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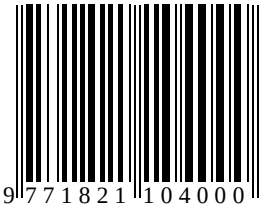

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CONTENT SADRŽAJ

Vol. 91

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Original scientific paper

GRONDWATER MONITORING AT THE AREA OF THE FLOODING FORESTS

*Sofija PAREZANOVIĆ[1], Vesna NIKOLIĆ JOKANOVIĆ[1]**

Abstract: *The Danube is a natural habitat for a diverse range of flora and fauna, and its floodplain forests provide numerous ecosystem services that directly contribute to an improved quality of life for people. The dominant tree species in the river's floodplain areas are willow, poplar, and alder. These forests play a crucial role in water filtration, shoreline protection from erosion, and carbon storage. Continuous monitoring of groundwater is essential for preserving this resource. The goal is to monitor groundwater level fluctuations to influence the selection of silviculture and management measures based on the results of long-term research, and to implement planned activities in forest management. In the "Apatinski rit" management unit, it is recommended to establish a network of piezometers.*

Keywords: Danube, floodplain forests, groundwater, groundwater monitoring, network of piezometer

MONITORING PODZEMNIH VODA NA PODRUČJU PLAVNIH ŠUMA

Sažetak: *Dunav je prirodno stanište raznovrsnoj flori i fauni, a njegove plavne šume pružaju niz ekosistemskih usluga koje direktno doprinose boljem životu ljudi. Dominantne vrste drveća u plavnim područjima reka su vrba, topola i lužnjak. Ove šume igraju ključnu ulogu u filtriranju vode, zaštiti obala od erozije i u skladištenju ugljenika. Stalan monitoring podzemnih voda je ključan za očuvanje ovog resursa. Na području gazdinske jedinice „Apatinski rit“ se preporučuje postavljanje mreže pijezometara. Cilj je praćenje oscilovanja nivoa podzemnih voda, kako bi, na osnovu rezultata višegodišnjih istraživanja, uticali na izbor uzgojno-gazdinskih mera i sproveli planske aktivnosti u domenu gazdovanja šumama.*

Ključne reči: Dunav, plavne šume, podzemne vode, monitoring podzemnih voda, mreža pijezometara

1. INTRODUCTION

In the process of water circulation in nature, part of the atmospheric and surface waters infiltrates into the lithosphere, forming aquifer zones under the

[1] Faculty of Forestry, University of Belgrade, Keza Višeslava 1, 11000 Belgrade, Serbia
*Corresponding author. E-mail: vesna.nikolic@sfb.bg.ac.rs

influence of gravity. Due to the specific hydrogeological characteristics of water-bearing rocks, groundwater occurs as aquifers of compacted and broken types, with the phreatic aquifer belonging to the compacted type. Phreatic waters constitute the shallowest aquifer in loose sediments above the impermeable layer and extend continuously throughout the entire area. Changes in the level of the first aquifer are caused by uneven inflow and outflow of water, which is related to the distribution of precipitation, temperatures and evaporation. (Josipović, Soro, 2012). Decline of lowland flood forests is a consequence of changeable ecological conditions, first of all due to huge groundwater level fluctuations and duration of surface water stagnation as well. (Nikolić, 2017). Decline of forests situated on alluvial soils on the banks od the Sava and Danube rivers was investigated from many different aspects such as: fluctuations of groundwater level and decline intensity (Dekanić, 1974; Đorović, Letić, 2002; Letić et al. 2014), species response to changeable site conditions (Prpić, 1976), intensity of radial increment as indicator of changed site conditions (Pranjić and Lukić, 1989), bioecological (Prpić et al., 1994) and silvicultural reasons (Bobinac et al. 1997). The important impact of groundwater on the characteristics of lowland sites is related to the fact that it leads to an increase in soil moisture, so that is impossible to compensate directly through rainfalls (Nikolić Jokanović et al. 2023 a). Many destructive human activities caused deviations of natural watering regime which affected the increased fluctuations of groundwater and surface waters and, as a result, stability and vitality of lowland forest ecosystems was very endangered (Nikolić Jokanović et al. 2024). According to global warming and long dry periods, pattern of decreased groundwater level was established, which negatively affects development and productivity of forest associations located in alluviums and that is especially harmful for pedunculate oak whose needs for water mainly are mainly satisfied from groundwater (Nikolić Jokanović et al. 2023 b). Based on the aforementioned, we can conclude that knowing of groundwater trend is a of great practical significance.

The main goal of the paper is conducting the permanent monitoring related to groundwater fluctuations in the alluvium of the Danube river in order to define as more precise as possible pattern of groundwater behaviour. This will give us a possibilty of carrying out a comprehensive management of lowland forests at this area, whose development depends the most on the available groundwater content.

2. MATERIAL AND METHODS

2.1. General features of MU „Apatinski rit“

The management unit "Apatinski rit" is located within the North Bačka Forest Area, managed by the Forest Management "Sombor" from Sombor, as an integral part of the Public Enterprise "Vojvodina šume", Petrovaradin. This management unit is located in the western part of Bačka, on the territory of the Apatin municipality. The management unit complex is divided into the districts of Harčas, Poluostrvo, Zverinjak, Duboki jendek, Staklara and Bakulja (Figure 1).

Forests, forest cultures and forest land make up 80.6% of the total area of the management unit, where forest cultures make up 54.0%. The area covered by this management unit is a lowland area, in a protected area along the Danube River.

The microrelief is very pronounced, the area is intersected by ponds, micro-depressions and channels. Alluvial surfaces, which are intersected by long and narrow depressions, are in fact former river arms.

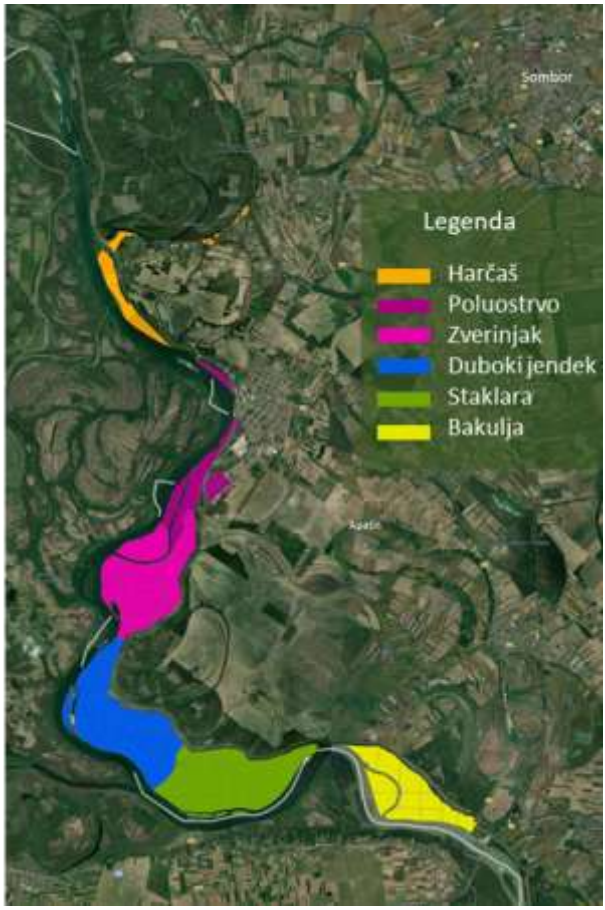

Figure 1. *Position of the revir within the GJ "Apatinski rit"*

The geological base is alluvium, which can be very heterogeneous in composition, depending on whether sand or clay predominates in the sediment. Fluvisols (alluvial soils), semigleys (meadow soils) and eugleas (swampy gley soils) are represented within the management unit (Figure 2).

The "Apatinski rit" management unit is located in an area protected from direct flooding by the Danube River. After the construction of the embankment, significant changes in the water regime occurred (removal of flood waters and lowering of groundwater levels), which led to drying of the soil and negatively affected domestic hygrophilous species. As for forest associations, there are most dominant willow and poplar forests, which are directly depending on the watering regime. At low positions, the most represented is white willow, while at upper parts of the relief are monocultures and mixed stands with black poplar, that is connected with the complexity of the whole ecosystem.

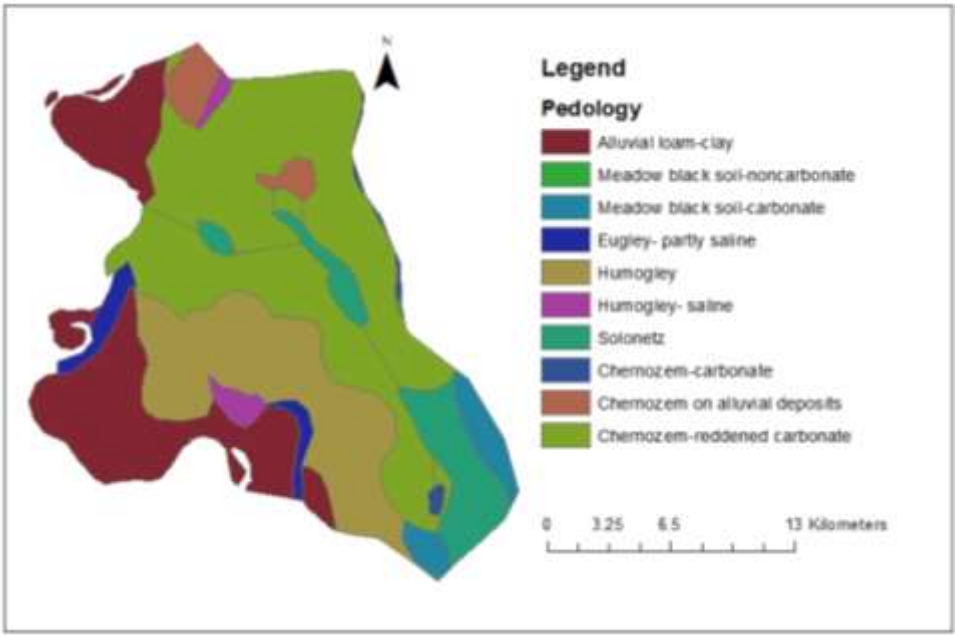

Figure 2. *Pedological map of the area*

2.2. Methodology

The investigation in the paper is divided into following phases:

First phase – Collecting and description of the ecological features of the researched area – in this phase, based on collected data from published scientific papers, and based on available technical documentation, as well, was described the studied area.

Second phase – The analysis of climate data – in this phase, based on the analysis of data for ten-years long period (2013-2022) from meteorological station Sombor, was conducted the analysis of climatological characteristics of the studied area.

Third phase – The analysis of hydrological data - within the third phase, there was carrying out the analysis of the river Danube water level based on available data recorded at the measuring station located in Apatin for period 2013-2022.

Fourth phase – Defining of piezometric net at the investigated area within the MU "Apatinski rit" – in this phase, based on all previously obtained results at the researched area, there was proposed the net of objects for groundwater level monitoring.

In the lowland forests of Serbia, piezometers are installed to monitor groundwater levels. Their construction consists of a 5/4" galvanized pipe, a 0.5 m sedimentation tank, a 1.5 m filter, and a part of the structure above the ground surface of 20 cm. The filter structure is a pipe perforated with circular holes with a diameter of 4 mm, around which a gravel fill is installed to a depth of 0.5 m from the ground surface, and a clay buffer is placed in this zone. The piezometer cap and the bottom of the sedimentation tank are closed with a metal screw cap. The top of the

piezometer structure should be placed 20 cm above the ground surface and should be flush with the concrete reinforcement.

Data loggers – Figure 3 (diver) are probes that are installed in observation facilities and are used for permanent monitoring of groundwater levels in wells (piezometers).

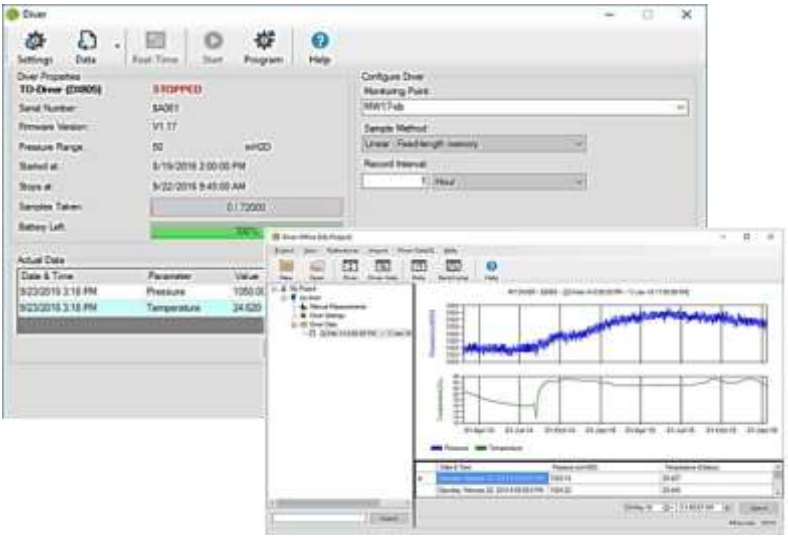

Figure 3. *Appearance of the Diver - office program*

3. RESULTS

3.1. The analysis of climate characteristics

In order to display climate characteristics of the investigated area, there was used data from meteorological measurements in period 2013-2022, at Sombor climate station, which is on 88 m elevation (19º09'E, 45º46'N). Based on the conducted analysis, for ten-years long period, we can deduce:

Air temperature is one of the most significant climate elements. During the observed period (2013-2022), the mean annual air temperature was 12.3 °C. The highest annual air temperature was 25,1 °C in July 2012, while the lowest was recorded in January 2017 (-5,3 °C) – Figure 4.

In addition to air temperature, rainfalls are the most important climate factor. Form, distribution, frequency, and level of the rainfalls during the whole year shows the continental character, not only of Serbian climate, but also of investigated area. They represent all forms of condensed and sublimated water vapor in the air, which appear on the Earth's surface in a liquid or solid state.

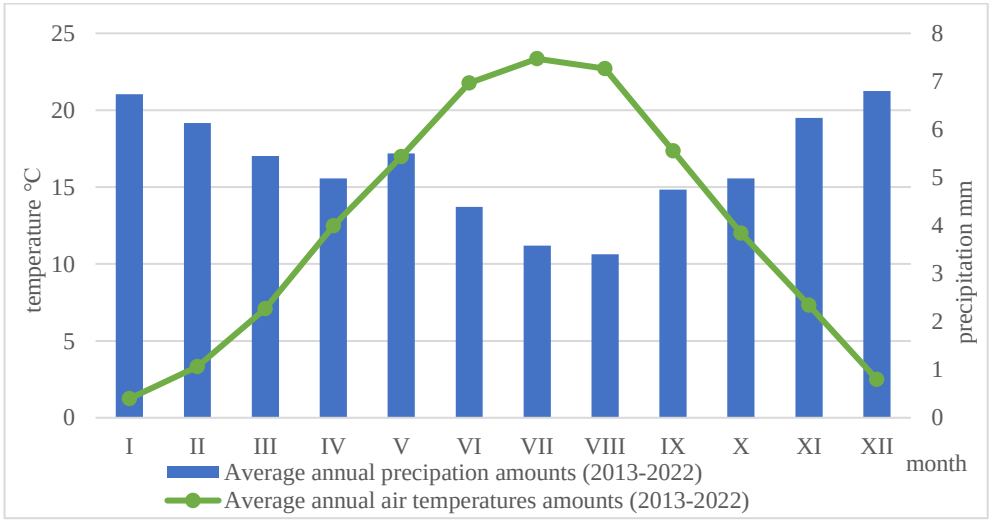

Figure 4. *Average annual air temperatures and average annual rainfalls amounts (2013-2022)*

In the period from 2013 to 2022, the average precipitation during the year is partially uniform, with a pronounced minimum in August. The total precipitation amounts during the growing season make up a large part of the total precipitation amounts during the year (Figure 5). The largest difference between the total and rainfalls during growing season was recorded in 2022.

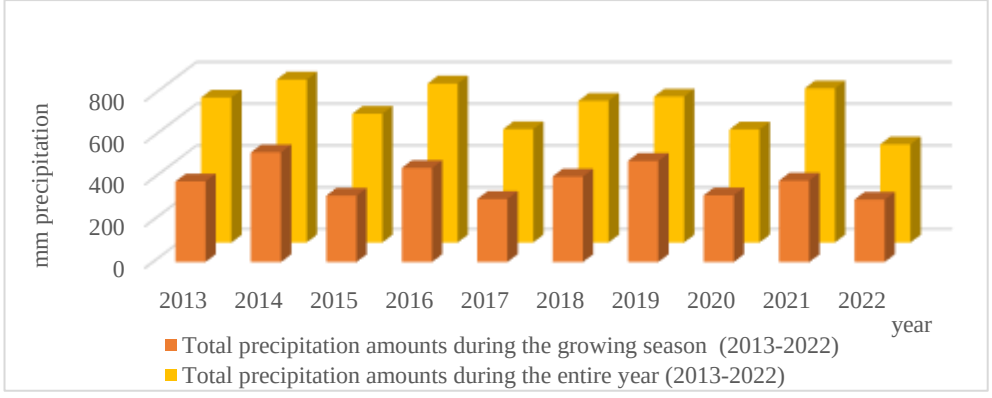

Figure 5. *Total rainfalls during the growing season and throughout the entire year (2013-2022)*

Relative air humidity, which expresses the degree of air saturation with water vapor, is an important climatic element. This value on an annual basis is inversely proportional to the annual air temperature. Relative air humidity is highest in the winter half of the year, more precisely in November and December (86%, 87%), and lowest in July (63%) – Figure 6. The annual variation in relative humidity

ranges between 71% and 81%. The average relative humidity is 74%, while the average value during the growing season is 65%.

Figure 6. *Relative air humidity (2013-2022)*

3.2. The analysis of hydrological characteristics

The water level regime of the Danube River was analyzed based on data from the Apatin water gauging station (Figure 7). The zero point of the water gauging station is at 78.84 m above the Adriatic Sea, and the basin area up to Apatin is 211.139 km^2. Data at this station have been recorded since 1876, and the ten-year period from 2013 to 2022 was analyzed (Figure 8) and the following can be concluded:

The Danube in the territory of the Apatin municipality is characterized by a nival regime. The highest average monthly water levels occur at the beginning of summer, in June.

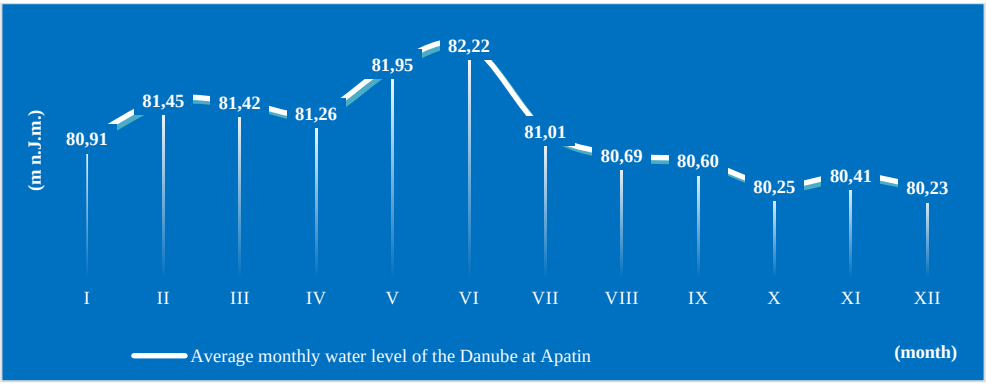

Figure 7. *Average monthly water level of the Danube at Apatin from 2013 to 2022*

High and extremely high water levels occur in early summer and late spring, while low water levels in autumn occur due to low rainfall in late summer and autumn. Extremely low water levels are also often recorded during the winter months. This condition occurs if an extremely dry autumn is followed by an

extremely cold winter, without a previous rainy period. High water levels, in contrast to low water levels, are of exceptional importance. They, among other things, raise groundwater levels and extremely high water levels lead to flooding.

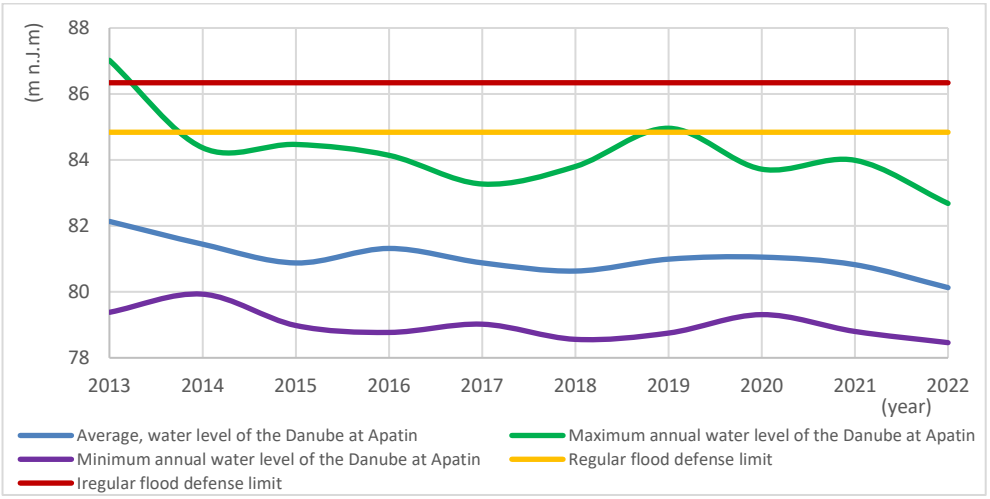

Figure 8. *Average, minimum, and maximum annual water level of the Danube at Apatin from 2013 to 2022*

The value of the absolute highest water level (June 24, 1965) is 825 cm, which means that its absolute height is 87.09 m. This shows that the Danube level was higher than the average height of the alluvial plain by about 3.6 m, and then the lower parts by 5-6 m.

Hydrogeological studies found that the thickness of the Quaternary deposits in the Danube coast is between 60 m and 70 m, most of which is made up of sediments of the older quarter, while above are situated up to the ground sediments originate from Halocene. The entire complex is made up of clayey, sandy, sandy-gravelly and gravelly deposits, with the proportion of coarser-grained sediments increasing with depth (Hajdin, 2013)

The influence of the river and good hydraulic connectivity have been confirmed by regime observations carried out at the Apatin water supply source. Moving away from the river, its influence weakens, and the importance of terraced deposits increases. In a wider area, the influence of precipitation in feeding the aquifers is significant, especially in zones where the surface layer is made up of sandy deposits with more favorable filtration characteristics. Part of the groundwater of this aquifer originates from tertiary deposits from which, under appropriate conditions, water overflows from the deep aquifer (Lazić, 2005).

3.3. Defining of bioindication profiles and piezometric distribution at the area of the part of MU "Apatinski rit"

Determining the position of bioindication lines (BIL) on which piezometer structures are installed in the research area depends on the position of the forest

complex in relation to the Danube River (as well as its water regime), habitat characteristics (orographic conditions, soil types, etc.), vegetation types (forest types, cover, age, etc.), road network and other characteristics of the area being researched.

The forest area of the management unit "Apatinski rit" includes departments 14 to 29, where it is proposed to install a network for monitoring groundwater (piezometers). In this area, alluvial soil (fluvisol) is present in the coastal part of the river floodplain, where natural forests of white willow, white poplar, as well as Euro-American poplars occur (Figure 9). In the central part of the plain, where the clayey alluvium is deposited, there is fluvial meadow soil (humofluvisol), on which forests of white willow, black poplar, field ash with elms and pedunculate oak are present. Marsh mulberry forests are highly productive habitats of hardwood forests, primarily pedunculate oak and ash forests. Pseudogley is a soil of lowland terrain, most often occurring in the depressions of old river and lake terraces. Pseudogley is also the habitat of natural forest communities such as pedunculate oak forests.

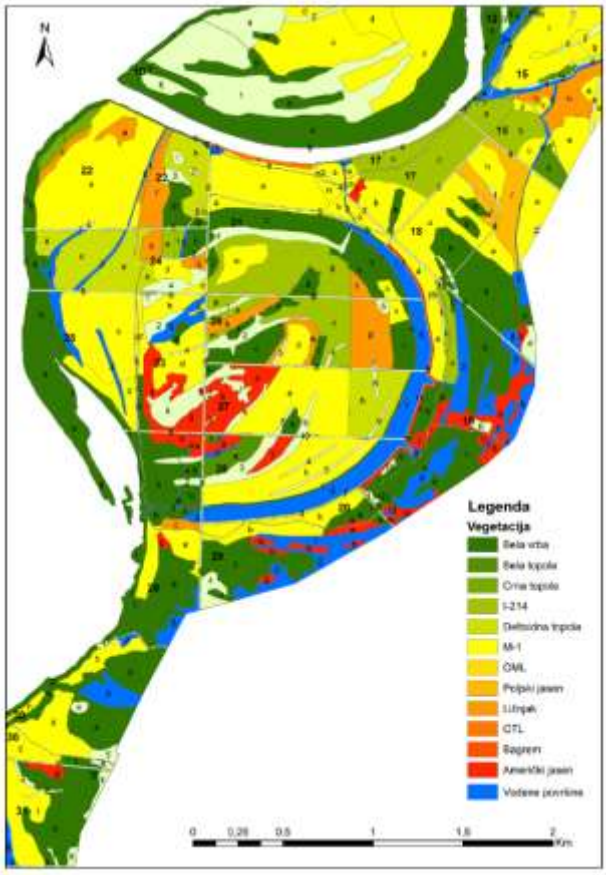

Figure 9. *Tree species distribution in GJ "Apatinski rit," revir Zverinjak*

In order to conduct monitoring of groundwater level at investigated area, it was proposed to install 3 bioindication profiles perpendicular on the river Danube river. Distribution of piezometers is shown in Figure 10.

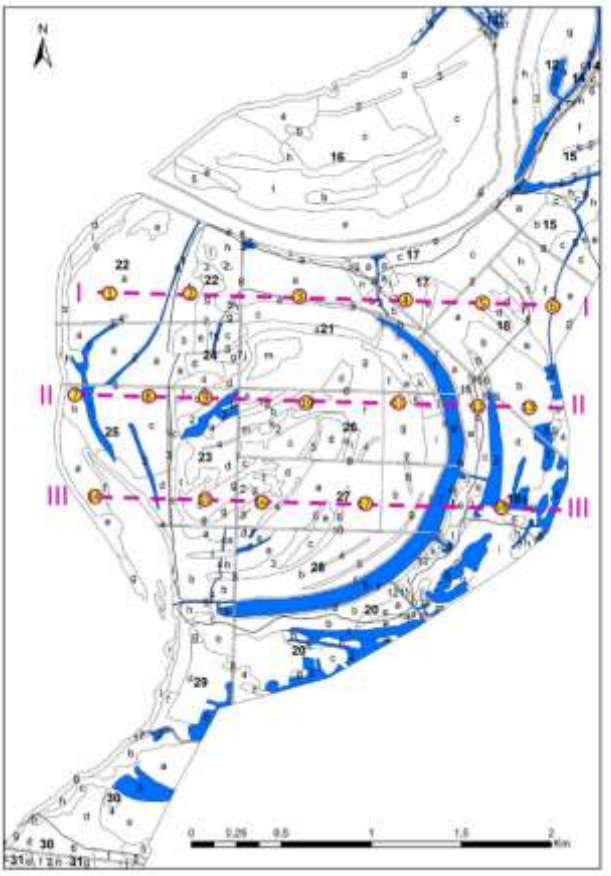

Figure 10. *Piezometer distribution in the studied area of the GJ "Apatinski rit"*

4. DISCUSSION

The installing of piezometric net at the area of Apatin represents the key activity related to groundwater level monitoring and its quality, as well, which contributes a lot to the conservation and management of forests. Piezometers together with special probes (diver) enable a precise groundwater fluctuations monitoring. Presence of some hygrophilous woody species such as willow, poplar, and pedunculate oak occurs as a consequence of specific watering regime in the alluvium of the river Danube. During artificial regeneration of the forest ecosystems in this area, preference should be given to native forest species that are already adapted to current site conditions. A special attention has to be paid to the area of Apatin, because some negative changes related to the groundwater level may endanger present vegetation. The obtained results in some papers (Nikolić-Jokanović

et al. 2024) found that pedunculate oak prefers soils with a dominant participation of groundwater. Several studies (Matić and Skenderović, 1993; Prpić and Anić, 2000; Vrbek, 2003) have investigated the relation between radial increment and minimal groundwater level by pedunculate oak during growing season. Mayer (1994) found that both long dry period or a great rainfalls quantity negatively affect groundwater level, which causes unsuitable site conditions for trees located in lowland forests. Nikolić-Jokanović et al. (2023 a) established significant deviations of groundwater level compared to reference level during extreme years (wet and dry period) in the area of Donji Srem. These deviations are good indicators of potential risk zones existing where forest species (first of all, pedunculate oak) may be endangered. Based on the determination of the risk zones, an appropriate management measures can be conducted. This action may prevent some significant damages in case of extreme climate scenario.

5. CONCLUSION

Water is a key ecological factor which affects development and productivity features of the lowland forests in the alluvium of the river Danube. The object of the paper is the analysis of the ecological conditions at the part of the MU "Apatinski rit" with the aim of piezometers installing in order to conduct the groundwater level monitoring. Based on the analysis of climate parameters in ten-years long period (2013-2022), there were obtained following values: an average annual air temperature was 12.3°C, while an average annual total rainfalls quantity was 652,2 mm, with more than 59 % occurred during growing season, which positively affects vegetation development at the investigated area. Presence of hygrophilous woody species such as willow, poplar, and pedunculate oak, is a result of the watering regime in the alluvium of the river Danube. During artificial restoration of the forest ecosystems in this area, natural vegetation should be represented due to its adaptability to the current site conditions. Within this paper was proposed forming of 3 bioindication profiles with total of 18 piezometers (6 at first, 7 at second, and 5 piezometers at third profile). Forming of piezometric net serves to monitor groundwater level fluctuations, and based on the obtained results during many years, adequate silvicultural and management strategy can be applied.

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GRONDWATER MONITORING AT THE AREA OF THE FLOODING FORESTS

Sofija PAREZANOVIĆ, Vesna NIKOLIĆ JOKANOVIĆ

Summary

Groundwater infiltrates into the lithosphere, forming outcrop zones under the influence of gravity. The type of these zone depends on several factors such as water feeding and release, rock characteristics, position, and circulation, and can be either compacted or fractured. The freatic aquifer belongs to the compact type. Changes in the water levels of the first aquifer are primarily due to uneven inflow and outflow, influenced by precipitation distribution, air and soil temperatures, and evaporation. The goal of the paper is multi-year groundwater level fluctuations monitoring within MU "Apatinski rit", so for that purpose was proposed installing of piezometric net at this area. The investigation includes detailed description of ecological (pedology and vegetation), climate (air temperature, relative air humidity, sum of precipitation), and hydrological (level of the river Danube and groundwater fluctuations) parameters. The decision about piezometric net installing should be made based on the results of papers related to this issue which are carried out at the area of MU "Apatinski rit". Permanent monitoring of the groundwater fluctuations would contribute a lot to conducting an appropriate management and silviculture measures in lowland forests of the river Danube alluvium.

MONITORING PODZEMNIH VODA NA PODRUČJU PLAVNIH ŠUMA

Sofija PAREZANOVIĆ, Vesna NIKOLIĆ JOKANOVIĆ

Rezime

Podzemne vode infiltrirajući se u litosferu formiraju izdanske zone, čiji tip zavisi od različitih faktora kao što su hranjenje i izdavanje, kao i karakteristike stena i cirkulacija vode. Freatska izdan pripada zbijenom tipu, a promene u nivou vode su posledica neujednačenog hranjenja i izdavanja, koji zavise od raspodele padavina, temperatura i isparavanja. Cilj rada je višegodišnji monitoring oscilovanja nivoa podzemnih voda u okviru gazdinske jedinice "Apatinski rit" i u tu svrhu se predlaže postavljanje mreže pijezometara na ovom području. Istraživanje obuhvata detaljan opis ekoloških (pedološko-vegetacijskih), klimatskih (temperature vazduha, relativna vlažnost vazduha, količina padavina) i hidroloških (vodostaj Dunava i oscilovanje nivoa podzemnih voda) parametara. Odluka o postavljanju mreže pijezometara donosi se na osnovu rezultata istraživanja koja su iz domena ove problematike sprovođena na području GJ "Apatinski rit". Redovan monitoring nivoa oscilovanja podzemnih voda veoma bi doprineo sprovođenju odgovarajućih gazdinskih i uzgojnih mera u nizijskim šumama priobalja Dunava.