Climate change and their imapct on karst groundwater

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FOREWORD

School of Engineering Management in Belgrade and Engineering Management Society of Serbia organised the third International Scientific and Practical Conference on Circular and Bioeconomy - CIBEK 21.

The Conference deals with more current topics, such as improving efficiency and reducing the use of resources; identifying and creating new opportunities for economic growth and promoting the innovation and competitiveness of cities and their surroundings as well as their companies; guaranteeing the security of supply of essential resources; fighting against climate change and limiting the environmental impact of the use of resources.

This conference brought in some different format, online, together scientists, professionals and students from Austria, Jordan, United Kingdom, Portugal, Spain, Italy, Luxembourg, Norway, United Arab Emirates, Romania, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Macedonia and Serbia due to exchange ideas and concepts of great importance for the future sustainable economic development.

The Book of Proceedings, as a result of the Conference, is published and will be available to a wider audience, scientifically and practically focused on circular and bioeconomy multidisciplinary issues.

Belgrade, Editor

July, 2021 Brankica Pažun, PhD

CONTENT

CLIMATE CHANGE AND IMPACT ON KARST GROUNDWATER

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Abstract: In the last 30 years, there have been progressively more dry and rainy years, a reduced presence or even absence of snow cover, an increase in air temperature, large-scale fires, intensified glacier melting, and the like. Climate change certainly has an effect on all areas of economic activity, but its largest impact is on water resources and existing ecosystems. One of the most important water resources is groundwater, on account of which more than 70% of the population of Serbia meets its water demand. Based on the rate of abstraction, intergranular aquifers are the largest source of groundwater, followed by karst springs and fractured aquifers. The vulnerability of groundwater to climate change varies. An unconfined intergranular aquifer suffers from climate change because of its shallow water table (higher rate of evaporation, less recharge, smaller reserves, poorer quality, etc.). Confined intergranular aquifers, however, are not directly exposed to the impact of rising temperatures. Finally, one of the most important groundwater resources is karst spring water, like that found in the karst massifs of eastern and western Serbia. The absence of settlements, roads, and intensive agricultural activity in these parts is one of the main reasons why the quality of karst groundwater is high and suitable for water supply, given that often only chlorination is required. The advantage of these waters over other resources is that groundwater levels are at great depths, so an increase in temperature will not have a significant effect on evaporation. The paper provides a detailed overview of the pressures of climate change on groundwater, with a focus on karst groundwater.

Keywords: climate change, aquifers, groundwater regime, vulnerability, karst.

1. INTRODUCTION

Climate change in Europe has resulted in an increase in temperature of 1°C in Europe in the last hundred years. According to international climate experts global temperature rise should not exceed 2°C to prevent the most dangerous consequences of climate change. Climate change can alter water consumption, with demand increasing during dry, warm periods and decreasing during cool, wet periods. These changes in water availability and demand will impact the municipalities in charge of water supply. Climate change may impact a municipality's ability to provide water to existing customers and their planning for future. New sources of water may require, and the evaluation of these new sources should consider potential climate change impact, which will not be the same in all parts of the world.

Europe has warmed by almost 1°C in the last century, fasten than the global average. A warmer atmosphere contains more water vapour but new precipitation patterns differ strongly from one region to another. Rainfall and snowfall have significantly increased in northern Europe, whereas droughts are more frequently observed in Southern Europe. Recent temperature extremes, such as the record-breaking 2003 summer heat wave are consistent with man-made climate change. While single weather events cannot be attributed to a single cause, statistical analyses have shown that the risk of such events has already increased considerably as a consequence and physical processes (e.g. trees are blossoming earlier, glacier are melting) are reacting to climatic changes in Europe and worldwide. More than half of Europe's plant species could be vulnerable or threatened by 2080.

The most vulnerable areas in Europe are:

- Southern and the entire Mediterranean Basin due to the combined effect of high temperature increases and reduced precipitation in areas that are already coping with water scarcity;
- Mountain areas, in particular the Alps, where temperatures increase rapidly;
- Costal zones due to sea level rise combined with increased risks for storms;
- Densely populated floodplains due to increased risks for storms, intense rainfall and flash floods;
- Scandinavia where much more precipitation is expected;
- The Artic region where temperature changes will be higher than in any other place on Earth.

All over the territory of Serbia an increasing trend of air temperature is happening including a period 1949-2008 year, except south and south-east. Meanwhile, the recent period a period 1982-2009 shows us that even in this part of Serbia this trend occurs, air temperature slightly increases [3].

2. THE CLIMATE CHARACTERISTICS OF TEST AREAS

There are two test areas, Pirot and Beljanica mountain with different topography, geological characteristics and altitudes.

Pirot is a city and the administrative center of the Pirot District in southeastern Serbia. The city has a rich geographical features, including the mountains of Stara Planina, Vlaška Planina, Belava, Suva Planina; rivers which flow through the town, including Nišava, Jerma, Rasnička Reka, Temštica and the Visočica; and four lakes, the Zavoj Lake, Berovacko Lake, Krupac Lake and Sukovo Lake. According to 2011 census, the urban area of the city has a population of 38,785, while the population of the city administrative area has 57,928 inhabitants. The Nišava river flows throught the alluvion of Nišava and Pirot, so has a great importance for this region. The data are collected and analysed from nearby located meteorological station (436 m).

Beljanica is a mountain in Homolje region in eastern Serbia, near the town of Žagubica. Its highest peak has an elevation of 1,339 meters above sea level. From meteorological station Crni vrh (1037m a.s.l.) data are used for analysis and interpretation. The absence of settlements, roads, and intensive agricultural activity in these parts is significant, geology has a karst characteristic predominantly.

2.1. METEOROLOGICAL STATION PIROT

On the meteorological station Pirot, for the period 1961-2000, there is increasing trend of the mean annual air temperatures (~0.3 °C for the whole period). The most intense increase is during summer (~1.6 °C for the whole period). There is increase of air temperatures during winter and spring (~1.0°C and 0.2°C) , while autumn temperatures decrease (~0.8°C) for the period 1961-2000 [3].

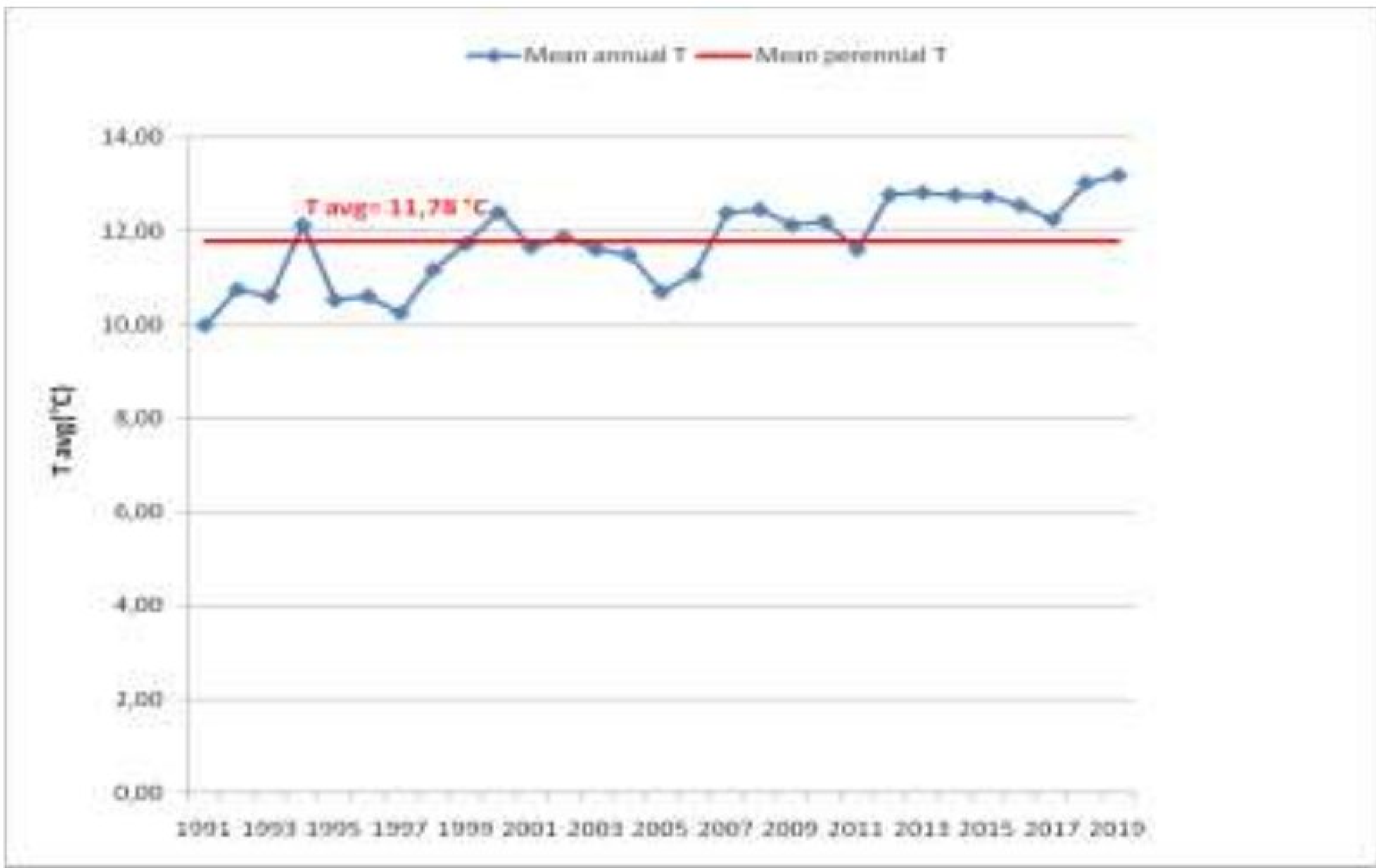

Figure 1. Diagram with mean annual and mean perennial temperature on the meteorological station Pirot for the period 1991-2019

Mean annual amount of precipitation on the station Pirot significantly decrease during 1961-2000. period (236 mm or 29% less). During each of the seasons there is decrease, but the most intense is during winter and spring (~108 mm or 57% during winter and ~92mm or 39 % during spring). The decrease of precipitation during summer (~58 mm) and autumn (~17 mm) is much smaller [3].

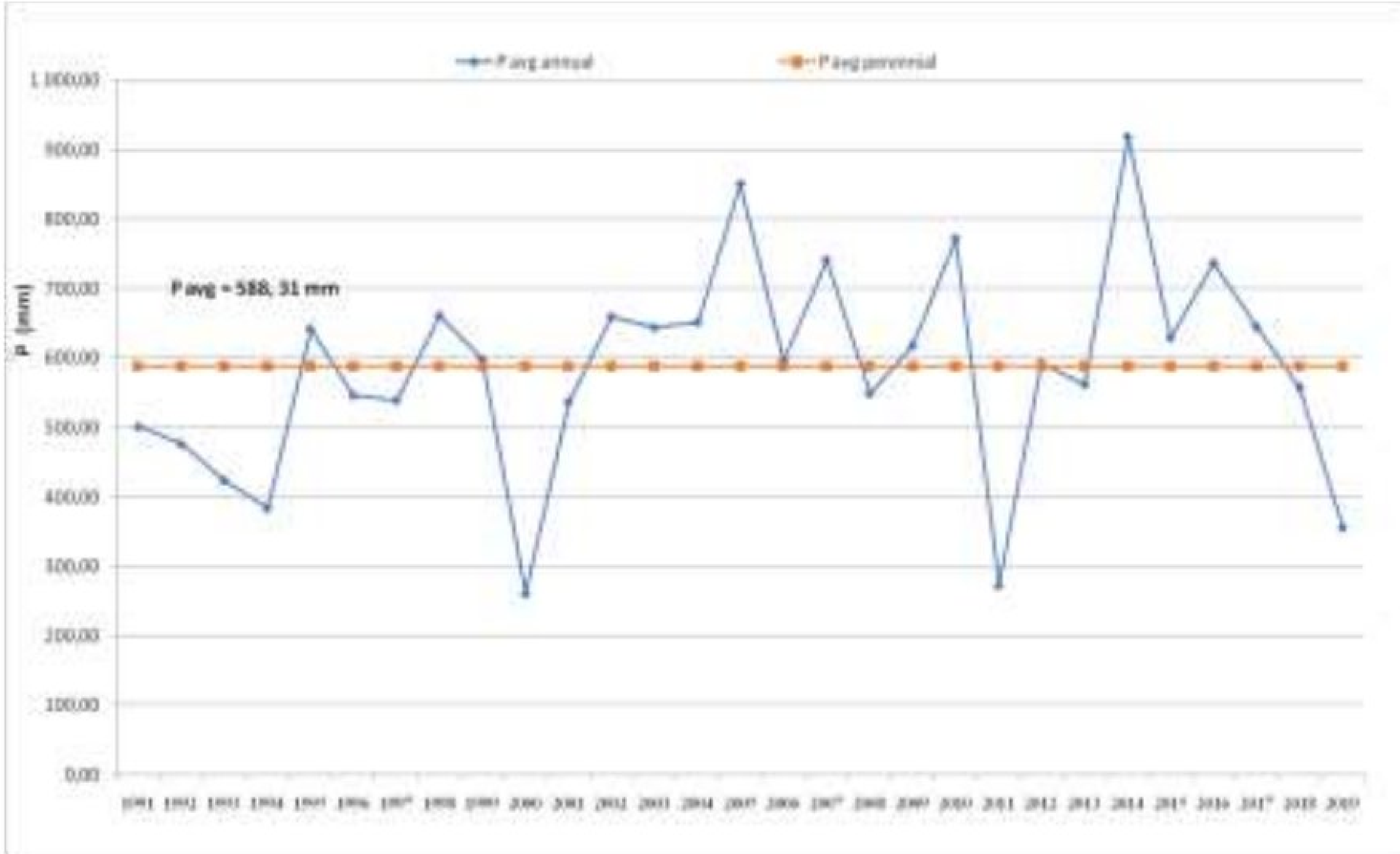

Figure 2. Diagram with average annual and average perennial precipitation on the meteorological station Pirot

2.2. METEOROLOGICAL STATION CRNI VRH

According to the data measured on the meteorological station Crni vrh, for the period 1961-2000, there is decreasing trend of mean annual air temperatures (~0.4 °C for the whole period), the summer and winter air temperatures increased (~0.5 °C, ~1.6 °C respectively for the whole period), and mean spring and autumn air temperatures significantly decreased (~1.3 °C, ~2.0 °C) [3] .

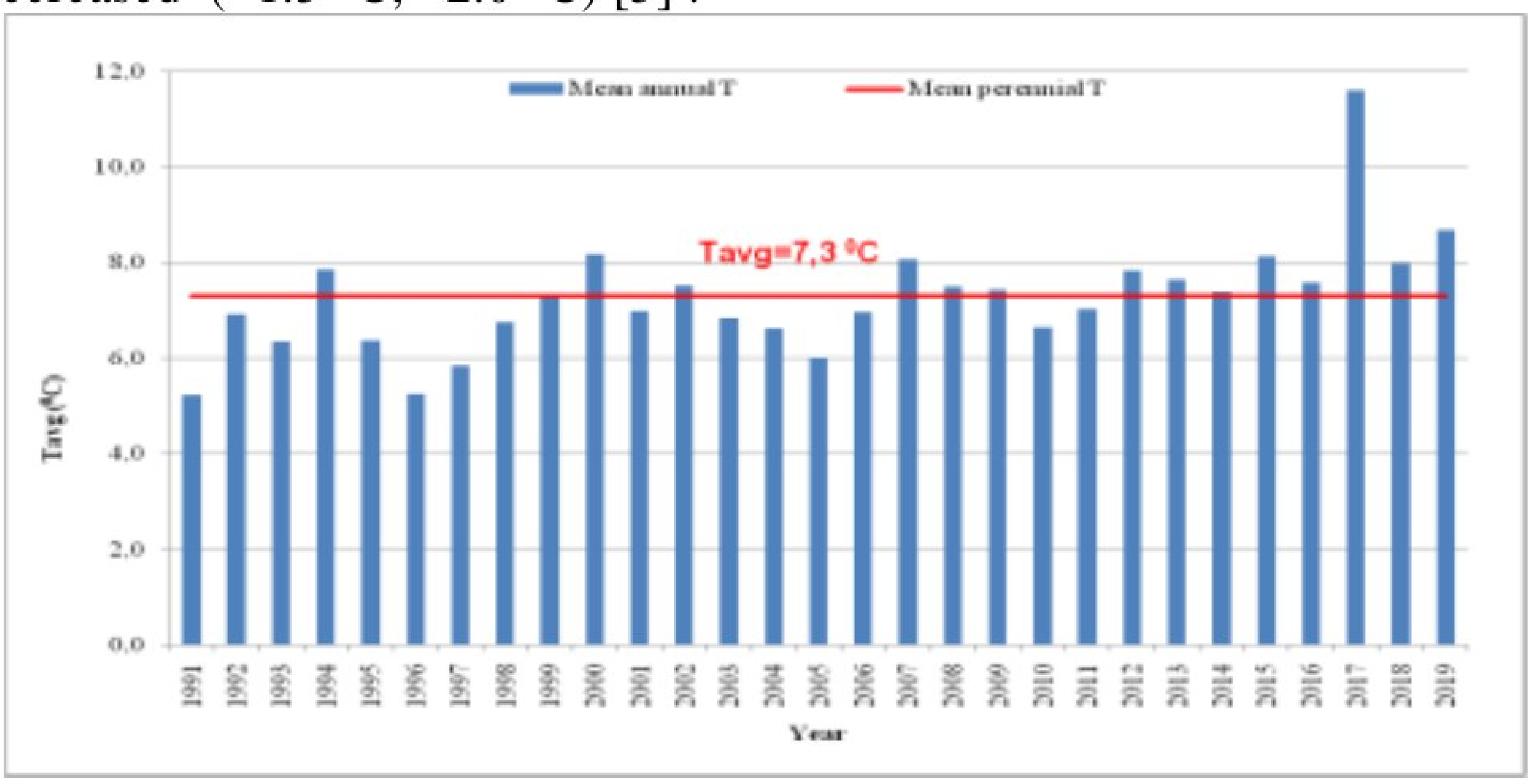

Figure 3. Diagram with mean annual and mean perennial temperature on the meteorological station Crni vrh for the period 1991-2019

On this station, on an annual scale, for the period 1961-2000. there is statistically significant decrease of precipitation amount (160 mm or ~20% less than the mean value in this period).

The most intense decrease is during spring and summer (~60 mm or 28%, 80 mm or 32 % respectively dor the whole period). The slightest decrease is during winter (38 mm or 27 %), while autumn months show mild increase (8 mm or 4 %) [3].

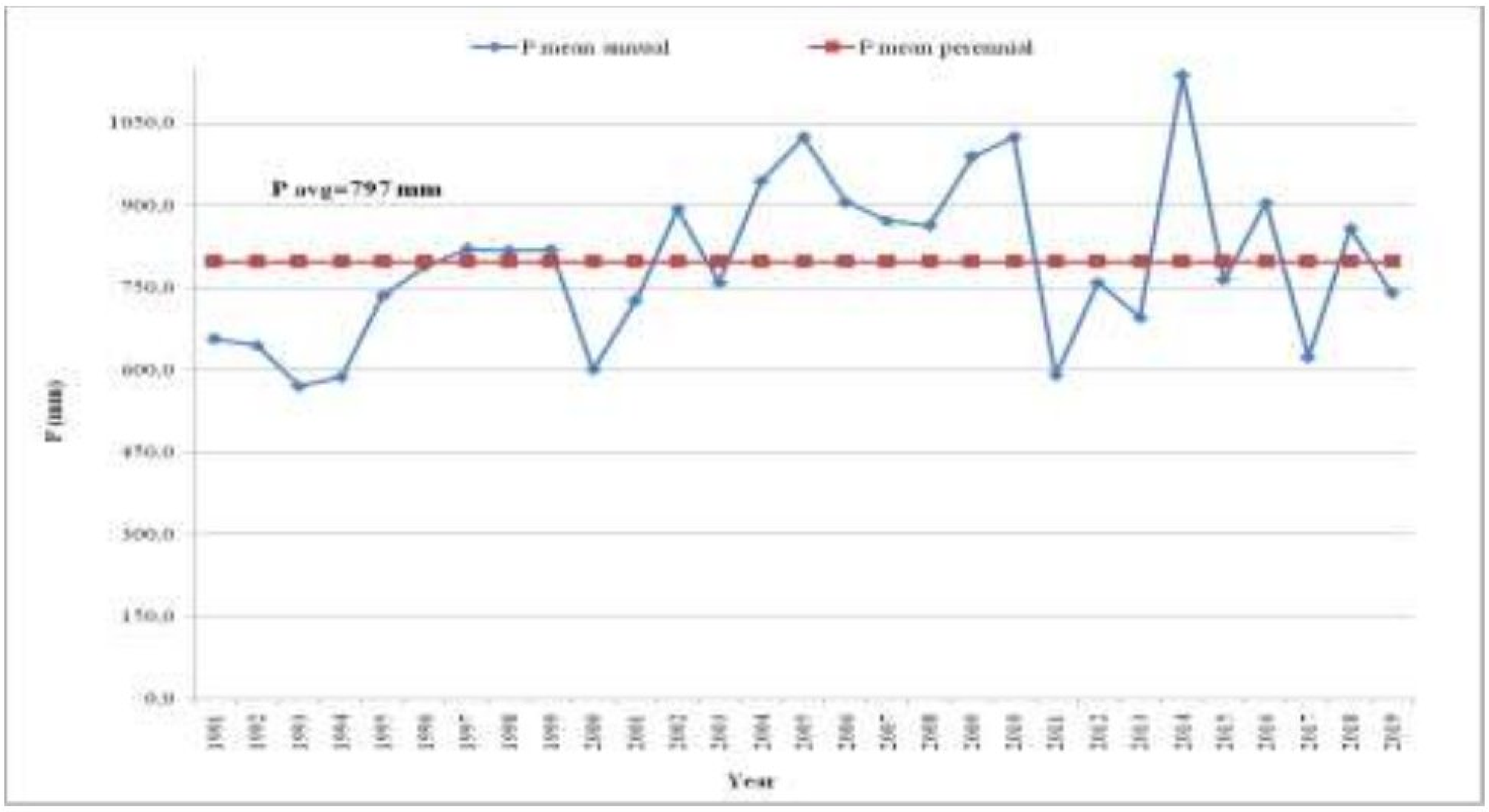

Figure 4. Diagram with average annual and average perennial precipitation on the meteorological station Crni vrh

3. GROUNDWATER CARACTERSTICS

Groundwater is an important natural resource. It acts as a reservoir from which good quality water can be abstracted for drinking and for use in industry and agriculture. It is also valuable in maintaining wetlands and river flows, acting as a buffer through dry periods. Groundwater moves slowly through the ground and so the impact of human activities may last for a relatively long time.

An **aquifer** is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt).

Confined aquifers have a layer of impenetrable rock or clay above them, while unconfined aquifers lie below a permeable layer of soil. Many different types of sediments and rocks can form aquifers, including gravel, sandstone, conglomerates, and fractured limestone [2].

To properly manage an aquifer its properties must be understood. Many properties must be known to predict how an aquifer will respond to rainfall, drought, pumping, and contamination. Where and how much water enters the groundwater from rainfall and snowmelt? How fast and what direction does the groundwater travel? How much water leaves the ground as springs? How much water can be sustainably pumped out? How quickly will a contamination incident reach a well or spring?

Porosity is an intrinsic property of every material. It refers to the amount of empty space within a given material. In a soil or rock the porosity (empty space) exists between the grains of minerals. In a material like gravel the grains are large and there is lots of empty space between them since they don't fit together very well.

Permeability is another intrinsic property of all materials and is closely related to porosity. Permeability refers to how connected pore spaces are to one another. If the material has high permeability than pore spaces are connected to one another allowing water to flow from one to another, however, if there is low permeability then the pore spaces are isolated and water is trapped within them. For example, in a gravel all of the pores well connected one another allowing water to flow through it, however, in a clay most of the pore spaces are blocked, meaning water cannot flow through it easily [2].

3.1. AQUIFER TYPES

3.1.1. Intergranular aquifer

Intergranular aquifers typically occur in sand and sandstone. Porous aquifer properties depend on the depositional sedimentary environment and later natural cementation of the sand grains. The environment where a sand body was deposited controls the orientation of the sand grains, the horizontal and vertical variations, and the distribution of shale layers. Even thin shale layers are important barriers to groundwater flow. All these factors affect the porosity and permeability of sandy aquifers.

There are two main types of intergranular aquifer: unconfined and confined. To reach an aquifer, surface water (rain, snow melting, river) infiltrates downward into the ground through tiny spaces or pores in the rock. The water travels down through the permeable rock until it reaches a layer that does not have pores; this rock is impermeable. This impermeable rock layer forms the base of the **unconfined aquifer**. The upper surface where the groundwater reaches is the **water table**.

An unconfined intergranular aquifer suffers from climate change because of its shallow water table (higher rate of evaporation, less recharge, smaller reserves, poorer quality, etc.), for example Nišava river alluvion at Pirot city.

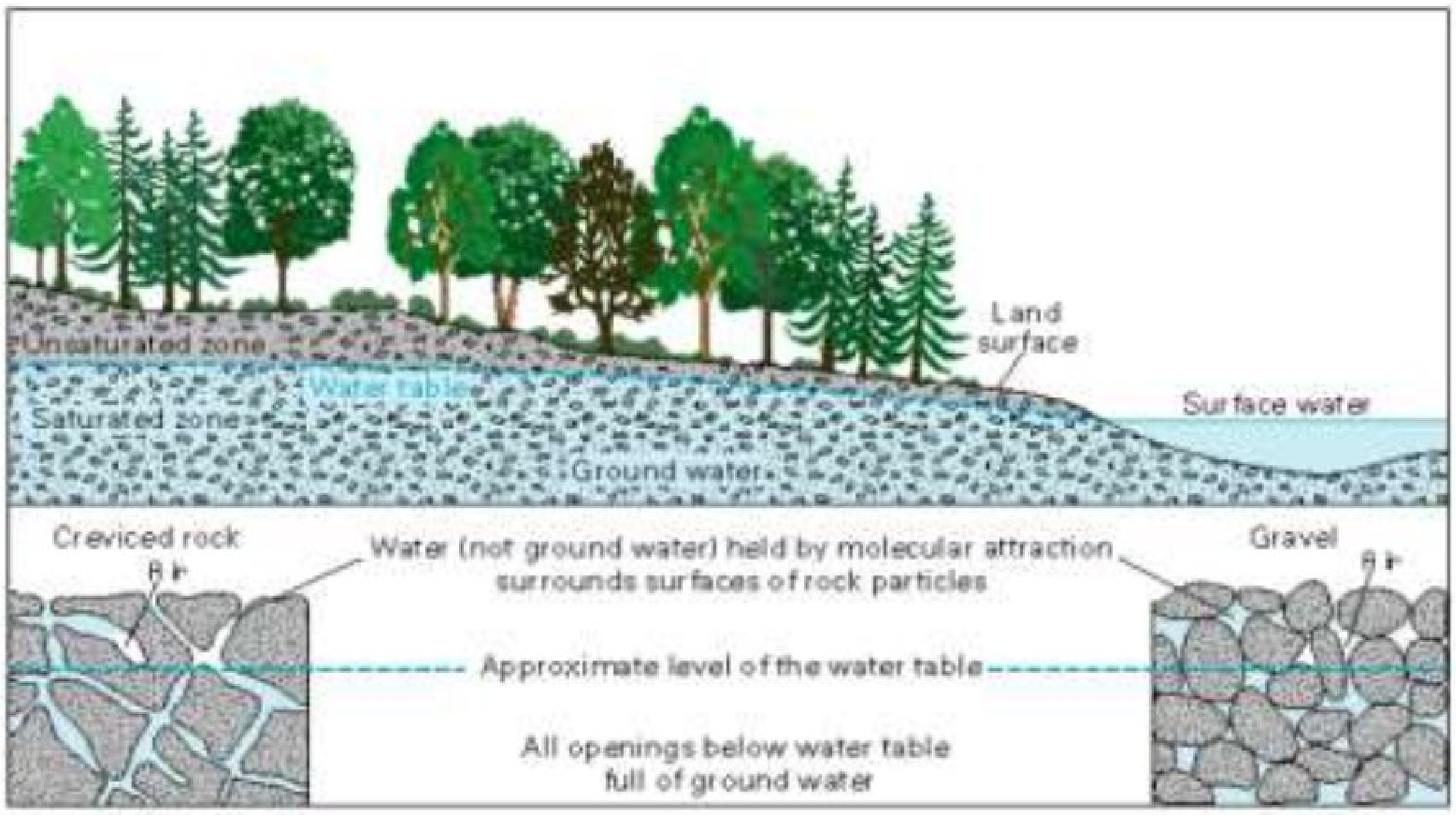

Figure 5. The shallow water table at unconfined intergranular aquifer

Confined aquifers have a layer of impenetrable rock or clay above them, while unconfined aquifers lie below a permeable layer of soil. Sometimes the porous rock layers become tilted in the earth. There might be a confining layer of less porous rock both above and below the porous layer. This is an example of a confined aquifer. In this case, the rocks surrounding the confined aquifer performs the pressure in the porous rock and its water. If a well is drilled into this "pressurized" aquifer, the internal pressure might (depending on the ability of the rock to transport water) be enough to push the water up the well and up to the surface without the aid of a pump, sometimes completely out of the well. This type of well is called artesian. Confined intergranular aquifers, however, are not directly exposed to the impact of rising temperatures, thereby evapotranspiration is less, have a better water quality and recharging power [2] .

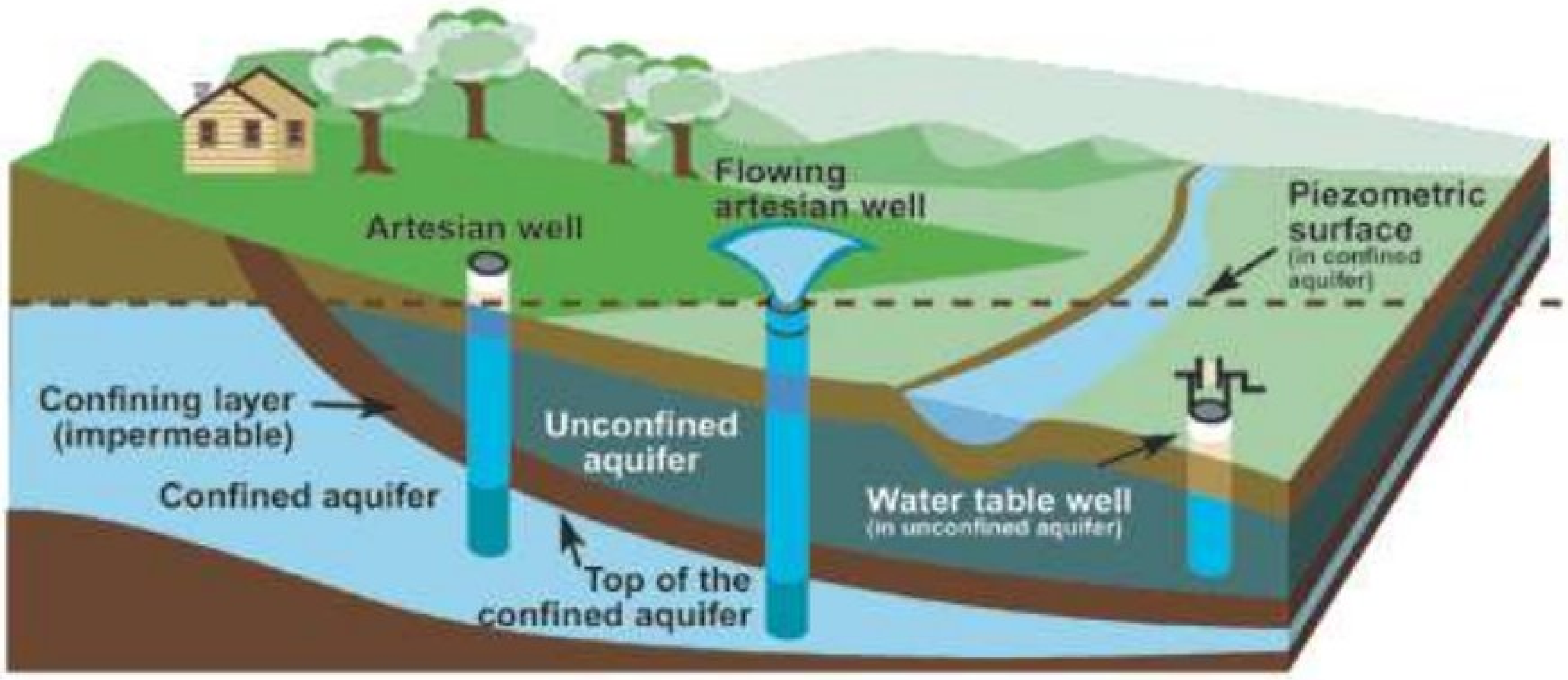

Figure 6. The illustration shows an artesian well and a flowing artesian well, which are drilled into a confined aquifer, and a water table well, which is drilled into an unconfined aquifer [2]

3.1.2. Karst aquifer

Karst aquifers typically develop in limestone. Surface water containing natural carbonic acid moves down into small fissures in limestone. The carbonic acid that causes karstic features is formed as rain passes through Earth's atmosphere picking up carbon dioxide (CO_2), which readily dissolves in the water. Once the rain reaches the ground, it may pass through soil that provides additional CO_2 produced by soil respiration. Some of the dissolved carbon dioxide reacts with the water to form a weak carbonic acid solution, which dissolves calcium carbonate.

This carbonic acid gradually dissolves limestone thereby enlarging the fissures. The enlarged fissures allow a larger quantity of water to enter which leads to a progressive enlargement of openings. Abundant small openings store a large quantity of water. The larger openings create a conduit system that drains the aquifer to springs. Characterization of karst aquifers requires field exploration to locate sinkholes, sinking streams, and springs in addition to studying geologic maps. Farming in karst areas must take into account the lack of surface water. The soils may be fertile enough, and rainfall may be adequate, but rainwater quickly moves through the crevices into the ground, sometimes leaving the surface soil parched between rains.

Karst aquifers are important sources of drinking water for many regions of the world, such as in the Dinaric Plateau (Slovenia, Croatia, Serbia, etc.) in Europe, in different regions of the United States, and much of southwestern China, all areas where ~ 50% of potable water comes from karst aquifers. Karst of Beljanica is characterised by an intensive karstification, a hydrogeological and speleological survey conducted identified many surficial and subterranean karst features [1].

On the other hand, the water supplies from wells in karst topography may be unsafe, as the water may have run unimpeded from a sinkhole in a cattle pasture, through a cave and to the well, bypassing the normal filtering that occurs in a porous aquifer. Groundwater in karst areas is just as easily polluted as surface streams. Karst formations are cavernous and therefore have high rates of permeability, resulting in reduced opportunity for contaminants to be filtered [5].

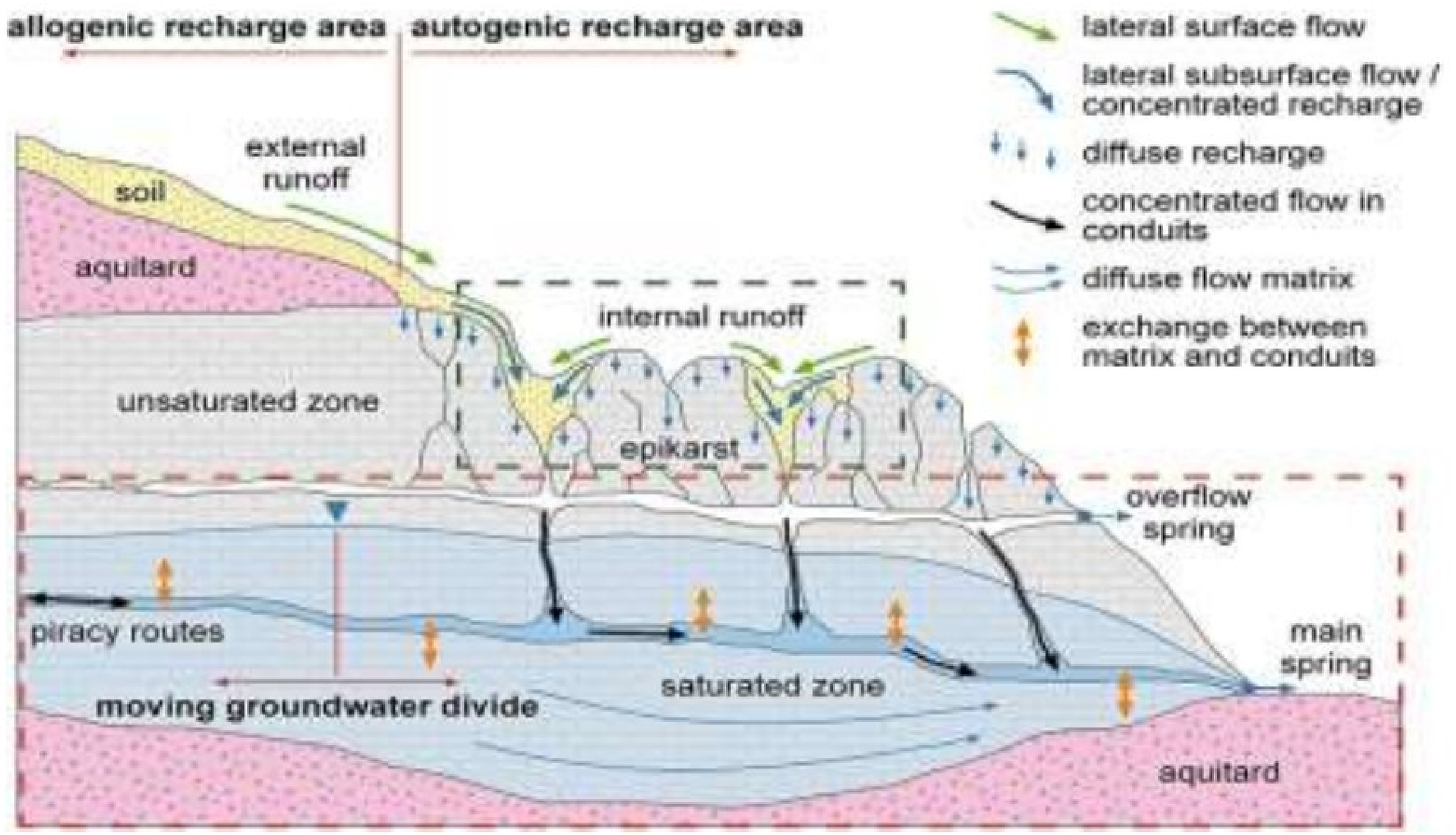

Figure 7. Water recharge in the karst aquifer and water movement [1]

The karst massifs has confirmed the existence of two main types of groundwater circulation, the existence of fast, gravitational circulation, and ascending water circulation, through much deeper channels [4].

Gravitational circulation of groundwater due to the existence of large channels, which is characterized by rapid water replacement, short water retention in the ground and with the characteristics of aerobic conditions (figure 9). This type of aquifer is exposed to the impact of rising temperatures and precipitation changing (decreasing during spring and summer) [3].

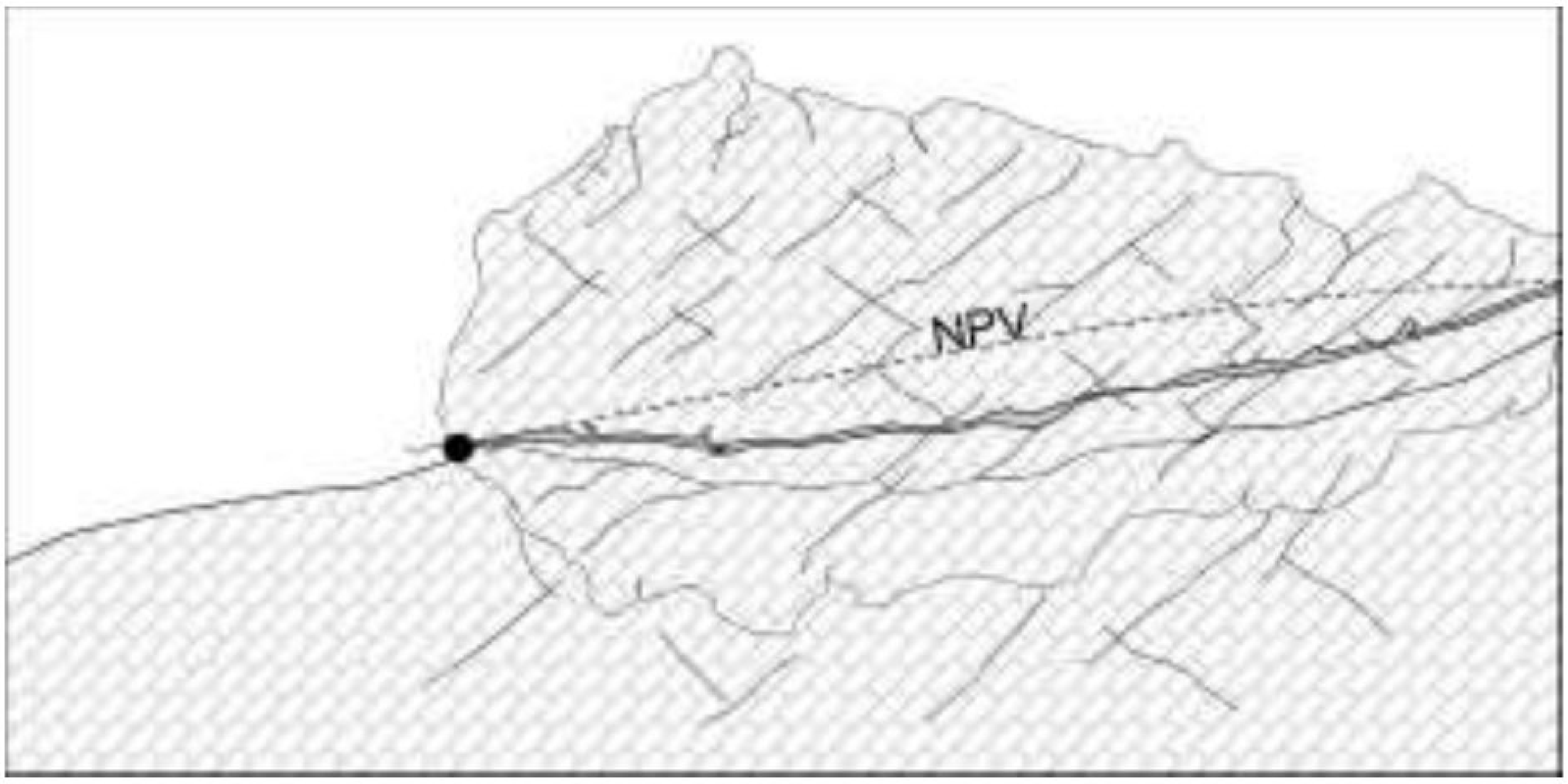

Figure 8. Gravitational type of groundwater circulation in Karst system [4]

Ascending circulation where groundwater goes to the deeper parts of the karst, it is not exposed to increased temperatures and other weather conditions as much as a gravitational type of circulation [4]. The most known spring at Beljanica massif is Mlava Spring with average spring flow 1.85 m^3/s. This is typically ascending spring with deep karstic channels, so it has a good protection from temperature increasing.

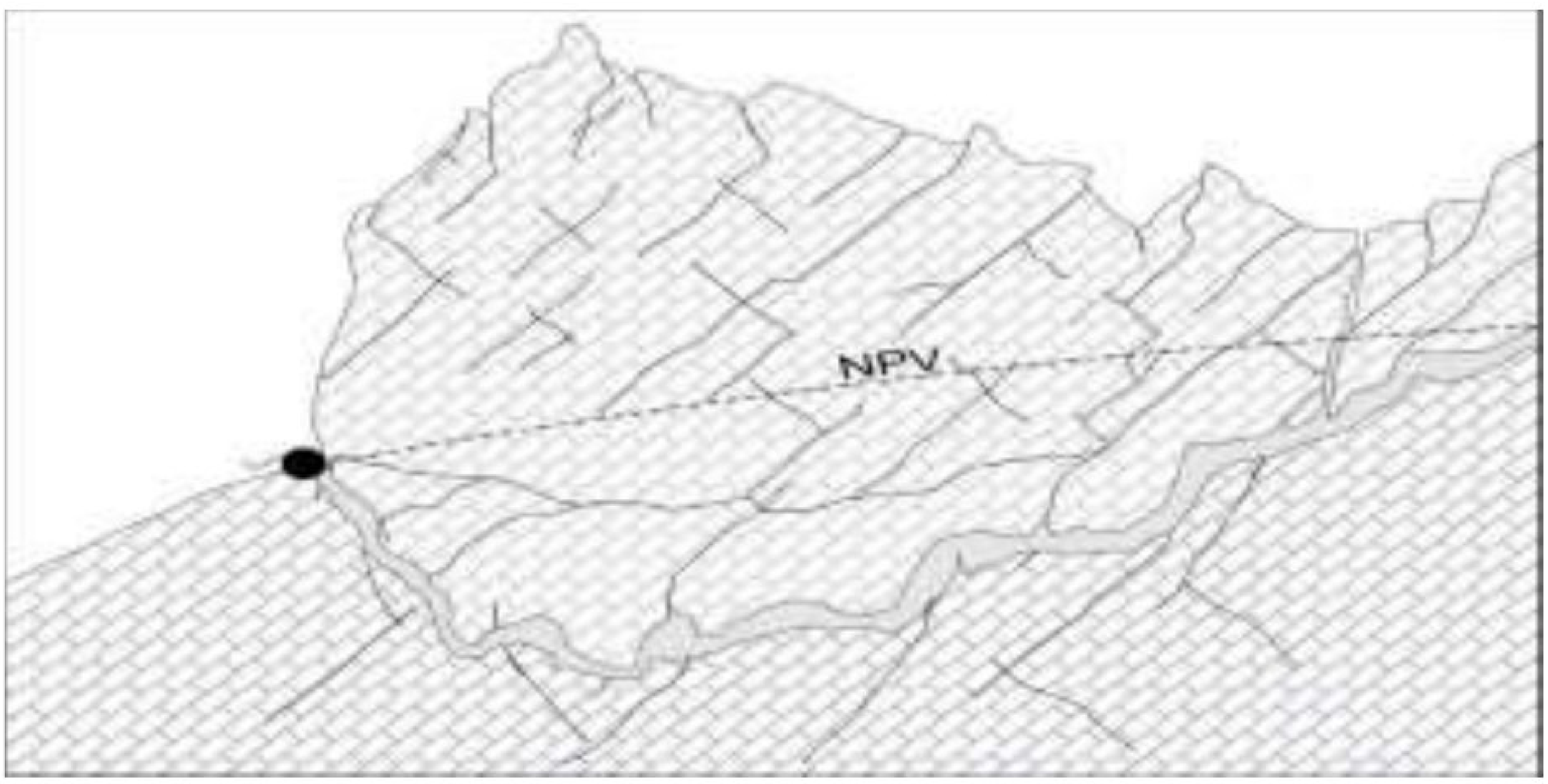

Figure 9. Ascending type of groundwater circulation in Karst system [4]

3.1.3. FRACTURED aquifer

If a rock unit of low porosity is highly fractured, it can also make a good aquifer (via fissure flow), provided the rock has a hydraulic conductivity sufficient to facilitate movement of water. This type is not significantly influenced by weather conditions.

3.1.4. Anhydrous / arid

Fractured aquifer or mixed forms of mentioned aquifer types with an insignificant amount of water.

4. CONCLUSION

By the end of the century the air temperature would probably increase at the Beljanica karst massif and Pirot District about 3°C. The general trend in the annual precipitation sum is negative and it is expected by the end of this century to decline by 40 mm.

At the Beljanica karst massif, effective infiltration of rainfall is in the range of 50-60 %. Current water utilization is just minimal: only abour 20 % in the cities nearby. Although more extensive tourist development is planned, the water demands would probably not significantly increase, thus a large reservoir would be kept for the future [3].

As it was mentioned, there are many risks of the combined effect of high temperature increases and reduced precipitation and extreme precipitations after long drought periods as well. It can be predicted that Southern and the entire Mediterranean Basin will be exposed to these weather conditions changes the most.

Preventive groundwater protection for future generations is crucial problem for an expert in this field. One of the main steps in this process is to show this mutual problem to the community. Developing a groundwater utilization strategy would be beneficial for their sustainable use.

REFERENCES

[1] Florindo, F., Hartmann, A. Karst water resources in a changing world: Review of hydrological modeling approaches, German Academic Exchange Service (DAAD). 2014.

[2] Herod, M. Aquifers and Groundwater, European Geosciences Union, 2013.

[3] Stevanović, Z., Vakanjac, M.R. Climate Change and Impacts on Water Supply, University of Belgrade – Faculty of Mining & Geology Department of Hydrogeology, Belgrade, 2012, 75-109.

[4] Vasić, Lj. Genesis and circulation of groundwater of complex karst systems of Kučaj-Beljanica massif, University of Belgrade – Faculty of Mining & Geology Department of Hydrogeology, Belgrade, 2017, 104-107.

[5] Vasić, Lj., Milovanović, Z. Microbiological pollution as the function of karst groundwater circulation University of Belgrade – Faculty of Mining & Geology Department of Hydrogeology, Belgrade, 2013, 7-10.