DOI: https://doi.org/10.3986/ac.v54i1.13933

CHARACTERISTICS AND IMPORTANCE OF PROTECTED KARST SPRINGS IN THE SOUTHERN MOUNTAINOUS REGION OF ALBANIA

ZNAČILNOSTI IN POMEN ZAVAROVANIH KRAŠKIH IZVIROV NA JUŽNEM GORSKEM OBMOČJU ALBANIJE

Ermira JASHIKU[1*], Ermiona BRAHOLLI[1] & Edlira MENKSHI[1]

Abstract UDC 502:556.36(496.5)

Ermira Jashiku, Ermiona Braholli & Edlira Menkshi: Characteristics and importance of protected karst springs in the southern mountainous region of Albania

Karst formations in Albania cover an area of 6750 km², which represents 24% of the country's territory. The country has 110 karst springs with discharges exceeding 100 litters per second. Among these, Bistrica springs stands out as the largest, with an average discharge of 18.4 cubic meters per second. This study focuses on the Southern Mountain Region of Albania, known for its important karst water resources. In this region, 12 karst springs are protected due to their essential natural, scientific, educational, aesthetic and economic value. The objective of this research is to perform a geoinformatics analysis and evaluation of these protected karst resources. To achieve this, we collected extensive literature on protected springs, as well as reach data about the protected springs of the study area and analysed them using ArcGIS 10.1 software to generate geoinformation about these resources. This geoinformation includes a wide range of geographic and geologic-hydrogeological data. We aim to improve the understanding and promotion of protected karst resources in the Southern Mountain Region of Albania

Keywords: Southern Mountainous Region of Albania, karst spring, geoinformation, geomonument.

Izvleček UDK 502:556.36(496.5)

Ermira Jashiku, Ermiona Braholli & Edlira Menkshi: Značilnosti in pomen zavarovanih kraških izvirov na južnem gorskem območju Albanije

Kraški pojavi v Albaniji pokrivajo 6.750 kilometrov² ali 24 % ozemlja države. V državi je 110 kraških izvirov z iztoki, večjimi od 100 litrov na sekundo. Med njimi izstopa izvir Bistrica, ki je največji izvir, njegov povprečni iztok pa je 18,4 metra³ na sekundo. Ta študija se osredotoča na južno gorsko območje Albanije, ki je znano po pomembnih kraških vodnih virih. Na tem območju je 12 kraških izvirov zavarovanih zaradi njihove bistvene naravne, znanstvene, izobraževalne, estetske in gospodarske vrednosti. Cilj te raziskave je izvesti geoinformacijsko analizo in oceno teh zavarovanih kraških virov. V ta namen smo zbrali obsežno literaturo o zavarovanih izvirih in razpoložljive podatke o zavarovanih izvirih na proučevanem območju, te smo analizirali s programom ArcGIS 10.1 in tako pridobili geografske informacije o teh virih. Te geografske informacije vključujejo širok nabor geografskih in geološko-hidrogeoloških podatkov. Naš cilj je izboljšati razumevanje in promocijo zavarovanih kraških virov na južnem gorskem območju Albanije.

Ključne besede: Južno gorsko območje Albanije, kraški izvir, geografske informacije, geološki spomenik.

[1] University of Fan S. Noli, Faculty of Education and Philology, Department of History and Geography, Shetitorja Rilindasit, Korçë, Albania, e-mail: ejashiku@unkorce.edu.al

* Corresponding author

Received/Prejeto: 11. 9. 2024

1. INTRODUCTION

Usually, a concentrated groundwater discharge on the land surface with visible flow is known as a spring (Krešić and Stevanović, 2010). The springs associated with karst formations and phenomena, developed in regions built up by carbonate rocks (limestone, dolomite, gypsum, rock salt, etc.), are called karst springs (Encyclopaedic Dictionary I, 2008). Generally, karst springs emerge at the lower outcrop elevation of carbonate rocks, usually in contact with impermeable formations and often along tectonic faults (Ford and Williams, 2007; Eftimi et al.,1985). However, there are also many springs issuing at the sea cost-line or in inside the sea (Eftimi et al., 2023a).

According to global analyses conducted under the WOKAM (World Karst Map) project (Chen et al., 2017; Goldscheider et al., 2020) about 15.2% of Earth's continental surface is underlined by karst rocks; but the highest percentage of karst rocks is in Europe, 21.8%. In the Mediterranean region within a 250 km focus area from the coastline, the carbonate rocks cover ~39.5% of the territory (Xanke et al., 2024). Karst regions provide drinking water to almost a quarter of the world's population (Hartmann et al., 2014) and the same is situated in the Mediterranean region of Europe (Stevanovic, 2019). Some big karst springs are the main water supply source for many capitals and important cities of central Europe and the Balkans such as Vienna, Sarajevo, Tirana, Skopje and Podgorica (Stevanović and Eftimi, 2010). Karst relief is one of the dominant types across the entire Albanian territory (Meço and Aliaj, 2000; Kabo, 1990). The karst aquifer layers primarily consist of limestone, dolomite, and to a lesser extent, of evaporates, all of which represent the most abundant aquifer types in Albania (Eftimi, 2010; Eftimi, 2024). In Albania, the karstic rocks cover an area of approximately 6,750 km², or about 23.5% of the country's surface (Qirjazi, 2019). Karst water resources account for 227 m³/s, consisting of around 80% of Albania's natural groundwater resources (Eftimi, 2010). About 70% of the country's population is supplied by karst water, including most of the cities of Albania including Kukës, Peshkopi, Burrel, Mamurras, Tirana, Gramsh, Pogradec, Bilisht, Vlora and Gjirokastër (Eftimi et al., 2023). In Albania, there are 110 karst springs, with an average discharge of 100 l/s, and 17 of them have discharges exceeding 1,000 l/s (Eftimi et al., 1985).

The World Conservation Union (IUCN) has developed strategies for declaring the water resources protected areas, for their conservation and sustainable management (Qiriazi and Sala, 2006). Between the six categories of protected areas, this study is focused of the third category, natural monuments. In the third category are included geological, hydrological and geomorphological features that are generally quite small, protected areas and often with high visitor values (Dudley, 2008). Recently, Albanian scientists have studied and protected within Albanian law about 98 water bodies/features. Between them, 46 water features with scientific, educational and touristic potential are karst springs (Qiriazi and Sala, 2006; Qiriazi, 2017).

The big karst springs have been the subject of the well-known World Karst Aquifer Map - WOKAM (Chen et al., 2017; BGR, IAH, KIT and UNESCO, 2017) in which three of Albania's karst springs are shown: Uji Ftohte-Vlore; Bistrica and St. Naum-Tushemisht. Some big karst springs of Albania are shown also in the Mediterranean Karst Aquifer Map (Xanke et al., 2022), such as Bistrica, Kroi Isake (Mat River), Pjosë-Tropojë, Uji

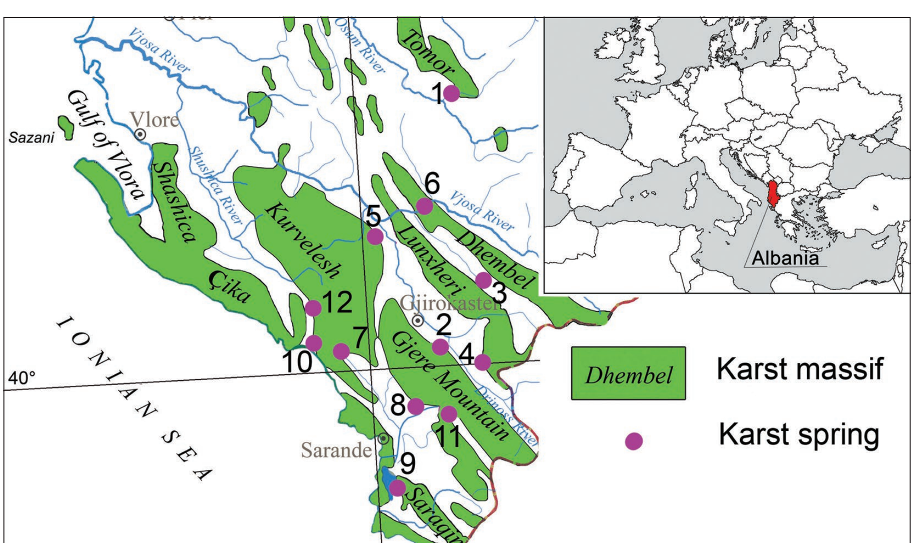

Figure 1: The geographical location of the twelve protected springs in the Southern Mountain Region in Albania: 1) Guaku spring, 2) Viroi spring, 3) Nivani spring, 4) Libohova spring, 5) Uji i Ftohte Spring, 6) Uji i Zi Spring, 7) Tatzati spring 8) Oknos spring, 9) Mulliri spring, 10) Ixuari spring, 11) Fterras spring, 12) Bistrica Spring. Source: R. Eftimi (2020).

Ftohte-Vlorë and Lera Pass (Himara) submarine spring. An important international project in which Albania also participated, is MIKAS (*Most Important Karst Aquifer's Springs*). The aim of this project is to select the most interesting and important springs on a global and national scale (Stevanović, 2023). This study is focused on the creation of geoinformation for the twelve karst springs, located in the Southern Mountainous Region of Albania, which have protected status as natural monuments.

2. STUDY AREA

The Southern Mountainous Region extends between Devoll River in the north and the Greek border in the south, the southeastern part of the Central Mountainous region in the east and the coastline of the Ionian Sea and Adriatic Sea in the west (Figure1). It covers an area of 6200 km², which consists of approximately 21.6% of Albania's total surface area (Krutaj, 1991; Qiriazi, 2019).

From a tectonic perspective, it spans across three tectonic zones: the Ionian Zone, the Kruja Zone, and the Sazan Zone (Xhomo et al., 2002; Qiriazi, 2019). The relief is a combination of mountain ranges and intermontane valleys. The folding of structures to the west, and the processes of erosion and karstification, have significantly influenced the morphology of this rugged mountainous area which dominates the karst landscape. As seen in Figure 1, some karst massifs in the study area are situated having NW-SE orientation and constituting of some important karst massifs such as Tomori, Shushica, Çika, Dhëmbeli, Lunxhëria Mali i Gjerë, Kurvelesh and Saraqini. The karst massifs usually have an elevation of more than 2000 m asl and consist mainly of Mesozoic carbonate rocks. The highest elevation of the karst massifs reaches up to 2486 m asl in Mount Nemërçka.

The climate of the study areas is typically Mediterranean with big variations according to the distance to the Sea and the influence of the intermountain river valleys. According to the "Climate of Albania" (Jaho, 1985), the average annual temperature ranges from 11.4° C in the east (Leskovik) to 17.6° C in Sarandë. Precipitation varies from 1163 mm in Leskovik to 1279 mm in Sarandë. The areas with the highest rainfall is the high-elevation karst massif of Kurvelesh (2000-2600 mm per year).

3. METHODOLOGY

The goal of this study is to examine the protected karst springs of the Southern Mountainous Region of Albania and create a digital inventory of these springs. Through fieldwork, literature review, and the use of ArcGIS 10.1 software, a table was compiled with digitized data on karst springs, including geographical width and length, elevation above sea level, average temperature values, flow velocity, strength, pH, and more (Table 1). This provides a way to manage and analyse information about these karst springs, considering their scientific, economic and tourist value, as well as to organize the monitoring of the of most important parameters (Stevanović at al., 2022). Another purpose of the paper is to increase public awareness and to contribute to the knowledge and promotion of protected karst springs of Albania.

4. MATERIALS AND RESULTS

Based on the criteria mentioned above, a list of geographical characteristics is evidenced in the twelve karst springs located inside the Southern Mountainous Region of Albania. In this study, it is important to analyse the value elements of Guaku spring, Viroi spring, Nivani spring, Libohova spring, Uji i Ftohte Spring (Tepelena), Uji i Zi (Këlcyra) spring, Tatzati spring, Oknos spring, Mulliri spring, Ixuari spring, Fterras spring and Bistrica Spring.

Guaku Spring is located in the valley of Çorovoda River, approximately 1.5 km north of the city of Çorovoda (Figure 2). The elevation of the Spring is about 315 m

Figure 2: The stratification of the water near to the spring of Guaku. Source: Shqiperia JONE 2021.

asl. The spring emerges at the contact point between upper Cretaceous limestone and the flysch formations. It has a funnel-like vertical channel formed by erosion and of a strong ascending flow and belongs to the so-called Vaucluse (syphon) type springs (Kresic and Stevanović, 2010). The minimum discharge of the spring is about 450 l/s, the average is about 1300 l/s and the maximal is about 6000 l/s. The water exhibits favourable physicochemical properties, it is low mineralised with a temperature of 9.4° C, the conductivity is 237 μS/cm, and the water chemical type is of HCO_3-Ca. Guaku Spring is tapped and 120 l/s are used for the water supply of the city of Çorovoda and the first zone of sanitary protection of the spring is fenced. The spring is allowed to be frequented only by the students for didactic purposes.

Viroi Spring (Figure 3) is located about 1.5 km north to the city of Gjirokastër on the edge of the eastern slope of the Gjere Mountain, at the elevation 196 asl. Geologically this mountain is an anticline structure consisting of Mesozoic carbonate sequences overthrown to the west on Paleogene flysch formations (Xhomo et al., 2002). This spring is the biggest temporary spring of Albania (Eftimi, 2024). During the rainy season, the maximum discharge of the spring reaches about 40 m^3/s, and downflow of the spring at that time forms a beautiful temporary lake as seen in Figure 3a. However, during the dry season (usually July-September), the spring dries up, the lake disappears (Figure 3b) and on the surface could be seen the giant throat of the spring's syphon (Figure 3c, 3d). The well-developed discharging siphon represents a big attraction for divers. During the last 20 years, many divers have attempted to find the depth of this syphon. Initially, the depth of Viroi Spring was measured to 83 m (Toulomudjian, 2005), but recently, diving robots have reached a depth of 279 m (Kicińska, 2017). This is currently the deepest known syphon in Albania.

The temperature of the spring water averages about 11.2° C, the water conductivity is 370 μS/cm and the water chemical type is HCO_3-Ca, with Ca-62 mg/l, HCO_3-161 mg/l and SO_4-46.5 mg/l (Eftimi, 2010; Eftimi, 2020). As the spring's water is relatively hard, total hardness being about 22° German degrees, it is not used as drinking water.

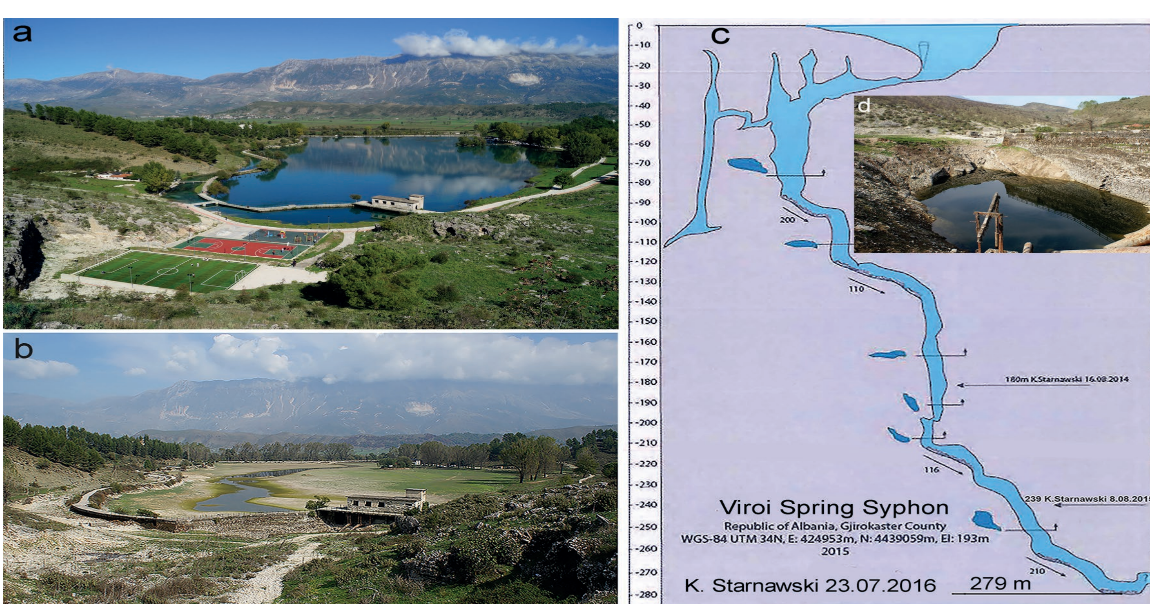

Figure 3: Viroi spring: the spring during wet season; b the dried-up spring during the dry season; c the spring's syphon; d the top of the syphon during low level season (Source: a and b, P. Stefanov; c, R. Eftimi).

Figure 4: The position of the source of Nivani spring (Gurra e Nivanit) in the ground of a Church (Source: Libohova post, 2018).

By contrast, the interest of the spring as a touristic attraction has notably increased. The area around the Lake has been transformed into a popular and attractive park, frequented not only by the local population, but also by tourists. Unfortunately, the sports grounds have been constructed in an inappropriate place, just upstream of the spring, creating a constant source of the pollution of the spring and of the area around it. The spring area is becoming an area with economic, scientific, geological and didactic values.

Nivani Spring is in the village of Nivan, Zagori municipality, of Gjirokastra region. It issues at the elevation of 960 meters asl as a four-source spring, near a small church (Figure 4). Geographically the spring is on the western slope of Dhëmbeli mount with the source emerging in argillaceous-siltstone-sandstone sheets with shear horizons and limestones olistoliths of the Lower Oligocene (Xhomo, 2002). The water of this spring is cold (about 10° C), low mineralized and of HCO_3-Ca type. This spring is in the centre of the village and has been a symbol where the population of the village gathers on special occasions. The spring is visitable via the rural road from Gjirokastra to Nivan.

Libohova Spring or Zhepa Spring (Figure 5), is in the centre of the homonymous city of the Gjirokastra region at an elevation of about 350 m asl. The source is in the western slope of Bureto mountain. This is a big spring, according to the monitoring measurements, the mean yearly discharge is about 70 l/s. This spring is known also for the very good water quality, the temperature is 12° C and, according to the salt content (about 110 mg/l), it is classified as an oligomineral spring. The area of location of the spring is very attractive and relaxing. Like the above-mentioned Gurra Nivani Spring, it is as also a symbol where the population of the Libohova Village gathers on special occasions. Near to the spring is a restaurant and the water is stratified in the scale furnace.

Figure 5: Stratification of the water of Libohova Spring (Source: E. Braholli).

Uji Ftohtë (Cold-Water) Spring of Tepelena (Figure 6). This spring is in the southeast of the small city of Tepelena, at a distance of about 3-4 km. The spring issues from the southern slope of Kurvelesh karst massif, just in

Figure 6: Uji Ftohte (Cold Water) spring, near Tepelena: a Spring discharge; b the capture tunnel constructed in 19th century by Ali Pasha Tepelena (Source: a, P. Malik; b, R. Eftimi).

the contact of Cretaceous carbonate rocks with the Paleogene practically impermeable rocks, at an elevation of about 225 m asl. The discharge of the spring varies from more than 400 l/s during the rainy season to about 110 l/s during the summer, while the average yearly discharge is about 200-250 l/s. The water temperature is about 11° C, and according to prevailing ions is of HCO_3-Ca type. The spring issues about 70 m above the Vjosa River valley, and is surrounded by quite an attractive environment, with very old oak trees, shrubs and cliffs, making it a significant tourist destination for the people travelling in the southeastern region of Albania.

As the Cold-Water Spring of Tepelena is one of the most popular low mineralised springs of Albania, near it, and near the Tepelena-Gjirokastra motor road is the modern bottling factory "Tepelena". It is worth mentioning that this spring has the oldest still functioning horizontal gallery (Figure 4b). It was constructed around 1810 by Ali Pasha, a well-known personality in Albania's history. In general, this spring has high scientific, geomorphological, aesthetic, and tourist values. It is visitable along the Tepelenë-Gjirokastër road.

Uji Zi (Black Water) Spring issues in Këlcyra Gorge which cuts the Dhembel karst massif (Figure 7). In this deep Gorge, the karst water resources of the above-mentioned karst massif totally drains, consisting on average of about 8.0 m^3/s (Eftimi, 2024). The Black Water Spring, the biggest one draining in Kelcyra Gorge, issues at elevation 176 m asl, and is a siphon-type spring (Figure 5). The average discharge of Black Water Spring is estimated at about 3.0 m^3/s, the biggest discharges reach about 6-7 m^3/s and the smallest one diminishes to about 1.0 m^3/s. The spring water temperature is relatively constant; it varies about 10-10.5° C. On the other hand, the spring's chemical water quality is widely ranging according to the discharge of the spring. During low spring discharges, the water is relatively mineralised, and the values of the main chemical parameters are as follows: the conductivity averages about 1200 μS/cm and the water chemical type is Cl-SO_4-Ca-Na. When the discharge of the spring increases to about 2.0-5.0 m^3/s the concentration of the chemical parameters is much lower: the conductivity varies from about 600-700 μS/cm and the water chemical type is HCO_3-Cl-Ca-Na. Particularly characteristic for the chemistry of this spring is the high concentration of SO_4^{2}, which vary from about 100 mg to more than nearly 250 mg. This fact is related to the contact of the groundwater of Dhembel karst massif with the gypsum deposits underlying the carbonate rocks. Due to the high sulphate concentration, this spring it is not used as a drinking water source, but during the last years the spring has becom a real touristic attraction particularly for the people who practice rafting along the Vjosa River.

Tatzat Spring issues near the village of Tatzat in Delvina Municipality and consists of the main spring recharging the Kalasa River (Figure 8). The spring issues near Kalasa River, at an elevation of 250 m asl, at the contact of the carbonate formations of the Kurvelesh karst massif with the peripherical flysch formations. This spring has two main issues (orifices) called Pezhga and Gurra. This spring is one of the biggest of Albania and the approximate characteristic discharges are the following: Q_{min}=0.85 m^3/s; Q_{mean}=1.6 m^3/s and Q_{max}>6.0 m^3/s. About 55 years ago most of the spring flow passing a tunnel was diverted to the Ionian Sea coastal line to be used for the irrigation of the orange and olive trees plantations cultivated at that time. The quality of Tatzat Spring is very good; the water temperature is 11.0° C, it is low mineralized with the total dissolved solids about 240 mg/l, while the water chemical type is HCO_3-Ca. The beautiful area

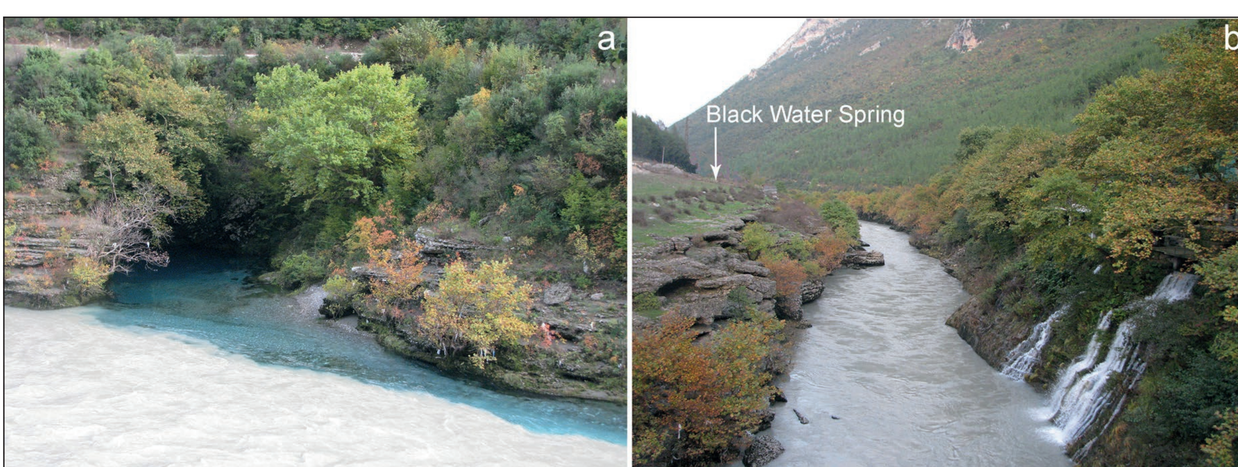

Figure 7: a) Black Water Spring drains in Kelcyra George of Vjosa River; b) Kelcyra Gorge and location of Black Water Spring (Source: R. Eftimi).

Figure 8: The outflow water from Tatazat Spring (Source: Th. Haxhi).

around the spring and the Kalasa River is becoming very attractive to visitors and the development of the rural tourism. The visitors can reach the spring with first class roads like that from Saranda, as well as the new one from Vlora.

Oknos Spring is located near the village of Lefterohor of Delvinë. This spring issues at an elevation of 570 m asl and the mean discharge is about 4 l/s. It is a significant source of cold and clean water, the total dissolved solids are about 180 mg/l, and the water chemical type is of HCO_3-Ca. Issuing at a relatively high elevation on the western limestone slope of Mali Gjerë karst massif, this spring has scientific, geological, cultural, didactic and touristic value. Visitors can reach the spring by following the road from the city of Delvina to the Village of Lefterohor.

Mulliri Salt Springs (Figure 9). There are two big karst springs north of Xara Village, at about 1 km distance from the south-eastern corner of Butrint Lagoon (Figure 1) and near to the small Bufi Lake. These springs represent the drainage of the northern part of the Saraqin carbonate massif. As this carbonate massif is in contact

Figure 9: The geographical position of Mulliri springs, near to the Reza lake (Source: Fation Plaku, 2020).

Figure 10: Ixuari Spring, Borsh: a Borsh Spring; b the coffee shop constructed above the spring (Source: Th. Haxhi).

with the Butrint salty lake, the karst water mixes with lake water and the spring become salty, too. The spring drains in Butrint Lagoon through a canal which connects the small Bufi Lake with the above-mentioned lagoon. The mean discharge of the springs is about 2.0 m^3/s, the minimal flow varies about 1.0-1.5 m^3/s and the maximal discharge approximately is more than 4.0 m^3/s. The water temperature ranges from 15.1°C to 15.5°C, the salt concentration is high; the total dissolved solids vary about 7000 mg/l.

These springs have geological, didactic and touristic values and can be visited along the Sarande-Butrint-Xarë road.

Ixuari Spring in Borsh Situated in the centre of Borsh village, at the elevation about 130 m asl (Figure 10). The spring is recharged by the south-western sector of the big Kurvelesh karst massif. Ixuari Spring issues at the tectonic-lithological contact between limestone and shale in southern slope of Kurvelesh karst massif. The spring issuer is a beautiful waterfall and is very popular visiting card off the village Borsh. According to non-systematic measurements, the smallest discharge of this spring varies about 150-200 l/s, the mean ones vary about 250-300 l/s, while the maximal ones are about 630 l/s. The water temperature varies about 13° C. The chemical quality of the spring water is very good, the conductivity is measured 250 μS/cm, the total hardness is 8.5 German degrees, and the water chemical type HCO_3-Ca. About 300 meters downstream, the spring water forms another waterfall about 20-30 m high and, where a hydroelectric power plant with a capacity of 500 kW supplies electricity to the village. The spring is not captured for centralised water supply, but by gravity, using small diameter rubber tubs is used for the separate family water supply. In the lower part of the village the spring water is used also for irrigation of Borsh plain. Although this spring is under protection the conservation measures are insufficient. As seen in Figure 10b, in front of the spring and above it is constructed a coffee shop totally hiding the spring from the main road. The visitors must pass through the coffee shop if they like to admire the beauty of the spring. This is one of the most negative examples of the human intrusion on a protected karst spring in Albania.

Figure 11: Ftera Springs without any protection measure (Source: Th. Haxhi).

Fterra Springs are in the Fterra village (Figure 11). They are part of Lukova Administrative Unit and Himara municipality. They are a group of springs (Inxori, Ngurrëza, Gjezhdanica and Langadha Springs) issuing at an elevation of about 415 m asl. Geologically, these springs issue in the southern part of the western periphery of big Kurvelesh karst massif consisting of different Mesozoic carbonate rocks. In the area of the Ftera Village, the carbonate rocks are covered by thick, non-cemented slope debris. Ftera Springs is recharged by the karst rocks of the above-mentioned karst massif, but the karst water flows through the slope debris recharging some spring issues (orifices) located at elevations around 380-415 m asl. Fterra Springs has the following characteristic discharges: the average about 230 l/s, the minimal around 150 l/s and the biggest one around 450 l/s. The water temperature is 11.6°C, the conductivity varies about 250 μS/cm, while the chemical type is HCO_3-Ca. A good road connects Ftera Springs with the coastline. The spring water is used for drinking, for irrigation as well as to produce electricity. As seen in Figure 11, the Ftera Spring practically seems abandoned, the capture structure and the area around it is not cleaned or maintained.

Bistrica Spring, represents a group of springs recharging the Bistrica River. This group of springs has six main issues, one of which, known as Blue Eye Spring, is the biggest (Figure 12). The spring emerges from Gjerë Mountain (GjM) karst massif having a total surface of 440 km^2, mostly located in Albanian territory (about 400 km^2).

The mountain crest is a natural surface divide between the Drinos River located to the east, and Bistrica River located to the west. GjM is an anticline consisting of Mesozoic carbonate sequences overthrown to Perm-Triassic gypsum and clay deposits, and to Paleogene-

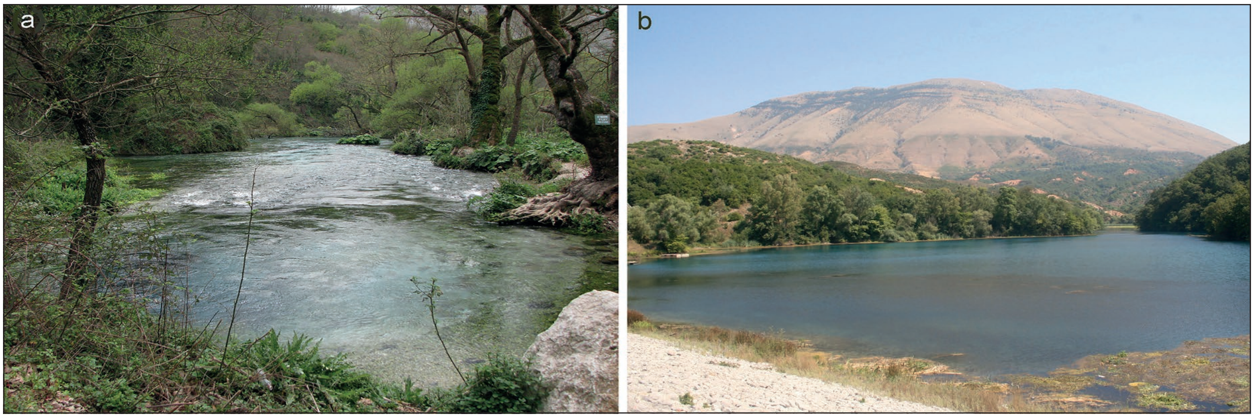

Figure 12: a) Blue Eye Spring is the biggest spring of Bistrica Spring group; b) the artificial lake collecting all the water of Bistrica Spring group (Source: a, Z. Stevanović; b, R. Eftimi).

Neogene flysch formations. The calculated total groundwater resources of the GjM karst massif are estimated to be about 7.42x10^8 m^3/year or 23.6 m^3/s (Eftimi, 2009).

Bistrica Spring mean discharge is 18.2 m^3/s, issues at an elevation about 150-155 m asl, or about 55 m lower than the elevation of Drinos River Valley. As mentioned in the Introduction, by the MIKAS Project (*Most Important Karst Aquifer's Springs*), the Bistrica Spring is ranked the second biggest spring of Europe, after the Dumanli spring in Turkey with 38 m^3/s (Stevanović, 2023). Through environmental isotopes, geological balance calculations and using SO_4^{2-} concentrations as an environmental tracer, it is estimated that about 35% of the total discharge of Bistrica Spring is replenished by the groundwater of the Drinos River gravelly aquifer. This is facilitated by good hydraulic connection between both aquifers, alluvial and karst ones, and by the natural karts water table dipping towards the Bistrica Spring. The remaining 65% of the yearly discharge of this spring is replenished by the recharge of precipitation in GjM karts massif (Eftimi, 2009). The Bistrica Spring has the following discharge characteristics: Q_{min}=10.6 m^3/s; Q_{mean}=18.2 m^3/s; Q_{max}=36 m^3/s. The main spring issue, that of Blue Eye Spring discharges about 55-60% of the total discharge of Bistrica Springs.

The water quality of Blue Eye Spring is characterised by small seasonal changes, and by relatively high SO_4^{2-} concentration and high conductivity, which accordingly are 130 mg/l and 575 µS/cm. The groundwater chemical type is HCO_3-SO_4-Ca-Mg, while the spring water temperature is 12.3° C. Due to the concentration of the different chemical parameters of this spring compared to the limits allowed by the Albanian Drinking Water Standards, one could conclude that the water quality of Blue Eye Spring is disputable as drinking water.

This spring, after the collection in an artificial lake (Figure 9b), since 1963 is used to produce the electricity by two power plants. Before flowing to the Ionian Sea, part of this spring flows to Butrint Lagoon contributing to maintaining the needed equilibria of the lake salt concentration and preservation of the local aquatic ecosystem (Stevanović et al., 2022). Another positive contribution of the Blue Eye Spring is the use of the water for the irrigation of about 2270 ha of the surrounding area.

Bistrica Spring is a real natural attraction not only due to his big discharge, but also for its location in har-

Table 1: Geoinformation of protect karst springs in Southern Region of Albania, Source: Arc GIS 10.1. created in 2024.

Spring name	Region	Municipality	Admin. Unit	Village	Location	Altitude (m a.s.l.)	Type	Discharge (m^3/s)
Viroi	Gjirokastër	Gjirokastër	Gjirokastër	-	Mali i Gjerë	**196**	Ascending	0-40
Uji Zi-Black Water	Gjirokastër	Këlcyrë	Këlcyrë	-	Dhëmbel	**176**	Ascending	1-7
Ixuari	Vlora	Himara	Lukova	Borsh	Mali i Omloit	**130**	Gravity	0.15-0.6
Fterra	Vlora	Himara	Lukova	Fterrë	Malet Bregdeta	**415**	Gravity	0.2-0.45
Oknos	Vlora	Delvina	Delvina	Lefterohor	Mali Gjere	**570**	Gravity	0.004
Libohova	Gjirokastër	Libohovë	Libohovë	Libohovë	Bureto	**350**	Gravity	0.07
Uji Ftohte	Gjirokastër	Tepelenë	Tepelenë	Luzat	Mali i Qershizë	**225**	Gravity	0.1-0.4
Bistrica	Vlora	Delvina	Mesopotam	Muzinë	Mali i Gjerë	**152**	Ascending	1.84
Gurra e Nivanit	Gjirokastër	Libohovë	Zagori	Nivan	Lugina e Zagor	**960**	Gravity	0.003
Guaku	Berat	Skrapar	Corrovoda	Radësh	Kulmakë	**315**	Ascending	0.45-0.6
Tatzati	Vlora	Delvina	Virgo	Tatzat	Përroi i Galishti	**250**	Gravity	0.85-0.6
Mulliri	Vlora	Konispol	Xarrë	Xarrë	Mali i Cukës	**5**	Ascending	1.0-4.0

mony with the environment, hidden by a beautiful dense forest and flowing to an artificial lake where is mirrored the Gjere Mountain (Figure 8b). It must be underlined that this big spring is an important touristic attraction. The popularity of this monument of nature has increased particularly during the last 4-5 years, as the touristic infrastructure has totally improved. While it has positively influenced the increasing didactic value of the spring, also. The spring could be easily reached by good roads in two direction, from Gjirokastra and from Saranda. However, as Siegel et al. (2023) point out the increasing tourism enhances the negative impact on many natural monuments, and this could be the case of Blue Eye Spring, of Bistrica group.

The collected information was put into the Arc GIS 10.1 software and a table was created (Table1) with the digital information. These data allow analyses of the differences and the similarities between the karst springs. Also, it is possible to make a comparative analysis in the future, if the climate changes or if humans impact their characteristics or their features.

5. CONCLUSIONS

The Southern Mountainous Region is the home of numerous karst springs, including 12 designated as geomonuments, the subject of this paper. These springs play a crucial role in supplying water to inhabited centres, irrigating agricultural land, and generating electricity. Their didactic and scientific significance, along with their aesthetic appeal, contribute to the economic importance, especially for tourism development. These springs are not only vital for the region but also for all of Albania. Renowned bottling water factories like Tepelena, Glina, and Trebeshina are located here. Springs such as Bistrica (Blue Eye), Viroi, Uji i Ftohtë (Cold Water) of Tepelena and Uji i Zi of Këlcyra George are significant tourist destinations for Southern Albania and beyond. Unfortunately, as described above, some of the springs are suffering increasing anthropogenic pressure, enhancing the negative impact. To prevent this, some main mitigation measures are advisable: (a) the introduction of systematic monitoring of water quantity and quality, as well as the status of biocenoses; (b) protection of the springs from the conflict of interest with the local people; (c) raising the awareness of the local population regarding the importance of protection of the springs and of the valuable related ecosystems.

AUTHORS' CONTRIBUTIONS

E.J., E.B. – conceptualization, E.B., E.J. – methodology, E.B. – software, E.J, E.M. – formal analysis, E.B. – data curation, E.J., E.B., E.M. – writing – original draft preparation, E.J. – writing – review and editing, E.J., E.M. – visualization. The authors declare no conflict of interest in this study. All authors have read and agreed to the published version of the manuscript.

Conflict of interest the authors declare that they have no conflict of interest in connection with the submitted material.

ACKNOWLEDGEMENTS

The authors thank the Prof. P. Qirjazi for his very useful suggestions and the anonymous reviews and associated editor for very helpful comments that substantially improved the manuscript.

REFERENCES

Chen, Z., Goldscheider, N., Auler, A.S., Bakalowicz, M., Broda, S., Drew, D., Hartmann, J., Jiang, G., Moosdorf, N., Richts, A., Stevanović, Z., Veni, G., Dumont, A., Aureli, A., Clos, P., Krombholz, M., 2017. World Karst Aquifer Map. IAH UNESCO https://doi.org/10.25928/b2. 21_sfkq-r406.

BGR, IAH, KIT and UNESCO, 2017. World Karst Aquifer Map 1:40.000.000. Berlin, Reading, Karlsruhe, Paris.

Dudley, N., (Editor) 2008. Guidelines for Applying Protected Areas Management Categories. Gland, Switzerland: IUCN.x +86pp.In: Stolton, S., Shadie, P., and Dudley, N., 2013. IUCN WCPA Best Practice Guidance on Recognising Protected Areas and Assigning Management Categories and Governance Types, Best Practices Protected Areas Guidelines Series No.21, Gland, Switzerland:IUCN.xxpp.

Eftimi, R., 2009. Investigation of the recharge sources of Blue Eye Spring by means of environmental isotope and hydrochemical tracers. In:Bonacci, O., (Eds.), Sustainability of Karst Environment-Dinaric Karst and other Karst regions, Proceedings of International Interdisciplinary Scientific Conference, Plitvice Lakes, Croatia, 23-26 September 2009, pp. 57-65.

Eftimi, R., 2010. Hydrogeological characteristics of Albania. AQUAmundi (2010) Am01012:79–92. DOI:10.4409/Am-007-10-0012.

Eftimi, R., 2020. Karst and karst water resources of Albania and their management. Carbonates and Evaporites 35: 69. https://doi.org/10.1007/s13146-020-00599-0.

Eftimi, R., 2024. Karst water of Albania, their characteristics and management, (in Albanian). In: Ormeni, Rr., Pambuku, A., Berberi, A., Misha, E., Shkreta, B., Geoinxhinieria e ujërave sipërfaqësore dhe nëntokësore në Republikën e Shqipërisë, Libri I Kumtesave, Tirana, Shqipëri, Mars 2024, pp 23-39. DOI: 10.13140/RG.2.2.18291.95524/1.

Eftimi, R., Bisha, G., Taflaj, I., Sheganaku, Xh., 1985. Hydrogeological map of Albania, scale 1: 200,000. Tirana: Edited by Shijaku, H., Tirana.

Eftimi, R., Shehu, K., Sara, F., 2023. Hydrogeological aspects of the municipal water supply of Albania: Situation and problems. Hydrology 2023, 10, 193. https://doi.org/10.3390/hydrology10100193.

Ford, D.C., Williams, P., 2007. Karst hydrogeology and geomorphology. John Wiley and Sons, Chichester, 565 pp.

Goldscheider, N., Chen, Z., Auler, A.S., Bakalowicz, B.S., Drew, H., Jiang, G., Moosdorf, N., Stevanović, Z., Veni, G., 2020. Global distribution of carbonate rocks and karst water resources. Hydrogeology Journal 28:1661–1677. https://doi.org/10.1007/s10040-020-02139-5 .

Hartmann, A., Goldscheider, N., Wagner, T., Lange, J., and Weiler, M., 2014. Karst water resources in a changing world: Review of hydrological modelling approaches, Rev. Geophys., 52, doi:10.1002/2013RG000443.

Jaho, S. (eds), 1985. Climate of Albania; Institute of Hydrometeorology: Tirana, Albania, 296 pp.

Kabo, M., 1990.Physiscal geography of Albania (in Albanian), Vol.1.Tirana, Albania, 398 pp.

Kresic, N., Stevanovic, Z. (eds) 2010: Groundwater hydrology of springs: Engineering editors, N. Krešic and Z. Stevanović, theory, management and sustainability, Elsevier, Amsterdam- New York, 573 pp. https://www.elsevier.com/books/groundwater-hydrology-of-spings/kresic/978-1-85617-502-9.

Krutaj, F., Gruda, Gj., Kabo, M., Meçaj, N., Qirjazi, P., Sala, S., Ziu, T., Kristo, V., Trojani, V., 1991. Gjeografia Fizike e Shqipërisë, Vol.II. Akademia e Shkencave të Republikës së Shqipërisë, Centre of Geographical Studies, Tirana, 590 pp.

Meço, N., Aliaj, Sh., 2000. Geology of Albania. Gebrüder Bornatraeger Berlin, Stuttgart, 246 pp.

Meçaj, N., 2005. Ujërat nëntokësore, origjina, përhapja, llojet, ndotësit dhe rëndësia e tyre ekonomike e jetësore dhe njeriun. Studime Gjeografike 15.

Qiriazi, P., Sala, S., 2006. Monuments of Nature of Albania, (in Albanian). Monumentet e Natyrës të Shqipërisë. Ministria e Mjedisit, Pyjeve dhe e Administrimit të Ujërave. Tirana, Albania, 140 pp.

Qiriazi, P., 2019. Physical Geography of Albania, (in Albanian). Tirana, Albania, 579 pp. ISBN:978-9928-08-0415-6.

Stevanovič, Z. 2019. Karst water in potable water supply: a global scale overview. Environmental Earth Science 78: 662. https://doi.org/10.1007/s12665-019-8670-9, 12.

Stevanovič, Z. 2023. Initiative to Select, Lebel and Protect the World's Most Important Karst Springs. In: Andreo, B., Barberá, J.Durán-Valsero, J.Gil-Márquez, M. Madurra (Eds). EuroKarst 2022, Malága. Advances in Karst Science. Springer, Cham, pp. 3-7, https://doi.org/10.1007/978-3-031-16879-1_1.

Siegel, L., Goldscheider, N., Petita, M, J. Xanke, Andreo, B., Bakalowicz, M., 2023. Distribution, threats and protection of selected karst groundwater-dependent ecosystems in the Mediterranean region. Hydrogeology Journal 31: 2231-2249, https/s10040-023-02711-9.

Stevanović, Z., Efrimi. R., 2010. Karstic sources of water supply for large consumers in southeastern Europe-sustainability, disputes and advantages, Geologia Croatica, 63/2: 179-185. DOI: 104154/gc.2010.15.

Stevanović, Z., Gunn, J., Goldscheider, N. and Ravbar, N., 2022. Karst: Environment and Management of Aquifers. Guelph, Ontario, Canada, 278 pp.

Stevanović, Z., Pekaš, Ž., Stevanović, A.M., Eftimi, R., Radulovic, M., 2022. Springs as essential water source for dependent ecosystems in karst. In: Pašić V. et al. (Eds.), Small Water Bodies of the Western Balkans, Springer Water, http://doi.org/10.1007/978-3-030-86478-1_1.

Kicińska, D., 2017. Polish Caving 2013-2017: published on the occasion of 17th International Congress of Speleology, Pracownia Kreatywna Bezliku, Krakow, 50 pp.

Toulomudjian, C., 2005. The springs of Montenegro and Dinaric karst. In Eds. Stevanović and Milanović, Water resources and environmental problems. Proceedings of the International Conference and field seminars, Belgrade & Kotor, pp. 443-450.

Xanke, J., Goldscheider, N., Bakalowicz, M., Barberá, J.A., Broda, S., Chen, Z., Ghanmi, M., Günther, A., Hartmann, A., Jourde, H., Liesch, T., Mudarra, M., Petitta, M., Ravbar, N., Stevanović, Z., 2022. Mediterranean karst aquifer map (MEDKAM), 1:5,000,000. Berlin, Karlsruhe, Paris. https://doi.org/10.25928/MEDKAM.1.

Xanke, J., Goldscheider, N., Bakalowicz, M., Barberá, J.A., Broda, S., Chen, Z., Ghanmi, M., Günther, A., Hartmann, A., Jourde, H., Liesch, T., Mudarra, M., Petitta, M., Ravbar, N., Stevanović, Z., 2024. Carbonate rocks and karst water resources in the Mediterranean region. Hydrogeology Journal, 32:1397-1418. https://doi.org/10.1007/s10040-024-02810-1

Xhomo, A., Kodra, A., Xhafa, Z., Shallo, M., 2002. Geology of Albania (in Albanian), Notes of Geological Map of Albania sc. 1: 200 000, Tirana, pp.464.