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Monitoring of Water Flow in the Springs of the Golesh Massif, Kosovo

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ABSTRACT

Water spring are vital to all human activities. The integration of hydrological, geological, hydrogeological and ecological characteristics of resource ecosystems provides a much needed tool for recognizing the characteristics and their distribution. The objective of this study was to identify springs in the study area, in order to evaluate their hydrogeological characteristics and parameters. Eight springs have been identified in the Golesh Massif area. They are mainly of lithological contact. Water flow ranging from 0.03 to 5 l/s, the temperature, pH and total hardness in the water of spring Curreli range within 11.1 to 15.7 °C, 5.51 to 8.03 °C and 18.8 to 21.67 ºdH, respectively. Their recharge mainly depends on the amount of precipitations that falls in the area.

Keywords: spring, Golesh Massif, physico-chemical parameters, flow.

INTRODUCTION

The springs are natural values and picturesque resources that have played an important role in the history of life and related activities in the Golesh Massif area. Springs play a crucial role in maintaining flow especially during prolonged dry periods (Meuli and Wehrle 2001). The ever-increasing demand for quality water and in sufficient quantities, their deteriorating quality and the effect of climate change are being seen with increasing concerns by the science community around the globe. In this regard, finding, conserving and monitoring water resources are of particular importance. Regarding spring, different researchers give different definitions related to resources. Wilson and Moore (1998) give the definition as follows: Springs are places where groundwater is exposed to the surface of the earth, often flowing naturally from rocks or soil to the surface of the earth or to a body of surface water. In general, spring emerge in most of the Earth's ecosystems, including a wide range of terrestrial underwater environments and as underwater discharges from freshwater floors and marine bodies. Springs, in addition to their importance for water supply, are also considered important from the ecological and cultural, tourist and recreational aspect for an area, region, etc. The springs located in the Goleshi Massif are the suppliers of drinking water to the whole community, which lives in its vicinity. They are also used to meet the requirements for drinking water, food preparation, water for livestock, irrigation and occasionally in the construction sector.

STUDY AREA

It is located in the central part of the Republic of Kosovo (Fig. 1) having an area of 38 km^2. This study area covers the Golesh Massif, which is characterized by its elongated angular shape (Labus 1973). It extends in the direction northwest-southeast in a length of 7 km. It has hilly relief with an altitude of 544 to 1019 m (the neck of Golesh). It is bordered on the north by the Prishtina-Peja highway, on the south by the Leletiq stream valley, on the west by the Drenica valley and on the east by the Fushë Kosovë lowlands. Continental and mountainous climate dominates in the study area (Pllana 2015). Although it is a small terrain area, some climatic changes are observed. According to the data presented in the work of the author (Labus 1973), it turns out that the air temperature for the period 1956–1972, range from -15 °C to + 25.3 °C. The lowest temperatures were observed at the neck of Golesh hydrometeorological station (quota 1019 m). According to data for the period 2001–2019 (Hydrometeorological Institute of Kosovo 2019), the average annual temperatures ranges from - 0.24 °C (January) with a maximum of 22.14 °C (July). The highest rainfall happened in 1972 (768 mm), while the lowest rainfall was shown in 1956 (407 mm) (Labus 1973). According to Kosovo Hydrometeorological Institute (2019) for the period 2001–2019, the average annual rainfall is 656.4 mm, the largest amount of rainfall falls in May by 70.43 mm, while the smallest in February 36.48 mm. The area has a poor hydrography, but thanks to the morphology, steep slopes and valleys, streams of water are derived in the period of intense rainfall and during the period of snowmelt.

GEOLOGICAL CONSTRUCTION

In relation to the geological structure, hydrogeological and tectonic characteristics of the Golesh Massif, data are found in the studies of the authors as: (Terzina et al. 1961; ICMM 2006; Meshi et al. 2012; Çadraku et al. 2016; Çadraku 2021) which are related to the Golesht Massif and the surrounding areas. According to them, peridotite rocks and serpentinite dominate in the geological construction of the Golesh Massif. On the east side this massif is in contact with the Pliocene sediments of Fushë Kosovë, while on the southwest side it is in contact with the Paleozoic rocks, which build the Blinaja Mountains. Peridotite is very fresh, yellow-green in color. In the surface, due to the influence of water and air it altered and takes on a reddish color. It consists of olivine, enstatite, and accessory chromite. The serpentinites of the Goleshi Massif are characterized by numerous and irregularly distributed cracks and fissures. According to (Labus 1973) in the serpentinite of the Golesh Massif there are three types of cracks: the first represent the slip lines on the east and west side of the Golesh Massif, the second appear in contact of serpentinite and magnesium and the third are formed by mechanical and chemical processes. The density of cracks and fissures is different and depends on the degree of destruction (alienation) of the rock. On the surface they are more pronounced, while with depth they decrease. In terms of tectonics, the Golesh Massif belongs to the inner Dinaric belt, i.e. the Vardar area. The most important tectonic lines are the one from Halilaq locality in the north to Magure locality in the south, which represents the border of Golesh Massif with the Tertiary basin of Fushë Kosovë and the line from Magura to Mirena locality, which represents the border between Golesh Massif and Paleozoic rocks of

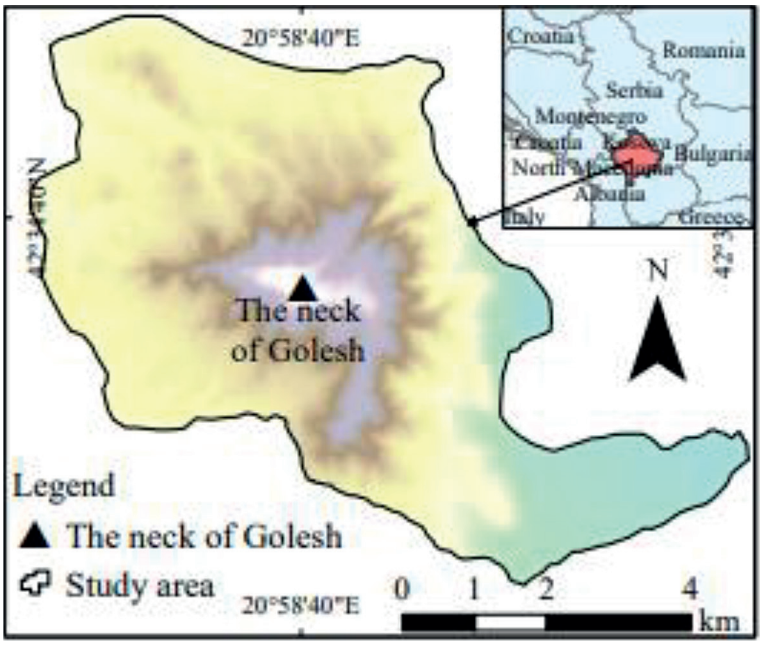

Figure 1. The geographic position of the study area

the Blinaja Mountains, as well as tectonic lines from the Mirena locality to the Sankovc locality. Hydrological characteristics-geological construction, types of lithological members, hydrogeological characteristics, relief and hydromorological conditions, provide favorable conditions for groundwater storage. According to Jovanovic (1938) in the serpetinite rocks of the Golesh Massif distinguishes three hydrological zones: the dry, rich and water-poor zone, while according to Kajlhak quoted by (Labus 1973) also distinguishes three zones: active, passive and neutral. In his work (Labus 1973) distinguishes four hydrological zones: the dry zone, which is located at an altitude above 960 m, the zone with temporary humidity at an altitude of 750 to 950 m, where water occurs only in periods with heavy rainfall and springs in this area are with small inflows. The third area with permanent humidity, which appears at an altitude of 350 to 750 m, is richer in water. The third area with permanent humidity, which occurs at an altitude of 350 to 750 m and is rich in water. The fourth hydrological zone is located below 350 m above sea level and is poor in water. In general in the Golesh Massif there are two characteristic areas. The upper area, which has the densest network of cracks and fissures of different dimensions, in which water infiltration is greater and faster and the lower area in which the number of cracks and fissures is smaller so even water infiltration is smaller and slower. From the hydrogeological point of view, this massif represents a hydrogeological environment with porosity of cracks and springs that drain water to the surface through cracks (fractures). Rainwater is stored in the deeper horizons of this massif, and then drains around it from a number of springs, which are used by community residents for drinking water and other vital requirements.

MATERIALS AND METHODS

For the realization of this study was followed a working methodology divided into three main phases: The first phase was characterized by the collection of data and earlier information conducted in this area. At this stage all relevant data for the purpose of the study were selected, they were systematized, processed and some of them are presented in this paper. The second phase is characterized by field work, to identify water sources, measure coordinates and altitude, measure some physical and chemical parameters such as: temperature, electrical conductivity, pH, etc., and obtain water samples at some of these sources for more detailed physico-chemical analyzes. Also during this phase, water flow measurements were performed. The measurement of water flows was performed in the time period from 2015 to 2022. The third phase was characterized by the elaboration of the data including the tabular, graphic, analytical, interpretive part and drawing conclusions. The materials used to achieve the purpose of this paper were: GPS-handheld, meter, camera, topographic maps (1:25000), geological (1:25000, 1:50000 and 1:100 000), hydrogeological (1:200000), stopwatch, graduated container with a volume of 10 liters, field refrigerator for storing water samples. For the construction of maps, the digital model Advanced Land Observation Satellite (ALOS), with 20×20 m spatial resolution was used. The hydrographic network was generated automatically using the toolbox in ArcGIS 10.5. The flow direction and the accumulation map of the catchment basin were created using the flow direction and accumulation tools of the same spatial analysis tools of the hydrological option. Also through the hydrological option raster was created and the rows of streams were divided.

RESULTS AND DISCUSSION

Topographic anomalies

The topographic anomalies were calculated from Advanced Land Observation Satellit, Digital Elevation Model (DEM) with spatial resolution 20×20 m data using profiling methods in the ArcGIS 10.5 software. The range of elevation in the study area differs from 544 to 1019 m. Topographic anomalies were delineated in two different sites, A–A' and B–B' profile (Fig. 2). The profile maps illustrate the shape of the terrain in the study area.

Slope

The slope is an essential attribute of land surface that has direct controls on runoff. Higher slope results in rapid runoff and increased erosion rate (potential soil loss) with less groundwater recharge potential. The slope in study area varied from low (< 4°), very gentle (4.1–8°), gentle (8.1–13°), moderate (13.1–19°) moderately steep

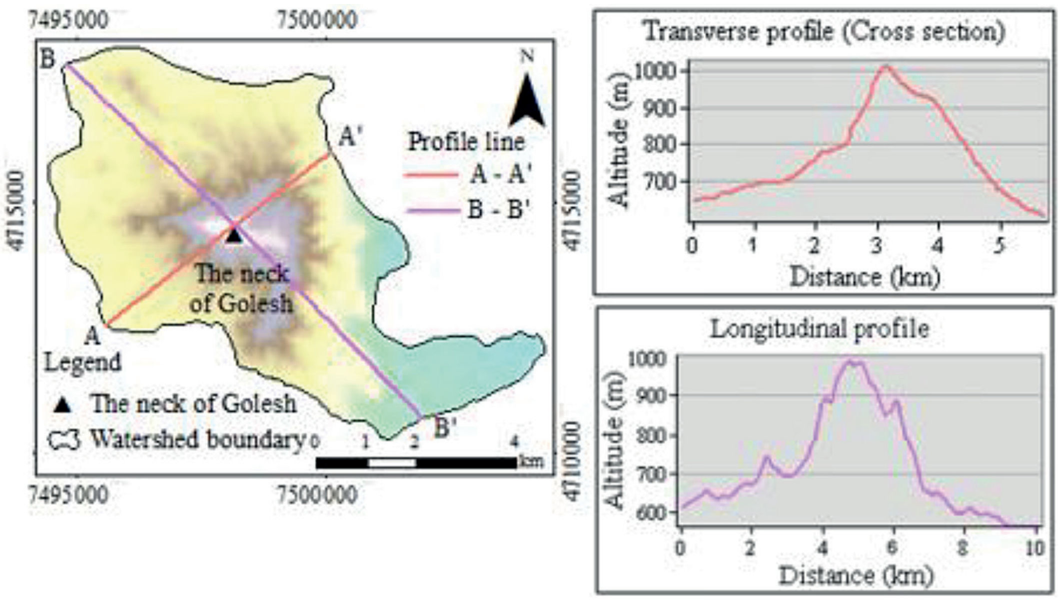

Figure 2. Profil line transversal profile (A–A') and longitudinal (B–B')

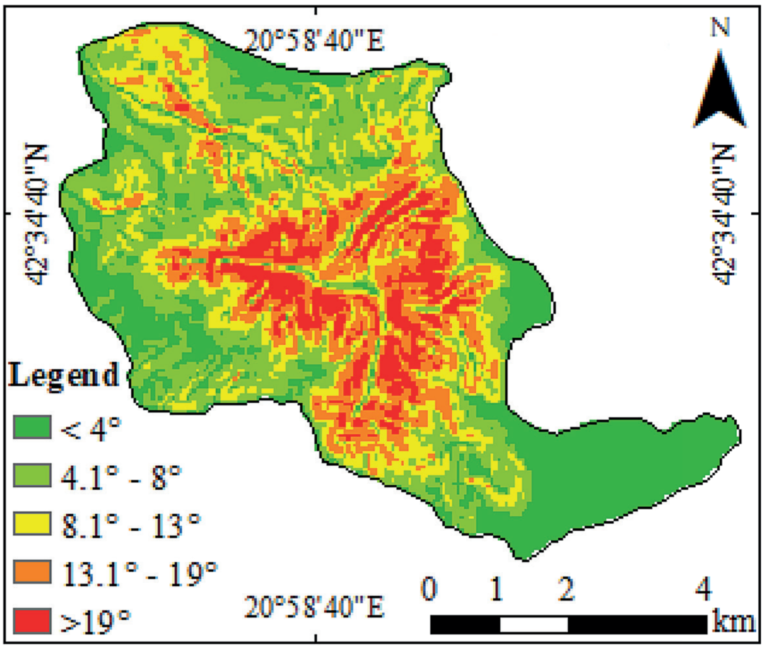

Figure 3. Slope in study area

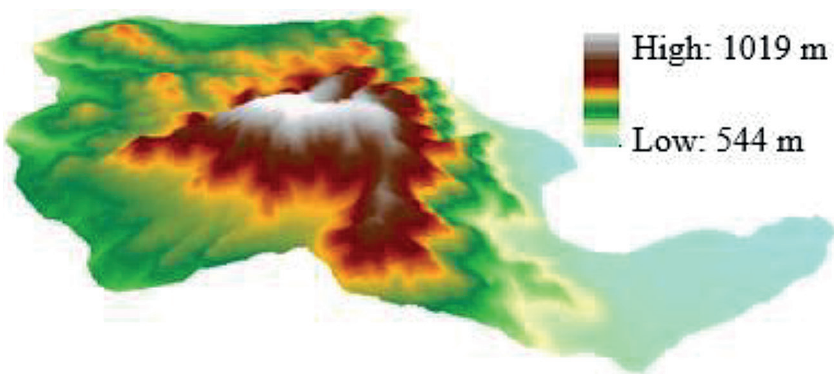

Figure 4. 3D models in study area

(> 19°) (Fig. 3). The flat to gentle slope could be more useful for agricultural activities. Figure 4 shows the 3D model of the study area.

The drainage network

The drainage network consists of several streams with permanent and temporary flows (stream type), which drain the water in all directions following the terrain topography. The stream order or water body order is a positive whole number used in geomorphology and hydrology to indicate the level of branching in a river system. There are various types of stream ordering technique (Horton 1945; Strahler 1957). Strahler's system, which is slightly modified the Horton's method was used to analyze the stream order in this study. The smallest (un-branched) streams are first order and where the two first-order streams join together, they form second-order and two second-order streams come together to change to third order and so on, whereas two different levels of streams come together; they will remain as the highest one. A total of 234 streams were identified in this study area, of which 185 streams are first-order, 40 second-order streams, 9 third-order streams (Fig. 5 and Table 1).

Drainage density

Drainage density is one of the parameters which affects the hydrological process of the watershed. It is defined as the ratio of the total length of the stream over the contributing area (Pallard et al. 2008; Pallard et al. 2009). Drainage density potentially affects both time of concentration and magnitude of the flow. High drainage density implies increase in flood peaks, whereas there is decrease in flood level in low drainage density

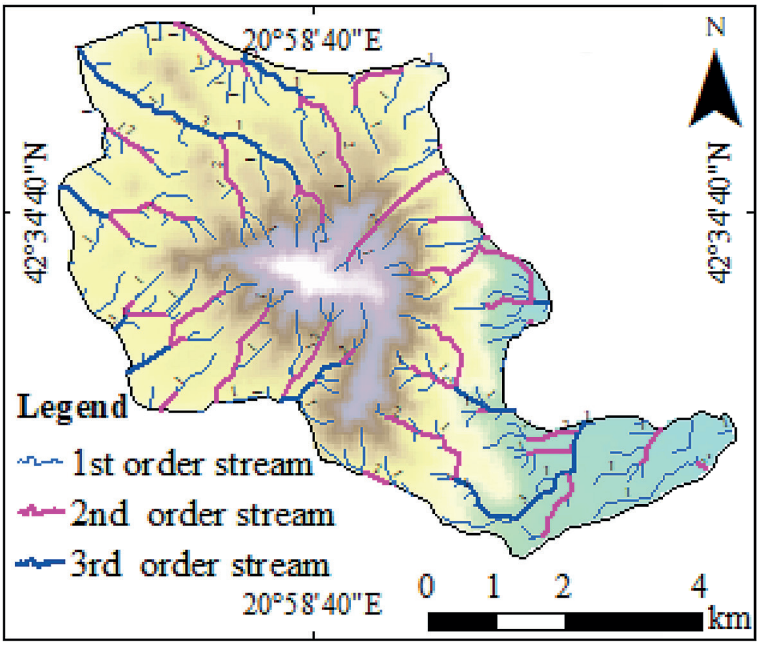

Figure 5. Drainage network

Table 1. Stream length measurement

Stream order	Stream number	Stream length (km)	Mean stream length (km)	Comulative stram length (km)
1st order	185	65.70	0.36	0.36
2nd order	40	29.00	0.73	1.08
3rd order	9	12.60	1.40	2.48
Total	234	107.30		
Bifurcation ratio				Mean bifurcation
First order/ second order	Second order/ third order			ratio
4.63	4.44			4.53

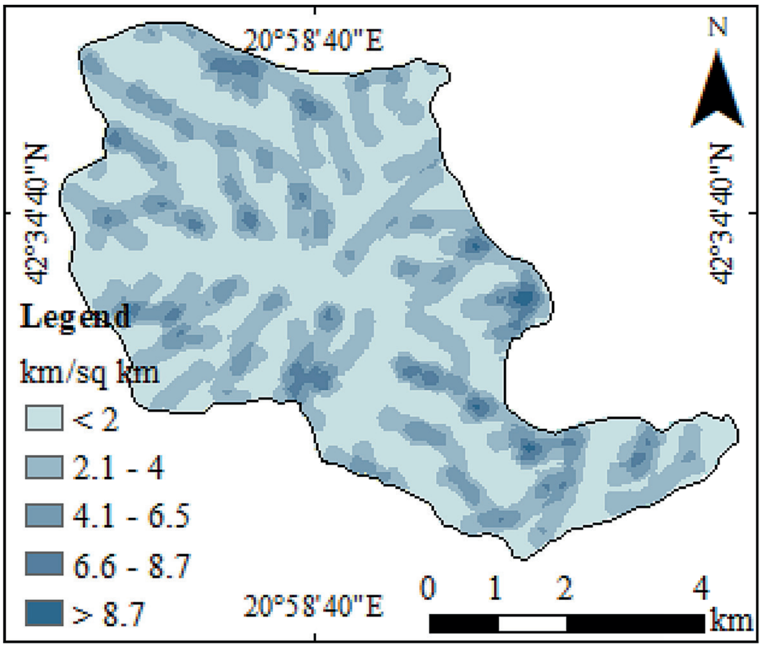

Figure 6. Drainage density

(Pallard 2009). It is because long concentration time allows more opportunities to infiltrate and distributing through time the flow. It is because long concentration time allows more opportunities to infiltrate and distributing through time the flow. Generally, drainage density and flood volume have direct relation. Drainage density of the study area range from 2 km/km^2 to 11 km/km^2 (Fig. 6) indicating low drainage densityes. In general, it has been observed over a wide range of geologic and climatic types that low drainage density is more likely to occur in regions of highly permeable subsoil material under dense vegetative cover, and where relief is smoothly steeped. The moderate drainage density indicates the basin is highly permeable subsoil and vegetative cover (Nag 1998). In contrast, high drainage density is developed in regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief (Nag 1998; Chakraborty et al. 2003).

The spring

The spring defines the visible groundwater drainage area above the earth surface. Eight permanently flowing springs were identified in the study area. Drilling wells have been drilled near the Vrellë and Paskash springs, from which water is pumped and the spring has no gravitational flow, while the Sankovci III spring has leaks but it was not possible to carry out water measurements (Table 2, Fig. 7).

The spring considered natural water intake works. Their emergence may be permanent (when they are fed by the aquifers of the saturation zone) and temporary (when they are fed by the waters of the aeration zone). In the study area, springs indicate permanent drainage, which indicates that they are fed from the saturation zone. Also evident are some water springs, which are temporary and drain water mainly in

Table 2. Coordinates and altitude of resources in the study area

No.	The name of spring	Coordinates		Elevation (m)
1	Dobraja e Madhe	42° 32' 36" N	21° 02' 40" E	550
2	Curreli	42° 32' 41" N	20° 58' 58" E	712
3	Mirena	42° 33' 44" N	20° 57' 59" E	734
4	Mirena I	42° 33' 17" N	20° 58' 01" E	696
5	Fushtica e Naltë	42° 33' 25" N	20° 56' 56" E	670
6	Sankovc I	42° 34' 35" N	20° 57' 12" E	689
7	Sankovc II	42° 34' 23" N	20° 56' 46" E	675
8	Kroni i Mbretit	42° 36' 07" N	20° 50' 53" E	628

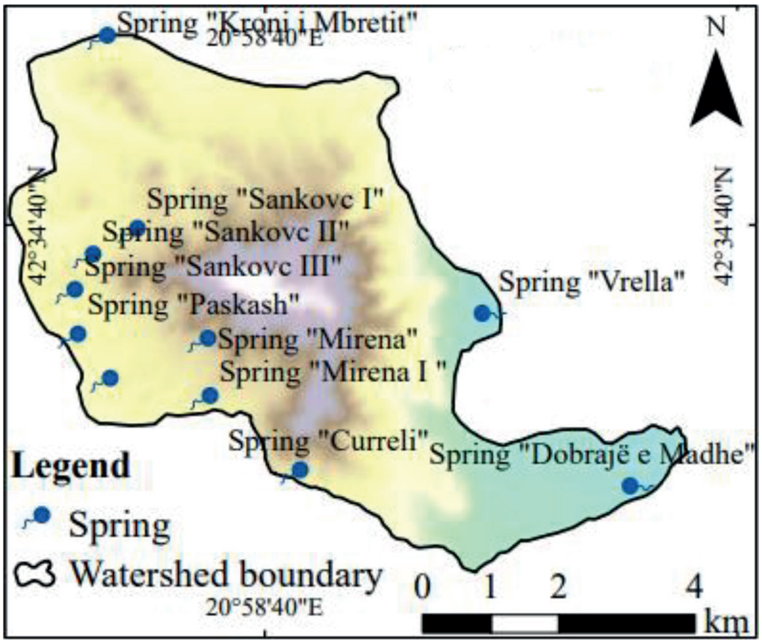

Figure 7. Map of the spring

Table 3. Minimum, average and maximum values of spring flows

Value	Name of the spring, flow (l/s)						
	Curreli	Kroni i Mbretit	Sankovc I	Sankovc II	Mirena	Fushtica e Naltë	Dobraja e Madhe
Min.	0.10	2.00	0.03	0.12	0.03	0.10	0.14
Average	0.23	3.09	0.078	0.21	0.14	0.29	0.30
Max.	0.50	5.00	0.13	0.28	0.28	0.46	0.53

the spring season. Based on geomorphological conditions, geological structure and hydrogeological characteristics, the spring are classified as stratified, fissured, contact, tectonic and karst. The spring types have been identified in the study area: stratified spring Dobraja e Madhe, cracks-contact-tectonic spring Currel, Mirena, Mirena I, Sankovci I, Sankovci II and Fushtica e Naltë, karst springs Kroni i Mbretit (Fig. 7). Water flows are determined by the volumetric method, respectively by the equation (Dakoli 2007, Bacani and Vlahovic, 2012).

$$Q = \frac{V}{t}\left(\frac{l}{s}\right) \tag{1}$$

where: V – the volume of bucket in liters;
t – is the time of filling the bucket;
Q – is the flow (l/s).

For the use of resources for drinking water or for other practical purposes it is necessary to know their flow regime. Monitoring data showed that the value of water flows to these springs ranges from 0.03 l/s to 5.00 l/s (Table 3). The minimum values are shown in two spring: Sankovc I and Mirena, while the highest values of the feeds are shown in the springs; Kron i Mbretit, Currel and Dobraja e Madhe (Table 3 and Fig. 8).

The amount of water provided by these springs was estimated by taking the average flow of each spring and it turned out that in total these springs have an average flow of 4.34 l/s (Table 4) or 374,803.20 liters per day or 136,803.168 m^3 per year (Table 4). This average water flow from all sources provides water supply in the study area for 4500 inhabitants, for an amount of 80 l/day per capita. If the demand will be estimated at 100 l/day then these springs would provide water supply for 3700 inhabitants in this area (Table 5).

According to Dakoli (2007) the flow, the springs are divided into eight classes (Table 6). Referring to this classification, it results that the water sources in this study area belong to class V and VI.

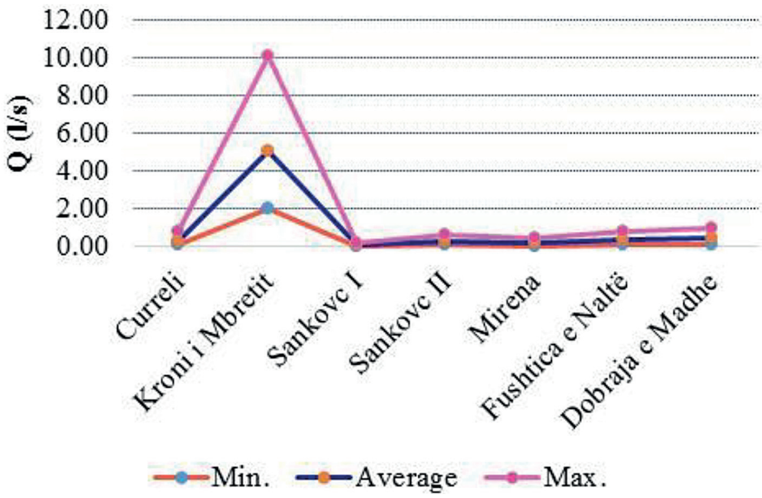

Figure 8. Variation of minimum, average and maximum values of spring water

Table 4. Average flow in the spring

Name of the spring	Average Q (l/s)	l/day	l/year	m^3/year
Curreli	0.23	19872.00	7253280.00	7253.28
Kroni i Mbretit	3.09	266976.00	97446240.00	97446.24
Sankovc I	0.078	6739.20	2459808.00	2459.81
Sankovc II	0.21	18144.00	6622560.00	6622.56
Mirenë	0.14	12096.00	4415040.00	4415.04
Fushtica e Naltë	0.29	25056.00	9145440.00	9145.44
Dobraja e Madhe	0.30	25920.00	9460800.00	9460.80
Total	4.34	374803.2	136803168	136803.168

Table 5. Water demand assessment

Nr. Inhabitants	Liter/day			
500.00	80.00	100.00	40000.00	50000.00
1000.00	80.00	100.00	80000.00	100000.00
1500.00	80.00	100.00	120000.00	150000.00
2000.00	80.00	100.00	160000.00	200000.00
2500.00	80.00	100.00	200000.00	250000.00
3000.00	80.00	100.00	240000.00	300000.00
3700.00	80.00	100.00	296000.00	370000.00
4000.00	80.00	100.00	320000.00	400000.00
4400.00	80.00	100.00	352000.00	440000.00

Table 6. Classes of spring according to flow

Class	Q (l/s)
I	up 10 000
II	1000 to 10 000
III	100 to 1000
IV	10 to 100
V	1 to 10
VI	0.1 to 1
VII	0.01 to 0.1
VIII	under 0.01

The currel spring

The Currel spring is located near the regional road Magurë-Shalë (Fig. 9a). The Currel spring emerges in the quota of 712 m defined with the coordinates 42°32’41” N, 20°58’58” E. This spring drains water from the ultrabasic rocks of the Golesh massif. The spring is of contact type and drains the water in contact of serpentines and Paleozoic shales, which build the mountains of Blinaja. Water discharge of this spring have been monitored in different periods from 2015 to 2022 (Fig. 9), having maximum value of flow (Q = 0.50 l/s) in 1969 (Labus 1973), while minimum value (Q = 0.10 l/s) dated 27.11.2021. The water supply of this spring is done at the expense of atmospheric precipitation, which falls in the Golesh Massif. Monitoring of water discharge at this spring showed that it has been reduced by over 50% compared to water discharge in 1969. This decrease in water is related to the reduction of precipitation (rain and snow), this statement was also supported by measurements of the amount of snow; so in 1985 the thickness of snow in this area was over 50 cm, in 2017 it was 16 cm and in 2022 it was 12 cm. Another impact on reducing spring water discharge is by human activities, which globally are affecting climate change. In four different periods water samples were taken to analyze in the laboratory the quality of water in this spring (data are reflected in Table 7). From the Table 7 it results that the water temperature in this spring varies from 11.1 to 15.7 °C having an average value of 13.85 °C. According to the water temperature, this spring belongs to the group of cold-water springs (t = 4–16 °C) (Dakoli 2007). The pH value ranges from 7.51 to 8.03 and the average value is 7.7, ranking the water of this spring in weakly alkaline waters (pH = 7 to 9).

The water quality index of Curreli spring was evaluated through the Canadian Water Quality Index (CWQI) methodology. Water Quality Index (WQI) is calculated according to the method of the Canadian Council of Environment Ministers (CCME) and referring to the World Health Organization (WHO) standard limit values (Table 7). The WQI value showed that the water of this spring is good (Table 9). The CWQI equation is calculated using three above mentioned factors, and index values, designation and descriptions are given in Table 10 (CCME 2001; CCME, 2003; CCME 2005; CCME 2017).

$$WQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right) \tag{2}$$

where: F_1 represents the scope, which means the number of parameters whose objective limits are not met and is expressed by the equation:

a)
b)

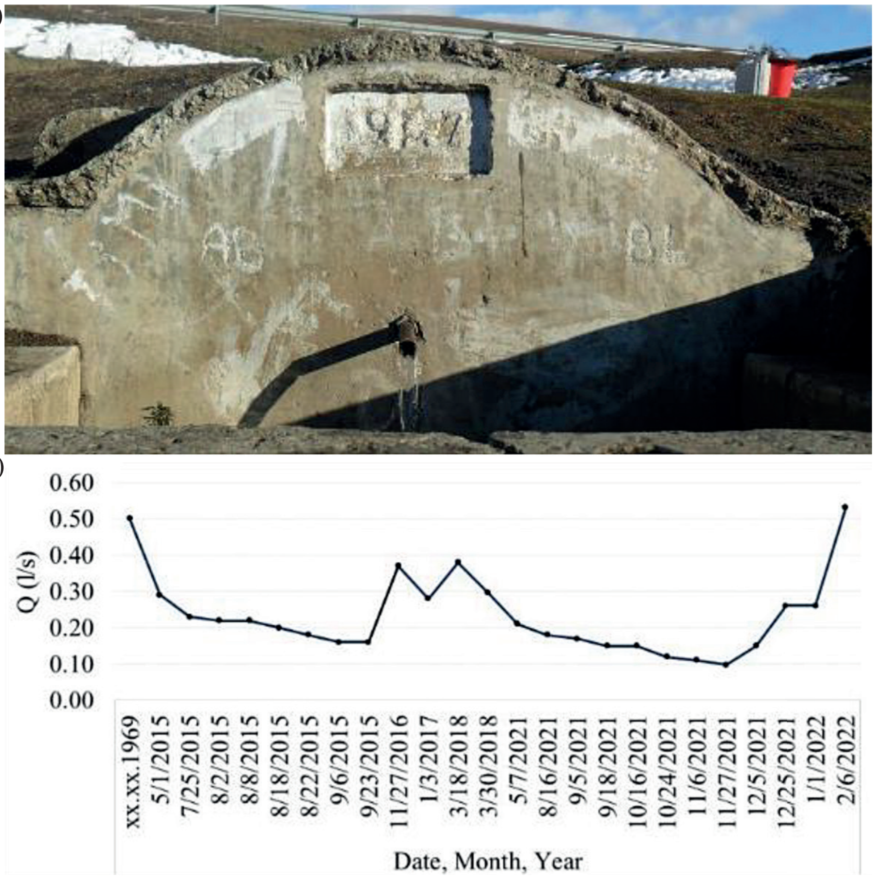

Figure 9. a) spring Curreli [Çadraku, 2016]; b) variation of water flows at the Currel spring

$$F_1 = \left(\frac{failed\ parameters}{total\ of\ parameters}\right) \cdot 100 \quad (3)$$

F_2 represents the frequency, which represents the percentage of individual tests that do not meet the objectives and is expressed by the equation:

$$F_2 = \left(\frac{failed\ tests}{total\ of\ tests}\right) \cdot 100 \quad (4)$$

F_3 represents the amplitude. The extent (excursion) to which the failed test exceeds the guideline. This is calculated in three stages. First, the excursion is calculated:

$$excursion = \left(\frac{failed\ test\ value}{guideline\ value}\right) - 1 \quad (5)$$

where: In the case of pH where a minimum and maximum guideline is given, the excursion equation must be run as above as well as in reverse i.e. guideline value/failed test value (CCME 2001).

Second, the normalized sum of excursions (nse) is calculated as follows:

$$nse = \left(\frac{\sum excursion}{total\ of\ tests}\right) \quad (6)$$

F_3 is then calculated using a formula that scales the nse within the range 0–100:

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right) \quad (7)$$

The Kroni i Mbretit spring

The Kroni i Mbretit spring is located near the highway Prishtina-Peja, on the northwest side of the Goleshi massif. It emerges in the quota 628 m defined with the coordinates 42°36’07” N, 20°50’53” E (Photo 2). It belongs to the gravitational type and is drained by cracks and fissures of the Paleozoic and marbled limestones of Lipoglava hill. Its discharge on August 20, 1963 were 2 l/s, while the water temperature was 13 °C; in March 1965 the water

Table 7. Physico-chemical parameters of water at the source Currel

Samples	Date of sampling	T (°C)	Tur. (NTU)	DO (mg/L)	COD (mg/L)	BOD_5 (mg/L)	pH	TDS (mg/L)
S1	13 Apr. 2015	14.2	nil	6.8	5.4	0.2	7.58	292.48
S2	08 Aug. 2015	15.7	nil	7.13	3.4	0.1	7.8	347.52
S3	8.Jan.16	11.1	1.91	7.67	3.7	0.4	8.03	339.84
S4	22 Sept. 2019	14.4	0.7	7.4	6.4	0.3	7.51	370.56
Min		11.1	nil	6.8	3.4	0.1	7.51	292.48
Average		13.85	nil	7.25	4.73	0.25	7.73	337.6
Max		15.7	nil	7.67	6.4	0.4	8.03	370.56
WHO		12 to 25	5	5	5	5	6.5-8.5	500

TH (°dH)	Na^+ (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	K^+ (mg/L)	HCO_3^- (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)
20.44	1.741	48.9	82.06	0.046	408.7	6.44	117	3.2
21.67	1.449	26.9	108.6	nil	457.6	28.6	76.4	2.7
21.5	1.121	34.5	72.43	nil	427	8.6	62	2.4
18.8	2.06	14	73.1	0.055	402.7	4.62	10.7	4.6
18.8	1.121	14	72.43	nil	402.7	4.62	10.7	2.4
20.6	1.59	31.08	84.05	nil	424	12.07	66.53	3.23
21.67	2.06	48.9	108.6	nil	457.6	28.6	117	4.6
10 to 17	50	75	50	12	250	250	150	50

Table 8. Physico-chemical parameters of water at the source source Kroni i Mbretit

Samples	Date of sampling	Tur. (NTU)	EC (μS/cm)	pH	COD (mg/L)	BOD_5 (mg/L)	PO_4^{3-} (mg/L)	TH (°dH)
S1	25 Oct. 2012	1.8	698	7.81	< 0.1	< 0.1	0.008	23.8

Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	HCO_3^- (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	NO_2^- (mg/L)
100	42.5	524.6	1.5	6.8	0.002

Table 9. Water quality index

Source	F1	F2	F3	CCME WQI	Designation
Currreli Spring	15.38	16	9.9	85.97	Good

Table 10. Water quality is classified

Value	Designation
95–100	Excellent
80–94	Good
65–79	Fair
45–64	Marginal
0–44	Poor

discharge was 5 l/s (Vilimonovic 1967). According to (Labus 1973) water discharge was: August 1969 (2 l/s), March 1970 (5 l/s) and June 1970 (4 l/s). Measurements in 2021 showed flows ranging from 2 l/s to 2.5 l/s (Fig. 10). Its catchment is small, while the position of the layers and cracks conditioned the drainage of atmospheric waters to the east. Therefore, for this reason the water flows to this source are variable. According to the data (Table 8), the water of this spring meets the usual criteria for drinking.

The Dobraja e Madhe spring

The spring Dobraja e Madhe is located in the eastern part of the Goleshi massif. This spring emerges in the quota 550 m with coordinates 42°32’36’’ N, 21°02’40’’ E (Fig. 11a). It belongs to the stratified type. The water drains from the porous aquifer in contact with impermeable layers. Water flows in this spring have been monitored in different periods from 2015 to 2022. This spring showed the following discharges: Max. 0.53 l/s, Min. = 0.0 l/s and Average = 0.25 l/s (Fig. 11b). Monitoring showed that during the summer months (July–August) this spring is reduced. Water reduction at this spring occurs due to increased demand from the village community in the summer season, who increased the extraction of water from the dug and drilled wells located in the nearby area of

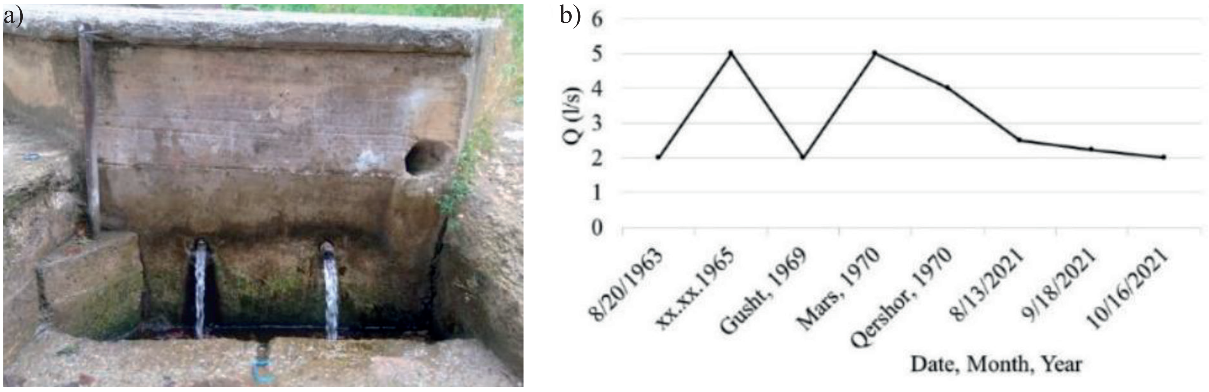

Figure 10. a) Spring Kroni i Mbretit [Çadraku, 2021];
b) variation of water flows in the spring Kroni i Mbretit

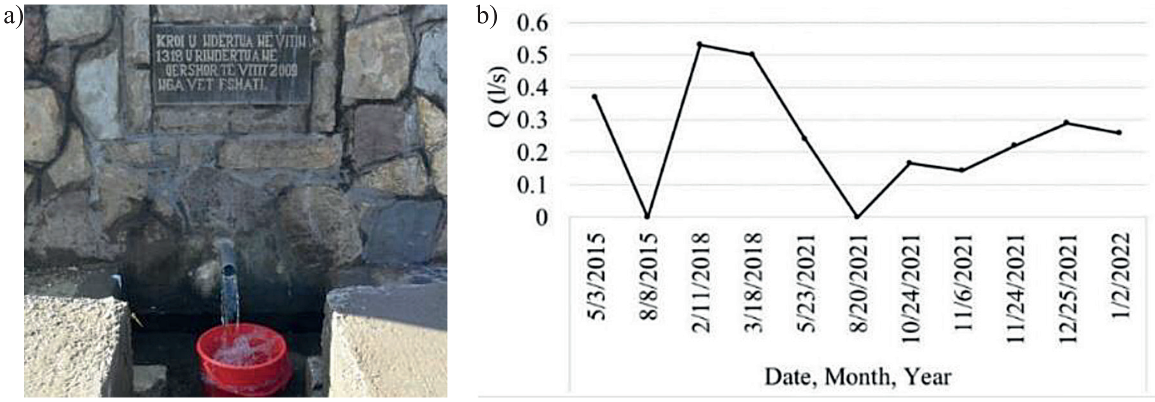

Figure 11. a) Spring Dobraja e Madhe [Çadraku, 2021];
b) variation of water flows in the spring Dobraja e Madhe

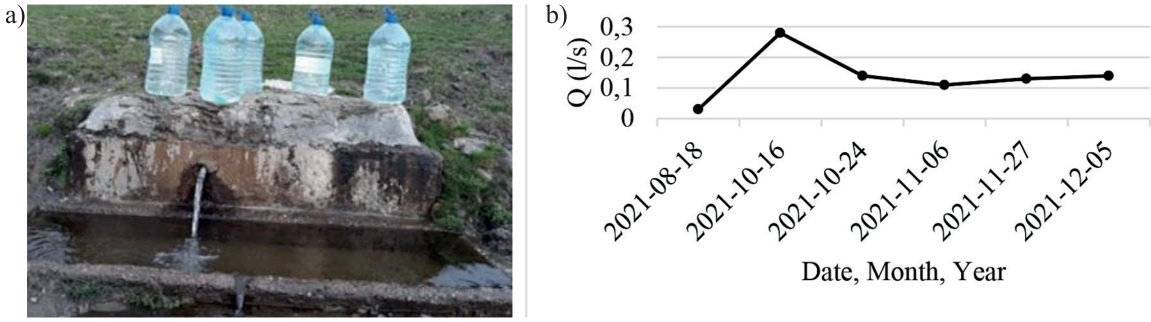

Figure 12. a) Spring Mirena [Çadraku, 2021]; b) variation of water flows in the spring Mirena

the spring, as well as the small amount of rainfall in this season. Another factor that affected reduction of spring water discharge is the small capacity of its recharge area. Therefore, the regime of this spring depends on two main factors: hydro meteorological conditions (precipitation) and human factors (pumping water from the aquifer, etc.).

The Mirena spring

The Mirena spring is located on the western side of the Goleshi massif. This spring emerges in the quota 734 m defined by the coordinates 42°33'44'' N, 20°57'59'' E (Fig. 12a). It belongs to the type of fountain springs, which drains water gravitationally from the ultrabasic rocks of the Goleshi massif. Water flows at this source were measured from August to December 2021. Water flow values showed fluctuations from 0.03 l/s to 0.28 l/s, having an average value of 0.14 l/s (Table 3). In Fig.12b the variation of water flows in the Mirena spring is shown.

The spring is fed by water from atmospheric precipitation (rain, snow) which falls in the Goleshi massif. The fluctuation of water flows depends on the amount of rainfall, thickness and days of snow cover. In the recharge basin area of this spring there are neither point nor diffuse pollutants which would affect the water quality. Water from this source is used by the local community as drinking water, food preparation and water for livestock.

The Mirena I spring

The Mirenë I spring is located on the western side of the Goleshi massif. This spring emerges in the quota 696 m defined by the coordinates 42°33'17'' N, 20°58'01'' E (Fig. 13). Water flows in this spring on 13.01.2022 were 0.23 l/s.

The Fushtica e Naltë spring

The spring Fushtica e Naltë is located on the western side of the Golesh massif. This spring emerges in the quota of 670 m defined by the coordinates 42°33'25'' N, 20°56'56'' E (Photo 14a). In Fig. 14b. the variation of water flows in the Fushtica e Naltë spring is shown.

The Sankovci I spring

The Sankovc I spring is located on the northern side of the Golesh massif, respectively in the village of Sankovc. This spring emerges in the quota 689 m defined by the coordinates 42°34'35'' N, 20°57'12'' E (Fig. 15a). The spring is in contact between serpentine rocks and Paleozoic shales and belongs to the contact type and drains water by gravity. The spring Sankovci I is simply captured and used by the inhabitants of the

Figure 13. Spring Mirenë I [Çadraku, 2021]

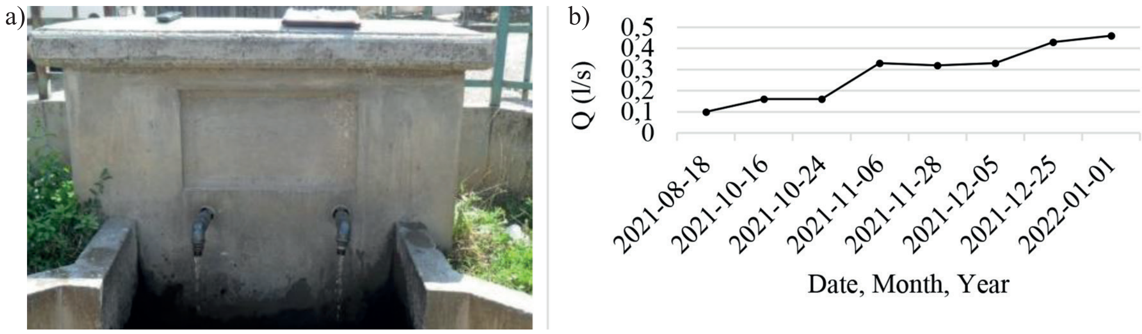

Figure 14. a) Spring Fushtica e Naltë (source: Çadraku H, 2021); b) variation of water flows in the spring Fushtica e Naltë

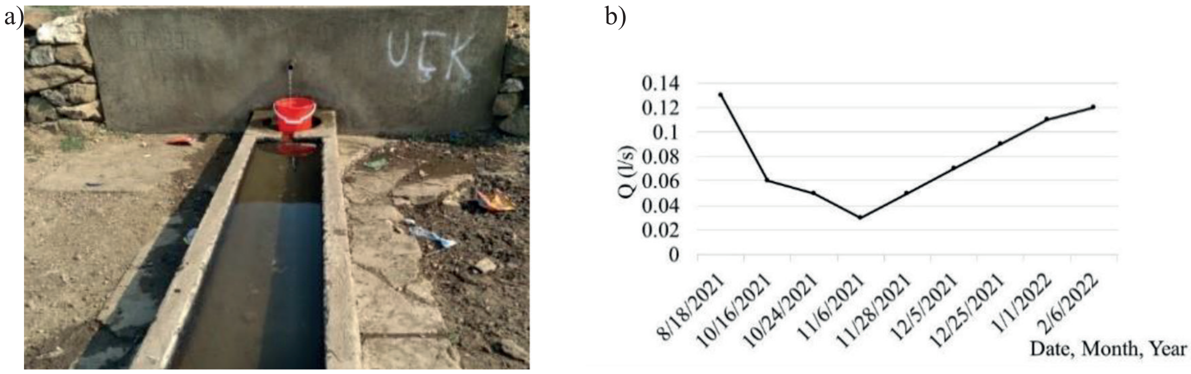

Figure 15. a) Spring Sankovci I [Çadraku H, 2021]; b) variation of water flows in the spring Sankovci I

village for drinking water and water for livestock. In Figure 15b the variation of water flows in the Sankovci I spring is shown.

The Sankovci II spring

The Sankovc II spring is located on the north side of the Golesh massif. This spring emerges in the quota of 675 m defined by the coordinates 42°34’23” N, 20°56’46” E (Fig. 16a). The spring is in contact between serpentine rocks and Paleozoic shales and belongs to the contact type and drains water by gravity. The spring Sankovci II is simply captured and used by the inhabitants of the village for drinking water and water for livestock. In Figure 16b the variation of water flows in the Sankovci II spring is shown.

CONCLUSION

The study area is located in the central part of Kosovo and has an area of 38 km^2. The range of elevation in the study area differs from 544

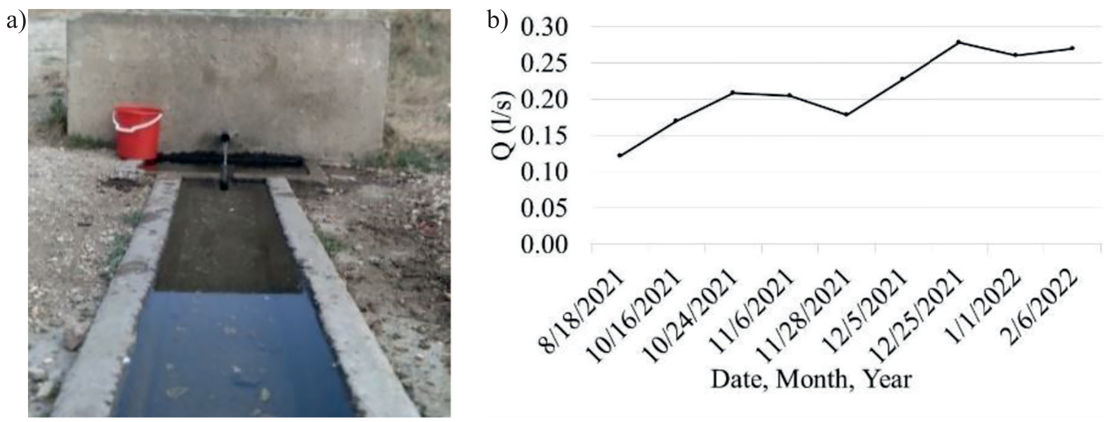

Figure 16. a) Spring Sankovci II [Çadraku, 2021]; b) variation of water flows in the spring Sankovci II

to 1019 m. The slope in study area varied from low 4°–20°. A total of 234 streams were identified in this study area. Mean bifurcation ratio is 4.53. Drainage density of the study area range from 2 km/km^2 to 11 km/km^2. In this area were identified 8 springs which are located at an altitude of 550 to 734 m. Water flows in them showed that they are affected by atmospheric precipitation. Their monitoring showed that the flows ranging 0.03 to 5 l/s. The spring are of lithological contact. The groundwater (springs) of the Golesh massif have good organoleptic and physico-chemical properties and meet the basic requirements to be used as drinking water. The water quality index of Curreli spring was evaluated through the Canadian Water Quality Index (CWQI) methodology (WQI = 89.97, good water). In the spring Dobraja e Madhe it was noticed that his regime is influenced by two main factors: hydrometeorological conditions (precipitation) and human factors (pumping water from the aquifer, etc.).

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