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Monitoring of water cycle in karst geosystems and its integration into ecosystem assessment framework

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ABSTRACT

Karst is a widely spread natural phenomenon which provides essential benefits to human society, such as drinking water. The water cycle in the karst geosystems is the main factor for their formation and at the same time one of the main drivers for ecosystem services (ES) provision. The monitoring of the water cycle can provide valuable information regarding its functioning and ensure data for ES assessment. This paper aims to present an overview of the monitoring of the water cycle in the karst geosystems and the opportunities to integrate the monitoring data into the water regulation ES assessment. The monitoring of the water cycle is based on the methodological framework ProKARSTerra. It is applied in model karst geosystems, which are representative of the main karst types in Bulgaria. One of them is the Brestnitsa karst geosystem, which is the case study of this work. The monitoring ensures data for analyses of the water cycle which can be used in the assessment of water-related ecosystem services. The results from the analyses of the data requirements and availability show that some services such as *water flow regulation* and *regulation of chemical condition of freshwaters* can be easily provided through data for quantification, while for others further studies are needed. The results of the long-term integrated monitoring in Brestnitsa karst geosystem provide the foundation for important conclusions and models for the karst genesis and function under global changes and active anthropogenic pressure. Their integration into the assessment framework and mapping of ecosystem services is an essential step towards the development of models for sustainable use of natural resources in the karst areas.

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1. Introduction

Karst as a natural phenomenon covers approximately 20% of the Earth's surface and ensures 13% of the drinking water (IYCK, 2021). Karst areas can be considered as specific geosystems (Andreychouk and Voropai 1993; Bella 1995; Andreychouk and Stefanov 2006, 2021), which have both surface and underground structures. They provide valuable ecosystem services (ES), such as freshwater and rich biodiversity above and below the earth's surface, caves with significant recreational and cultural value, and soils that provide the basis for agricultural production (Goldscheider 2019). On the other hand, karst geosystems are vulnerable to different impacts which can have natural or anthropogenic origins. Groundwater resources in karst aquifers are vulnerable to contamination, and overexploitation (Bakalowicz 2005). The caves provide habitats that are sometimes restricted to very small areas and the rare and endemic species in them are vulnerable to extinction (Bonacci et al. 2009; Furey et al. 2010; Biondic et al. 2010). The soils in the karst geosystems are extremely vulnerable to irreversible erosion caused by maladjusted agricultural techniques (Goldscheider 2019). The water cycle in the karst geosystems is the main factor for their formation and at the same time one of the main drivers for ES provision. The monitoring of the water cycle in the karst geosystems can provide valuable information about most of the karst processes and ensure data for ES assessment, which can address most of the above-mentioned problems.

The problem of the karst's geosystems vulnerability is even more serious in the context of global changes. Furthermore, the specifics of the karst even in the 21st century remain "terra incognita" for both society and decision-makers (Stefanov 2020b). Therefore, karst studies become even more relevant and necessary. On the other hand, they are interdisciplinary and require good coordination between different disciplines and appropriate methodological approaches. The system approach with its two holistic branches, ecosystem, and geosystem, is considered to be the most appropriate for the above-mentioned purposes (Andreychouk and Stefanov 2021). The ecosystem approach is biocentric, focused on the interrelations object-environment, but it underestimates the interrelations between the abiotic elements of the system. However, the geosystem approach considers all elements of the karst system and focuses on the interactions between them. Van Ree et al. (2016) argue that making geosystem services explicit in ecosystem services assessments provides a more integrative and inclusive description of the ecosystem and specifies the impact that mankind has on nature's shape and functioning. Thus, the monitoring in the karst areas should be organized by following the geosystem approach.

Water regulation is considered as a key regulating ES in both ecosystem assessment and accounting, includes several ES, such as *water retention* and *storm and high-water protection (including flood control on rivers and coasts)*. These *water regulation services* are closely related to other regulating ES, such as *erosion and sedimentation control* and *water purification* (Nedkov et al. 2022). The assessment of *water regulation services* needs various data related to the different elements of the water cycle. Furthermore, such assessment necessitates long-time data series that can be obtained only by a well-organized monitoring system. This paper aims to present an overview of the monitoring of the water cycle in the karst geosystems and the opportunities to integrate the monitoring data into the water regulation ES assessment.

2. Monitoring of the karst geosystems

According to the concept for karst geosystems: i) the karst processes have system-formation function and arrange their structure by formation of spatially unified and functionally integrated entities called karst geosystems; ii) these geosystems have spatial, functional, dynamic, and genetic hierarchy of interrelated and interacting elements. The contact and interaction between the elements of the karst geosystems occurs at great depth, which means that they have a very well-established vertical structure. The main systemic features of the karst geosystems according to many authors (Voropai and Andreychouk 1985; Andreychouk and Voropai 1993; Andreychouk and Stefanov 2006, 2008, 2021; Andreychouk 2016; Andrejczuk and Stefanow 2017) are:

- Volumetric in space and metachronous in time dynamic structure with two main parts (subsystems): surface and underground. The material-energy interactions between them are the foundation for the functioning and dynamics of the karst geosystem;
- Structural complexity (a necessary condition for the resilience of the system) which is much greater in the karst geosystems due to the intra-system surface-subsurface connections and interactions;
- Paradynamic and paragenetic connections between the surface and underground parts – positive feedback (mutually stimulating);
- Delay in the response of the underground subsystem to events on the surface, and vice versa, asynchrony of changes in the structural subsystems (relative dynamic autonomy);
- Buffer mechanism (additional factor for sustainability) between the surface and underground subsystems against external impacts (redistribution of destructive processes) which results in the formation of azonality;
- High structural permeability between the subsystems, and high general vulnerability;
- High general resource potential, both surface, and underground.

These features make the karst geosystems some of the most comprehensive in the global system (Andreychouk and Stefanov 2006, 2008, 2021; Andrejczuk and Stefanow 2017). They are characterized by high risk from external impacts, especially in respect of global changes, which require the preservation of both subsystems (surface and underground). At the same time, their specifics determine another problem: discrepancies between the spatial extent and the border of the surface and underground parts. The function of the karst geosystem is characterized by the flows of energy and matter as input and output of the system. For modeling purposes, the karst geosystems are most often studied using the "grey-box" approach (Xue et al. 2019). The caves ensure accessibility to their inside structure and some of the flows and interrelations can be studied "in situ". The karst geosystems are considered to have "memory" as they store a vast amount of information "written" in their karstolites (karst rocks, including stalactite and stalagmite, etc.) which are very well preserved in the caves. The analysis and interpretation of this information enable both paleogeographic reconstructions and predictive models. The systems approach as a conceptual tool for the study of karst geosystems gives further opportunities for the application of quantitative methods and modeling.

The water flow within the karst geosystems has a main structure formation role. Therefore, the water cycle is an important object of the karst's geosystem and ecosystem studies (Andreychouk and Stefanov 2021). The water cycle in the karst geosystems includes five main components: 1) incoming water; 2) evaporation; 3) transport; 4) accumulation; 5) outflow. The incoming water comes from precipitation, infiltration from river water, condensation, as well as infiltration and sewage waters sinking. The outflow forms mainly karst springs. The water cycle has particular fluctuations which form the water regime of the karst geosystem. Many factors impact this regime. The karst geosystems are extremely vulnerable to pollution. The system of cavities and channels facilitates the very fast movement of pollutants to the karst aquifers, which minimizes self-purification time. Therefore, the underground karst water necessitates better preservation than the other areas (Shilegarska et al. 2020). On the other hand, the underground subsystems may act as reservoirs in cases of extreme precipitation contributing to flood regulation ES and as specific deposition pools for water pollutants contributing to water purification ES. However, such deposition pools are potential sources of contamination for the underground water when their water table rises to the pool's level. Therefore, the studies on circulation, water regime, and the balance of the karst water necessitate specialized monitoring in representative sites around the whole karst geosystem.

Identifying the global change impact on the karst and the resulting problems at regional and local scale is a relevant but also quite responsible task (Gorjanc et al. 2022). This is especially valid for Bulgaria, where the karst areas are widely spread (they account for approximately a quarter of the country's territory). This makes it a natural laboratory for experimenting with the geosystem approach, which has been successfully applied since the end of the 20th century (Andreychouk and Stefanov 2021). For this purpose, model karst geosystems, a representative of the main karst types in the country have been chosen. One of them is the Brestnitsa karst geosystem, which is the case study of this work (see 3.1).

The methodological framework ProKARSTerra (Fig. 1) is developed by the Experimental laboratory of karstology at the National Institute of Geophysics, Geodesy and Geography at the Bulgarian Academy of Sciences (NIGGG-BAS). It is based on long-time studies and the research experience of the lab's team. The framework is based on the concept of the systemic nature of the karst and incorporates the main elements of the impact of global changes. The main "pillars" of the framework are the system analysis, the integrated karst monitoring, and the karst cadaster (database)

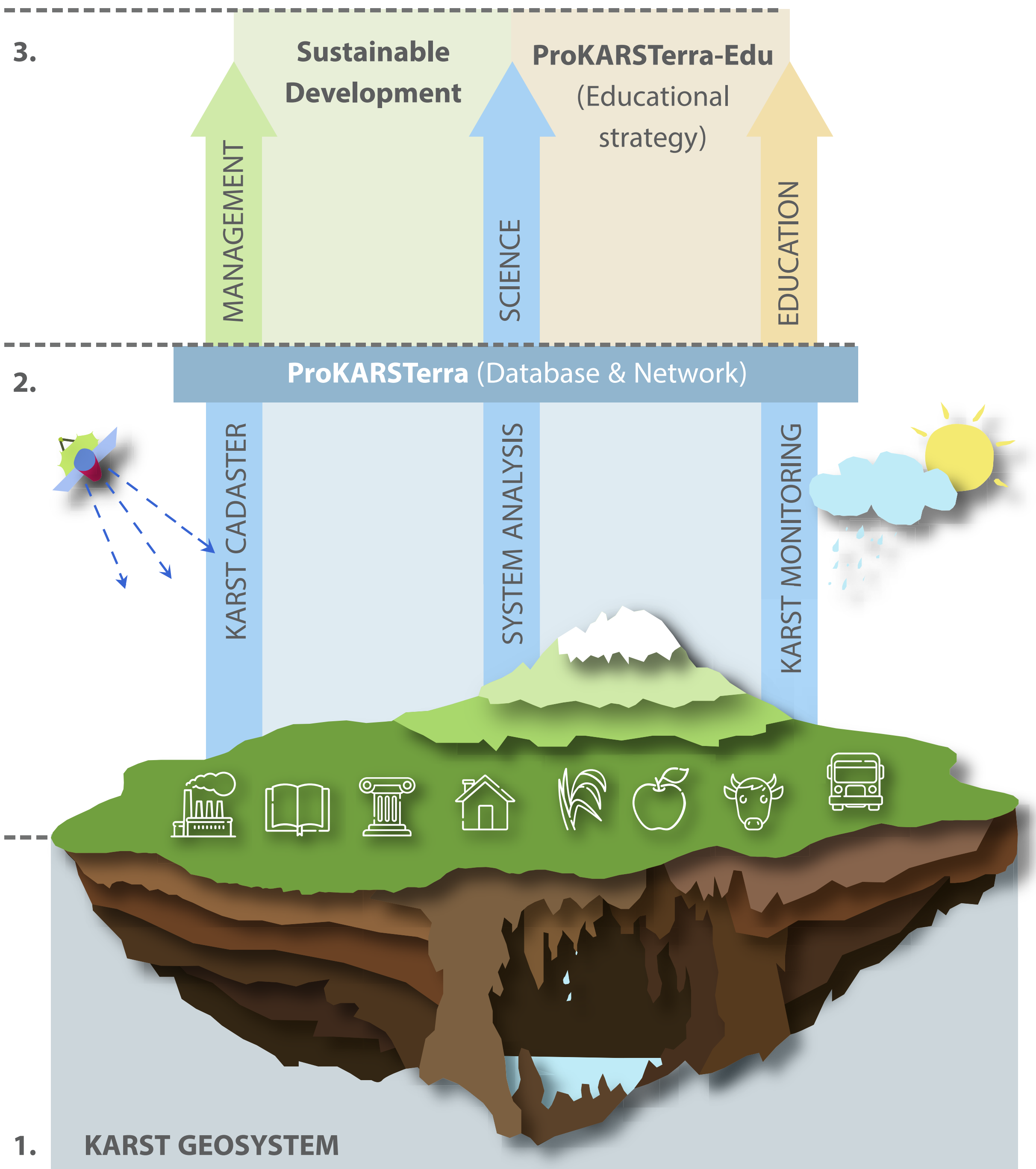

Figure 1. Methodological Platform ProKARSTerra. Includes the three main parts: 1) A karst geosystem with various land use types and human activities; 2) ProKARSTerra Database and Network including all mapping, system analysis and monitoring activities; 3) Application of the research outcomes through sustainable development of karst territories and the educational strategy ProKARSTerra-Edu (after Stefanov et al. 2013).

of the studied geosystems (Fig. 1). The information of the karst cadaster is organized into a GIS database (Mikhova and Stefanov 1993, 1995, 1999). The Integrated Monitoring of the Karst Systems (MIKS) is a continuous process of observation and measurements of the parameters that determine the state (condition) of the geosystem (Stefanov 2013, 2020a, 2020b). Due to the specifics of the underground part of the karst geosystems, integrated monitoring of a cave karst system (Speleo-MIKS) has been developed within the MIKS framework (Stefanov 2013, 2020b). It covers almost all indicators of the cave environment that can be observed and measured using the available tools. They are carried out both in field studies (in different months and seasons and extreme situations) and continuously by measurement devices (including automatic stations and established monitoring networks). MIKS ensures a background for original research with an emphasis on the impact of global changes on karst, but also on the opposite relation concerning the role of karst in global changes (Stefanov 2020b; Jelev et al. 2021).

Apart from research activities, ProKARSTerra ensures support for the management of the karst resources and teaching for and by the karst. The framework has a specialized educational strategy ProKARSTerra-Edu which has been developed through international collaboration and with the support of UNESCO (Stefanov et al. 2013; Stefanov and Stefanova 2014). In the long term, the ProKARSTerra platform will provide a background for a new strategy for the sustainable development of karst territories, based on the knowledge of karst geosystems (Stefanov 2020a, 2020b).

3. Materials and methods

3.1 Brestnitsa karst geosystem

Brestnitsa karst geosystem is formed within the watershed of the Vit River (Fig. 2) and it is representative of the classic type of karst. Its area is estimated at 60 km^2, which comprises 26 km^2 of closed effluent territory (Stefanov 2020b). The karst formation takes place in micro-grained or organogenic (often biomorphic) limestones with a width between 200 and 450 m and a very high carbonate content that reaches 97-99% (Kovachev 1959; Popov 1979). These limestones are assigned to the Brestnitsa Formation (brJ3-K1bs) in the lithostratigraphic division of Bulgaria (Tsankov et al. 1991). They form a planar rifted fold structure with a northward vergence, known as the Assen structure (Gochev 1971). It is part of the Predbalkan block step (Aleksiev, 2002), which is formed between the Miesian continental microplate (from the north) and the Balkan longitudinal fault-flexure belt (from the south). The upper parts of the Assen structure, called Lednishki rut, are cleaved by the Garvanish fault that has a subparallel (east-west) direction (Gochev 1971). The northern tectonic block collapsed by more than 120-140 m along the fault (Kovachev 1959; Popov 1962), forming an Eopleistocene graben, reshaped into the Brestnitsa karst field (Popov 1962; Briestenský et al. 2015).

The karst formed in these limestones is a combination of allogenic and autogenic types (according to Jakucs 1979). The karst geomorphology of the area comprises typical karst landforms that form a full subphase complex. It encompasses the Brestnitsa

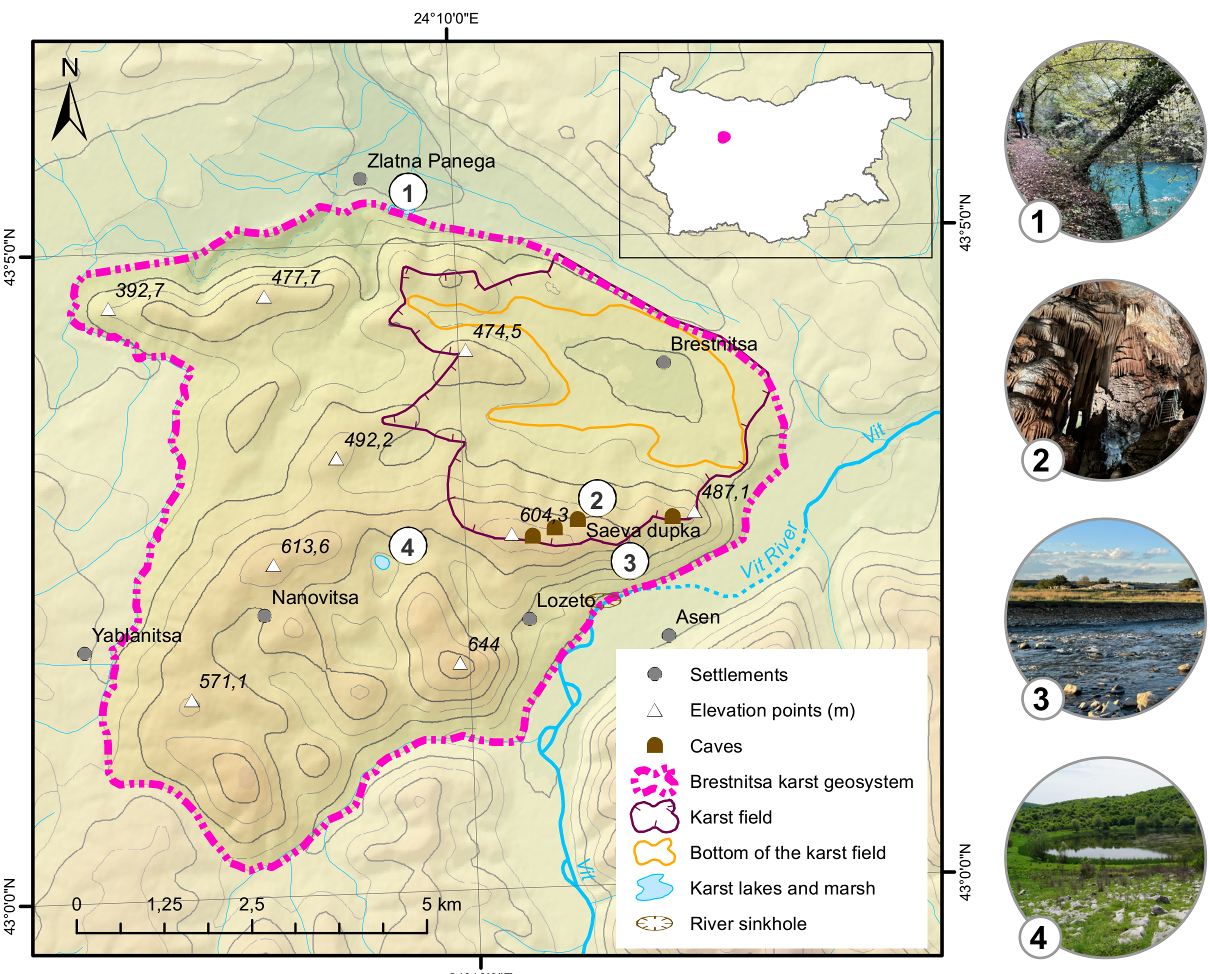

Figure 2. Brestnitsa karst geosystem: 1) Glava Panega karst spring, 2) Saeva dupka cave, 3) Vit River, 4) Nanovitsa karst marsh (Blatoto).

karst field, which is one of the largest in Bulgaria with an area of 9 km^2 (Popov 1962). The underground part of the geosystem includes several dozens of explored caves such as the abyssal cave Bezdanniya pchelin (-105 m) and one of the most visited tourist caves in Bulgaria - Saeva Dupka (230 m long) (Stefanov 2020b).

The latest climate studies in the area that are aimed at global changes, define the climate of the Brestnitsa karst geosystem as a low-mountain type in the transitional zone between the temperate and the subtropical (Mediterranean) climate (Nojarov 2020; Nojarov et al. 2020). The average annual precipitation for the period 1979-2018 is 845 mm with the highest values in May and June (111 mm and 98 mm, respectively) and two the lowest in November and January (52 mm and 53 mm, respectively). About 55% of the average annual precipitation supplies infiltrates into the karst geosystem (Shilegarska et al. 2020). Another main source of groundwater recharge is the runoff from the Vit River, which is sinking north of the village of Glozhene in a series of sinkholes located in the river bed. The precipitation, the surface runoff, and the underground water in the Brestnitsa karst geosystem are interconnected into a complex that forms typical karst hydrogeological zones (Kovachev 1959; Galabov et al. 2000; Shilegarska et al. 2020). They drain into the Glava Panega karst spring (type of vaucluse), which has the highest water flow (3765 l/sec) among the karst springs in Bulgaria (Shilegarska et al. 2020). Experiments undertaken in 1955 proved that the sinking waters of the Vit River also flowed into this spring and it took them 12 days to reach the spring (Kovachev 1959). Taking into account that the straight-line distance between the sinkholes and the spring is about 7 km, this long period of drainage is an indicator of the complexity of the underground sub-system. There is an underwater cave that is at the source of the Glava Panega. During a diving expedition in 1992, a speleologist managed to reach 230 m and a critical depth of 52 m (Zhalov 1999), which indicates quite a large size of this subterranean reservoir. Indirect evidence for this is the reported case of temporary drying up in 1867 of this large spring for 8 hours (Shkorpil and Shkorpil 1900). Borehole studies in the area of the geosystem also confirm a great depth of karst processes – up to 250 m (Kovachev 1959).

The Glava Panega spring is used for industrial ("Zlatna Panega Cement" JSC) and drinking water supply (14 settlements from 3 municipalities: Yablanitsa, Lukovit, Cherven Bryag) (Shilegarska et al. 2020). Water extraction is carried out from the artificially formed Dolno Ezero lake, into which the waters of the karst spring flow through natural underground channels. The permitted water intake is nearly 8.5% of the exploitable resources of the spring (Shilegarska et al. 2020). Due to the socio-economic importance of the spring, a project for a sanitary and protective zone was drawn up, which is tailored to the karst specifics of the hydrogeological basin (Shilegarska et al. 2020). However, there are no built sewers and treatment plants in the karst geosystem, that drains into the spring. The case of the wastewater in the village of Brestnitsa, located in the karst field, is particularly serious. There are also several unregulated landfills, some of which are in karst forms (dolines and uvalas) and the river bed and floodplain terraces of the Vit River. Until 2020, a Municipal Solid Waste Depot also operated near the river sinkholes. The problem with the toilets of the Saeva Dupka tourist cave, which have been proven to pollute the cave waters, has also not been resolved (Stefanov 2020b). Sewage from livestock farms is also a serious problem, as well as the unregulated disposal of animal feces in the karst terrain. The problems with the pollution of karst waters in the Brestnitsa karst geosystem are summarized in a separate publication, which emphasizes the analysis of the anthropogenic pressure in the karst territories influenced by the political and socio-economic changes in regional and global aspect.

The area of Brestnitsa karst geosystem has different types of land use, which ensure a variety of economic activities such as agriculture, livestock breeding, logging, extraction of construction materials (quarries for limestone and marl), industrial production (cement plant - Titan "Zlatna Panega Cement" JSC), and tourism. All of them directly or indirectly affect the circulation and pollution of karst waters. The new section of the "Hemus" highway was built in 2019-2020 and goes through the karst geosystem. However, there are only two protected karst territories with a limited area within the karst geosystem. The Natural landmark "Saeva Dupka" was declared in 1962 and has 20 ha. The Natural landmark "Glava Panega" (1.5 ha) was declared in 1966. Saeva Dupka cave has been open for tourist visits since June 4, 1967 (Popov 1969).

The changes in land use and land cover (LULC) for the period 1990-2018 have been studied using remote sensing data and GIS analyses (Stefanova et al. 2020). The most significant identified changes are 1) the transformation of broad-leaved forests into transitional coppice forests and shrub vegetation as a result of cutting off; 2) the conversion of pastures into cropland; 3) the conversion of deciduous forests into quarries. The latter is a consequence of the growing need for construction materials in connection with the increased road construction in the area (the new sections of the Hemus highway). These changes lead to structural-functional impacts on the karst geosystem (Andrejczuk and Stefanov 2017) and cause the transformation of karst types (Stefanova et al. 2020): e.g., green (covered) karst into bare karst, subsoil karst into karst fields (due to intensive erosion of arable Rendzic Leptosols (LPk) and Calcic Cambisols or deforestation/logging). Another practically important consequence is the pollution of underground karst waters (chemical, biological, mechanical).

A specific case of land use in the Brestnitsa karst geosystem is cement production based on local resources. It began in 1907, and since 2004 it has been conducted by Titan "Zlatna Panega Cement" company. The plant is near the "Glava Panega" karst spring and is one of the main consumers of its water. Close to the spring in the periphery of the karst geosystem are the main limestone quarries of the plant. Zlatna Panega Cement maintains a specialized monitoring program for the ecological condition of the used karst territories (Shilegarska et al. 2020). Three monitoring wells were built in the quarries to monitor the quality of underground water in 2018 and hydro-chemical analyzes are performed by certified laboratories. Wastewater from the production cycle at the plant is purified through a three-stage treatment facility. Titan "Zlatna Panega Cement" also develops an active social program for environmentally friendly activities in the conditions of a specific karst territory.

3.2 Water regulation ecosystem services

The water topic is one of the key themes in the ES concept, and is more or less included in all ES classifications. Water-related ecosystem services (WRES), also recognized as hydrologic services, are defined as the services that encompass the benefits to people produced by terrestrial ecosystem effects on freshwater (Brauman et al. 2007). These authors organize them into five extensive categories: improvement of extractive water supply, improvement of in-stream water supply, water damage mitigation, provision of water-related cultural services, and water-associated supporting services. The CICES classification (Common International Classification of Ecosystem Services) contains 12 classes that can be assigned to the water-related ES (Nedkov et al. 2022). Six of them are provisional and the other six can be assigned to WRES. They include *dilution by freshwater and marine ecosystems* (CICES code *5.1.1.1.*), *mediation by other chemical or physical means (5.1.1.3.)*, *liquid flows (5.2.1.2.)*, *control of erosion rates (2.2.1.1.)*, *hydrological* *cycle and water flow regulation (2.2.1.3.), regulation of the chemical condition of freshwaters by living processes (2.2.5.1.).*

The assessment and mapping of ecosystem services are set as a significant element in the European Biodiversity Strategy and are coordinated by the MAES (Mapping and Assessment of Ecosystems and their Services) working group. It develops the methodological framework for conducting these activities in the EU member states and also coordinates the integration of ecosystem services in several European environmental policies. The methodological framework for the assessment and mapping of ecosystems and their services in Bulgaria is developed in the form of nine separate documents, each of which covers one of the nine main ecosystem types: urban, agricultural, forest, grass, shrub, sparsely vegetated land, freshwater, wetlands, and marine. They have a common structure that follows the framework of MAES and includes typology and ecosystems mapping, ecosystems state assessment, and ecosystem services assessment. They cover part of the country's territory that is outside the scope of NATURA zones. Applying that data to water management activities would result in at least two serious problems: 1) the fragmentation of spatial units into nine separate GIS layers and the related disparities between them in the form of gaps and overlaps; 2) the lack of mapping for large parts of the country's territory will result in impossibility to cover the entire catchment area with data. The INES (INtegrated assessment and mapping of water-related Ecosystem Services for nature-based solutions in river basin management) project is set up to find solutions to these problems. The main objective of the project is to develop a methodological framework for mapping, modeling, and evaluating water-related ecosystem services to implement nature-based solutions in water management activities.

The karst geosystems have a specific water cycle that differs significantly from the other areas of the river basin. Therefore, it is necessary to carry out a thorough study of a representative karst geosystem in order to collect data for the water-related ecosystem services assessment and mapping. The Brestnitsa karst geosystem is an appropriate case study for fulfilling these requirements (see 3.1).

3.2.2 Defining indicators for water regulation ecosystem services from karst monitoring

Ecosystem service quantifications need a variety of information and long-term time series and data quality, which very often is not available to the extent required, so often only a small group of potentially representative variables can be used as indicators (Muller and Burkhard 2012). To assess WRES provided by karst geosystems it is necessary to analyze all potential sources of data and the ecosystem parameters that can be represented by each of them. The indicators can be divided into two groups: i) indicators for ecosystem condition; ii) indicators for ES.

The assessment of ecosystem condition in the methodological framework for mapping and assessment of the ecosystems in Bulgaria is based on the concept of ecosystem integrity. The key indicators for assessing condition within the ecosystem integrity concept should allow: i) representation of key elements of ecosystem integrity; ii) high sensitivity to environmental changes; iii) critical relevance for environmental modeling (Bratanova-Doncheva et al. 2017). The proposed set of indicators consists of five main groups of indicators including biotic heterogeneity, abiotic heterogeneity, energy budget, matter budget, and water budget. In our case, the most important indicators are from the water budget group but particular indicators from the other groups could also be used. For this study, we selected a set of condition indicators (Table 1) related more or less to WRES to be used for analyses of data requirement and availability from the karst monitoring.

Table 1. Ecosystem condition indicators (selected from Apostolova et al. 2017; Kostov et al. 2017; Uzunov et al. 2017).

Ecosystem condition Indicator group	Indicators
1. Biotic diversity	*1.1 Plant diversity* *1.2 Animal diversity*
2. Abiotic heterogeneity	*2.1 Hydrological heterogeneity* *2.2 Soil heterogeneity* *2.3 Disturbance regime* *2.4 Geo-morphological heterogeneity*
3. Energy budget	*3.1 Energy balance* *3.2 Entropy production* *3.3 Metabolic efficiency*
4. Matter budget	*4.1 Matter storage* *4.2 Alluvial regime/Suspended solids* *4.3 Matter balance (input, output)* *4.4 Element concentrations*
5. Water budget	*5.1 Water balance (input, output)* *5.2 Water storage*

The assessment of ecosystem services is based on the relationship between ecosystem components and processes, on the one hand, and ecosystem services on the other. Indicators are needed to describe this relationship quantitatively (de Groot et al. 2010, Rendón et al. 2022). As recognised by Czúcz et al. 2021, Levin et al. 2013 the existing lists of indicators are not necessarily transferable across cases, and vital pieces of information might not be covered by easily available indicators (Tanács et al. 2022). The methodological framework for mapping and assessment of ES in Bulgaria provides a variety of indicators as they differ significantly between the ecosystem types. For this study, we selected a set of ES indicators (Table 2) related to WRES to be used for the analyses of data requirements and availability from the karst monitoring. However, for some services such as dilution by freshwater and liquid flows, there were no appropriate indicators. Therefore, additional indicators were selected from the MAES report for mapping and assessment of ecosystems at the European level (Maes et al. 2014).

3.2.3 Analyses of data requirements and availability

To assess ecosystem services provided by karst geosystems it is necessary to analyze all potential sources of data that can be used to quantify the indicators selected at the previous stage (see 3.2.2). Each of the selected indicators has been assessed for data requirements and the quality of the available data to be used in ES quantification. The indicators were ranked into four categories following the quality label scheme proposed by Maes et al. (2016). The *high-quality label (1 - green)* is assigned to indicators that can rely on long-term monitoring data which can be easily transformed by appropriate methods for assessment of ecosystem condition and ES quantification. The *medium quality label (2 - yellow)* is assigned to indicators that could not rely on long-term available data but there are occasional or irregular data sources that can be used. The *low-quality label (3 - red)* refers to indicators that could not be supplied by the existing monitoring system but can be incorporated in the future through improvement of the monitoring sites. The *unknown*

Table 2. Ecosystem services indicators (selected from Apostolova et al. 2017; Kostov et al. 2017; Maes et al. 2014; Uzunov et al. 2017).

Ecosystem services	Indicators
1. Dilution by freshwater ecosystems (5.1.1.1.)	*1.1 Concentration of pollutants in water* *1.2 Water storage/delivery capacity*
2. Mediation by other chemical or physical means (5.1.1.3.)	*2.1 Sulphur (S) and Nitrogen (N) retention and removal by biota* *2.2 Sulphur (S) and Nitrogen (N) retention and removal by abiotic processes* *2.3 Concentration of pollutants in soil* *2.4 Concentration of nutrient elements (C, N, P, K, Ca, Mg, S) in soil* *2.5 Carbon storage per unit of area* *2.6 Potential mineralization or decomposition*
3. Liquid flows (5.2.1.2.)	*3.1 Water retention* *3.2 Capacity for maintaining baseline flow (modeling)*
4. Control of erosion rates (2.2.1.1.)	*4.1 Soil erosion rate* *4.2 Sediment load* *4.3 Vegetation cover*
5. Hydrological cycle and water flow regulation (2.2.1.3.)	*5.1 Water storage* *5.2 Retention capacity* *5.3 Area of wetlands located in flood risk zones*
6. Regulation of the chemical condition of freshwaters by living processes (2.2.5.1.)	*6.1 Chemical status* *6.2 Ecological status* *6.3 Potential of water purification of water bodies*

quality label (4 - grey) is assigned to the unknown availability of reliable data without appropriate methods for assessment and mapping. Additionally, for each indicator, the possibility for mapping has been assessed. It is made by the assumption that the available monitoring data can be transformed into spatially explicit information.

4. Results and discussion

4.1 Monitoring system of the Brestnitsa karst geosystem and its integration into ES assessment and mapping

The Brestnitsa karst geosystem is one of the main field research sites of the Experimental laboratory of karstology. The system for Integrated Monitoring of the Karst Systems (MIKS) functions there since 2009 (Stefanov 2020b). The measurements of the water cycle are important elements of the system. They include quantitative and qualitative measurements of the karst water, which are located at the main input (ponors of the Vit River) and output (Glava Panega spring) points of the geosystem as well as in the Saeva Dupka cave (infiltration and condensation water). A network for continuous instrumental monitoring (Speleo-MIKS) was also built in the cave in 2018 (Stefanov 2020b). The measurements are organized "in situ" following a methodology developed especially due to the specifics of the karst water and the unstable carbon balance (Světlík et al. 2009; Stefanov 2020b). The measurements are conducted using a modernized field hydro-chemical equipment type MP (Marcowicz and Pulina 1979) of the Experimental laboratory of karstology. Another site for regular monitoring is the karst marsh Nanovitsa (Fig. 3).

The monitoring of the water cycle covers surface waters in the recharge area (precipitation, slope runoff, river waters, swamps) and spring karst waters in the discharge area. Karst groundwater in the transit zone (infiltration, condensation, cave ice, cave, and sinter lakes) is measured and analyzed in the Saeva Dupka cave. In case of suspicion of specific forms of pollution, water samples are taken and analyzed in certified laboratories. An experimental site with two lysimeters for soil water monitoring was also equipped above the Saeva Dupka cave in 2021. The lysimeter studies are conducted in accordance with a tried-and-tested methodology with original sample collection devices constructed in the Experimental Laboratory of Karstology (Ninov et al. 2002; Stefanov 2020b).

The monitoring system of the Brestnitsa karst geosystem provides data for analyses of the water cycle which can be used in the assessment of water-related ecosystem services. The most appropriate ES is the *hydrological cycle and water flow regulation* which assessment demands a variety of parameters that are usually not available. The integration of the measured water parameters into an assessment approach requires in-depth analyses of the karst water cycle and the development of a conceptual model for the ES assessment.

From an ecological point of view, the karst processes have a significant impact on all landscape elements which lead to its transformation and formation of specific habitats for plants and animals as well as specific conditions for human life. At the same time, karst geosystems are open systems that determine energy and matter exchange with the surrounding, not karst areas. Therefore, the impact of the karst processes extends beyond the karst geosystem itself. There is also an increasing extent of this impact due to the dynamics of the elements of the environment (Andreychouk and Stefanov 2021). The Brestnitsa Karst Geosystem is a typical example of such impact which ensures the possibility to enlarge the extent of the studies and better integration into the whole ES assessment framework.

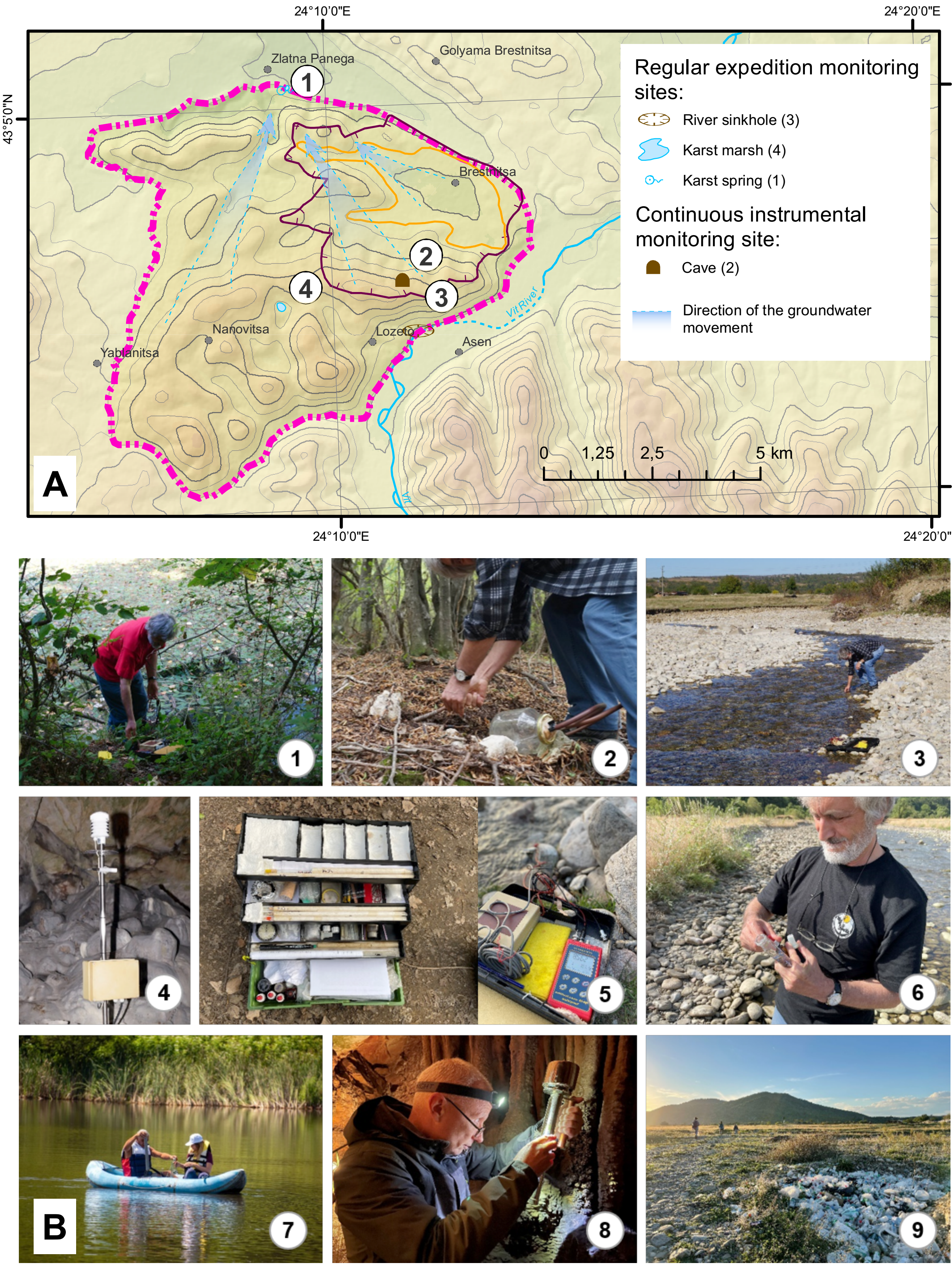

Figure 3. Monitoring sites of the Brestnitsa karst geosystem. A - Map: 1) Glava Panega karst spring, 2) Saeva dupka cave, 3) Vit River, 4) Nanovitsa karst marsh (Blatoto); B - Pictures representing hydrochemical water analyses: 1) from the karst spring, 2) from the soils above the cave, 3, 5 and 6) from the river, 4 and 8) Speleo-climatic measurements in the cave, 7) Water sampling from the karst marsh, 9) Solid waste across the river bank.

4.2 Perspectives for assessment and mapping of ecosystem condition

The analyses of the data requirements and availability for assessment and mapping of ecosystem condition show that most indicators are not backed up by reliable data. The predominant red colour of the *low-quality label* (Fig.4) indicates that most of the indicators could not be provided by the existing monitoring system but can be incorporated in the future by improving the monitoring sites. In general, the assessment is better secured than the mapping, which is expected and is dictated by the fact that the system consists only of point sources. Mapping of the ecosystem condition requires spatial data which can be generated by using geospatial techniques (Rendón et al. 2019). No assessment indicator falls into the lowest category of *unknown availability of reliable data* without appropriate methods, which is a positive mark as regards the perspectives on the assessment of ecosystem condition. The only indicator that can bank on long-term monitoring data which can be easily transformed by appropriate methods is water storage. This is due to the well-developed karst water quantity measurement system. The geomorphological heterogeneity stands out with the best prospects for both mapping and assessment.

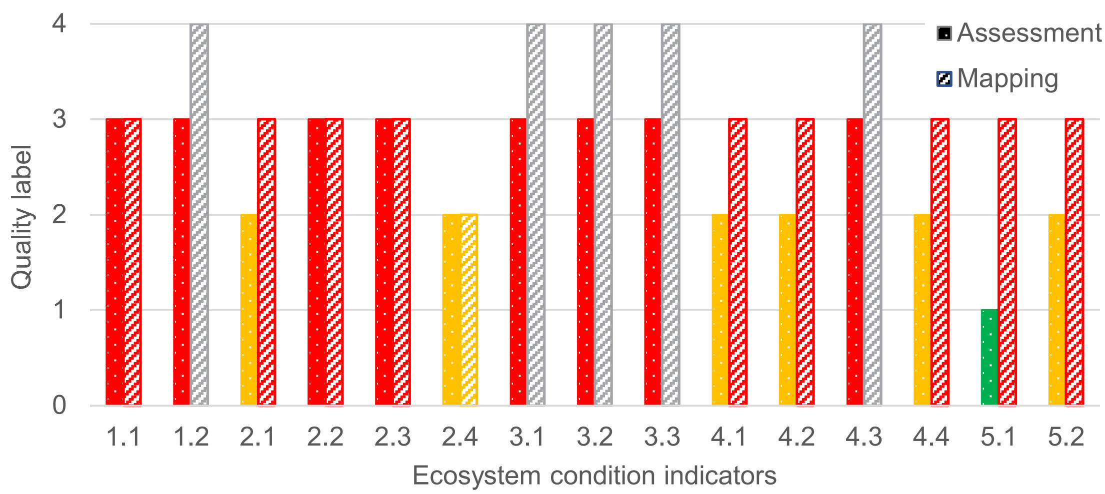

Figure 4. Analyses of data requirements and availability for assessment and mapping of ecosystem condition. Color keys: green - high quality label (1), yellow - medium quality label (2), red - low quality label (3), gray - unknown quality label (4).

4.3 Assessment and mapping of ecosystem services

The analyses of the data requirements and availability for assessment and mapping of ecosystem services show slightly better prospects than the ecosystem condition (Fig. 5). Three indicators for ES assessment are marked with a *high-quality label*: *concentration of pollutants in water*; *water storage*; and *chemical status*. Ten indicators are marked with a *medium quality label* (seven for ecosystem condition). Most indicators have better mark for assessment than mapping, seven have equal scores and no indicator have a higher rating for mapping.

The most difficult service for assessment and mapping is *liquid flow* with all mark in red or gray. Furthermore, this is the service with fewer indicators found in the available literature sources. This outcome is in line with the findings of Nedkov et al. (2022) who puts this service in the lower category of services, modeled in a few

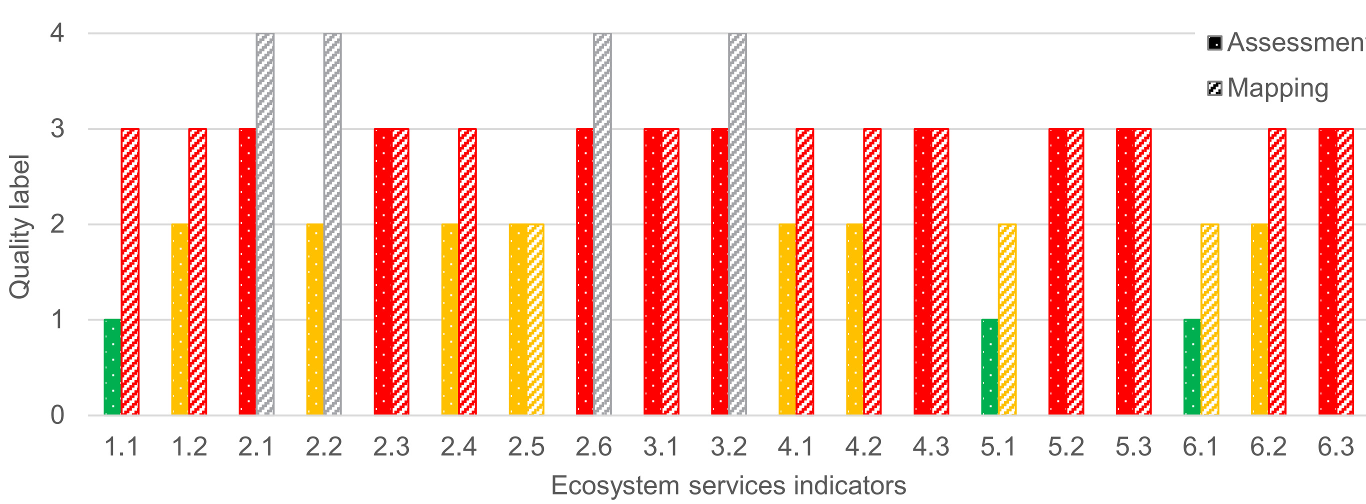

Figure 5. Analyses of data requirements and availability for assessment and mapping of ecosystem services. Color keys: green - high quality label (1), yellow - medium quality label (2), red - low quality label (3), gray - unknown quality label (4).

studies, with little correlation that has low confidence in regard to the recommendations for integration in ecosystem accounting. The services with the highest perspective for assessment and mapping are *hydrological cycle and water flow regulation* and *regulation of the chemical condition of freshwaters by living processes*. Both of them have three optional indicators and at least one indicator with a *high-quality label* for assessment and a *moderate-quality label* for mapping. Three services have indicators with scores that vary from *moderate* to *unknown quality label* which means that more efforts are needed to better link the monitoring data with the framework for assessment and mapping of ES.

5. Conclusions

The system of karst monitoring of the Experimental Laboratory of Karstology is well developed and covers the main types of these unique natural phenomena in Bulgaria (ProKARSTerra, 2023). The monitoring provides reliable information on the responses of the systems to various impact such as anthropogenic pressure, extreme natural events, and global changes. The experience gained from the various activities so far proves that the methodological framework ProKARSTerra effectively combines important aspects in three directions: 1) research; 2) management and business with karst resources; 3) education and training for and by karst (Fig. 1). All three of them are essential for the integration into the framework for assessment and mapping of ecosystem services. This research provides the necessary data for indicators as to ES supply. The management aspect ensures the connection with human well-being and opportunities for ES demand analyses. The education and training aspect completes the assessment process with the involvement of the end-users.

The results of the long-term integrated monitoring in the Brestnitsa karst geosystem (especially karst waters) lay the foundation for important conclusions and models for the karst genesis and function affected by global changes and active anthropogenic pressure. Their integration into the framework for assessment and mapping of ecosystem services is an important step towards the development of models for sustainable use of natural resources in the karst areas. The karst geosystems function as open systems that have active energy and matter exchange with the surroundings, not karst areas. This determines the impact of the karst processes outside the karst geosystem, which extent increases due to the dynamics of the environment. The Brestnitsa Karst Geosystem is a typical example of an impact which ensures the possibility to enlarge the extent of the studies and the better integration into the whole ES assessment framework.

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References

Aleksiev G (2002) Morphostructural analysis. The Pre-Balkan block escarpment. In: Geography of Bulgaria. ForKom, Sofia, 86 pp. (in Bulgarian)

Andreychouk V (2016) The system nature of karst landscape and principles of cave protection resulting from it 2016 Zeitschrift für Geomorphologie Supplementary Issues 60(2): 257-291. http://dx.doi.org/10.1127/zfg_suppl/2016/00300

Andreychuk V, Stefanov P (2006) Karst geosystems and principles of protection of karst territories. GEOgraphy`21 1: 5-11. (in Bulgarian)

Andreychouk V, Stefanov P (2008) Principles of protection of karst areas. Speleology and Karstology 1: 54-59. http://www.institute.speleoukraine.net/uisk_pages/sk_abstract.php?id=1112&lang=en (in Russian)

Andreychouk V, Stefanov P (2021) Some methodological remarks concerning of karst studies from the system approach perspective. Problems of Geography 1: 12-24. https://doi.org/10.35101/prg-2021.1.2

Andreychouk V, Voropai L (1993) Karst landscape as geosystem. Problems of karst landscapes study. Perm, 37-52. (in Russian)

Andrejczuk W, Stefanow P (2017) Podstawowe zasady ochrony krajobrazu krasowego i jaskiń. Acta Geographica Silesiana, 11/1(25), WNoZ UŚ, Sosnowiec, 5–10. https://www.ags.wnoz.us.edu.pl/download/wydawnictwa/ags/ags_25_2.pdf (in Polish)

Apostolova I, Sopotlieva D, Velev N, Vassilev V, Bratanova-Doncheva S, Gocheva K (2017) Methodology for assessment and mapping of wetland ecosystems condition and their services in Bulgaria. Clorind, Sofia, 56 pp. ISBN 978-619-7379-14-3. https://eea.government.bg/en/projects/Ecosystems/wetlandses/WETLAND_ENG.pdf

Bakalowicz M (2005) Karst groundwater: a challenge for new resources. Hydrogeol J 13:148–160. https://doi.org/10.1007/s10040-004-0402-9

Bella P (1995) Territorial structure of the karst geosystems and the interpretation of negative anthropogenic interventions. Acta Carstologica 24: 83-95.

Biondic B, Biondic R, Measki H (2010) The conceptual hydrogeological model of the Plitvice Lakes. Geologia Croatica 63:195–206.

Bonacci O, Pipan T, Culver DC (2009) A framework for karst ecohydrology. Environ Geol 56:891–900

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 bases and principles of application. Clorind, Sofia, 48 pp. ISBN:978-619-7379-21-1

Brauman KA, Daily GC, Duarte TK, Mooney H (2007) The nature and value of ecosystem services: an overview highlighting hydrologic services. Annual Review of Environment and Resources 32: 67-98. https://doi.org/10.1146/annurev.energy.32.031306.102758

Briestenský M, Rowberry M, Stemberk J, Stefanov P, Vozár J, Šebela S, Petro Ľ, Bella P, Gaal Ľ, Ormukov C (2015) Evidence of a plate-wide tectonic pressure pulse provided by extensometric

monitoring in the Balkan Mountains (Bulgaria). Geologica Carpathica 66(5): 427-438. https://doi.org/10.1515/geoca-2015-0035
Czúcz B, Keith H, Maes J, Driver A, Jackson B, Nicholson E, Kiss M, Obst C (2021) Selection criteria for ecosystem condition indicators. Ecological Indicators 133, 108376. https://doi.org/10.1016/j.ecolind.2021.108376.
De Groot R, Alkemade R, Braat L, Hein L, Willemen L (2010) Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7: 260-272. https://doi.org/10.1016/j.ecocom.2009.10.006
Furey NM, Mackie IJ, Racey PA (2010) Bat diversity in Vietnamese limestone karst areas and the implications of forest degradation. Biodivers Conserv 19:1821–1838. https://doi.org/10.1007/s10531-010-9806-0
Galabov M, Gergov G, Damyanov A, Kovachev S (2000) Groundwater transfer from the Vit river to the Iskar river through the karst reservoir "Zlatna Panega". BGD Journal 1-3: 151-156. (in Bulgarian)
Gochev P (1971) The Teteven anticlinorium. In: Bonchev E (Ed.) Tectonics of the Fore-Balkan. Publishing house of the BAS, Sofia, 229-332pp. (in Bulgarian)
Goldscheider NA (2019) A holistic approach to groundwater protection and ecosystem services in karst terrains. Carbonates Evaporites 34: 1241–1249. https://doi.org/10.1007/s13146-019-00492-5
Gorjanc S, Simončič T, Poljanec A, Kuslits B, Arany I, Tanács E, Vári Á, Aszalós R, Drasovean A, Mos A, Maeso Velasco L, Reuter A, Gattenlohner U (2022) A new ecosystem services approach to enable identification of pro-biodiversity businesses of protected karst areas in Central and South-Eastern Europe. Hungarian Geographical Bulletin 71(2): 181-195. https://doi.org/10.15201/hungeobull.71.2.6
Jakucs L (1979) Morphogenetics of karst regions. Variants of karst evolution. Progress Publishing House, Moscow, 389 pp. (in Russian)
Jelev G, Stefanova D, Stefanov, P (2021) Land cover and land use change in karst region Devetashko plateau. Aerospace Research in Bulgaria 33: 51-78. https://doi.org/10.3897/arb.v33.e05
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/woodlandforestes/FOREST_ENG.pdf
Kovachev I (1959) Karst and Ground Karst waters in the Valley of Upper and Middle Vit and Glava Panega. In: Yaranov D (Ed.) Karst Ground Waters in Bulgaria. Technika Publishing House, Sofia, 183-229. (in Bulgarian)
Maes J, Teller A, Erhard M 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, 80 pp. https://data.europa.eu/doi/10.2779/75203
Maes J, Liquete C, Teller A et al. (2016) An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020. Ecosystem Services 17: 14–23. https://doi.org/10.1016/j.ecoser.2015.10.023
Markowicz M, Pulina M (1979) Ilosciowa polmikroanaliza chemiczna wod w obszarach krasu weglanowego. Universytet Slaski, Katowice, 67 pp. (in Polish)
Mikhova D, Stefanov P (1993) Design of an information system for modeling of karst geosystems. Problems of Geography 2: 68-82. (in Bulgarian)
Mikhova D, Stefanov P (1995) Cartographic modeling of natural systems with GIS (on the example of karst geosystem). In: Sat. Reports "Geography '94", 68-76 (in Bulgarian).
Mikhova D, Stefanov P (1999) Gis-based Modeling of Karst Geosystems. In: Towards Digital Earth/Proceedings of the International Symposium on Digital Earth, Beijing (China), November-December 1999. Science Press, Beijing, China, 1-5.
Muller 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
Nedkov S, Campagne S, Borisova B, Krpec P, Prodanova H, Kokkoris I, Hristova D, Le Clec'h S, Santos-Martin F, Burkhard B, Bekri E, Stoycheva V, Bruzon A, Dimopoulos P (2022) Modeling water regulation ecosystem services: A review in the context of ecosystem accounting. Ecosystem Services 56: 101458. https://doi.org/10.1016/j.ecoser.2022.101458
Ninov N, Stefanov P, Iliev M (2002) A preliminary model for of soil cover cadastre in karst terrains devised with a view to Sustainable development of Protected areas (the Shumen Plateau Nature park Case study). In: Collection of papers from a Scientific Conference with International Participation in Memory of Prof. D. Yaranov, Varna, September 2002. Ter-ART Publisher, Sofia, Vol. 2.: Development and state of Environment, 355-369. (in Bulgarian)
Nojarov P (2020) Climate and its changes over the period 1979-2018 in selected model karst regions in Bulgaria. Problems of Geography 4: 11-28. https://doi.org/10.35101/PRG-2020.3.2
Nojarov P, Stefanov P, Turek K (2020) Influence of some climatic elements on radon concentration in Saeva Dupka Cave, Bulgaria. International Journal of Speleology 49 (3): 235-248. https://doi.org/10.5038/1827-806X.49.3.2349
Popov V (1962) Morphology of the karst in the area between the valleys of the rivers Vit and Batulska. Journal the Bulgarian Geographical Society 13: 21-33. https://geography.bg/publication/magazines/item/741-vol13-1962-2 (in Bulgarian)
Popov V (1979) Saeva Dupka [cave]. Medicine and Physical Culture Publishing House, Sofia, 27 pp. (in Bulgarian).
Rendón P, Erhard M, Maes J, Burkhard B (2019) Analysis of trends in mapping and assessment of ecosystem condition in Europe. Ecosystems and People 15(1): 156-172. https://doi.org/10.1080/26395916.2019.1609581
Rendón P, Steinhoff-Knopp B, Burkhard B (2022) Linking ecosystem condition and ecosystem services: A methodological approach applied to European agroecosystems. Ecosystem Services 53: 101387. https://doi.org/10.1016/j.ecoser.2021.101387
Shkorpil H, Shkorpil K (1900) Natural resources of Bulgaria: Karst phenomena (underground rivers, caves, springs). Publishing house of the bookstore "Pchela", Plovdiv, 55 pp. (in Bulgarian)
Shilegarska E, Toleva Ts, Petkov P, Pophristova A (2020) Karst Monitoring at Zlatna Panega Quarry. Problems of Geography 3: 145-156. https://doi.org/10.35101/prg-2020.3.8
Stefanov P (2013) The model "Speleo-MIKS Biserna". In: Proceeding papers of the Second International Conference "Geografical Sciences and Education", Shumen (Bulgaria), November 2013. Univ. ed. „Episkop Konstantin Preslavsky", Shumen, 34-48.
Stefanov P (2020a) International Scientific and Practical Forum "Protected Karst Territories – Legislation, Tourism, Monitoring" (ProKARSTerra`2019). Problems of Geography 3: 3-10. https://doi.org/10.35101/PRG-2020.3.1 (in Bulgarian)

Stefanov P (2020b). Integrated monitoring of the Saeva Dupka cave system (Speleo-MIKS „Saeva Dupka"). Problems of geography 4: 3-40. https://doi.org/10.35101/PRG-2020.4.1 (in Bulgarian)

Stefanov P, Stefanova D (2014) The educational strategy "ProKARSTerra-Edu" - integration between modern scientific concepts of karst and the educational concept "Lifelong Learning". In: Proceedings "30 years of the Department of Geography at the University of Veliko Tarnovo" St. St. Cyril and Methodius", Veliko Tarnovo (Bulgaria). IVIS Publishing House, 82-89 (in Bulgarian).

Stefanov P, Stefanova D, Mikhova D, Štefka L. (2013) ProKARSTerra–Edu – a karst-educational project. In: Filippi M, Bosák P. (Eds) Proceedings of the 16th International Congress of Speleology, July 21–28, Brno. Czech Speleological Society. Praha. Vol.1, 307-311. https://uis-speleo.org/wp-content/uploads/2020/08/16th_proceedings-v001.pdf

Stefanova D, Stefanov P, Jelev G (2020) Changes in land coverage and land use in selected model karst areas of Bulgaria. Problems of Geography 3: 157-186. https://doi.org/10.35101/PRG-2020.3.9 (in Bulgarian)

Světlík I, Molnár M, Váňa M, Stefanov P (2009) Estimation of 14CO2 amount in the atmosphere. Journal of Radioanalytical and Nuclear Chemistry 281: 137–141. https://doi.org/10.1007/s10967-009-0065-z

Tanács E, Bede-Fazekas Á, Csecserits A, Kisné Fodor L, Pásztor L, Somodi I, Standovár T, Zlinszky A, Zsembery Z, Vári Á (2022) Assessing ecosystem condition at the national level in Hungary - indicators, approaches, challenges. One Ecosystem 7: e81543. https://doi.org/10.3897/oneeco.7.e81543

Tsankov Ts, Nedyalkova L, Aladzova – Hrischeva K, Hrischev H, Angelova D (1991) Geological Map of Bulgaria 1:100 000, Map sheet Cherven Bryag, Geological Institute – BAS, Sofia (in Bulgarian).

Uzunov Y, Pehlivanov L, Chipev N, Vassilev V, Nedkov S, Bratanova-Doncheva S (2017) Methodology for assessment and mapping of freshwater ecosystems condition and their services in Bulgaria. Clorind, Sofia, 64 pp. ISBN 978-619-7379-17-4. https://eea.government.bg/en/projects/Ecosystems/riverlakeses/FRESHWATER_ENG.pdf

Van Ree C, van Beukering P (2016) Geosystem services: A concept in support of sustainable development of the subsurface. Ecosystem Services 20: 30-36. https://doi.org/10.1016/j.ecoser.2016.06.004

Voropai L, Andreychouk V (1985) The peculiarities of karst landscapes as geosystems. Chernivtsy: Chernivtsy University Publishing House, 81 pp. (in Russian).

Xue P, Ai Z, Cui D, Wang W (2019) A Grey Box Modeling Method for Fast Predicting Buoyancy-Driven Natural Ventilation Rates through Multi-Opening Atriums. Sustainability 11(12):3239. https://doi.org/10.3390/su11123239

Zhalov A (1999) Glava Panega – the longest karst spring in Bulgaria. Bulgarian Caves 6: 29-30.

http://iyck2021.org - International Year of Caves and Karst (IYCK) - 2021 and 2022.

http://www.prokarstterra.bas.bg/lab/EN/base.html - ProKARSTerra Experimental laboratory, 2023.

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Conceptualization: PS, HP and VS; Data curation: PS, HP, VS and GP; Formal Analysis: HP and VS; Investigation: PS, HP, DS, VS and GP; Methodology: PS and HP; Resources: PS and DS; Validation: HP and VS; Visualization: HP and VS; Writing – original draft: PS, HP, VS and DS; Writing – review and editing: PS and VS.

Conflict of interest

The authors have declared that no competing interests exist.

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