

PAPER • OPEN ACCESS

Water Resources in the Bratunac Municipality as an Opportunity for Irrigation in Agriculture

To cite this article: M Markovic *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **222** 012024

View the [article online](#) for updates and enhancements.

You may also like

- [Extreme citizens science for climate justice: linking pixel to people for mapping gas flaring in Amazon rainforest](#)
Francesco Facchinelli, Salvatore Eugenio Pappalardo, Giuseppe Della Fera et al.
- [Are African irrigation dam projects for large-scale agribusiness or small-scale farmers?](#)
Mokganedi Tattheho and Paolo D'Odorico
- [Palm oil's contribution to the United Nations sustainable development goals: outcomes of a review of socio-economic aspects](#)
Maria Vincenza Chiriaco, Matteo Bellotta, Jasmina Jusi et al.



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Water Resources in the Bratunac Municipality as an Opportunity for Irrigation in Agriculture

M Markovic¹, P Begovic², B Ivankovic², M Sipka¹, D Pesevic³ and M Markovic³

¹ University of Banja Luka, Faculty of Agriculture, Institute of Agroecology and Soil Science, RS, Bosnia and Herzegovina

² Ibis-Inženjering d.o.o. Banja Luka, RS, Bosnia and Herzegovina

³ University of Banja Luka, Faculty of Natural Sciences and Mathematics, RS, Bosnia and Herzegovina

mihajlo.markovic@agro.unibl.org

Abstract. The aim of the investigation is to determine water resources available in the Bratunac municipality as an opportunity for irrigation in agriculture, one of the most important economic sectors in that municipality at the present time. The study area covers almost the whole Bratunac municipality and includes 20 of the total of 27 local communities. Research of the hydrogeological characteristics and the required quantities of water for irrigation in the studied local communities showed that in 10 local communities, irrigation can be provided using underground water withdrawn by means of excavated or drilled wells. Adequate water supply in many other local communities could be obtained from nearby surface water streams. In five local communities, the surface water from local rivers is not sufficient to ensure adequate water supply; therefore, an alternative solution consisting in the catchment of water from the Drina river has been proposed. The alternative solution for all local communities situated in the Glogovac river valley could consist in securing the required amounts of water from that water stream.

1. Introduction

Bosnia and Herzegovina, as well as many other countries in the region, is faced with the consequences of climate change and more frequent occurrence of droughts mainly affecting agricultural production, which in these circumstances becomes impossible without irrigation [1]. Bosnia and Herzegovina has experienced serious incidences of extreme weather events over the past two decades, causing severe economic losses [2]. It is estimated that in 2012 alone, the drought caused losses of over USD 1 billion in agricultural production and yield reduction up to 70% [3]. A similar situation regarding the increase in water requirements for irrigation in growing of plants in agriculture exists in the neighboring countries. Thus, e.g. in the neighboring Republic of Croatia the research results allow the conclusion that climatic changes in the last investigation period (1994 to 2003) caused increased water requirements of the crops grown, compared to the period from 1961 to 2003, and thereby also a higher water deficit in soil and an increased demand for providing larger quantities of suitable irrigation water [4]. The current climate change and the occurrence of frequent droughts that damage the yield of agricultural crops imposes the need for increasing water resources for irrigation in agriculture. In the course of the past 10 years, the Bratunac municipality has made a significant economic progress, mainly based on the agriculture, specifically on the production of raspberries. A favorable



geographical position, as well as the pedologic predisposition and the climate conditions with no extreme droughts make this region one of the most favourable areas for the raspberry cultivation in the Republika Srpska. Valuing this potential, the Ministry of Agriculture, Forestry and Water Management of Republika Srpska commissioned this research for the World Bank, which co-finances the irrigation project in Bratunac municipality together with the municipality of Bratunac.

Solving the irrigation problem in Bratunac municipality will enable a more intensive agricultural production, with raspberry growing as the main activity. An intensive agricultural production will bring an increase in production and, accordingly, the profits in this sector. The economic growth will enable the continuation of the irrigation development project. According to the calculation, the overall requirements for irrigation water in the Bratunac municipality equal 122.59 L s^{-1} , and 43.22 L s^{-1} out of that sum is intended to be provided through water supply from surface water; the remaining water supply will come from wells, with or without artificial recharge. The type and extent of the research need to be adapted to the conditions on the ground as well as the investor's requirements.

Taking into consideration that a groundwater source is the most important element of the watering system, a special attention has been paid to the well dimensioning so as to facilitate a maximum groundwater abstraction and provide for sufficient water amounts. It is emphasised that there is a possibility for two well pumps (a main and a reserve pump) to be installed in the wells.

2. Material and methods

2.1. Description of investigated area

The municipality of Bratunac covers an area of 293 km^2 in the eastern part of Bosnia and Herzegovina, in the Republika Srpska. This municipality area is situated between $44^{\circ}01'34''$ and $44^{\circ}16'39''$ N and $19^{\circ}05'54''$ and $19^{\circ}37'25''$ E (Figure 1).

Its neighboring municipalities are: Srebrenica to the south-west, Milići to the north-west, and Zvornik to the north. The north-eastern boundary of the studied area is the river of Drina, whose 68 km long left bank forms the natural border of Bratunac municipality with the neighboring Republic of Serbia (the municipalities of Ljubovija and Bajina Bašta). The land along the Drina is a plain belt covering 30% of the total area of the municipality. The plain belt along the left bank of the Drina is at an altitude of about 174 m above sea level, which continues to the interior of the municipality and the hilly belt (70% of the total area of the municipality), with altitudes of 300 to 772 m above sea level.

The territory of the municipality belongs to an area of moderate continental climate with long and warm summers and cold winters, with heavy snowfall. The average annual temperature is 16°C . January is the coldest month, with an average temperature of 1 to 2°C , and July is the hottest month with an average temperature of 24°C . The average rainfall is 1,000 mm and is most abundant in spring and autumn. The city core, as well as the ravine belt along the Drina are surrounded by hills, which causes fogs to persist in the morning, which in turn adversely affects the cultivation of certain crops.

2.2. Geomorphological characteristics of the investigated area

The geomorphological evolution has determined the fluvial relief type and this applies to all rivers in the area. The karst type of relief is dominant in the Glogova mountain area which represents a topographic divide between the sub-catchment areas of the Glogovska river and the Kravička river. The river valleys are small and are characterized by faults, resulting in regular streamflow courses with the exception of some small meanders situated in the actual valleys. The rivers have torrent-type flows that have considerably influenced the relief shapes.

Geomorphological characteristics are a consequence of the geologic structure of the terrain and of the geomorphological processes that took part in its formation. Taking into consideration the geologic diversity of the studied area, various geomorphological processes are represented.

The area is characterized by the hilly-mountainous type of relief (Figure 2), with distinctive moderate relief forms found in the parts characterized by the presence of clastic sediments.

The following geomorphological processes can be found in the designated territory: fluvial, delluvial, and colluvial geomorphological.

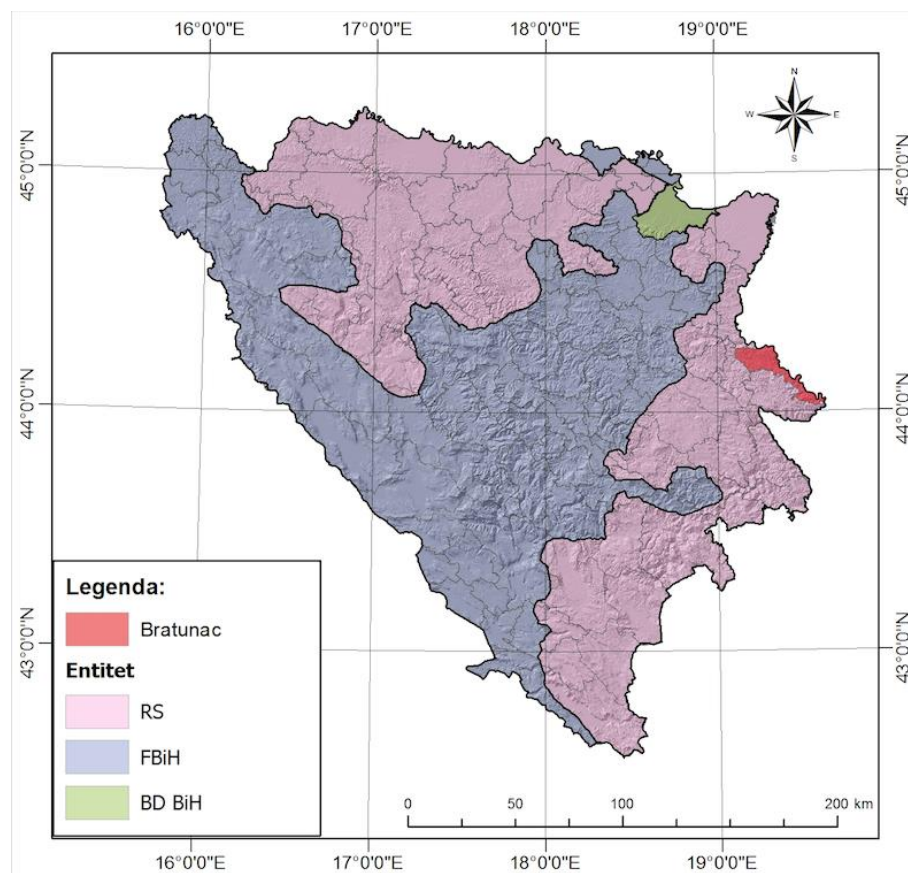


Figure 1. The location of the studied area in Bosnia and Herzegovina (Bratunac area, RS – the entity of Republika Srpska, FBiH – the entity of Federation of Bosnia and Herzegovina, BD BiH – Brcko District of the BIH)

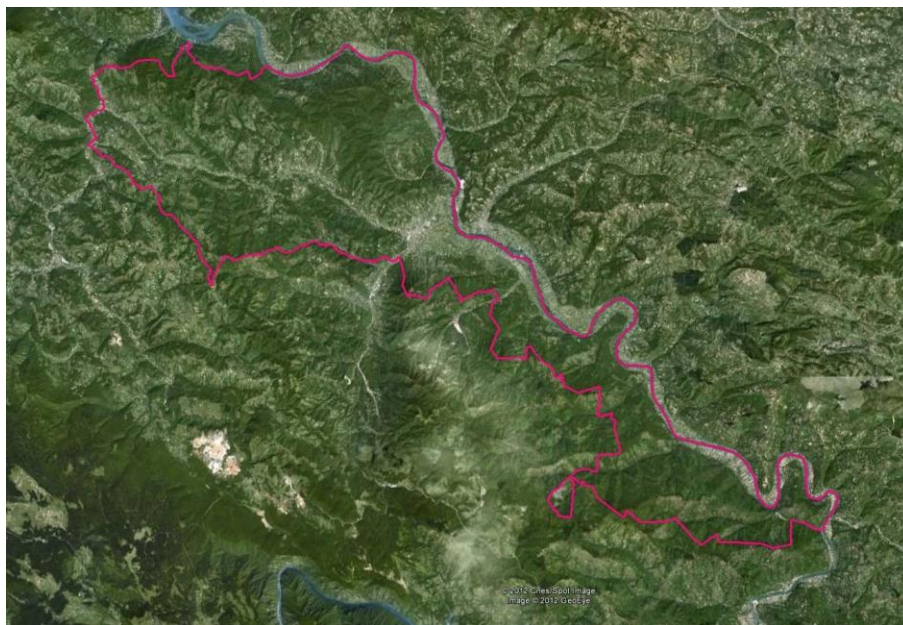


Figure 2. A satellite image of the Bratunac municipality (Source: Google Earth, 2012).

Fluvial process is a result of the occurrence of numerous watercourses, such as: the Križevica, the Grabovička river, the Kravička river, the Glogovska river, the Jagodnja and the Slapašnička river. A delluvial geomorphological process results from sporadic diffuse flows. Delluvial deposits, as a cumulative form of this process, occur in the contour parts of all the streams, including the Drina. The thickness of these sediments is not large, measuring between 2 and 4 metres.

The investigation is based on the analysis conducted as part of a previous hydrologic research [5–6], using available geologic [7–8] and hydrogeologic documentation [9–10] and a detailed hydrogeologic assessment obtained through field survey [11]. Locations where the hydrogeological potential for groundwater abstraction has been identified have been analyzed and the construction of wells for water exploitation is planned at these sites.

On the basis of the investigation of water resources, a proposal for water abstraction for the purposes of irrigation in agriculture has been made including economic justification of the proposed solutions regarding the irrigation project and an overview of costs of the wells' construction.

The study area comprises almost the entire municipality of Bratunac as it covers 20 of the total of 27 local communities.

3. Results and discussion

3.1. Hydrogeological features of the studied area

For the purpose of hydrogeological sectioning of the studied area, the following factors have been taken into account: the lithological composition of the charted units, tectonic configuration of the terrain, geomorphological characteristics, types of aquifers and their distribution, as well as their well capacity, the aquifer recharge conditions and the groundwater drainage. Based on the aforementioned factors, the following types of aquifers were identified in the studied area (Figure 3):

- a continual water-level aquifer, i.e. an intergranular aquifer;
- a karst aquifer;
- a fracture aquifer;
- a hydrogeologic complex of mainly fracture porosity and partly provisionally "waterless" (insignificant) sectors of the terrain.

The intergranular type of aquifer, i.e. the continual water-level aquifer, is formed in the alluvial and terrace sediments characterized by good permeability. Taking into consideration a relatively large area diffusion of these sediments, as well as their considerable thickness and good seepage characteristics, this aquifer is of great importance for groundwater exploitation. The Drina alluvium is expected to have a great water abundance, although the related watercourses have limited alluvial deposits of 3 m maximum, which reduce the obtainable water capacity. On the other hand, the effect the groundwaters would have on the regulation unit in prospect is not large, for the relevant groundwaters are of an unconfined type, and it is not anticipated that the groundwater hydrostatic pressure would have an impact on the future construction of the relevant river regulations. Drainage is achieved artificially, through wells or other tapping objects, as well as through outflow of water into a river. Principally, in the conditions of standard average discharge, all rivers function as the base level of erosion and all water gravitates towards those flows, which represent the main recipient on the relevant locality. In the segments where the Drina is eroding the right bank, the alluvial deposits are very thin, under 1 meter in thickness, and in some locations they are entirely absent. This was taken into account when the locations of the exploitation-production wells were determined, together with the required water capacity for each individual system.

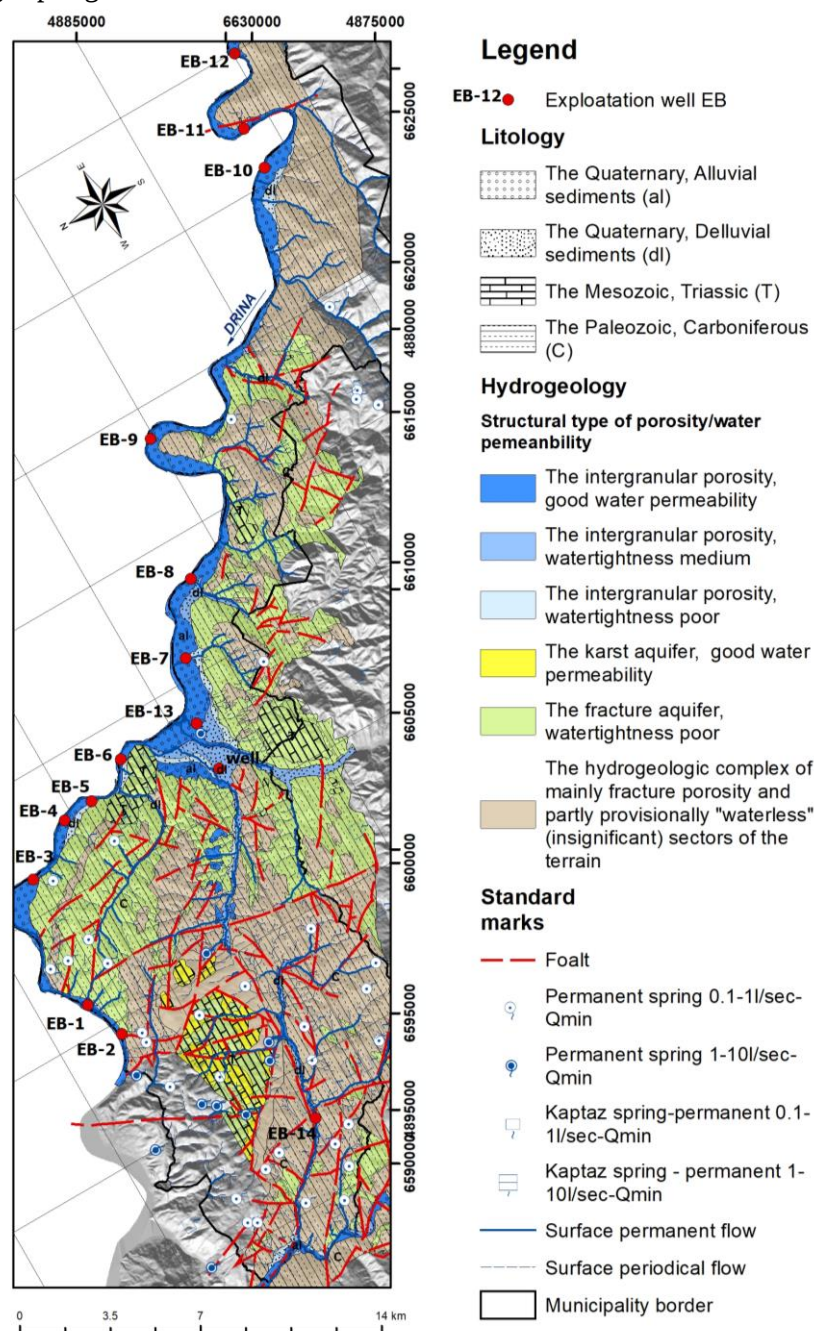
The karst aquifer is formed in the Triassic carbonate sediments. The karst aquifer has a good permeability and is formed in a number of varieties of limestone and dolomitic limestone. This type of aquifer is most commonly found in terrains with carbonate rocks broken and cracked by tectonic movements [12].

The water-bearing properties of this aquifer type depend on the degree of karsting (a result of karstification) of limestone sediments. Since these sediments are located in the upper part of the

catchment basin, beyond the planned regulations, they will not be discussed further; however, it is emphasised that the rivers mentioned herein exist on account of this aquifer, as it discharges through the springs that feed the related rivers.

The karst aquifer is located above Kravica, on the slopes of the Glogova mountain. Sources with capacity of $5\text{--}10\text{ L s}^{-1}$ have been ascertained in the area of this aquifer. Those are contact karst springs that are situated in the upper part of the Kravička river catchment. Some of these karst springs are exploited as water supply for the population.

In addition to the karst aquifer, there is also a fracture type aquifer present in the terrain. This aquifer is being recharged through the infiltration of atmospheric precipitates, while the drainage is achieved through springs.



The fracture type of aquifer is formed in igneous rocks, which are characterized by poor permeability and are chiefly limited to the right bank of the lower course of the Slapašnička river and the southern part of the research area. This, primarily, refers to dacite. The fracture type of aquifer is also formed in the Carbon complex of terrigenous rocks (sandstone, quartz breccia, conglomerates). In fracture porosity rocks, the yieldingness reduces with depth because the fractures, too, lessen with depth. Significant quantities of water can be abstracted from unconfined aquifers with a saturated thickness of 5–10 m, but the selection of a suitable abstraction system is the key to success [13].

The hydrogeological complex of mainly fracture porosity and partly provisionally "waterless" (insignificant) sectors of the terrain is represented by the most widely distributed rocks of the Paleozoic age. Hence, these sediments act as hydrogeologic isolators, but it is also possible that some minor groundwater quantities could be present within them and could be used as local water supply. This is also attested by the presence of a number of minor springs (up to 1 Ls⁻¹) throughout this area. Additionally, these sediments represent a barrier for waterflows in the karst aquifer, so that springs with significant groundwater capacity appear on the contact points of these sediments and the Triassic limestone. Also belonging to provisionally "waterless" sectors of the terrain, and of poor permeability, are the delluvial sediments, which can store minor groundwater quantities; consequently, water from this aquifer can be used for individual water supplies. A field prospection indicated a large number of wells in these sediments, but the wells are of small depth and capture a surface weathering crust of carbonate rocks. The yieldingness of those water wells ranges from 5 to 10 m³day⁻¹, which is not sufficient to include them in the irrigation system.

3.2. Existing water supply objects

During detailed field survey, special attention was paid to existing wells and surface water intakes as the possible water supply for irrigation purposes.

3.2.1. Existing surface water supply objects

The current means of water intake are based on individual solutions used for a limited area of 0.1-1 ha, and rarely for larger areas. The intake consists in a primitive water gate made of sacks or boulders. A pump bucket is lowered into the accumulation formed by those water gates and water is pumped into cisterns placed in the highest parts of the orchards. From these water reservoirs, water flows through pipes to land parcels where the plants (raspberry) grow.

Another method to supply water consists in the creation of small water-accumulations in the lateral streams, i.e. tributaries of the rivers. In that manner, the accumulations of a few cubic meters are formed and water is transported using gravity to plastic or metal tanks situated on the actual plantations. This method is viable only for small land parcels because their capacity is very small, and it can provide up to 10-15 m³day⁻¹.

A frequently used method for obtaining water is to construct wells at the actual river banks, by extending the well below the river bed, thus allowing water to directly discharge into the well.

A water capacity of 100-150 m³day⁻¹ can be obtained using this method. A disadvantage of this intake method is that rivers in Bratunac are of torrential character as the catchment area mainly consists of poor permeability rocks; consequently, surface outflow from the catchment is prevailing.

The discharge oscillation is large, resulting in considerable lateral erosion of the river banks, which endangers these systems.

Another disadvantage of this scheme consists in significant water impurities and water shortages as the current demand requires the construction of numerous systems, which exceed the stream's water capacity.

3.2.2. Existing water supply from groundwater

3.2.2.1. Excavated wells

There are numerous wells situated all over the study area. They are mainly excavated wells with the groundwater intake from the surface weathering crust. The depth of those wells generally ranges from

3 to 9 m, rarely more. Taking into consideration the geological configuration and the hydrogeologic function, the well depth would not provide significant water quantities.

The excavated wells in carbonate rocks are an optimal solution for water intake because the crust is an environment unable to accumulate larger water quantities; therefore, an aquifer formed in the weathering crust is very thin and an excavated well enables the intake of minor water quantities of around $5\text{--}10\text{ m}^3\text{day}^{-1}$. Some excavated wells have already been specifically constructed for the purpose of irrigation.

Except for the public water source in Bjelovac, all other tapping objects were established without any previous hydrogeological research, so they mainly consist of wells that are located in suboptimal hydrogeological predisposition zones and some supply little to no water.

The optimum groundwater intake in the carbonate complex is provided by excavated wells, provided that their location is determined so as to be set on the points of contact of two components where the groundwater circulation is the largest. Wells in these deposits can be excavated even in the parts of terrain which morphologically incline the waters to drain into one zone (amphitheatral forms).

Since the excavated wells are constructed as “imperfect” wells, their bottoms (hole backs) should be suspended above the aquifer zone bottoms; a bottom is an active part of the filter.

Well locations of these characteristics cannot provide sufficient water quantities for irrigation in the designated zones because the greatest demand for watering exist in the hilly parts of the research area, which are made of carbonate rocks. For that reason, the research is not directed towards the investigation of the hydrogeologic potentials of the carbonate complex as the probability that the area could be supplied with sufficient groundwater quantities is low and this would jeopardize the whole irrigation project.

Four such wells are located in sections without water and some are very deep. On the other hand, all the wells are equipped with pumps exceeding the capacity of the wells, which means they pump out all the accumulated water in 5–10 minutes, where the recharge lasts up to 6 hours.

Among all the investigated wells, the best one was situated in Podčauš; it has been excavated on private land but serves as a public water source for the purpose of irrigation. This well is situated on the bank of the river Križevica, about 10 m from the regulated river flow (on the right bank).

The well's yield was 0.4 Ls^{-1} , which is around $34.5\text{ m}^3\text{day}^{-1}$. Unfortunately, even this capacity is not sufficient for the irrigation in Podčauš.

3.2.2.2. Drilled wells

Field survey has also revealed the presence of drilled wells. The purpose of their construction was to reach potential deeper aquifers and thus provide the required amounts of water.

The hydrogeological investigation was followed by the micro-locations where the drilled wells were evident. The wells are situated in the zones of micro-depressions or in the flaws zones (in the rock cracks), where groundwater circulation is the largest, but their yieldingness is also very small. A well of 60 m in depth has a capacity of around 0.2 Ls^{-1} . This amount of water is, indeed, sufficient for a household, but it is insignificant in terms of quantities projected for irrigation purposes. Moreover, a 32 m well in the local community of Ježeštica is already equipped with a pump and hydrophore, as well as solar panels, but its yieldingness is only 0.15 Ls^{-1} . This well is also equipped with a much more powerful pump than the well capacity can support, which means that if exploitation using this pump should continue, it might lead to a decline in the well's capacity. Furthermore, another test-drilling was performed in Ježeštica, but since the results were negative the borehole was not turned into a well.

A well drilling of 125 m in depth in Triassic limestone was performed in the local community of Kravice. Water was found 60 m below the surface and testing determine the well's capacity of 0.3 Ls^{-1} .

3.2.2.3. Captured springs

A number of springs are verified in the research area. The majority of them have a water yield of 0.1 Ls^{-1} , rarely higher. The exceptions are the contact springs, rising from Triassic limestone, with a

yieldingness of up to 10 L s^{-1} . The karst springs are up to 5-10 km distant from the irrigated plots, and the water flowing out of them runs in the form of brooks to the closer locations.

All springs of a constant type within the zones of inhabited places are captured for the purpose of supplying drinking water. Concerning the fact that drinking water is a priority in any water supplying process, those springs are not taken into consideration as a potential water source for irrigation.

3.3. *Proposals for the water supply in accordance with the requirements of the projected irrigation system in the Bratunac municipality*

Securing sufficient water quantities for irrigation is the biggest problem of every watering system and it sets the requirements on the technical solution for the irrigation system. The optimal solution is to utilize groundwater, but there the available quantity is often insufficient. The basic goal of the study is to try and solve the water deficit problem through the use of groundwater. The ground waters, generally, are of a better quality than surface waters, which is a the advantage. Through the analysis of the indicated hydrogeological characteristics, and by calculation of the required water for irrigation during field research at the potential areas for irrigation in 10 local communities, it was determined that the problem of water supply for irrigation can be solved by groundwater intake from wells. In 5 local communities, the surface water from the local water-streams are not sufficient to provide adequate water quantity for irrigation needs and the survey offered an alternative solution by catching water from the Drina river. And for all local communities located in the Glogovska river valley the alternative solution in supplying the required amount of water for irrigation is from that, Glogovska water stream.

3.3.1. *Proposed water supply from surface water streams*

All waters in the research area belong to the Drina river catchment area, with the exception of the zone of the local community of Glogova-Magašići where the catchment area is divided into two sub-catchments, one belonging to the Kravička river and the other belonging to the Glogovska river. The area on the actual divide represents a waterless terrain with no options to provide the required water capacities in the local community's territory. Bearing in mind that these are insufficiently studied river basins that were not the subject of long-term hydrological observations for the purpose of defining water intakes, we relied on the "Preliminary analysis of the river network in the Bratunac municipality for the purpose of defining the possibility of constructing the flow of hydroelectric power plants" [6]. This analysis defines the river network, sub-basins and minimal river flows: the Kravička river, the Slapašnica, the Jagodnja-Žljebac, the Mlečanska river-Fakovići, the Loznička river, the Grabovička river and the Glogovska river (Table 1).

Table 1. Water flow measuring results using the hydrometric wing, in a multi-year minimum [6].

No.	Name of the watercourse	Rate of flow (m^3s^{-1})
1	Kravička river	0.075
2	Slapašnica	0.038
3	Jagodnja-Žljebac	0.050
4	Mlečanska River Fakovići	0.068
5	Loznička river	0.031
6	Grabovička river	0.095
7	Glogovska river	0.038

The potential surface water abstraction sites, as well as the assessment of the available water quantities required to sustain the biological minimum in the rivers, have been defined on the basis of the data shown in Table 1.

Taking into consideration that the local water-streams have distinctly torrential character, the water abstraction from those surface water-streams is proposed, by using so called "Tyrolean intake", which implies enable water intake from the river bed bottom during the hydrological minimum when the water demand is the highest.

Table 2 shows a list of the local communities that will be supplied with water from surface water-streams. It is emphasized that two local communities: Glogova and Glogova – Magašići, are connected to one tapping object which abstracts water from the Glogovska River.

Table 2. A survey of the local communities projected for the water abstractions from surface watercourses.

No.	Location	Type of facility	Facility coordinates		Water capacity	
			X	Y	Water demand (Ls ⁻¹)	Flow of watercourse (Ls ⁻¹)
1	Slapašnica	tapping object	6604793.34	4898882.67	7.24	17.3
2	Fakovići - Grabovačka Rijeka	tapping object	6618728.01	4885452.50	3.63	67.0
3	Blječeva+Zagoni	tapping object	6601257.72	4893435.71	2.85	13.0
4	Glogova	tapping object	6600685.50	4897216.83	12.29	9.7
	Glogova - Magašići					
5	Ježešnica	tapping object	6598371.57	4896261.97	7.19	24.0
6	Kravica - Šiljkovići	tapping object	6595885.59	4897885.59	5.64	17.8
7	Kravica - Mandići	tapping object	6598253.05	4898995.96	4.38	7.4

3.3.2. Proposed water supply from wells

As has already been stated, the aim of the hydrogeological field investigation was to provide maximum quantities of water through wells. Unfortunately, it has been verified that there was no valid hydrogeological potential to open a groundwater source in all of the local communities. This is partly a result of the fact that, so far, the supply of drinking water has not been adequately ensured in those areas; it follows that irrigation is only a secondary priority.

Wells are planned to be built in the alluvial plain of the Drina River. For the local communities requiring greater water quantities, the well locations are defined so as to be able to ensure artificial recharge and thus the required amounts of water. Table 3 presents an estimation of the water supply that can be obtained from projected wells based on the research. According to the projected solutions, the total exploitation of groundwater in the Bratunac municipal area corresponds to an irrigation capacity of 79.37 Ls⁻¹.

Table 3. The expected water supply by projected wells.

No.	Location	Type of facility	Facility coordinates		Expected water supply (Ls ⁻¹)	Well diameter	Well construction material
			X	Y			
1	Polom 1	well	6601125	4903132	0.98	800 mm	steel
2	Polom 2	well	6599492	4902548	0.63	800 mm	steel
3	Osamsko	well	6606347	4902555	6.34	1000 mm	polyester
4	Krasanpolje 1	well	6607697	4900356	3.74	800 mm	steel
5	Krasanpolje 2	well	6607831	4899104	2.99	800 mm	steel
6	Mihaljevići	well	6608651	4897303	1.40	800 mm	steel
7	Repovac	well	6606450	4894194	12.63	Old well in the locality of Lamele	concrete excavated well
	Hranča - Smoljeva						
	Hranča						
	Podčauš + Podgradac						

8	Voljavica	well	6610776	4893190	2.17	800 mm	steel
9	Bjelavac + Bijača + Zalužje	well	6613297	4891487	12.42	1400 mm	polyester
10	Tegare	well	6618741	4890159	8.34	1000 mm	polyester
11	Fakovići	well	6625566	4881127	9.33	1200 mm	polyester
12	Žljebac-Vranjkovina + Ž. - G. Vrankovina + D- Žljebac	well	6627259	4881072	3.23	1000 mm	polyester
13	Žljebac - Vatljevići	well	6629944	4879928	2.50	800 mm	steel
14	Bratunac II and Pobrđe	well	6608384	4894081	6.45	1000 mm	polyester
15	Konjević Polje -Pobuđe	well	6592970	4897660	6.22	1000 mm	polyester
Total					79.37		

The well situated in the local community of Glogova-Magašići can provide only 0.2 Ls^{-1} , which is very low compared to the capacity required. For this reason, an intake the water into the irrigation system by the surface water supply from the Glogovska River was proposed. The proposed solution will not be entirely sufficient, but it provides a reasonable alternative at the moment.

3.4. Explanation of the planned solutions for irrigation water supply in the Bratunac municipality

Extreme climate events in Bosnia and Herzegovina have become increasingly frequent.

Out of the last twelve years, six were very dry to extremely dry: 2003, 2007, 2008, 2011, 2012 and 2013 [14].

In that context, the actual water capacity for the projected irrigation system in the Bratunac municipality is estimated at around 122.59 Ls^{-1} . Relying on the study of the terrain, a part of the system will be supplied with water from the surface streams while the remaining part part from the wells.

The design was not preceded by a prospection drilling so that all the wells with small hydrogeological potential or with a more significant water demand were envisaged to feature a hydraulic connection with the river Drina through drainage channels, or with the Kravička River in the case of Konjević Polje – Pobuđe area.

The project encompasses the regeneration of a well situated at the old water source in "Lamele" locality and putting that well into operation as part of four irrigation systems.

Concerning the locations of the wells, an attention was paid to place them on municipal land, at locations which satisfy the requirements on the hydrogeological potential.

Care was also taken to position the wells as close as possible to the central point of the irrigation zone system, in order to have pipelines as short as possible; additionally, a particular attention was paid to ensure their proximity to electric power sources to supply them with electricity.

The wells are designed in a way that allows maximum capture of groundwater. All wells are projected to facilitate two well pumps (one operational, one reserve).

On average, the Drina river high water mark lies 10 m above the well openings, so it is not feasible to raise the well openings above those elevation marks.

3.5 Economic justification of the proposed solutions for the irrigation project

Table 4 shows the overview of the costs of the wells' construction and restoration of the well in "Lamele" locality. The costs of the channels for artificial wells recharge are included.

Considering the exceptional quality of raspberries from the Bratunac area, the wholesale purchase price of raspberries is guaranteed at and above 3.5 BAMkg^{-1} . This price makes raspberries a very profitable commercial crop. An area of around 0.1 ha planted with raspberries gives a usual yield of 1,500 kg of raspberries, which – given the price of 3.5 BAMkg^{-1} – gives the revenue of $52,500 \text{ BAMha}^{-1}$. This price must cover the costs of hoeing, nutrition, pruning and picking, which are

Table 4. The costs overview of the wells construction for the irrigation project in Bratunac mun.

No.	Location	Well symbol	Expected water supply (Ls ⁻¹)	Well diameter	Well construction material	Price of the well without VAT, in BAM
1	Polom 1	EB-1	0.98	800 mm	Steel	44.748,00
2	Polom 2	EB-2	0.63	800 mm	Steel	
3	Osamsko	EB-3	6.34	1000 mm	Polyester	56.180,00
4	Krasanpolje 1	EB-4	3.74	800 mm	Steel	44.143,00
5	Krasanpolje 2	EB-5	2.99	800 mm	Steel	
6	Mihaljevići	EB-6	1.40	800 mm	Steel	19.437,00
7	Repovac Hranča - Smoljeva Hranča Podčauš + Podgradac	Well in Lamele	12.63	Old well in "Lamele" locality	Concrete excavated well	21.131,00
8	Voljavica	EB-7	2.17	800 mm	Steel	25.261,50
9	Bjelavac + Bijača + Zalužje	EB-8	12.42	1400 mm	Polyester	64.240,00
10	Tegare	EB-9	8.34	1000 mm	Polyester	51.813,00
11	Fakovići	EB-10	9.33	1200 mm	Polyester	75.471,00
12	Žlijebac-Vranjkovina + Ž. - G. Vrankovina + D-Žlijebac	EB-11	3.23	1000 mm	Polyester	168.839,00
13	Žlijebac - Vatljevići	EB-12	2.50	800 mm	Steel	
14	Bratunac II and Pobrđe	EB-13	6.45	1000 mm	Polyester	32.706,00
15	Konjević Polje -Pobuđe	EB-14	6.22	1000 mm	Polyester	38.098,50
Total			79.37 Ls ⁻¹		Total	642.068,00

estimated at 1.5 BAMkg⁻¹ or 22,500 BAMha⁻¹. This calculation indicates profit from raspberry production in the Bratunac municipality equal to 30,000 BAMha⁻¹. The initial investment into the development of the raspberry plantations is not included in the price.

When raspberry groves are irrigated according to professional instructions and the plants are provided with humidity they lacks in dry periods, the yield increases up to 25,000 kgha⁻¹. According to the above calculation, the revenue per 0.1 ha used to grow raspberries equals 87,500 BAMha⁻¹; with expenses deducted, this corresponds to 65,000 BAMha⁻¹.

In view of the facts stated above, the turnover from the raspberry production utilising the described irrigation system increases by 100%. Investments into drip irrigation systems at land parcels containing the raspberries plantations were not included in the calculation.

The income from raspberry production constitutes a significant economic potential for the Bratunac municipality and it should to be supported through the implementation of the project.

4. Conclusions

Agricultural production and primarily the production of raspberries forms the basis for the economic development of the Bratunac municipality.

The study of water resources in the Bratunac municipality and their availability for irrigation in raspberry production is presented in this paper.

The results of research which has included 20 of the total of 27 local communities in Bratunac showed that in 10 local communities, irrigation can be provided using underground water abstraction by means of excavated or drilled wells. In many other local communities, water supply could be ensured by using water from surface water streams flowing through these local communities. In five of the local communities, surface water from local rivers is not sufficient to provide adequate water supply, so an alternative solution consisting in catching water from the Drina river has been proposed. The alternative solution for all local communities situated in the Glogovac river valley consists in water supply by catching the required water quantities from that water stream.

References

- [1] Zurovec J and Cadro S 2010 Climate changes, the need and importance of crop irrigation in northeastern Bosnia and Herzegovina *Proceedings of the 21st Scientific-Expert Conference in Agriculture and Food Industry* pp 705–16
- [2] Zurovec O, Vedeld P and Sitaula B 2015 Agricultural Sector of Bosnia and Herzegovina and Climate Change—Challenges and Opportunities *Agriculture* **5**(2) pp 245–66 DOI: 10.3390/agriculture5020245
- [3] Hodzic S, Markovic M and Custovic H 2011 Drought conditions and management strategies in Bosnia and Herzegovina *Proceedings of the 1st Regional Workshop on Capacity Development to Support National Drought Management Policies for Eastern European Countries* pp 42–5
- [4] Šimunić I, Senta A and Tomic F 2006 Irrigation requirements and potentials of agricultural crops in northern Croatia *Agronomski glasnik* **1** pp 13–29
- [5] Bešlagić O 1982 *The main project of water supply system in Bratunac* Books: 1, 2 and 3 (Water Management of Bosnia and Herzegovina: Composite Organization of Associated Labour Spreča Tuzla)
- [6] Filipić Z 2011 *The preliminary analysis of the river system in the Bratunac municipality area for the purpose of defining of the prospects for the construction of freeflow hydroelectric power plants* (Kriptos Ltd Milići)
- [7] Kubat I et al 1963 *The Basic Geological Map 1:100000* Sheet Ljubovija (The Institute for Geologic Studies Sarajevo)
- [8] Mojsilović S et al 1966 *The Basic Geological Map 1:100000* Sheet Valjevo (Bureau of Geologic and Geophysical Studies Belgrade)
- [9] Lazić M 1990 *The special hydrogeology Part I the Meliorative hydrogeology* (Belgrade: University of Belgrade the Faculty of Mining Engineering and Geology Belgrade)
- [10] Lazić M 2005 *The construction of no-filter wells* (Belgrade: University of Belgrade the Faculty of Mining Engineering and Geology the Institute of Hydrogeology)
- [11] Begovic P and Ivankovic B 2016 *Detailed design for construction of irrigation system in Bratunac municipality, Hydrogeological characteristics of the Bratunac area and the possibility of providing water for irrigation purposes* Book 2 (Banja Luka: IBIS - INŽENJERING d.o.o.)
- [12] Okiljevic M and Markovic M 2005 *Pedology, Book I, Agrogeology-silvogeology* (Banja Luka : University of Banja Luka, the Faculty of Agriculture)
- [13] Rushton K R and Brassington F C 2016 Pumping from unconfined aquifers of limited saturated thickness with reference to wellpoints and horizontal wells *Hydrogeology Journal* **24** (2) pp 335–48
- [14] Trbic G, Bajic D, Djurdjevic V, Ducic V, Cupac R, Markez D, Vukmir G, Dekić R and Popov T 2018 Limits to Adaptation on Climate Change in Bosnia and Herzegovina: Insights and Experiences In *Limits to Climate Change Adaptation* (Cham: Springer) pp 245–59