



## Habitat maintenance assessment and mapping as priority ecosystem service in mountain protected areas

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ecological condition, ecosystem services, habitat maintenance, MAES, mountain ecosystems, protected areas

### ABSTRACT

Habitat maintenance as an ecosystem service (ES) is essential for the protection of natural capital, however, it is among the most challenging services for definition and evaluation. The present study is focused on assessing and mapping habitat maintenance ecosystem service in Rila and Pirin Mountains in Bulgaria for strategic planning purposes by better understanding the link between the potential of providing this ecosystem service and biodiversity in five protected areas (PAs). An integrated approach for the assessment of the condition of ecosystems in PAs and their potential to provide ecosystem services was applied and further developed in the present study. The results showed that the conservation regime allowed the territories to preserve a high degree of naturalness in a very good ecological condition – 96477 ha (73%) of the total case-study area, and 33078 ha (77%) of the target PAs, respectively. The potential of ecosystems to provide habitat maintenance ES is high to very high for 84% of the total studied area (81258.9 ha) and for 96.4% (31906 ha) of the area of the target PAs. A current assessment and mapping show the role of protected areas as spatial natural capital assets that purposefully and actively support their prioritized habitat maintenance functions as spatial guarantors for the sustenance of rich packages of material, regulating, and cultural functions in significant geographic areas. The results demonstrate the importance of protected site management in mountain areas in ensuring sustainable cooperation and consumption of ecosystem services in peripheral mountain communities of the European Union highly dependent on available natural capital.

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### 1. Introduction

The concept of ecosystem services (ES) entered the international environmental discussion due to the increasing demands of humankind upon the limited resources of the earth, biodiversity loss, fragmentation and degradation of natural habitats, and the complex problem of energy and climate, considering the increasing anthropogenic pressure on ecosystems (Daily 1997; Costanza *et al.* 1997; de Groot *et al.* 2002; Díaz *et al.* 2015; Costanza 2020). It has dominated the debate on sustainable land use management since the Millennium Ecosystem Assessment (MEA 2005). Recently, ecosystem services approach became an important policy tool to protect biodiversity mainly concerning the global strategic plan 2011–2020 of the Convention on Biological Diversity (Aichi Biodiversity Targets) and their follow-up the EU Biodiversity Strategy 2030, making the efforts to face the challenge to maintain areas of high biodiversity value, to sustain and improve the ecological integrity of landscapes for the maintenance and enhancement of ecosystems and their services (Maes *et al.* 2014; Hermoso *et al.* 2022). The attractiveness of the ES concept is further emphasized by its integrative, interdisciplinary, and transdisciplinary character, as well as its link to environmental and socio-economic elements (Müller and Burkhard 2007).



Mountain ecosystems have an essential role in biodiversity conservation and are well known as “hot spots of biological diversity” at genetic, species, and ecosystem levels, encompassing a high diversity of ecosystem types, supplying a vast variety of provisioning, regulating, and cultural ES (Maes et al. 2011; Grêt-Regamey et al. 2012). They are considered significant “science labs” since mountain ecosystems are highly sensitive and vulnerable to climate change (Beniston 2003; Löffler et al. 2011).

The diversity of ecosystems, biotic associations, landscapes, ES, and biodiversity are often mentioned simultaneously (Ridder 2008; TEEB 2009). There is a numerous of evidence supporting a positive relationship between biodiversity, ecosystem functions, and the delivery of particular ecosystem services (Isbell et al. 2011; Egoh et al. 2012; Cardinale et al. 2012; Mace et al. 2012; Harrison et al. 2014; Duru et al. 2015; Soliveres et al. 2016; Pastur et al. 2016) stated that the highest capacity of ES provision is detected in semi-natural habitat types, rich in biodiversity, in good condition and absence of pressures (Manolaki and Vogiatzakis 2017). However, up to now, there is a lack of quantitative data linking ecosystem conditions to the ecosystem's potential capacity to deliver services (Erhard et al. 2016; Maes et al. 2016) but the existing datasets of biodiversity and anthropogenic pressures could be used to reveal this link (Maes et al. 2016).

“Maintenance of nursery populations and habitats” in the Common International Classification of Ecosystem Services (CICES) or “Habitats for species” in The Economics of Ecosystems and Biodiversity (TEEB) has a special place in the history of the emergence and development of the concept of ecosystem services and in the process of its establishment as a policy instrument for the protection of natural capital. It is among the most challenging services for definition and evaluation (Liquete et al. 2016). This service is a result of the specifics of the habitat functions of ecosystems and their role in the functioning of the natural environment. Habitat functions, as ecosystem services, refer to the natural processes and functions in an ecosystem that maintain and support the conditions necessary for the development of different species, contribute to the conservation of biological and genetic diversity, and sustain evolutionary processes. It plays a fundamental role in supporting other ecosystem services by ensuring that the basic building blocks of ecosystems remain healthy, diverse, and functional, supporting the benefits people derive from these ecosystems. Habitat functions feature prominently as supporting services in discussions of ecosystem service typologies (MEA 2005; TEEB 2010; CICES 2018).

The need for an approved scientific priority in the study of ecological integrity, sustainability of ecological processes, conservation of biological diversity, and reproduction processes in mountain ecosystems provokes the interest to assess and map habitat maintenance. But from the standpoint of the anthropocentric concept of ecosystem services, the interest is focused directly on a traceable, measurable, and understandable for decision-makers link between habitat maintenance as an environmental phenomenon and the real results as public benefits and human well-being. In this sense, it is a scientific responsibility to demonstrate the role of protected areas as geographically defined territories whose essential landscape functions of habitat maintenance in the face of changing environmental conditions and human activity are the primary sources of a spectrum of ecosystem services over a geographic area well beyond the extent of the protected site. In the case of protected mountain landscapes, these scientific facts carry even more significance. Ecosystem services mapping takes on the importance of universal language for visualizing scientific facts and addressing them to a very wide range of stakeholders and decision-makers.

Despite the challenges in monitoring this ecosystem service, its assessment in the context of climate change acquires additional significance which is related to the vulnerability of ecosystems in the adaptation process, with the potential danger of habitat loss (under the combined influence of anthropogenization and climatic change), and with the high dependence of the population on ecosystem functions and services, especially in mountainous territories. It is of particular interest in the mountains of the European deep periphery (Koulov 2018, 2020).

Habitat functions are categorized as “regulating and sustaining the life cycle” and contributing to “qualitative reproduction of species diversity” (Liquete et al. 2016). They provide suitable living space for wild plants and animals (refugium function) and create conditions to ensure the productivity of the ecosystem (nursery function) (de Groot et al. 2002). They are a mandatory prerequisite for the supply of provisioning ecosystem services (Haines-Young and Potschin 2018). The maintenance of habitats is a public necessity as they preserve the natural heritage and protect inherent human values (Burkhard et al. 2009). This is particularly true for the well-being of people in mountainous areas – territories that are highly and permanently vulnerable to socio-economic and climatic changes (Grêt-Regamey et al. 2012; Pătru-Stupariu et al. 2020). However, such targeted and informative research (Hatziziordanou et al. 2019) is still rare.

This study presents an approach for the assessment and mapping of habitat maintenance ecosystem service in mountain areas. It is applied in ecosystems representative of the Balkan Peninsula – Rila and Pirin Mountains in Bulgaria. The study analyzes the link between the biodiversity in selected protected areas and their habitat functions as ecosystem services. The research team approached with the understanding that the sustainable supply of ecosystem services is an integral part of scenarios for optimal management of mountain areas at the regional scale and for the optimization of quality of life. The results aim to demonstrate the importance of protected site management in mountain areas to ensure sustainable cooperation and consumption of ecosystem services in peripheral mountain communities of the European Union highly dependent on available natural capital. The immediate results here are addressed to extend information to decision-makers and encourage the motivation of local communities to maintain and manage protected habitats.

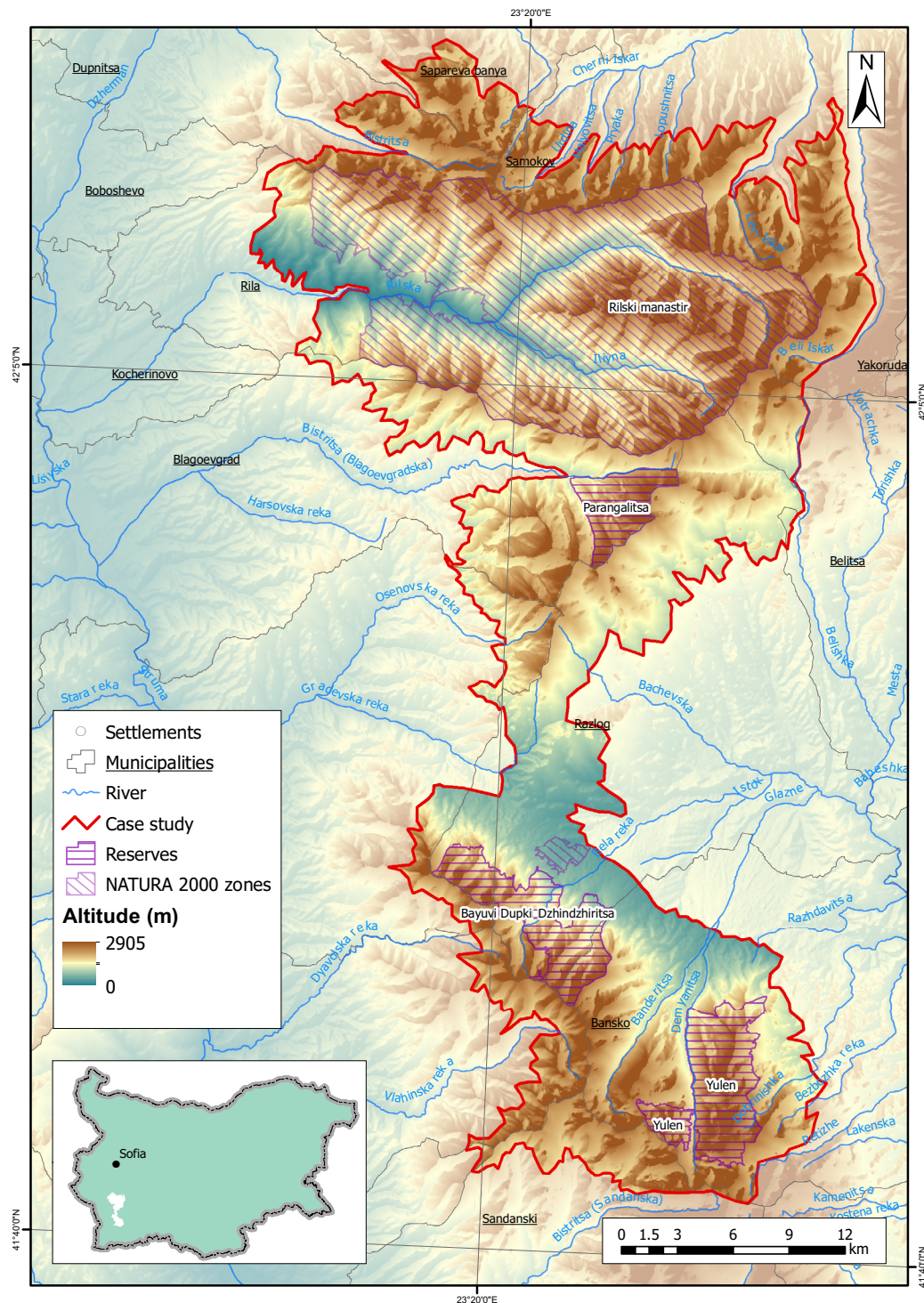
## 2. Materials and methods

### 2.1 Case study area

The case study covers the Rila Mountains (Mt Musala, 2925 m) and Pirin Mountains (Mt Vihren, 2914 m) in the southwestern part of Bulgaria: mountain systems with a distinctive alpine relief and a rich landscape spectrum, including azonal karst landscapes on marbles (Pirin). Their distinctive biodiversity and geodiversity are the basis for their management as protected sites of national importance – National Parks. The “Pirin” National Park has also been designated (in 1983) as a World Natural Heritage Site (UNESCO, World Heritage List), confirming the exceptional value of nature in the park. Mountain PAs are identified as main hotspots of biodiversity and they are configured and managed with the objective of maintaining or restoring ecological functions to conserve biodiversity while also providing appropriate opportunities for the sustainable use of natural resources (Bennett 2004). In order to successfully fulfill their functions, it is important to achieve maintenance of the ecological state of PAs in the entire network of protected areas (NPAs), and not of individual species, ecosystems, and/or genes (Prezioso et al. 2018).

The present study was conducted with a territorial scope of three Reserves (I category, IUCN) - “Bayuvi Dupki-Dzhindjiritsa”, “Yulen” and “Parangalitsa”, and two NATURA 2000 zones - BG0000626 “Krushe” and BG0000496 “Rila Monastery” (Fig. 1). The selected model territory contains a significant part of the flora found in the country, with centuries-old virgin spruce forests, unique forest communities dominated by subendemic tree species Macedonian pine (*Pinus peuce* Gris.) and Bosnian pine (*Pinus heldreichii* Crist.) and specific subalpine and alpine ecosystems and rare species habitats. The vegetation in the forest belts is

represented by some of the most typical and widely distributed coniferous forest species in Bulgaria – *Pinus sylvestris* L., *Pinus nigra* Arn. and *Abies alba* Mill. The vegetation in the subalpine belts is presented with typical plants *Pinus mugo* Turra and *Juniperus communis* L. The alpine vegetation belts are very well expressed and diverse and many endemic, subendemic, and rare species are found here. Many habitat types of conservation priority are also distributed here, such as 4070\* Bushes with *Pinus mugo* and *Rhododendron hirsutum*, 6210\* Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia),



**Figure 1.** Scope of the case study in Rila and Pirin Mts.

6230\* Species-rich *Nardus* grasslands, 91D0\* Bog woodland, 9530\* (Sub)-Mediterranean pine forests with endemic black pines, as well as many conservation significant taxa and species included in the Red Book of the Republic of Bulgaria.

The border of the case study was outlined using the contour lines derived from 50 m Digital Elevation Model (DEM) (generated from 1:50 000 topographic maps). In Rila, it follows predominantly the 1500 m contour line while in Pirin it varies from 1000 m in the north-eastern part to 1700 m in the western part. The elevation varies according to the location of the protected areas in the two mountains. The total area of the case study covers 96477.5 ha, while the protected territories are distributed over 33078.6 ha. The territory is drained by the tributaries of the Struma and Mesta rivers – transboundary rivers flowing into the Aegean Sea.

## 2.2 Methodology

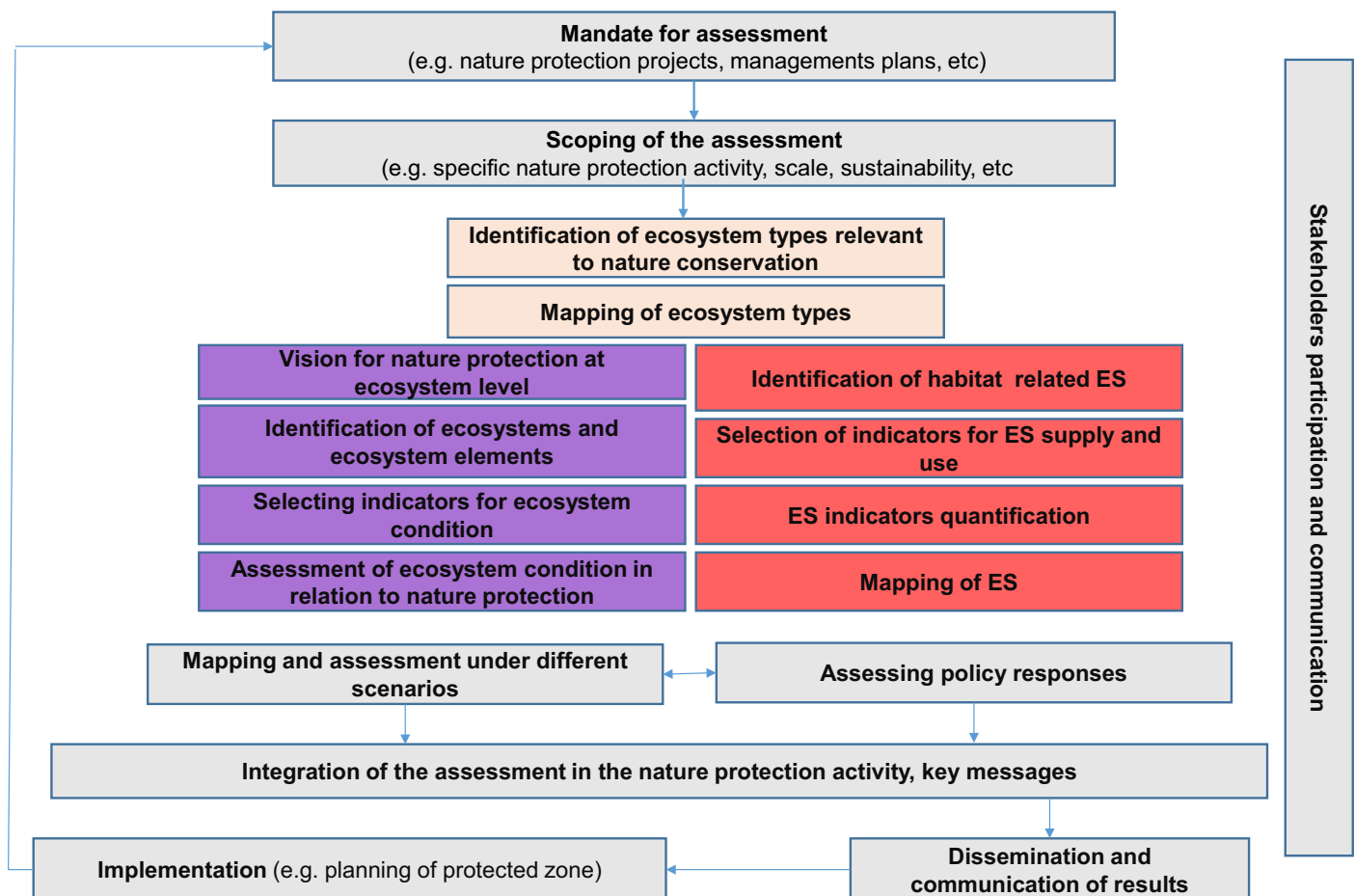
For this study we developed an integrated approach (Fig. 2) which is in line with Bulgarian experience in applying the analytical framework for Mapping and Assessment of Ecosystems and their Services (MAES) (Maes et al. 2013), both for national assessments in fulfillment with EU Biodiversity Strategy 2020 commitments (MetEcosMap project) and for follow-up up-to-date studies, reflecting the close relationship between Bulgarian natural heritage and ecosystem services (Nedkov et al. 2021). It includes mapping of ecosystem types, assessment of ecosystem conditions, and their

potential to provide habitat maintenance ES. The assessment is based on a set of indicators whose selection was influenced by discussions on ecosystem service valuation of habitat maintenance and methodological decisions applied in the study of Hatziiordanou et al. (2019). Arguments in support of an analytical framework for mapping and assessing ecosystem services (Maes et al. 2014, 2018), the results of which serve spatial analyses for territory management purposes, are also taken into consideration.

The conceptual scheme of the study includes the following main steps:

### 2.2.1. Identification and mapping of ecosystem types

The mapping of ecosystem types is based on the methodological approach which provides a coherent typology designed: (i) to be used for the different types of broad ecosystems and (ii) to be considered in the assessment to ensure consistency across the European Union member states (Maes et al. 2013). The typology is organized into two main levels applicable at the European scale. The first corresponds to major ecosystem categories (terrestrial, freshwater, and marine), and the second to nine ecosystem types (urban, agricultural, forests, grasslands, shrublands, sparsely vegetated land, wetlands, freshwater, marine) for mapping and assessment. Its structure enables CORINE Land Cover (CLC) data to be applied for spatial delineation by a reference table where each of the nine ecosystem types is linked with a particular CLC class. This typology is further developed in



**Figure 2.** Conceptual scheme of an integrated ecosystem-based assessment of the PAs in Bulgaria (based on Burkhard et al. 2018; Brown et al. 2018, Nedkov et al. 2021).



the methodological framework for mapping and assessment of ES in Bulgaria at the third level (subtypes) based on different sources for the nine ecosystem types (Bratanova-Doncheva et al. 2017). The mapping has been performed by seven projects covering by developing nine ecosystem databases, each of them corresponding the one of the main ecosystem types. However, the mapping does not cover the whole territory of the country and it excludes the NATURA 2000 areas. The case study area falls entirely within the NATURA 2000 zones, therefore a new mapping has to be made there. The forest inventory database from 2017 (Executive Forest Agency 2017) at the level of subdivisions was used to delineate the subtypes of the forest ecosystems and part of the other ecosystems such as grasslands and bare rocks which were incorporated into the inventory. For the areas outside the forest inventory area, CLC classes were correlated to the ecosystem subtypes to develop a relevance table (Hristova and Stoycheva 2021). The correlated classes were incorporated into the CLC GIS data and the resulting dataset is integrated with the data from the forest inventory.

### 2.2.2. Assessment and mapping of the condition of mountain ecosystems

The condition of ecosystems is considered a function of the contemporary structure of ecological units and the dominant processes in them under the combined influence of human activities (external interference in ecosystems, reflected by the application of the “hemeroby index”) and natural factors of ecological change (naturally occurring internal changes in forest ecosystems through expert analysis of the biophysical characteristics of forestry units).

The indicator “hemeroby index” was used to reveal the anthropogenic impact (Table 1, columns 1, 2, and 3). Such a choice is aimed both at reflecting the current state of the mountain areas, and the indication of potentially negative impact of land use/land cover change in neighboring territories. The indicator reflects the degree of deviation from potential natural vegetation caused by human activities – targeted or accidental. Hemeroby grows with increasing influence and is assessed by a scale in which the lowest values (ahemeroby) correspond to “natural” or undisturbed landscapes and habitats, and the highest values (metahemeroby) are awarded to completely disturbed or “artificial” landscapes and habitats (Steinhardt et al. 1999). The index is interpreted as a “degree of naturalness” of habitats and landscapes or as a measure of complex anthropogenic impact (Paracchini and Capitani 2011).

The ecological processes caused by climatic change and leading to adaptation of ecosystems are perceived as natural factors of change in the case study area. For the assessment and mapping, a sequential expert analysis was applied here: firstly, the relationship between the available ecological units in the study areas (Table 1, columns 4, 5, and 6). In the second stage – assessment of the relationship of the ecosystem subtype to a past or ongoing process of human intervention – by the hemeroby index.

The third stage – is the status of forestry units concerning the overall ecological status of the ecosystem subtypes in which they are located. For this control assessment, we used the results of an expert assessment of the ecological status of forest ecosystems in “Rila” NP and “Pirin” NP (Glushkova et al. 2023), which was carried out according to the methodology of Kostov et al. (2017), through a selection of indicators and their respective parameters (Table 2) on input data from the forest inventory (Executive Forest Agency 2017). The condition of the ecosystems was assigned with scores from 1 (bad condition) to 5 (very good condition), depending on the measured/assessed values of every indicator (by expert evaluation for each specific polygon). The Index of Performance (IP) for a particular ecosystem was used in order to collate all separate

indicator scores into one single measure of ecosystem structural-functional condition. The IP was calculated as the ratio of the sum of the indicator scores to the maximum possible indicator sum:  $IP = Sni/Sni(max)$ , where:  $Sni$  – the sum of the scores, assigned to every indicator, and  $Sni(max)$  – the sum of the maximum possible indicator (score 5) for every indicator. The IP takes values between 0 and 1, according to the following scale:  $IP = 0.00 \div 0.20$  – very bad condition;  $IP = 0.21 \div 0.40$  – bad condition;  $IP = 0.41 \div 0.60$  – moderate condition;  $IP = 0.61 \div 0.80$  – good condition;  $IP = 0.81 \div 1.00$  – very good condition. A total of 4297 polygons (forestry subunits) in “Rila” NP and 1635 polygons in “Pirin” NP were assessed.

In the final stage, the environmental status assessment (results from hemeroby index assessment, and control assessment of forest ecosystem condition) is summarized. The results are normalized to a five-point scale (Table 1, columns 7 and 8).

### 2.2.3 Assessment and mapping the potential of mountain ecosystems to provide ES habitat maintenance

CICES assigns habitat functions to services in the section “Regulating and supporting services” of biota using the formulations: group “Lifecycle maintenance, habitat, and gene pool protection”, classes “Maintaining nursery populations and habitats (Including gene pool protection)”, “Seed dispersal”, “Pollination” (Haines-Young and Potschin 2018). The current assessment uses the following short-term habitat maintenance and interprets it as the natural capacity of ecosystems, ensuring the provision to society of habitat-derived and habitat-dependent ecosystem services. The main arguments in support of this interpretation are: in natural aspects – the mountainous nature of the geographical environment, landscape diversity, and ecosystem representation, and in cultural aspects – the social importance of the areas of interest for this study and their protected status (five PAs: three Reserves (I category, IUCN) – “Bayuvi Dupki-Djindjiritsa”, “Yulen”, and “Parangalitsa”, and two NATURA 2000 zones – BG0000626 “Krushe” and BG0000496 “Rila Monastery”).

To assess the potential of the ecosystems to supply the ecosystem service habitat maintenance, the relationship between two indicators was applied: the conservation significance of the sites (through the designation of the sites, the conservation regime and management under the Protected Areas Act of the Republic of Bulgaria), and the current ecological status of the ecosystems within the sites (through the results of the condition assessment in the previous step 2) (Table 3). The names of the protected areas under Bulgarian legislation are indicated. The spatial overlap of sites with different designations within the scope of the study area is noted – for example, between NATURA 2000 protected areas and Nature Parks, as well as the full range of protected sites within the territorial scope of the “Rila” and “Pirin” National Parks. A 6-point rating scale was used (from 0 – no potential, to 5 – very high supply potential, Table 2). The scale is adopted from a widely applied approach to ecosystem service assessment, the Burkhard matrix (Burkhard et al. 2009), which facilitates outcome mapping and derived spatial analyses.

The mapping of the results of such assessments is in line with the methodological decisions and recommendations in the use of the Spatial Proxy Method for the assessment of ecosystem services (Maes et al. 2014). This method is based on indirect measurements which deliver a biophysical value in physical units, but these values need further interpretation or data processing (Vihervaara et al. 2018). In our case, the ecosystem subtypes are used as a spatial unit and the values of the indicators (as a proxy of habitat maintenance ES) are assigned to them in GIS: The values obtained from the assessments in steps 2 and 3 are assigned to the spatial units of the

**Table 1.** Ecosystem condition assessment as a prerequisite for providing habitat functions.

Hemeroby Index			Relativity between ecological units in the study area			Final assessment - ecological status of the ecosystem at the study site	
1	2	3	4	5	6	7	8
Score	Degree of naturalness	Description	MAES BG Ecosystem type (level 2)	Ecosystem subtype (level 3)	Forest division subtype	Description	Score
7	Artificial	Metahemerobic - Excessively strong human impacts	1. Urban	J7. Transport networks and other constructed hard-surfaced sites	road, parking	Artificial	1
6	Strange to natural	Polyhemerobic - Very strong human impacts	1. Urban	J10. Artificial water bodies and associated structures	water canal, page, fish pond		
5	Far from natural	Euhemerobic - Strong human impacts	1. Urban	J3. Residential and public low-density areas	courtyard	Far from natural, the condition depends on targeted anthropogenic maintenance	2
			1. Urban	J5. Urban green areas (incl. sports and leisure facilities)	skiing slope/ track		
			6. Sparsely vegetated land	H3. Inland cliffs, rock pavements, and outcrops	gully, bare ground		
4	Relatively far from the natural	Euhemerobic - Moderate - strong human impacts	4. Woodland and forest	G1. Broadleaved deciduous woodland	logging site, thinning of plantations		
3	Semi-natural	Mesoheemorobic - Moderate human impacts	4. Woodland and forest	G1. Broadleaved deciduous woodland	coppice forest plantation	Natural and semi-natural in moderate condition	3
			3. Grassland	E2. Mesic grasslands	meadow, firebreak		
2	Close to natural	Oligohemerobic - Weak human impacts	3. Grassland	E4. Alpine and subalpine grasslands	high mountain pasture, meadow	Natural in good condition, requiring attention	4
1	Natural	Ahemerobic - No disturbance	5. Heathland and shrub	F3. Temperate continental and Mediterranean-mountainous	dwarf pine	Natural in very good condition	5
			5. Heathland and shrub	F2. Arctic, alpine, and subalpine	bog, swamp		
			6. Sparsely vegetated land	H3. Inland cliffs, rock pavements, and outcrops	moraines, bare rocks, and cliffs, sipes		
			8. Rivers and lakes	C1.2. Constant non-tidal, fast, turbulent water currents	water area, lake, river		
			4. Woodland and forest	G1. Broadleaved deciduous woodland G3. Coniferous woodland	seed plantation		

**Table 2.** Assessment of the ecological status of forest ecosystems (after Kostov et al. 2017).

Indicator groups	Indicator	Parameter	Assessment scale				
			1	2	3	4	5
Ecosystem structure	Plant Diversity	Species composition (% mixed forest of the total stock of relevant species)	From 0 to 20% mixed	21-40	41-60	61-80	81-100
		Plantation dynamics, (% young forests from initial to optimal stage)	81-100	61-80	41-60	21-40	0-20
		Grass cover (% cover)	0-10; 91-100	11-20; 81-90	21-30; 71-80	31-40; 61-70	41-60
	Animal Diversity	Presence of species in the Red Data Book	0	Near Threatened	Threatened	Vulnerable	Endangered
	Habitat Diversity	Single/Multi-aged	100 % same-age	Young forests of different ages	Mature forests with regeneration	Two-storey, with the first floor being a mature timber stand	100 % of different ages
	Soil heterogeneity	Soil status – fertility, Pogrebnik scale	A	B, AB	C, BC	CD	D
	Geomorphological heterogeneity	Slopes, degrees	> 30	21-30	11-20	5-10	0-4
Ecosystem Processes	Matter storage - biomass	Completeness, % for test area	< 0.3	0.3-0.4	0.5-0.6	0.9-1.0	0.7-0.9
		Stock, m <sup>3</sup> /ha	< 50	51-100	101-250	> 500	250-500

**Table 3.** Ecosystem service habitat maintenance evaluation matrix.

Study sites conservation status, under the Protected Areas Act of the Republic of Bulgaria						
Ecological status of the ecosystems at the study site						
	Reserves (I cat. IUCN)	National Parks (II cat. IUCN) and Managed Reserves (IV cat. IUCN)	Natural monuments (III cat. IUCN) and Nature parks (IV/V cat. IUCN)	Protected area (IV/V cat. IUCN)	No conservation status	
Artificial	N/A	0	0	0	0	
Far from natural, the condition depends on targeted anthropogenic maintenance	N/A	4	3	2	1	
Natural and semi-natural in moderate condition	4	4	4	3	2	
Natural in a good condition, requiring attention	5	5	4	4	4	
Natural in very good condition	5	5	5	5	4	
Habitat maintenance supply potential, score	5. Very high	4. High	3. Medium	2. Low	1. Very low	0. No capacity

ecosystem subtypes identified in step 1. The data processing and mapping were made in ArcMap 10.4. (ESRI 2016) Protected area status and specific usage of the territory were derived from the Protected Areas Act (2022), whereas geospatial data for the protected areas part of NATURA 2000 and part of the case study was derived from the geospatial portal of the Bulgarian Ecological network NATURA 2000 (MEW 2022). A cross-walking with CLC (ecosystem subtypes) and forest dataset is made for the terms used in the forest database (NARB 2015).

### 3. Results and discussion

#### 3.1 Ecosystem types and subtypes diversity in the study area

After the cross-walking, the case study has 7 ecosystem types (MAES BG, level 2) distributed in 19 ecosystem subtypes (MAES BG, level 3). The largest coverage has the Woodland and forest type (45.5%), followed by the Grassland (24%), Sparsely vegetated land (15.5%), Heathland and shrub (13.1%) and Cropland, Urban and Rivers and lakes types with 1.8% overall. The protected areas with the biggest forest coverage are PA “Rila Monastery” (53.5%) and “Bayuvi Dupki-Djindjiritsa” Reserve (50.4%). On the other hand, the Grassland ecosystem type occupies 82.9% of PA “Krushe” and 23.6% of PA “Rila Monastery”.

As the proxy data was used for the ES assessment, some of the data sources had one limitation which affected the data processing. This includes the lack of data for some specific areas from the main source of data in the case study (lack of mapping in NATURA 2000 zones) which reflects on usage of two different sources for filling out the missing parts.

#### 3.2 Ecosystem ecological condition as a prerequisite to providing ES

The results obtained in this study revealed that the conservation regime allowed the territories to preserve a high degree of naturalness in very good ecological condition – 96477 ha (73%) of the total case-study area, while 33078 ha (77%) of the target protected areas have received the most favorable score (Table 4; Fig. 3). Special attention is required for ecosystems rated with score 2: “Natural in a good state, attention is required” which are 22494 ha (23%) of the total area of 7254 ha (23%) of the area of the target protected areas. The results from spatial analysis revealed that these

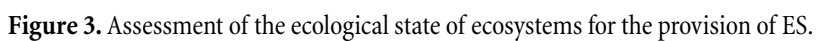
are mainly ecosystems distributed above the upper limit of the forest which are highly vulnerable to environmental processes related to climate change. For the territorial scope of the “Parangalitsa” Reserve, the result can be explained by the high sensitivity of alpine ecosystems to climate change making the high-mountain meadows and pastures especially vulnerable. According to Stoyanova (2013) at the upper border of the forest in Rila, the growing season is severely shortened and lasts about 2.5 months at an altitude of 1750–1800 m, where strong winds and heavy snowfalls, avalanches, and debris at more steep slopes, cause difficult conditions for the survival and natural regeneration of forests. However, natural disturbances and disasters contribute to forest heterogeneity, and biodiversity and improve the adaptability of tree species to changing environmental conditions. Greater diversity in the species composition and genetic characteristics of individual species are of crucial importance for the sustainability and productivity of forests (Panayotov et al. 2016). On the other hand, some of the successional changes in the forest belt, closely related to climate change, lead to quantitative and qualitative changes in soil quality and species composition, and species or populations of conservation priority can be replaced by others (Bozhkov et al. 2022). An example of such a succession process is the natural increase of the territories occupied by *Pinus mugo* and the reduction of the areas of alpine meadows and pastures, where a significant number of plant species of conservation importance are concentrated (NP “Rila”).

Despite the low overall scores for the presence of ecosystems assessed in scale 3, “Natural and semi-natural in moderate condition”, and 4, “Far from natural, condition dependent on targeted anthropogenic maintenance”, the data indicate anthropogenization, and subsequent fragmentation of landscapes, towards the periphery of the “Rila” and “Pirin” National Parks. These are primarily linear elements of transport and recreational sports infrastructure and adjacent areas. The results on the state of the ecosystems in contact with the protected areas indicate that increased attention to the intensity of land use in mountain conditions and control over direct forms of influence on the spatial structure and condition of ecosystems is necessary: pastoral livestock farming, mixed agricultural land, construction, tourist and sports infrastructure and services. To a particularly high degree, such a recommendation applies to the range of sites located in Pirin Mountain, which are additionally vulnerable to destructive processes caused by

**Table 4.** The territorial scope of ecosystems assessed on the scale of ecological condition.

Ecological condition scale	The full scope of research, area (ha)	Target protected areas, area (ha)					
		Total target objects	“Bayuvi Dupki-Djindjiritsa” Reserve	“Yulen” Reserve	“Parangalitsa” Reserve	PA “Krushe”	PA “Rila Monastery”
1	70200	25368	2692.5	2886.8	528.6	48.5	19211.6
2	22494.2	7254.4	99.8	215.8	958.1	0	5980.6
3	2193.1	344.2	51.8	50.8	0.1	241.5	0
4	1429.2	109.2	04	0	0	1.3	107.6
5	161	2	1.5	0.5	0	0	0
<b>Total</b>	<b>96477.5</b>	<b>33078.6</b>	<b>2845.9</b>	<b>3153.8</b>	<b>1482.8</b>	<b>291.3</b>	<b>25299.8</b>





climate change (increasing seasonal temperatures, longer growing season, shorter and warmer winters with decreasing snowfall, and increasing rain, Grunewald et al. 2009), given the presence of azonal karst landscapes in marbles (Gachev 2017) and distinctive biophysical characteristics of the ecosystems (Panayotov et al. 2010). Here, part of the ecosystems assessed as 3, “Natural and semi-natural in moderate condition”, are attached to exposed areas under the immediate influence of weathering and denudation processes activated under climate change conditions.

The results of the control forest ecosystem condition assessment – presented here by habitat type (Fig. 4) provide a good basis for discussing the prerequisites for habitat maintenance service provision within specific spatial parameters. The habitats typical for “Rila” National Park (91CA, 91D0, 9270, 9410, 95A0) are in good general ecological condition (scale 4, Fig. 4). The main challenge for their maintenance is the steep slopes of the topographic surface, which imply higher activity of slope processes. The highest scores were obtained for habitat types 91BA, 9410, and 95A0, located at higher altitudes in the upper part of the slopes and north – north-east exposures.

Against this favorable background, lower overall scores were recorded for habitat 4070 (moderate condition - scale 3, Fig. 4) at altitudes above 2100 m, especially with south and south-east exposure and a high degree of fire danger recorded (Yakoruda municipality). High geomorphological heterogeneity and unfavorable values of matter storage-biomass are reported here (individual values for particular polygons – scale 1, Table 2).

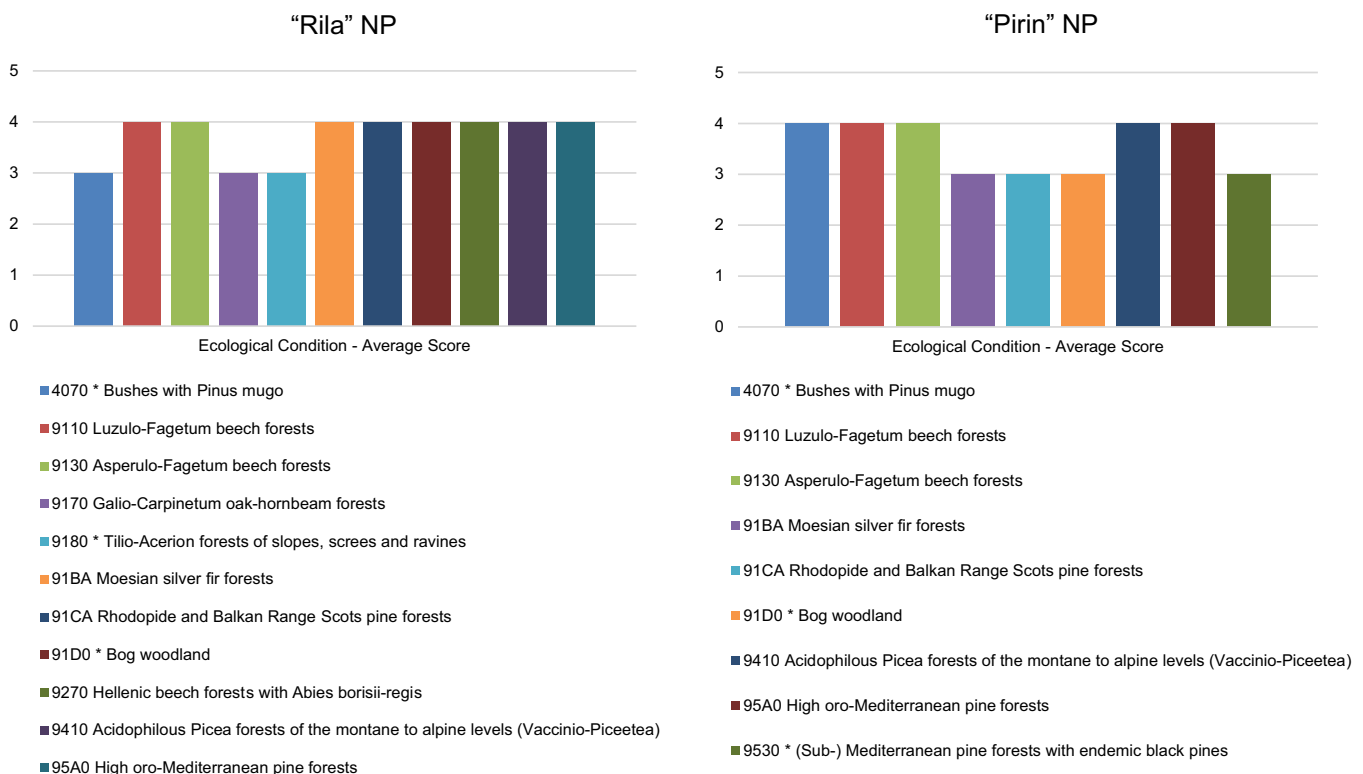
Habitats 95A0, 4070, and 9410 in “Pirin” National Park are in good general condition (scale 4, Fig. 4), but there is also evidence of the high vulnerability of individual polygons (e.g. Bansko municipality, northern exposure, above 1900 m) to active slope processes (denudation, gravity disturbances, sipes, debris), as

well as low values of the matter storage-biomass indicator. This also applies to habitats 9530 and 91D0\* (moderate condition - scale 3) above 1700 m a.s.l., at south and east exposures (Bansko municipality).

The summary condition assessment can be very informative for discussing strategic management objectives. However, there is subjectivity derived primarily from the aggregation of information while identifying ecosystem subtypes. This is particularly true in mountainous environments, where the heterogeneity of the terrain implies distinctive ecological conditions and the spatial contiguity of many diverse ecosystem units that are difficult to reflect at a generalized geographic scale. For example, the results for the status of the “Parangalitsa Reserve” (“Rila” NP) reflect the ecological status assessment of E2. Mesic grasslands and E4. Alpine and subalpine grasslands. On this basis, in the analysis of the data here, a secondary expert analysis was conducted with supporting data from the long-term monitoring of the state of forest ecosystems under the ICP Forests Programme, performed by the Forest Research Institute at the Bulgarian Academy of Sciences (Cudlín et al. 2017).

### 3.3 Ecosystem potential to provide ES habitat maintenance

The results obtained from the analysis of the potential of ecosystems to provide ES habitat maintenance confirm the representative character of the selected for assessment mountain ecosystems. A significant part of the ecosystems received the highest score (class 5, very high supply potential) - 84% of the total studied area (81258.9 ha) or 96.4% (31906 ha) of the area of the target protected areas (Table 5, Fig. 4). About 13.6% of the territories (2.5% of the target sites) are assessed with high potential (class 4). According to the applied evaluation criteria – there is no potential for provision in the range of nearby artificial ecosystems - 0.2%



**Figure 4.** Results of assessment of the ecological status of forest ecosystems in “Rila” NP and “Pirin” NP.

of the area (159 ha) and 0% (0.001 ha) of the area of the target protected areas.

Most ecosystems in protected areas in Rila and Pirin have a very high capacity to provide ES habitat maintenance including the whole territory of the reserves and PA “Rila Monastery”, part of which, mostly in the lower fragments of the zone, was assessed as “high potential”.

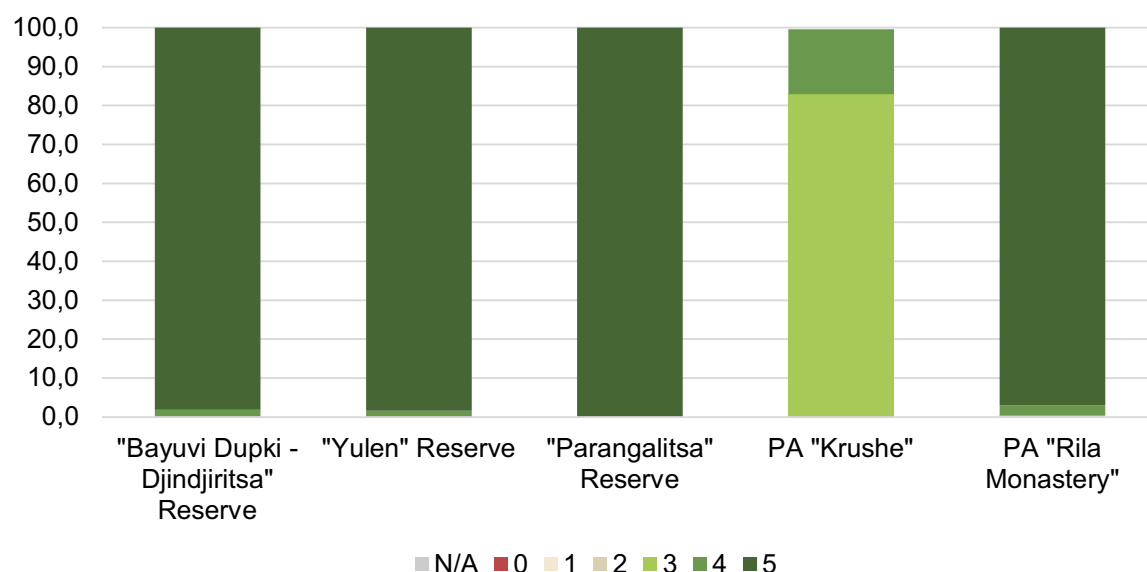
The analysis of the results with a focus on the target sites highlights the spatial distribution of ecosystems with medium and low potential to provide ES habitat maintenance. This is primarily related to the area presence of units whose current condition is defined as “Natural and semi-natural in the moderate state” (for PA “Krushe” - 83% of the area) and “Far from natural, the state depends on intentional anthropogenic maintenance” (PA “Rila Monastery” - 0.4% of the area) (Figs 5-6). The latter undoubtedly shows the dependence of this potential assessment on the accuracy of the results related to the ecological status assessment. Here, we

once again share the view of Hatzziordanou et al. (2019) on the need to base this type of assessment on a composite of indicators, and in this case (within the scope of protected sites) with particular attention to structural elements of biodiversity.

The analysis of the results provokes the question of the relevance and adequacy of management practices in protected areas and the permission of some forms of human intervention with a focus on strengthening mountain ecosystems, especially the distinctive and vulnerable habitats (91BA, 95A0). The anthropogenic impact can be considered as an additional disturbing factor that can have both positive and negative effects on the state of ecosystems (in the present case – as a prerequisite for providing habitat-maintaining ecosystem service), but the study of the impacts of anthropogenic activity is insufficient to draw more substantial conclusions, given that constantly changing ecosystems adapt to different processes simultaneously (Panayotov et al. 2011; Nikolova 2022). On the other hand, land cover changes in past periods associated with the

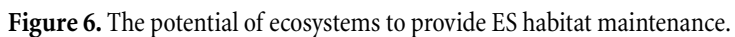
**Table 5.** The territorial scope of ecosystems according to their potential to provide ES habitat maintenance.

Potential for provision Scale	The full scope of the study area (ha)	Target protected areas, area (ha)					
		Total target objects	“Bayuvi Dupki-Djindjiritsa” Reserve	“Yulen” Reserve	“Parangalitsa” Reserve	PA “Krushe”	PA “Rila Monastery”
5	81258.9	31906	2792.2	3102.6	1486.1	0	24524.9
4	13098.2	818.9	51.7	50.7	0.62	48.4	667.3
3	689	241.5	0	0	0	241.5	0
2	1269.9	108.8	0	0	0	1.3	107.5
1	0	0	0	0	0	0	0
0	159.4	0.4	0	0	0	0	0
N/A	0	1.9	1.2	0.2	0	0	0



**Figure 5.** Ratio in the territorial scope of ecosystems classified according to their potential to provide ES habitat maintenance, %.







interruption of agricultural and grazing activities in the mountains may affect several areas with specific functions (Tasser et al. 2009), including biodiversity conservation (Komac et al. 2011). However, there is still not enough detailed information on the degree of vulnerability and sensitivity of high mountain ecosystems, since they are characterized by a complex and individual character, providing a wide variety of habitats and microclimate types within small areas (Schuler 2004).

#### 4. Conclusion

The assessment and mapping of ecosystem services are recognized as important activities that can significantly contribute to a better understanding of the importance of ecosystems to human well-being and provoke a discussion on the need for the implementation of nature-based measures in regional and local planning for territorial development and sustainable use of natural resources.

The analysis of the results from the assessment of the condition of forest ecosystems in the studied NPAs revealed that the largest part of them is characterized by very good and good ecological conditions and a high degree of naturalness, emphasizing the importance of the conservation regime. Special attention is necessary to be paid for the ecosystems rated with score 2: "Natural in a good state, attention is required" mainly distributed above the upper limit of the forest which is highly vulnerable to environmental processes related to climate change and, especially high-mountain meadows and pastures and Dwarf pine communities.

The majority of studied mountain ecosystems received the highest score – very high supply potential for ES habitat maintenance, as the well-preserved rich in biodiversity nature in PAs is an important prerequisite for the provision of a wide variety of ES. The spatial distribution of ecosystems with medium and low potential to provide habitat maintenance reveals that these are primarily areas defined as "Natural and semi-natural in the moderate state" and "Far from natural, the state depends on intentional anthropogenic maintenance", indicating a possible positive relationship between biodiversity, ecosystem condition, and ES supply.

The summary of the results allowed the expert assessment to be confirmed underlining the primary importance of the natural self-development of the ecosystems for the provision of their inherent "habitat functions" which are the foundation for the supply of all other ecosystem services. While in scientific research the link between the naturalness of landscape structure and the richness of its derived functions is evident and demonstrable for the public direct evidence is needed related to direct and sustained over time access to resources that support well-being and, in this sense, the research on the impact of habitat maintenance ES can be extended with an assessment of a package of direct and indirect ecosystem services with a specific monetary value.

Although the PAs's objectives are mainly conservation-oriented having direct impacts on the preservation of natural resources and the natural heritage within its boundaries, they purposefully and actively support their prioritized habitat maintenance functions as spatial guarantors for the sustenance of rich packages of material, regulating, and cultural functions in significant geographic areas. It could also be noted that the recognition, assessment, and mapping of ecosystem services from NPAs can significantly influence stakeholders' attitudes and can directly support the decision-makers in their planning activities to achieve sustainable utilization of ecosystem services and to keep the balance between environmental protection, and socio-economic development.

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#### References

- Beniston M (2003) Climatic change in mountain regions: a review of possible impacts. *Climate Change* 59:5–31. <https://doi.org/10.1023/A:1024458411589>
- Bennett G (2004) Integrating Biodiversity Conservation and Sustainable Use: Lessons Learned From Ecological Networks. IUCN, Gland, Switzerland, and Cambridge, UK.
- Bozhkov P, Grigorov B, Sarafov A (2022) Comparative analysis of soil organic carbon in selected river catchments. *Journal of the Bulgarian Geographical Society* 47: 45-51. <https://doi.org/10.3897/jbgs.e98660>
- Bratanova-Doncheva S, Chipev N, Gocheva K, Vergiev S, Fikova R (2017) Methodological framework for assessment and mapping of ecosystem condition and ecosystem services in Bulgaria. Conceptual basis and principles of application, ISBN:978-619-7379-21-1.
- Brown C, Burns A, Arnell A (2018) A Conceptual Framework for Integrated Ecosystem Assessment. *One Ecosystem* 3: e25482. <https://doi.org/10.3897/oneeco.3.e25482>
- 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. <https://doi.org/10.3097/L.O.200915>
- Burkhard B, Santos-Martin F, Nedkov S, Maes J (2018) An operational framework for integrated Mapping and Assessment of Ecosystems and their Services (MAES). *One Ecosystem* 3: e22831. <https://doi.org/10.3897/oneeco.3.e22831>
- Cardinale BJ, Duffy JE, Gonzalez A, Hooper DU, Perrings C, Venail P, Narwani A, Mace GM, Tilman D, Wardle DA, Kinzig AP, Daily GC, Loreau M, Grace JB, Larigauderie A, Srivastava DS, Naeem S (2012) Biodiversity loss and its impact on humanity. *Nature* 486 (7401): 59-67. <https://doi.org/10.1038/nature11148>
- Costanza R (2020) Valuing natural capital and ecosystem services toward the goals of efficiency, fairness, and sustainability. *Ecosystem Services* 43: 101096. <https://doi.org/10.1016/j.ecoser.2020.101096>
- Costanza R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P (1997) The value of the world's ecosystem services and natural capital. *Nature* 387 (6630): 253-260. <https://doi.org/10.1038/387253a0>
- Cudlín P, Klopčič M, Tognetti R, Máliš F, Alados CL, Bebi P, Grunewald K, Zhiyanski M, Andonowski V, La Porta N, Bratanova-Doncheva S, Kachaunova E, Edwards-Jonášová M, Ninot JM, Rigling A, Hofgaard A, Hlásny T, Skálák P, Wielgolaski FE (2017) Drivers of treeline shift in different European mountains. *Climate Research* 73: 135-150. <https://doi.org/10.3354/cr01465>

- Daily GC (1997) Introduction: What Are Ecosystem Services? In: Daily GC (ed) *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington DC, 1-10.
- de Groot RS, Wilson MA, Boumans RMG (2002) A typology for the classification, description, and valuation of ecosystem functions, goods, and services. *Ecological Economics* 41(3): 393–408. [https://doi.org/10.1016/S0921-8009\(02\)00089-7](https://doi.org/10.1016/S0921-8009(02)00089-7)
- Díaz S, Demissew S, Carabias J, Joly C, Lonsdale M, Ash N, Larigauderie A, Adhikari JR, Arico S, Báldi A, Bartuska A, Baste IA, Bilgin A, Brondizio E, Chan KM, Figueroa VE, Duraipapp A, Fischer M, Hill R, ... Zlatanova D (2015) The IPBES Conceptual Framework — Connecting nature and people. *Current Opinion in Environmental Sustainability* 14: 1-16. <https://doi.org/10.1016/j.cosust.2014.11.002>
- Duru M, Therond O, Fares M (2015) Designing agroecological transitions; A review. *Agronomy for Sustainable Development* 35: 1237-1257. <https://doi.org/10.1007/s13593-015-0318-x>
- Egoh B, Drakou EG, Dunbar MB, Maes J, Willemen L (2012) Indicators for mapping ecosystem services: a review. Report EUR 25456 EN. Luxembourg: Publications Office of the European Union.
- Environmental Systems Research Institute (ESRI) (2016) ArcGIS v. 10.4
- Erhard M, Teller A, Maes J et al. (2016) Mapping and Assessment of Ecosystems and Their Services. Mapping and assessing the condition of Europe's Ecosystems: Progress and Challenges. Publications Office of the European Union, Luxembourg.
- Executive Forest Agency (2017) <http://www.iag.bg/>
- Gachev E (2017) High mountain relief in marble in Pirin Mountains, Bulgaria: structure, specifics and evolution. *Revista de Geomorfologie* 19: 118–135. <https://doi.org/10.21094/rig.2017.012>
- Glushkova M, Zhiyanski MK, Yaneva R (2023) Assessment and cultural ecosystem service mapping in mountain protected areas – “Pirin” National park. *Silva Balcanica* 24(2): 45-57. <https://doi.org/10.3897/silvabalcanica.24.e106658>
- Grêt-Regamey A, Brunner SH, Kienast F (2012) Mountain ecosystem services: Who cares? *Mountain Research and Development* 32(S1): S23–S34.
- Grunewald K, Scheithauer J, Monget JM et al. (2009) Characterisation of contemporary local climate change in the mountains of southwest Bulgaria. *Climatic Change* 95: 535–549. <https://doi.org/10.1007/s10584-008-9508-8>
- Haines-Young R, Potschin MB (2018) Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure. [www.cices.eu](http://www.cices.eu)
- Harrison P, Berry P, Simpson G, Haslett J, Blicharska M, Bucur M, Dunford R, Egoh B, Garcia-Llorente M, Geamăna N, Geertsema W, Lommelen E, Meiresonne L, Turkelboom F (2014) Linkages between biodiversity attributes and ecosystem services: A systematic review. *Ecosystem Services* 9: 191-203. <https://doi.org/10.1016/j.ecoser.2014.05.006>
- Hatziordanou L, Fitoka E, Hadjicharalampous E, Votsi N, Palaskas D, Malak D (2019) Indicators for mapping and assessment of ecosystem condition and of the ecosystem service habitat maintenance in support of the EU Biodiversity Strategy to 2020. *One Ecosystem* 4: e32704. <https://doi.org/10.3897/oneeco.4.e32704>
- Hermoso V, Carvalho SB, Giakoumi S, Goldsborough D, Katsanevakis S, Leontiou S, Markantonatou V, Rumes B, Vogiatzakis IN, Yates KL (2022) The EU Biodiversity Strategy for 2030: opportunities and challenges on the path towards biodiversity recovery. *Environmental Science and Policy*, 127: 263-271. <https://doi.org/10.1016/j.envsci.2021.10.028>
- 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>
- Isbell F, Calcagno V, Hector A, Connolly J, Harpole WS, Reich PB, Scherer-Lorenzen M, Schmid B, Tilman D, van Ruijven J, Weigelt A, Wilsey BJ, Zavaleta ES, Loreau M (2011) High plant diversity is needed to maintain ecosystem services. *Nature* 477: 199-202. <https://doi.org/10.1038/nature10282>
- Komac B, Alados C, Bueno C, Gómez D (2011) Spatial patterns of species distributions in grazed subalpine grasslands. *Plant Ecology* 212(3): 519-529. <https://doi.org/10.1007/s11258-010-9842-6>
- Kostov G, Rafailova E, Bratanova-Doncheva S, Gocheva K, Chipev N (2017) Methodology for assessment and mapping of woodland and forests ecosystems condition and their services in Bulgaria. Clorind, Sofia, 84 pp. ISBN 978-619-7379-08-2. [https://eea.government.bg/en/projects/Ecosystems/woodlandforests/FOREST\\_ENG.pdf](https://eea.government.bg/en/projects/Ecosystems/woodlandforests/FOREST_ENG.pdf)
- Koulov B (2018) Social and economic transformations in Bulgarian mountain periphery: A 1986–2014 comparative analysis. *Journal of the Bulgarian Geographical Society* 39: 73-78. <https://doi.org/10.3897/jbgs.2018.39.14>
- Koulov B (2020) Europe's Core-Periphery Relations and Horizontal Disparities. National Publishing House for Education and Science "Az-Buki" at the Ministry of Education. ISBN: 9876197065305.
- Liquete C, Cid N, Lanzanova D, Grizzetti B, Reynaud A (2016) Perspectives on the link between ecosystem services and biodiversity: The assessment of the nursery function. *Ecological Indicators* 63: 249-257. <https://doi.org/10.1016/j.ecolind.2015.11.058>
- Löffler J, Anschlag K, Baker B, Finch OD, Dieckrüger B, Wundram D, Schröder B, Pape R, Lundberg A (2011) Mountain ecosystem response to global change. *Erdkunde*, 65(2): 189-213. <https://doi.org/10.3112/erdkunde.2011.02.06>
- Mace GM, Norris K, Fitter AH (2012) Biodiversity and ecosystem services: A multilayered relationship. *Trends in Ecology & Evolution* 27(1): 19-26. <https://doi.org/10.1016/j.tree.2011.08.006>
- Maes J, Braat L, Jax K, Hutchins M, Furman E, Termansen M (2011) A Spatial Assessment of Ecosystem Services in Europe: Methods, Case Studies, and Policy Analysis – Phase 1, PEER Report No 3, Ispra: Partnership for European Environmental Research. <https://data.europa.eu/doi/10.2788/42116>
- Maes J, Teller A, Erhard M, Grizzetti B, Barredo JI, Paracchini ML, Condé S, Somma F, Orgiazzi A, Jones A, Zulfan A, Petersen JE, Marquardt D, Kovacevic V, Abdul Malak D, Marin AI, Czúcz B, Mauri A, Löffler P, Bastrup-Birk A, Biala K, Christiansen T, Werner B (2018) Mapping and Assessment of Ecosystems and their Services: An analytical framework for ecosystem condition. Publications office of the European Union, Luxembourg. <https://data.europa.eu/doi/10.2779/055584>
- Maes J, Teller A, Erhard M, Liquete C, Braat L, Berry P (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, Luxembourg. <https://data.europa.eu/doi/10.2779/12398>
- Maes J, Teller A, Erhard M, Murphy P, Paracchini ML, Barredo JI, Grizzetti B, Cardoso A, Somma F, Petersen J, Meiner A, Gelabert ER, Zal N, Kristensen P (2014) Mapping and

- Assessment of Ecosystems and their Services. Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. Publications office of the European Union, Luxembourg. <https://data.europa.eu/doi/10.2779/75203>
- Maes J, Crossman ND, Burkhard B (2016) Mapping ecosystem services. In: Potschin M, Haines-Young R, Fish R, Turner RK (Eds) Routledge Handbook of Ecosystem Services. 1. Routledge, London, 188-204.
- Manolaki P, Vogiatzakis I (2017) Ecosystem services in a peri-urban protected area in Cyprus: A rapid appraisal. *Nature Conservation* 22: 129-146. <https://doi.org/10.3897/natureconservation.22.13840>
- Millennium Ecosystem Assessment (MEA) (2005) Ecosystems and Human Well-being: Synthesis. Washington, DC. Island Press.
- Ministry of Environment and Water (MEW) (2022) Information system for protected areas from the ecological network NATURA 2000. <https://natura2000.egov.bg/EsriBg.Natura.Public.Web.App>
- Müller F, Burkhard B (2007) An ecosystem-based framework to link landscape structures, functions, and services. In: Mander Ü, Wiggering H, Helming K (Eds) Multifunctional land use—Meeting future demands for landscape goods and services. Berlin, Springer, 37–64.
- National Assembly of the Republic of Bulgaria (NARB) (2015) Order No. 18 from October 7, 2015, for inventory and planning in the forest areas (supplement to SG No. 82 of 23.10.2015).
- 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 (2021) 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 (2022) Valuation of recreation-related cultural ecosystem services provided by Pirin National Park, Bulgaria. *Journal of the Bulgarian Geographical Society* 47: 61-72. <https://doi.org/10.3897/jbgs.e97901>
- Panayotov M, Bebi P, Trouet V, Yurukov S (2010) Climate signal in tree-ring chronologies of *Pinus peuce* and *Pinus heldreichii* from the Pirin Mountains in Bulgaria. *Trees* 24 (3): 479–490. <https://doi.org/10.3929/ethz-b-000018213>
- Panayotov M, Dimitrov D, Yurukov S (2011) Extreme Climate Conditions In Bulgaria – Evidence From *Picea Abies* Tree-Rings, *Silva Balcanica*, 12(1).
- Panayotov M, Tsvetanov N, Gogushev G, Tsavkov E, Zlatanov T, Anev S, Ivanova A, Nedelin T, Zafirov N, Aleksandrov N, Dountchev A, Vasileva P, Shishkova V, Stoyanov B, Sotirova N, Vatov A, Bebi P, Yurukov S (2016) Mountain coniferous forests in Bulgaria – structure and natural dynamics. University of Forestry, Sofia, 332 pp.
- Paracchini ML, Capitani C (2011) Implementation of an EU-wide indicator for the rural-agrarian landscape. In support of COM(2006)508 “Development of agri-environmental indicators for monitoring the integration of environmental concerns into the Common Agricultural Policy”. European Commission - Joint Research Centre. <https://data.europa.eu/doi/10.2788/26827>
- Pastur GM, Peri PL, Lencinas MV, García-Llorente M, Martín-López B (2016) Spatial patterns of cultural ecosystem services provision in Southern Patagonia. *Landscape Ecology* 31: 383–399. <https://doi.org/10.1007/s10980-015-0254-9>
- Pătru-Stupariu I, Hossu CA, Grădinaru SR, Nita A, Stupariu M-S, Huzui-Stoiculescu A, Gavrilidis A-A. (2020) A Review of Changes in Mountain Land Use and Ecosystem Services: From Theory to Practice. *Land* 9(9): 336. <https://doi.org/10.3390/land9090336>
- Prezioso M, Coronato M, D’Orazio A, Pigliucci M, Sargolini M, Idone MT, Perna P, Pierantoni I, Omizzolo A, Cetara L, Streifeneder T, Favilli F, Huber M, Jungmeier M, Werner Kirchmeier H, Julien A, Elodie B, Myriam M, Matthieu V, Zhiyanski M, Georgieva M, Glushkova M, Yaneva R (2018) LinkPAs – Linking networks of protected areas to territorial development. Targeted analysis - Scientific report. ESPON, ESPON EGTC, 2018, 1-207.
- Protected Areas Act of the Republic of Bulgaria (2022). <https://www.lex.bg/laws/ldoc/2134445060>
- Ridder B (2008) Questioning the ecosystem services argument for biodiversity conservation. *Biodiversity and Conservation* 17: 781-790. <https://doi.org/10.1007/s10531-008-9316-5>
- Schuler TM (2004) Fifty years of partial harvesting in a mixed mesophytic forest: composition and productivity. *Canadian Journal of Forest Research* 34: 985-997. <https://doi.org/10.1139/x03-262>
- Soliveres S, van der Plas F, Manning P, Prati D, Gossner MM, Renner SC, Alt F, Arndt H, Baumgartner V, Binkenstein J, Birkhofer K, Blaser S, Blüthgen N, Boch S, Böhm S, Börschig C, Buscot F, Diekötter T, Heinze J, ... Allan E (2016). Biodiversity at multiple trophic levels is needed for ecosystem multifunctionality. *Nature* 536: 456-459. <https://doi.org/10.1038/nature19092>
- Steinhardt U, Herzog F, Lausch A, Müller E, Lehmann S (1999) Hemeroby index for landscape monitoring and evaluation. In: Pykh YA, Hyatt DE, Lenz RJ (Eds) *Environmental Indices – System Analysis Approach*. Oxford, EOLSS Publ., 237-254 pp. [https://www.researchgate.net/publication/237201744\\_Hemeroby\\_index\\_for\\_landscape\\_monitoring\\_and\\_evaluation](https://www.researchgate.net/publication/237201744_Hemeroby_index_for_landscape_monitoring_and_evaluation)
- Stoyanova N (2013) Climatic conditions at the upper limit of the forest. *Forest* 1/2013, pp. 17.
- Tasser E, Ruffini F, Tappeiner U (2009) An integrative approach for analysing landscape dynamics in diverse cultivated and natural mountain areas. *Landscape ecology* 24(5): 611-628. <https://doi.org/10.1007/s10980-009-9337-9>
- The Economics of Ecosystems and Biodiversity (TEEB) (2009) TEEB for National and International Policy Makers. Summary: Responding to the Value of Nature. Geneva: The United Nations Environment Programme.
- The Economics of Ecosystems and Biodiversity (TEEB) (2010) The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. Pushpam Kumar (Ed). Earthscan: London and Washington.
- Vihervaara P, Mononen L, Nedkov S, Viinikka A et al. (2018) Biophysical mapping and assessment methods for ecosystem services. Deliverable D3.3 EU Horizon 2020 ESERALDA Project, Grant agreement No. 642007.

### Author contributions (CRediT roles)

Conceptualization: SN, MKZ, BB. Formal analysis: MG, VS, BB. Funding acquisition: MG. Investigation: BB, VS, MG. Methodology: SN, BB. Project administration: MG, MKZ. Resources: BB, MG, VS. Visualization: VS. Writing - original draft: BB, MG, VS, MKZ. Writing - review and editing: BB, SN, MKZ, MG.

### Conflict of interest

The authors have declared that no competing interests exist.

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