig. 2). The analysis of the spatial resolution of the data sources at different tiers would bring important information about the accuracy of the resulting maps and the uncertainty analyses of the ES scores. The main data source for assessment at tier 1 is the CLC dataset which was processed to generate the ecosystem subtypes layer. This layer contains the spatial units used in the expert assessment and it was used to analyse the data at tier 1. The statistical information at tier 2 is available at the municipality level; therefore, the municipality's outlines should be considered as spatial units for the mapping. The modelling approaches applied at tier 3 combine different data sources and, as a result of the modelling procedures, the output layers have different data characteristics. To compare the quality of the data at the different tiers, we combined the layers from the assessment of the different ES. The comparison of the data quality is made using four characteristics of the polygons from the resulting vector layers (Table 6). The spatial resolution of the resulting data at tier 3 is the highest, while at tier 2, it is much lower. The resolution at tier 1 is in the middle of the others.

The results of the ES layers generated at tier 3 significant differences in the spatial resolution (Table 7). The highest spatial resolution has the resulting data from the LCZ model applied for the assessment of the local climate regulation (ES VIII). The lowest resolution has the results from the assessment of the aesthetic value (ES IX) by the InVEST model. The results from ESTIMAP about recreation are comparable to the spatial proxy methods applied for regulation of natural hazards (ES VI) and maintaining population and habitats (ES VII).

Discussion

The ES assessment at a national level

The assessment of multiple ES at the national level is a challenging task because it necessitates a variety of data that should be available for the whole country and the application of various methods that requires a large team of experts with different expertise. This is possible only for large and well-funded projects that are not easy to be achieved. Even the ES matrix (which is easy and not resource-intensive) is more often used at the local and regional than at the national level (Campagne et al. 2020). The multi-tiered approach presented in this study ensured the mapping and assessment of 15 ES at a national scale and the integration of the results for the needs of one specific activity (tourism). The dataset which was developed during this study enables easy and fast generation of national scale maps for various purposes that can ensure further analyses to support the sustainable use of the NH for various tourism activities in the country. Particular examples are the studies on specific tourist activities, such as outdoor tourism (Ihtimanski et al. 2020), ski tourism (Silvestriev et al. 2021), forest therapy (Dodev et al. 2021) and speleological tourism (Nikolova et al. 2021b).

The results demonstrate that the NH of Bulgaria is a valuable resource that ensures the generation of various ES which are important for the development of tourism activities in the country. The areas with very high potential can be found throughout the country which proves the hypothesis behind tourism regionalisation which covers the whole country and distinguishes the regions depending on their specialisation. The clusters of very high potential correspond to six out of nine tourist regions. The Rhodopes Region contains two clusters and has also one of the highest overall ES potential scores. Stara Planina is the other region with two clusters, but its overall score is lower. The reason behind this difference could be explained by the more compact mountainous character of the Rhodopes Region and the high forest cover. Both mountain relief and forests cover stand out as the main factors for the high ES potential. Thus, the Stara Planina Region contains also some lowland areas with a higher anthropogenic impact which reduces the overall score of the region. Although the increase in the elevation tends to refer to an increase in the ES potential, the highest areas in Rila and Pirin are not assessed with the highest potential. In this case, the lack of forest in the alpine and subalpine areas is the factor for the decrease in the overall potential. This could be defined as one of the limitations of the approach that needs to be studied in more detail in the future. The application of some kind of a rapid assessment approach that exploits available datasets and triggers more detailed and disciplined specific studies on ecosystem condition indicators (Kokkoris et al. 2018) is needed.

The multi-tiered approach and the ES assessment of the NH

In this work, we develop and apply an approach for mapping and assessment of the NH as a source of ES for recreation and tourism. It is based on the multi-tiered approach proposed by Burkhard et al. (2018b) which relies on integrating different methods at different levels of detail and complexity. The authors state that it “can be applied to specific needs, data and resources availability”. The multi-tiered approach presented in this paper builds on the above-mentioned approach by developing its application one specific need, the assessment of NH for recreation and tourism. The results of its application at a national level in Bulgaria prove its applicability and potential to solve such a complex task. The main advantage of the approach is the possibility to assess various ES with different data availability and specifics which necessitates the application of different methods. This enables the development of NH tourism assessment beyond the usually assessed cultural services (such as outdoor recreation, cultural heritage and aesthetic experiences) to the relevant regulating (such as maintenance of habitats and local climate regulation) and provisioning services (such as water supply and crop production). Thus, the assessment of the ES potential for tourism can be better related to nature conservation which is crucial for the preservation of the NH and the achievement of sustainable tourism.

The integration of the ES matrix into the approach allows for the assessment of more ES, especially at tier 1, as it helps to overcome the limitations of data availability and the lack of proper proxies for quantification (Campagne et al. 2020, Prodanova and Varadzhakova 2022). At tier 3, we apply a combination of already proven and well-documented modelling tools such as InVEST and ESTIMAP with new modelling approaches developed for this study. The application of the LCZ model for the assessment of local climate regulation has a high potential as it relies on the freely-available Copernicus dataset and a tool for LCZ delineation which is applicable to all EU countries (Demuzere et al. 2019). The spatial proxy modelling approaches developed for two ES (water for drinking purposes and maintaining of population and habitats) rely on spatial analysis techniques available in the main GIS software packages (such as ArcGIS and QGIS) and easily-available spatial data. Thus, they can be applied in various areas for studies with limited resources.

The use of the multi-tiered approach

The multi-tiered approach was applied predominantly at different levels of scales. The most representative example is provided by Grêt-Regamey et al. (2015) by tier 1 at the continental level, tier 2 at the national level and tier 3 at the local level. In our study, the three tiers are applied at the national which gives the opportunity to compare the results obtained by methods at different tiers. The comparison between the results from the expert-based assessment at tier 1 and the more complex modelling methods at tier 3 shows differences that rarely exceed 1 unit on a 0 to 5 scale. Therefore, the results at these two tiers have a general agreement and the modelling results can be considered as a validation of the expert assessment. The deviations from this general agreement show that the expert-based assessment gives slightly higher scores. One possible explanation could be in some kind of exaggeration of the NH by the experts. They have been asked to evaluate the potential of the NH and this term refers to something valuable. Furthermore, the experts evaluate ecosystems defined from land-cover data. For instance, they give a very high score to the deciduous forest and this score is transferred to all such forests in the dataset, which is an inherent limit of the expert-based matrix as discussed in many papers (Jacobs and Burkhard 2017, Campagne et al. 2020). However, the modelling methods at tier 3 rely on more indicators that reveal the inherent heterogeneity of the forest and different scores according to this heterogeneity.

The spatial data resolution at the different tiers can be used as an indicator of the data quality and consequently of the accuracy of the results. The spatial resolution of the tier 2 data is quite low due to the specifics of the data which is available at the municipality level. The multi-tiered approach could be further developed by considering the specifics of the ecosystem types, especially the necessity of finer-scale mapping of urban and freshwater ecosystems. As Haase et al. (2014) mentioned, scales appropriate for urban ecosystem analysis need to be developed. On the other hand, mapping at a national scale necessitates easily-accessible open data instead of the more precise, but resource-intensive unmanned aerial vehicle data. The Copernicus data provides appropriate means and new opportunities for the assessment of urban areas (Sarafova 2021). There is also a lack of more detailed data for some ecosystem types, such as sparsely vegetated and shrublands. Recent habitat mapping studies (Grigorov et al. 2021) provide some data, but further studies are needed.

Conclusions

The multi-tiered approach for ES mapping and assessment developed to facilitate the MAES process in the EU countries considers different levels of details and complexity and can be applied according to specific needs, data and resources availability (Burkhard et al. 2018b). In this work, we developed the methodology for the specific need for mapping and assessment of the NH as a source of ES for recreation and tourism. Our multi-tiered approach is applicable on a national scale and solves the problem of data availability limitations for various ES. The conceptual scheme of the study demonstrated how the MAES framework can be adapted to the specific needs of the work and to arrange the methods in an appropriate algorithm for spatial data analyses. This algorithm ensures the optimal quality of the results using the available data and resources. Instead of an expert-based assessment for all services which is easier, but less accurate, the proposed approach provided the means how to define more precise indicators, based on statistical data or models where possible. The application of the proposed approach enabled us to map and assess the potential of the NH at a national level to provide ES for recreation and tourism in high detail. The results showed that the NH of Bulgaria is a valuable source of ES which are well presented in most parts of the country. The areas with very high potential form several clusters that correspond to the country's tourist regions. The Rhodopes, Rila and Pirin and the Valley of the Roses regions are distinguished by higher ES potential. In general, the mountain areas have higher potential, but the correlation between the elevation and the potential is not linear. The main factor for the high ES potential is the forest cover which is high in the mountain areas, but decreases to the alpine and subalpine belt of the higher mountains. The study provides appropriate data for analyses of the methods' performance at different tiers. The results from the expert-based assessment at tier 1 and the more complex modelling methods at tier 3 are comparable with a slight excess of tier 1 scores. Further studies are needed to confirm or deny this observation and find an appropriate explanation.

Funding program

This research was funded by the BG05M2OP001-1.001-0001 Project "Creation and development of "Heritage BG" Centre of Excellence", Operational Programme Science and Education for Smart Growth, Priority axis 1, Procedure BG05M2OP001-1.001, Component 4 "New technologies in creative and recreation industries".

Conflicts of interest

References

- Assenova M, Nedkov S, Assenov A, et al. (2018) Assessment and Mapping of cultural ecosystem services of urban ecosystems in Bulgaria. In: Marinov V, Vodenska M, Assenova M, Dogramadjieva E, et al. (Eds) Traditions and Innovations in Contemporary Tourism. Cambridge Scholars Publishing [ISBN ISBN:1-5275-0829-3].
- Burkhard B, Kroll F, Müller F, Windhorst W (2009) Landscapes capacities to provide ecosystem services - a concept for land-cover based assessments. Landscape Online 15: 1-22. https://doi.org/10.3097/LO.200915
- Burkhard B, Kroll F, Nedkov S, Müller F (2012) Mapping supply, demand and budgets of ecosystem services. Ecological Indicators 21: 17-29. https://doi.org/10.1016/j.ecolind.2011.06.019
- Burkhard B, Kandziora M, Hou Y, Müller F (2014) Ecosystem service potentials, flows and demands - concepts for spatial localisation, indication and quantification. Landscape Online V/ 34: 132. https://doi.org/10.3097/LO.201434
- Burkhard B, Maes J (Eds) (2017) Mapping Ecosystem Services. Pensoft, Sofia, 377 pp. https://doi.org/10.3897/ab.e12837
- Burkhard B, Santos-Martin F, Nedkov S, Maes J (2018a) An operational framework for integrated Mapping and Assessment of Ecosystems and their Services (MAES). One Ecosystem 3 https://doi.org/10.3897/oneeco.3.e22831
- Burkhard B, Maes J, Potschin-Young M, Santos-Martín F, Geneletti D, Stoev P, Kopperoinen L, Adamescu C, Adem Esmail B, Arany I, Arnell A, Balzan M, Barton D, van Beukering P, Bicking S, Borges P, Borisova B, Braat L, M Brander L, Bratanova-Doncheva S, Broekx S, Brown C, Cazacu C, Crossman N, Czúcz B, Daněk J, Groot Rd, Depellegrin D, Dimopoulos P, Elvinger N, Erhard M, Fagerholm N, Frélichová J, Grêt-Regamey A, Grudova M, Haines-Young R, Inghe O, Kallay T, Kirin T, Klug H, Kokkoris I, Konovska I, Kruse M, Kuzmova I, Lange M, Liekens I, Lotan A, Lowicki D, Luque S, Marta-Pedroso C, Mizgajski A, Mononen L, Mulder S, Müller F, Nedkov S, Nikolova M, Östergård H, Penev L, Pereira P, Pitkänen K, Plieninger T, Rabe S, Reichel S, Roche P, Rusch G, Ruskule A, Sapundzhieva A, Sepp K, Sieber I, Šmid Hribar M, Stašová S, Steinhoff-Knopp B, Stępniewska M, Teller A, Vackar D, van Weelden M, Veidemane K, Vejre H, Vihervaara P, Viinikka A, Villoslada M, Weibel B, Zulian G (2018b) Mapping and assessing ecosystem services in the EU - Lessons learned from the ESMERALDA approach of integration. One Ecosystem 3 https://doi.org/10.3897/oneeco.3.e29153
- Campagne CS, Roche P, Müller F, Burkhard B (2020) Ten years of ecosystem services matrix: Review of a (r)evolution. One Ecosystem 5 https://doi.org/10.3897/oneeco.5.e51103
- Ching J, Mills G, Bechtel B, See L, Feddema J, Wang X (2018) WUDAPT: An urban weather, climate, and environmental modeling infrastructure for the anthropocene. Bulletin of the American Meteorological Society 99 (9). https://doi.org/10.1175/BAMS-D-16-0236.1

- Council of the European Union (1992) Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal of the European Communities. URL: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:31992L0043
- Demuzere M, Bechtel B, Middel A, Mills G (2019) Mapping Europe into local climate zones. PLoS One 14 (4). https://doi.org/10.1371/journal.pone.0214474
- Directorate-General for Environment (European Commission), et al. (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. 1st MAES report. Publications office of the European Union, Luxembourg. https://doi.org/10.2779/12398
- Directorate-General for Environment (European Commission), et al. (2014) Mapping and Assessment of Ecosystems and their Services. Indicators for ecosystems assessments under action 5 of the EU biodiversity strategy to 2020. 2nd MAES report. Publications office of the European Union, Luxembourg. https://doi.org/10.2779/75203
- Dodev Y, Zhiyanski M, Glushkova M, Borisova B, Semerdzhieva L, Ihtimanski I, Dimitrov S, Nedkov S, Nikolova M, Shin W (2021) An integrated approach to assess the potential of forest areas for therapy services. Land 10 (12). https://doi.org/10.3390/land10121354
- Goldenberg R, Kalantari Z, Destouni G (2021) Comparative quantification of local climate regulation by green and blue urban areas in cities across Europe. Scientific Reports 11 (1). https://doi.org/10.1038/s41598-021-03140-y
- Grêt-Regamey A, Weibel B, Kienast F, Rabe S, Zulian G (2015) A tiered approach for mapping ecosystem services. Ecosystem Services 13: 16-27. https://doi.org/10.1016/j.ecoser.2014.10.008
- Grigorov B, Velev N, Assenov A, Nazarov M, Gramatikov M, Genova B, Vassilev K (2021) Shrubland habitats in Dragoman municipality: a case study from western Bulgaria. Journal of the Bulgarian Geographical Society 44: 21-24. https://doi.org/10.3897/jbgs.e66377
- Haase D, Larondelle N, Andersson E, Artmann M, Borgström S, Breuste J, Gomez-Baggethun E, Gren Å, Hamstead Z, Hansen R, Kabisch N, Kremer P, Langemeyer J, Rall EL, McPhearson T, Pauleit S, Qureshi S, Schwarz N, Voigt A, Wurster D, Elmqvist T (2014) A quantitative review of urban ecosystem service assessments: Concepts, models, and implementation. AMBIO 43 (4): 413-433. https://doi.org/10.1007/s13280-014-0504-0
- Haines-Young R, Potschin M (2018) Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure. URL: www.cices.eu
- Hölting L, Beckmann M, Volk M, Cord A (2019) Multifunctionality assessments – More than assessing multiple ecosystem functions and services? A quantitative literature review. Ecological Indicators 103: 226-235. https://doi.org/10.1016/j.ecolind.2019.04.009
- Hristova D (2020) Assessment of the recreation potential in Smolyan municipality through gis-based modelling. In: K N (Ed.) Geography and regional development. "LOPS" Foundation, Sozopol, 47-54 pp. [In Bulgarian]. URL: https://lopsbg.com/wp-content/uploads/2021/01/GRD_2020_Hristova_D_Foundation-LOPS.pdf [ISBN 978-619-91670].
- Hristova D, Stoycheva V (2021) Mapping of ecosystems in Bulgaria for the needs of natural heritage assessment. Journal of the Bulgarian Geographical Society 45: 89-98. https://doi.org/10.3897/jbgs.e76457

- Ihtimanski I, Nedkov S, Semerdzhieva L (2020) Mapping the natural heritage as a source of recreation services at national scale in Bulgaria. One Ecosystem 5 https://doi.org/10.3897/oneeco.5.e54621
- Jacobs S, Burkhard B (2017) Applying expert knowledge for ecosystem services quantification . In: Burkhard B, Maes J (Eds) Mapping Ecosystem Services. Pensoft Publishers, Sofia
- Kokkoris I, Dimopoulos P, Xystrakis F, Tsiripidis I (2018) National scale ecosystem condition assessment with emphasis on forest types in Greece. One Ecosystem 3 https://doi.org/10.3897/oneeco.3.e25434
- Lankia T, Kopperoinen L, Pouta E, Neuvonen M (2015) Valuing recreational ecosystem service flow in Finland. Journal of Outdoor Recreation and Tourism 10: 14-28. https://doi.org/10.1016/j.jort.2015.04.006
- Mallarach JM, Verschuuren B (2019) Changing concepts and values in natural heritage conservation: A view through IUCN and UNESCO policies. In: Avrami E, Macdonald S, Mason R, Myers D (Eds) Values in Heritage Management: Emerging Approaches and Research Directions;. The Getty Conservation Institute, Los Angeles, CA, USA. URL: https://www.getty.edu/publications/heritagemanagement/part-two/10/
- Miller SN, Semmens DJ, Goodrich DC, Hernandez M, Miller RC, Kepner WG, Guertin DP (2007) The Automated Geospatial Watershed Assessment tool. Environmental Modelling & Software 22 (3): 365-377. https://doi.org/10.1016/j.envsoft.2005.12.004
- Müller F, Burkhard B (2012) The indicator side of ecosystem services. Ecosystem Services 1 (1): 26-30. https://doi.org/10.1016/j.ecoser.2012.06.001
- Naidoo R, Balmford A, Costanza R, Fisher B, Green RE, Lehner B, Malcolm TR, Ricketts TH (2008) Global mapping of ecosystem services and conservation priorities. Proceedings of the National Academy of Sciences 105 (28): 9495-9500. https://doi.org/10.1073/pnas.0707823105
- Nedkov S, Burkhard B (2012) Flood regulating ecosystem services—Mapping supply and demand, in the Etropole municipality, Bulgaria. Ecological Indicators 21: 67-79. https://doi.org/10.1016/j.ecolind.2011.06.022
- Nedkov S, Boyanova K, Burkhard B (2015) Quantifying, modelling and mapping ecosystem services in watersheds. Ecosystem Services and River Basin Ecohydrology133-149. https://doi.org/10.1007/978-94-017-9846-4_7
- Nedkov S, Zhiyanski M, Dimitrov S, Borisova B, Popov A, Ihtimanski I, Yaneva R, Nikolov P, Bratanova-Doncheva S (2017) Mapping and assessment of urban ecosystem condition and services using integrated index of spatial structure. One Ecosystem 2: 14499. https://doi.org/10.3897/oneeco.2.e14499
- Nedkov S, Mitova R, Nikolova M, Borisova B, Hristova D, Semerdzhieva L, Zhiyanski M, Prodanova H (2021a) Prioritization of ecosystem services related to the natural heritage of Bulgaria. Journal of the Bulgarian Geographical Society 45: 19-30. https://doi.org/10.3897/jbgs.e73687
- Nedkov S, Borisova B, Nikolova M, Zhiyanski M, Dimitrov S, Mitova R, Koulov B, Hristova D, Prodanova H, Semerdzhieva L, Dodev Y, Ihtimanski I, Stoyanova V (2021b) A methodological framework for mapping and assessment of ecosystem services provided by the natural heritage in Bulgaria. Journal of the Bulgarian Geographical Society 45: 7-18. https://doi.org/10.3897/jbgs.e78680

- Nikolova M, Nojarov P, Nedkov S (2021a) National natural heritage at risk: The Seven Rila Lakes. Journal of the Bulgarian Geographical Society 45: 67-80. https://doi.org/10.3897/jbgs.e78709
- Nikolova M, Stoyanova V, Varadzhakova D, Ravnachka A (2021b) Cultural ecosystem services for development of nature-based tourism in Bulgaria. Journal of the Bulgarian Geographical Society 45: 81-87. https://doi.org/10.3897/jbgs.e78719
- Nikolova M, Nedkov S, Borisova B, Zhiyanski M, Dimitrov S (2021c) Natural heritage as a source of ecosystem services for recreation and tourism in Bulgaria. Journal of the Bulgarian Geographical Society 45: 3-6. https://doi.org/10.3897/jbgs.e79485
- Norman J, Annerstedt M, Boman M, Mattsson L (2010) Influence of outdoor recreation on self-rated human health: comparing three categories of Swedish recreationists. Scandinavian Journal of Forest Research 25 (3): 234-244. https://doi.org/10.1080/02827581.2010.485999
- Paracchini ML, Zulian G, Kopperoinen L, Maes J, Schägner JP, Termansen M, Zandersen M, Perez-Soba M, Scholefield P, Bidoglio G (2014) Mapping cultural ecosystem services: A framework to assess the potential for outdoor recreation across the EU. Ecological Indicators 45: 371-385. https://doi.org/10.1016/j.ecolind.2014.04.018
- Prodanova H (2020) A conceptual model for investigation of the geoecological state of the landscapes and their capacity to provide ecosystem services. In: K N (Ed.) Geography and regional development. "LOPS" Foundation, Sozopol, 15-22 pp. [In Bulgarian]. URL: https://lopsbg.com/wp-content/uploads/2020/12/GRD_2020_Prodanova_H.pdf [ISBN 978-619-91670].
- Prodanova H (2021) Experimental mapping and assessment of ecosystem services based on multi-level landscape classification. Journal of the Bulgarian Geographical Society 45: 31-39. https://doi.org/10.3897/jbgs.e78692
- Prodanova H, Varadzhakova D (2022) How individual scores affect the final expert-based assessments of ecosystem services: Range and mean scores analysis of natural heritage supply maps. European Journal of Geography 13 (4): 74-97. https://doi.org/10.48088/ejg.h.pro.13.4.074.097
- Prodanova H, Petkova G, Stoyanova E (2022) Modeling of the recreational potential of the Poreche region in the Republic of North Macedonia. Geograf 6: 77-90. [In Bulgarian]. URL: https://www.researchgate.net/publication/359930044
- Rendon P, Steinhoff-Knopp B, Burkhard B (2022) Linking ecosystem condition and ecosystem services: A methodological approach applied to European agroecosystems. Amsterdam [u.a.] : Elsevier https://doi.org/10.15488/12507
- Roche PK, Campagne CS (2017) From ecosystem integrity to ecosystem condition: a continuity of concepts supporting different aspects of ecosystem sustainability. Current Opinion in Environmental Sustainability 29: 63-68. https://doi.org/10.1016/j.cosust.2017.12.009
- Sarafova E (2021) How green the urban development units in Sofia are: Earth observation and population time series analysis. Journal of the Bulgarian Geographical Society 44: 25-37. https://doi.org/10.3897/jbgs.e69814
- Semerdzhieva L, Borisova B (2021) Urban ecosystems assessment: An integrated approach to maintenance of habitats and their biodiversity. Journal of the Bulgarian Geographical Society 45: 99-106. https://doi.org/10.3897/jbgs.e78975

- Silvestriev M, Borisova B, Mitova R (2021) Natural heritage: Provision of cultural ecosystem services from the Malyovitsa Range of the Rila National Park. Journal of the Bulgarian Geographical Society 45: 41-59. https://doi.org/10.3897/jbgs.e72500
- Stewart ID, Oke TR (2012) Local climate zones for urban temperature studies. Bulletin of the American Meteorological Society 93 (12): 1879-1900. https://doi.org/10.1175/bams-d-11-00019.1
- Szilassi P, Bata T, Szabó S, Czúcz B, Molnár Z, Mezősi G (2017) The link between landscape pattern and vegetation naturalness on a regional scale. Ecological Indicators 81: 252-259. https://doi.org/10.1016/j.ecolind.2017.06.003
- UNESCO (1972) Convention concerning the protection of the world cultural and natural heritage. Standard-Setting at UNESCO URL: http://whc.unesco.org/en/conventiontext/.
- 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 https://doi.org/10.3897/oneeco.4.e26368
- Weibel B, Rabe S, Burkhard B, Grêt-Regamey A (2018) On the importance of a broad stakeholder network for developing a credible, salient and legitimate tiered approach for assessing ecosystem services. One Ecosystem 3 https://doi.org/10.3897/oneeco.3.e25470
- Zhiyanski M, Glushkova M, Dodev Y, Bozhilova M, Yaneva R, Hristova D, Semerdzhieva L (2021) Role of the cultural ecosystem services provided by natural heritage in forest territories for sustainable regional development. Journal of the Bulgarian Geographical Society 45: 61-66. https://doi.org/10.3897/jbgs.e72766
- Zulian G, Paracchini M, Maes J, Liquete C, et al. (2013) ESTIMAP: Ecosystem services mapping at European scale. European Commission. https://doi.org/10.2788/64369

Endnotes

*1 http://www.esmeralda-project.eu/
*2 https://www.nasledstvo.bg/en/about-project/
*3 https://www.flickr.com/

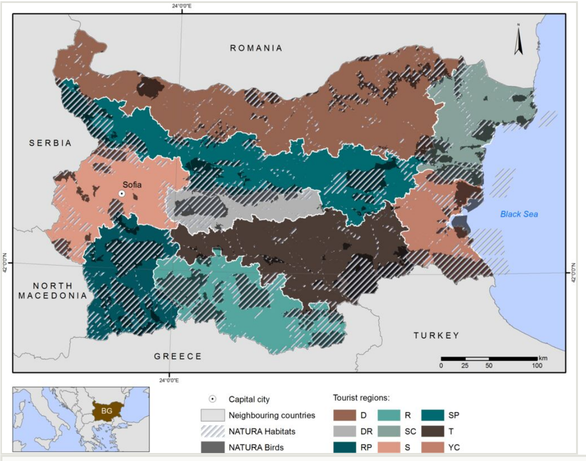

Figure 1.

Case study area. Tourist regions: D - Dunav (The Danube); DR - Dolina na Rozite (Valley of the Roses); RP - Rila and Pirin; R - Rodopi (The Rhodopes); SC - Severno Chernomorie (North Black Sea coast); S - Sofia; SP - Stara Planina (The Balkan); T - Trakia (Thrace); YC - Yuzhno Chernomorie (South Black Sea coast).

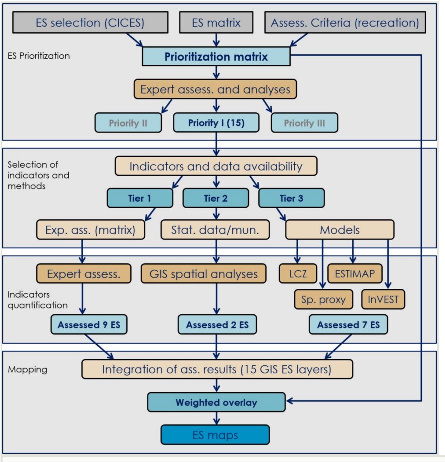

Figure 2.

Conceptual scheme of the multi-tiered approach. The four boxes in the scheme correspond to the four subsections below.

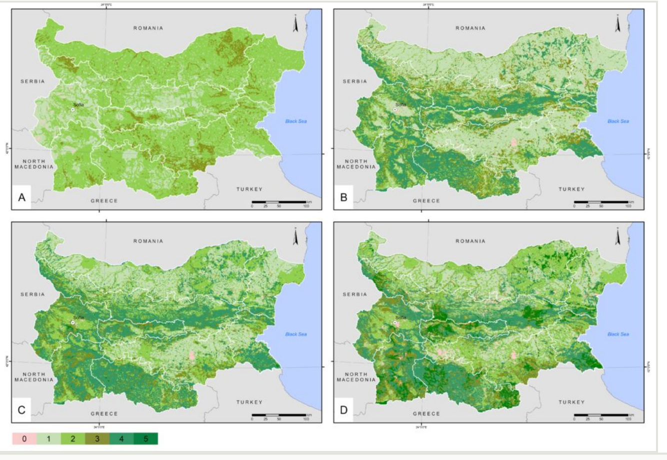

Figure 3.

Potential of the natural heritage to provide ES. A - provisioning, B - regulating, C - cultural, D - overall. 0 - no potential; 1 - very low potential; 2 - low potential; 3 - moderate potential; 4 - high potential; 5 - very high potential.

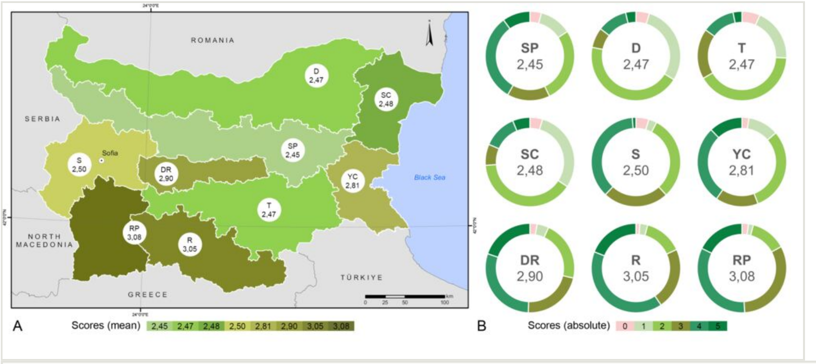

Figure 4.

Potential of the tourist regions to provide ES. A - Mean potential of the tourist regions to provide ES, B - Distribution of the potential scores within the tourist regions by area. Tourist regions: D - Dunav (The Danube); DR - Dolina na Rozite (Valley of the Roses); RP - Rila and Pirin; R - Rodopi (The Rhodopes); SC - Severno Chernomorie (North Black Sea coast); S - Sofia; SP - Stara Planina (The Balkan); T - Trakia (Thrace); YC - Yuzhno Chernomorie (South Black Sea coast).

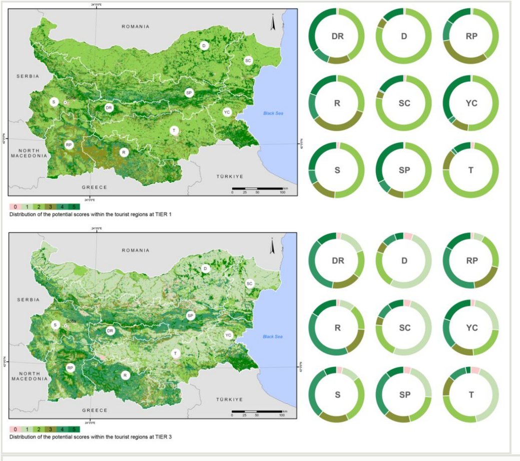

Figure 5.

ES potential and the differences at tier 1 and tier 3. Tourist regions: D - Dunav (The Danube); DR - Dolina na Rozite (Valley of the Roses); RP - Rila and Pirin; R - Rodopi (The Rhodopes); SC - Severno Chernomorie (North Black Sea coast); S - Sofia; SP - Stara Planina (The Balkan); T - Trakia (Thrace); YC - Yuzhno Chernomorie (South Black Sea coast).

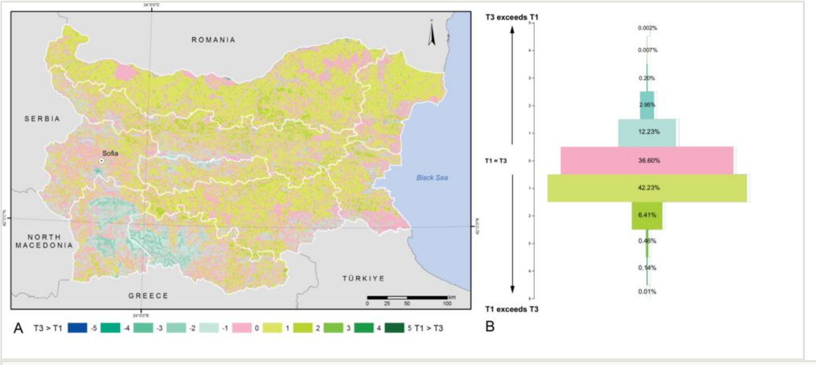

Figure 6.

Comparison between tier 1 and tier 3. A - Spatial distribution of a negative image between both layers where T3 exceed T1 and vice versa, B - % of the whole area.

Table 1.

Data sources used for quantification and mapping of ES (for the numbers of ES, see Table 2). E.A. – expert assessment; Ec. – ecosystem subtype; Stat. – analysis of statistical data; Mun. – municipality; Sp. Pr. – spatial proxy model; Var. – various spatial units.

Data type	**Dataset**	**Used in ES assessment**	**Used for method**	**Source**
Land cover	CLC 2018	I, II, V, VIII, X, XI, XII, XIII, XV	E.A.	Copernicus dataset
Rivers	JICA dataset	IV	Sp. Pr.	The study on integrated water management in the Republic of Bulgaria – MOEW by Japan International Cooperation Agency (JICA)
Mineral water	Mineral water	IV	Sp. Pr.	NIGGG digital archive
Ground water	JICA dataset	IV	Sp. Pr.	The study on integrated water management in the Republic of Bulgaria – MOEW by Japan International Cooperation Agency (JICA)
Number of reared animals	Registry of domestic animals in BG	III	Stat.	Ministry of agriculture and forests
DEM 50m	JICA dataset	VI	Sp. Pr.	The study on integrated water management in the Republic of Bulgaria – MOEW by Japan International Cooperation Agency (JICA)
Soil data	Soil data archive	VI	Sp. Pr.	Ministry of Agriculture and Forests
Local climate zones	World Urban Database and (WUDAPT)	VIII	LCZ model	LCZ dataset
Nationally designated areas (CDDA)	CDDA (ArcGIS geodatabase file)	IX	ESTIMAP	EEA dataset
Bathing water quality (European Environment Agency - EEA)	Bathing Water Directive - Status 1990 - 2018	IX	ESTIMAP	EEA Dataset
Urban areas in Republic of Bulgaria	JICA dataset	XIV	ESTIMAP	The study on integrated water management in the Republic of Bulgaria – MOEW by Japan International Cooperation Agency (JICA)
The road network in Republic of Bulgaria	JICA dataset	XIV	ESTIMAP	The study on integrated water management in the Republic of Bulgaria – MOEW by Japan International Cooperation Agency (JICA)

Table 2.

Indicators and methods at different Tiers. E.A. – expert assessment; Ec. – ecosystem subtype; Stat. – analysis of statistical data; Mun. – municipality; Sp. Pr. – spatial proxy model; Var. – various spatial units.

№	Ecosystem Services	n Indicators	Tier 1		Tier 2		Tier 3	
			Method	Sp.unit	Method	Sp.unit	Method	Sp.unit
I	Cultivated plants and animals used for nutrition	1	E.A.	Ec.				
II	Wild plants used for nutrition	1	E.A.	Ec.				
III	Animals reared to provide energy	1			Stat.	Mun.		
IV	Water for drinking	3					Sp. Pr.	Var.
V	Regulation of pollution and other harmful impacts	1	E.A.	Ec.				
VI	Regulation of natural hazards	1					Sp. Pr.	Var.
VII	Maintaining populations and habitats	2					Sp. Pr.	Var.
VIII	Local climate regulation	1	E.A.	Ec.			LCZ model	Var.
IX	Conditions for recreation by biotic systems	2					ESTIMAP	Var.
X	Science and education value	2	E.A.	Ec.	Stat.	Mun.		
XI	Cultural heritage	1	E.A.	Ec.				
XII	Aesthetic experiences	2	E.A.	Ec.			InVEST	
XIII	Symbolic and spiritual value by biotic systems	1	E.A.	Ec.				
XIV	Conditions for recreation by abiotic systems	2					ESTIMAP	Var.
XV	Symbolic and spiritual value by abiotic systems	1	E.A.	Ec.				

Table 3.

Weighted indices for mapping of the overall ES potential.

№	Ecosystem Services	Weighted index
I	Cultivated plants and animals used for nutrition	0.6
II	Wild plants used for nutrition	0.7
III	Animals reared to provide energy	0.6
IV	Water for drinking	0.8
V	Regulation of pollution and other harmful impacts	0.7
VI	Regulation of natural hazards	0.6
VII	Maintaining populations and habitats	0.8
VIII	Local climate regulation	0.6
IX	Conditions for recreation by biotic systems	1
X	Science and education value	0.8
XI	Cultural heritage	1
XII	Aesthetic experiences	1
XIII	Symbolic and spiritual value by biotic systems	1
XIV	Conditions for recreation by abiotic systems	0.9
XV	Symbolic and spiritual value by abiotic systems	1

Table 4.
Statistics of the ES scores.

ES score	n/area/%	Provisioning	Regulating	Cultural	Overall
0	n poly	1104	2198	1561	4960
	area km^2	573	1242	1023	4552
	%	0.5	1.1	0.9	4
1	n poly	12439	17273	6964	10948
	area km^2	24096	45147	24017	16594
	%	22	41	22	15
2	n poly	4780	84767	14801	19755
	area km^2	77525	21638	29883	34687
	%	70	20	27	32
3	n poly	6810	102418	12708	20025
	area km^2	8798	16281	10483	18174
	%	8	15	10	17
4	n poly	0	15215	6682	13132
	area km^2	0	26501	32611	26070
	%	0	24	30	24
5	n poly	0	1	2150	6606
	area km^2	0	0.01	11640	9578
	%	0	0.0	11	9

Table 5.
ES scores calculated at tier 1 and tier 3.

ES score	n/area/%	Tier 1	Tier 3
0	n poly	1639	13358
	area km^2	1255	4484
	%	1	4
1	n poly	125	40012
	area km^2	134	32999
	%	0.1	29
2	n poly	30615	72538
	area km^2	64415	23984
	%	58	21
3	n poly	13017	88667
	area km^2	15762	15350
	%	14	13
4	n poly	4091	53782
	area km^2	6448	23451
	%	6	21
5	n poly	5428	16146
	area km^2	22974	10772
	%	20	9

Table 6.

Spatial data characteristics of the resulting layers at the different tiers.

Parameter	Tier 1	Tier 2	Tier 3
n polygons	54910	264	284503
min. polygon area	0.01	44	0.006
max. polygon area	5451.5	1365.7	2552.1
mean polygon area	2.0	420.4	0.4

Table 7.
Spatial data characteristics of the resulting layers at tier 3.

Parameter	ES IV	ES VI	ES VII	ES VIII	ES IX	ES XII
n polygons	15894	36070	57590	180348	50485	7601
min. polygon area	0.002	0.0016	0.002	0.0001	0.0016	0.3
max. polygon area	11958.1	15464.4	24688.1	22981.5	27791.2	97039.9
mean polygon area	7.0	3.1	1.9	0.6	2.2	14.4

Supplementary materials

Suppl. material 1: Prioritization matrix

Authors: Nedkov S et al.
Data type: Table
Download file (413.26 kb)

Suppl. material 2: Priority ES maps of the NH potential

Authors: Nedkov S et al.
Data type: Pdf | maps
Download file (12.38 MB)