Monitoring of groundwater level fluctuations at flooded area of lowland forests of the Sava River (Serbia)

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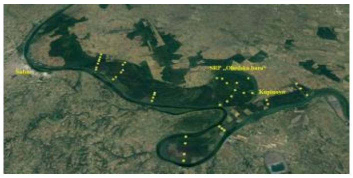

ARTICLE INFO

Citation:
Nikolić Jokanović V, Lazović A, Šoškić T, Živanović K (2023) Monitoring of groundwater fluctuations at flooded area of lowland forests of the Sava River (Serbia). Reforesta 16: 55-65.
DOI: https://dx.doi.org/10.21750/REFOR.16.05.110

Editor: Jovana Devetaković
Received: 2023-12-08
Accepted: 2023-12-22
Published: 2023-12-29

Abstract

Lowland pedunculate oak forests in the alluvium of the river Sava are of a great economic and ecological importance. Their growth and development features, and their survival, as well, mostly depend on soil moisture and available water. The paper deals with the influence of groundwater level on pedunculate oak forests condition in flooded area of Donji Srem. During four-year long research, the average (reference) groundwater level was determined, and extremes, the wettest and the driest year, were determined based on climate factors such as temperature and rainfalls. Deviation of the average from the reference groundwater level in the vegetation period during some years indicates possibility of risk zones presence. These zones are defined according to geostatistical analysis – ArcGIS, Kriging model and they are very significant for forestry practice, because they can predict some drought events and warn forestry experts to react in time in order to prevent big damages. Bearing in mind that investigated area is flooded, and that groundwater level is close to the soil surface, these anaerobic site conditions are obviously more suitable for another hygrophilous species than for pedunculate oak.

Keywords

Pedunculate oak; Flooded area; Groundwater level; Risk zones

Contents

1 Introduction

The growth and development of the lowland forests mostly depends on the soil moisture (Nikolić 2017; Nikolić Jokanović et al. 2023 a, 2023 b). Some authors have established the presence of specific species in a wide range of different site conditions whose genetic traits are characterized by a narrow ecological valence that is connected to the availability of water as the most important ecological factor (Prpić 1977). As for the water regime, it represents a qualitative assessment of all available water resources in the soil over a long period of time, and it is actually the total amount of water that enters the soil in different ways and is also spent during different physiological processes (Burlica 1987; Nikolić Jokanović et al. 2019). Many papers related to the problem of the decline of tree species located on alluvial soils near the Sava and the Danube river take into account several factors which are the most responsible for this phenomenon: groundwater level and the intensity of decline (Dekanić 1974; Đorović and Letić 2002; Letić et al. 2014), the response of the species to changed hydrological conditions (Pripić 1976), radial increment as an indicator of habitat changes (Pranjić and Lukić 1989), bioecological (Prpić et al. 1994) and silvicultural reasons (Bobinac et al. 1997). Lowland forests are highly dynamic ecosystems established on flooding areas close to the riverbank (Hughes 2007). Some authors (Sperduto and Nichols 2004) noted that these ecosystems are transitional plant associations located between aquatic and terrestrial environmental conditions.

Decline of oak pedunculate forests is a huge problem and some papers related to its site features and watering regime in Ravni Srem area are familiar with this issue (Medarević et al. 2009; Letić et al. 2014; Nikolić 2017). Considering that pedunculate oak is a species of great ecological and economical importance for Serbian forestry, it is necessary to prevent its decline which may affect not only reduced radial and height growth but also physiological conditions of the trees. Some authors (Jokanović et al. 2017; Jokanović et al. 2018) found that the stagnation of flooding water, as well as the height of the capillary rising of groundwater, have a great influence on the morphological and anatomical features of some exotics.

Nikolić Jokanović et al. (2020) assessed the decline risk of forest ecosystems in the area of Ravni Srem using geostatistical methods and multicriteria analysis. Aforementioned authors concluded that reduced groundwater level compared to the reference level negatively affects the water regime of the investigated area which is closely related to the amount of available water.

The main goal of the paper is to define risk zones on the basis of changeable groundwater level during the investigated period. In terms of ecology and economics, it may be very beneficial due to the fact these forests are very endangered and this can determine what kind of management measures should be applied.

2 Material and methods

The investigated area is located in the flooding zone. Among present plant associations there are two the most dominant species: *Quercus robur* L. and *Fraxinus angustifolia* Vahl. The net of piezometers, installed in the area of Donji Srem in period 1992-2000, were used for the purpose of this paper (Figure 1). Total of 40 piezometers (Figure 2) are located at nine hydrogeological profiles. Groundwater level was measured every 10 days (three times a month) during the investigated period.

As for the constructive details related to the piezometers, it should be emphasized that the holes were made by the handmade probe. Galvanized tubes with diameter of 5/4 inch and long about 6 m were put in the holes. The whole construction is consisted of 0.5 m long precipitator, 1.5 m long filter and a part of construction above the ground for about 20 cm. Constructive filter is a tube perforated by circular openings 4 mm thick. Around the tube, the gravel construction was mounted to the depth of 3.5 m, and clay buffer was mounted from this depth to the soil surface. Piezometric cap and precipitator bottom are closed with a metal cap. As for piezometric construction cap, it is about 20 cm above the soil surface and equal with a concrete insurance.

Spatial interpolation of data related to groundwater level at investigated area was displayed using ArcGIS software, model Kriging. Kriging is a geostatistical method of interpolation for which the interpolated values are modeled by a Gaussian process governed by prior covariances, as opposed to a piecewise-polynomial spline chosen to optimize smoothness of the fitted values. Under suitable assumptions on the priors, Kriging gives the best linear unbiased prediction of the intermediate values. The basic idea of Kriging is to predict the value of a function at a given point by computing a weighted average of the known values of the function in the neighborhood of the point. The method is mathematically closely related to regression analysis. Both theories derive a best linear unbiased estimator, based on assumptions on covariances.

For the complete investigated period four years long, an average (reference) groundwater level during growing season was determined and, based on climate factors (primarily sum of precipitation during growing season), there were established the driest and the wettest year, respectively. For mentioned extreme years, an average groundwater level during growing season was determined and after that the deviations were recorded. It actually means to assess reduced groundwater level compared to reference level in the driest, and increased groundwater level during the wettest period. Based on this, the risk zones were defined. Spatial interpolation of an average monthly piezometric levels was conducted in order to have an insight related to groundwater level fluctuations at studied area. Extreme values of groundwater level at the beginning and the end of growing seasons of two critical years (wet and dry) were shown.

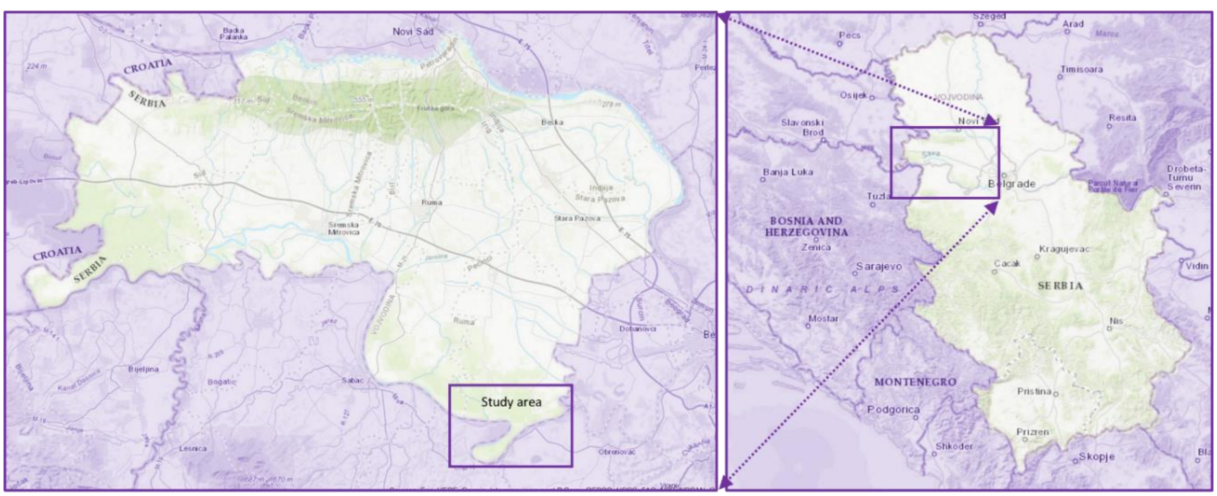

Figure 1. Display of study area.

Figure 2. Distribution of piezometers installed at investigated area.

3 Results

There are displayed an average groundwater levels during growing season of the wet and dry year for the whole investigated period (Figure 3 and 4).

Based on spatial distribution of an average groundwater level in growing season of the wet year (Figure 3), there were determined following zones of groundwater level in the area of Donji Srem:

- piezometric level of groundwater from the top of piezometric construction to the depth of 0.5 m includes area of 3651 ha, that is 38.34 % from the total area;
- piezometric level of groundwater at the depth 0.5-1 m includes area of 3190 ha, that is 33.50 % from the total area;
- piezometric level of groundwater at the depth 1-1.5 m includes area of 2574 ha, that is 27.03 % from the total area;
- piezometric level of groundwater at the depth 1.5-2 m includes area of 107 ha, that is 1.13 % from the total area.

The least area is occupied with groundwater level at the depth of 1.5-2 m, while the greatest is at the area from the top of piezometric construction to 0.5 m. This means that groundwater level is on the greatest part of the area very shallow, directly under the ground surface.

Based on spatial distribution of an average groundwater level in growing season of the dry year (Figure 4), there were determined following zones of groundwater level in the area of Donji Srem:

- piezometric level of groundwater at the depth 2-2.5 m includes area of 1726 ha, that is 18.13 % from the total area;
- piezometric level of groundwater at the depth 2.5-3 m includes area of 5521 ha, that is 57.98 % from the total area;
- piezometric level of groundwater at the depth 3-3.5 m includes area of 2275 ha, that is 23.89 % from the total area.

The least area is occupied with groundwater level at the depth of 2-2.5 m, while the greatest is at the depth 2.5-3 m.

In order to precisely establish the first groundwater level position, there have been made maps related to an average groundwater level for a four-year long investigated period. The greatest part of the water needed to maintain basic physiological functions of plants is adsorbed during growing season.First groundwater level, defined with an average values during growing season for the whole investigated period is a reference level.

In the area of Donji Srem, according to defined reference level, there are following zones (Figure 5):

- piezometric level of groundwater at the depth 0.5-1 m includes area of 772 ha, that is 8.10 % from the total area;
- piezometric level of groundwater at the depth 1-1.5 m includes area of 2298 ha, that is 24.13 % from the total area;
- piezometric level of groundwater at the depth 1.5-2 m includes area of 4548 ha, that is 47.76 % from the total area;
- piezometric level of groundwater at the depth 2-2.5 m includes area of 1904 ha, that is 20.00 % from the total area.

Obtained results show that the least area occupies piezometric level of groundwater at the depth 0.5-1 m, while the greatest is at the depth 1.5-2 m. It should also be emphasized that the least dominant area includes about 10 %, while the most dominant includes close to 50 % from the total area.

Reference groundwater level compared to an average values of groundwater level for each year during growing season can show whether the analyzed period deviates from reference level or not. If there are some significant deviations, no matter if it's about rising or falling of groundwater level, it is possible to define areas with significant changes. In order to define areas with less or more significant changes related to reference level, maps have been made. In these maps, deviation of the first groundwater level from reference level in extreme years has been displayed. Bearing on mind above mentioned, for more precise defining areas with established changes, these maps were overlapped with forest units net in investigated area.

Height deviation of an average from reference groundwater level in Donji Srem during growing season of the wet year (Figure 6) can be divided into two zones:

- piezometric level of groundwater at the depth 0.5-1 m includes area of 9357 ha, that is 98.26 % from the total area;
- piezometric level of groundwater at the depth 1-1.5 m includes area of 166 ha, that is 1.74 % from the total area.

It can be deduced that the groundwater is at almost the whole area at the depth 0.5-1 m.

Height deviation of an average from reference groundwater level in Donji Srem during growing season of the dry year (Figure 7) can also be divided into two zones:

- piezometric level of groundwater at the depth 0.5-1 m includes area of 1712 ha, that is 17.98 % from the total area;
- piezometric level of groundwater at the depth 1-1.5 m includes area of 7811 ha, that is 82.02 % from the total area.

In the extremely dry year, a deeper groundwater level was recorded in the largest part of the investigated area, in contrast to the extremely wet year. Based on obtained results, there was recorded an average increasing of groundwater level of about 0.9 m in wet year, while an average decreasing of about 1.0 m compared to reference level was found for the dry year.

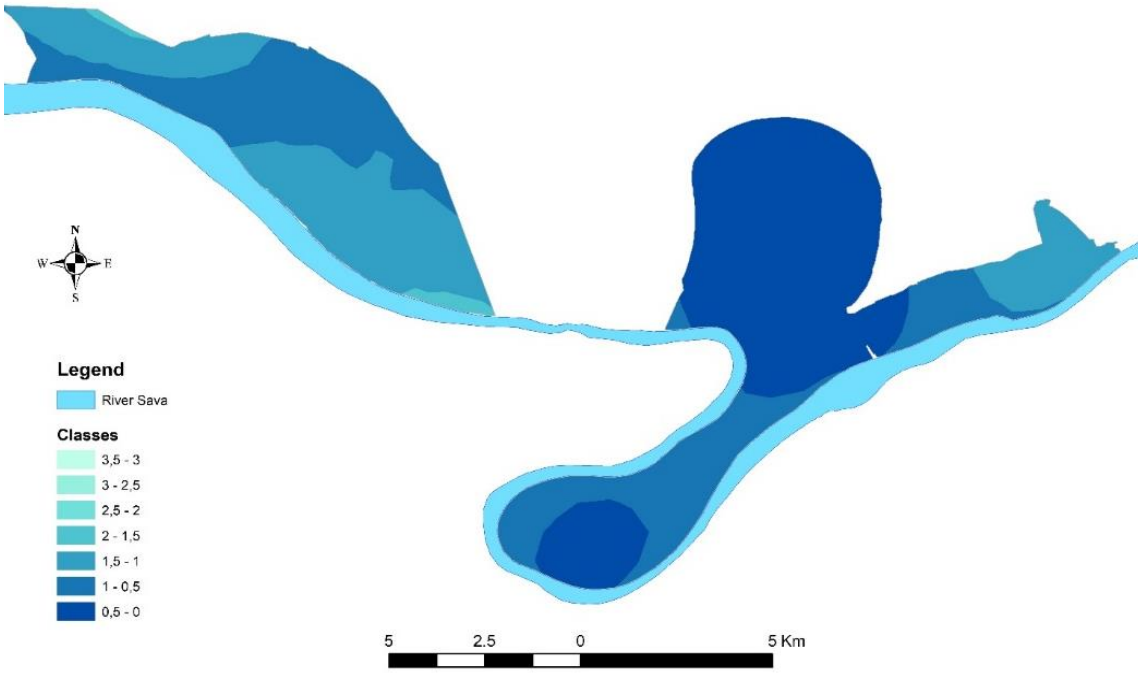

Figure 3. Spatial distribution of an average groundwater level during growing season of the wet year.

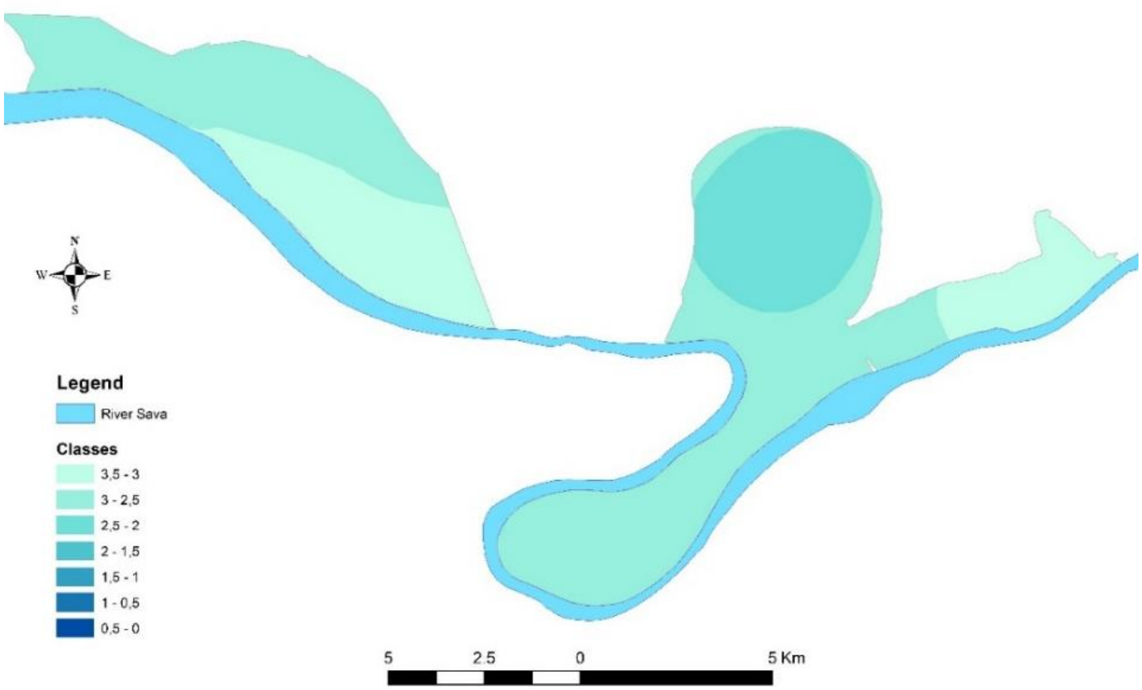

Figure 4. Spatial distribution of an average groundwater level during growing season of the dry year.

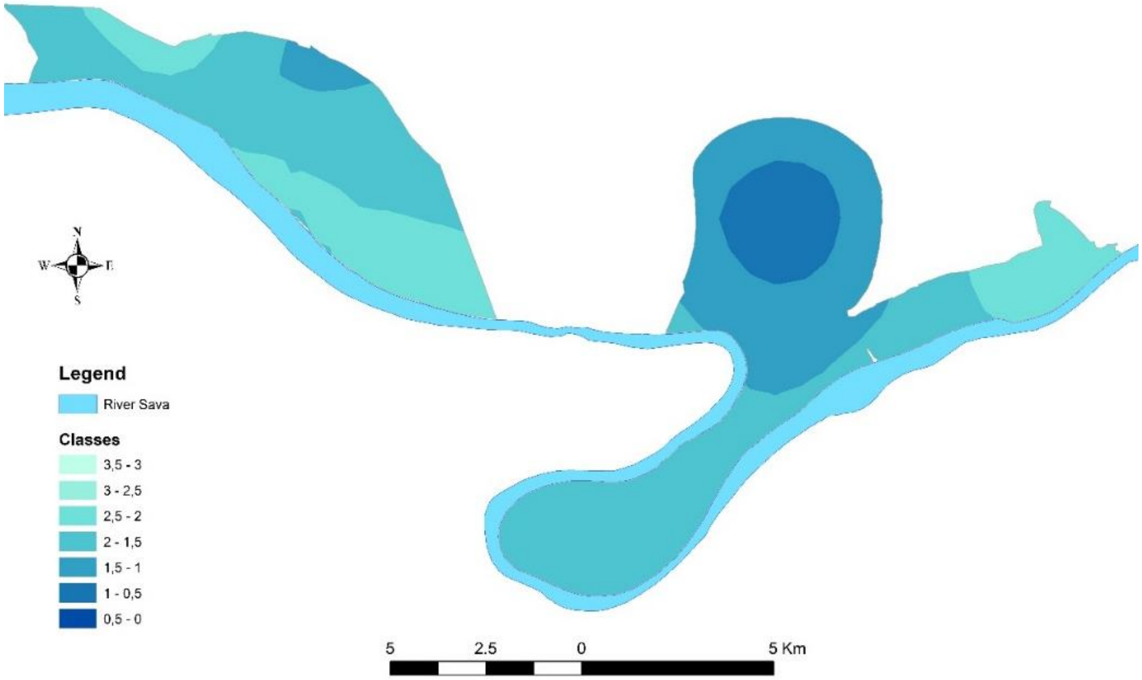

Figure 5. Areas occupied by piezometric level of groundwater for investigated four years long period.

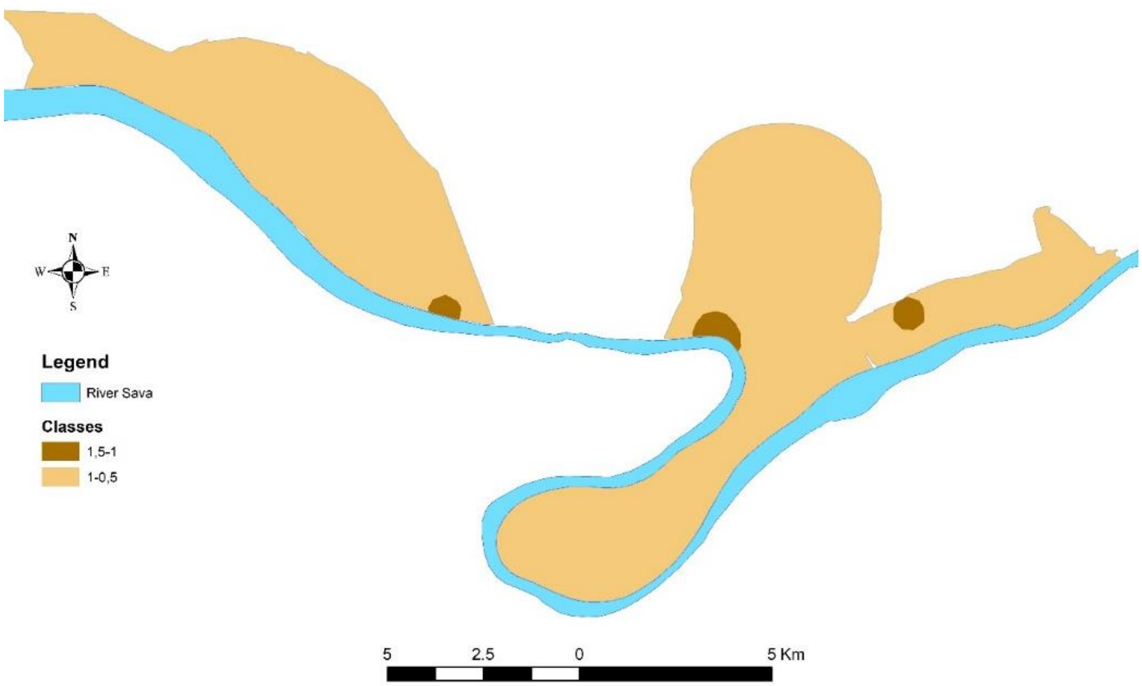

Figure 6. Height deviation of an average from reference groundwater level during growing season of the wet year.

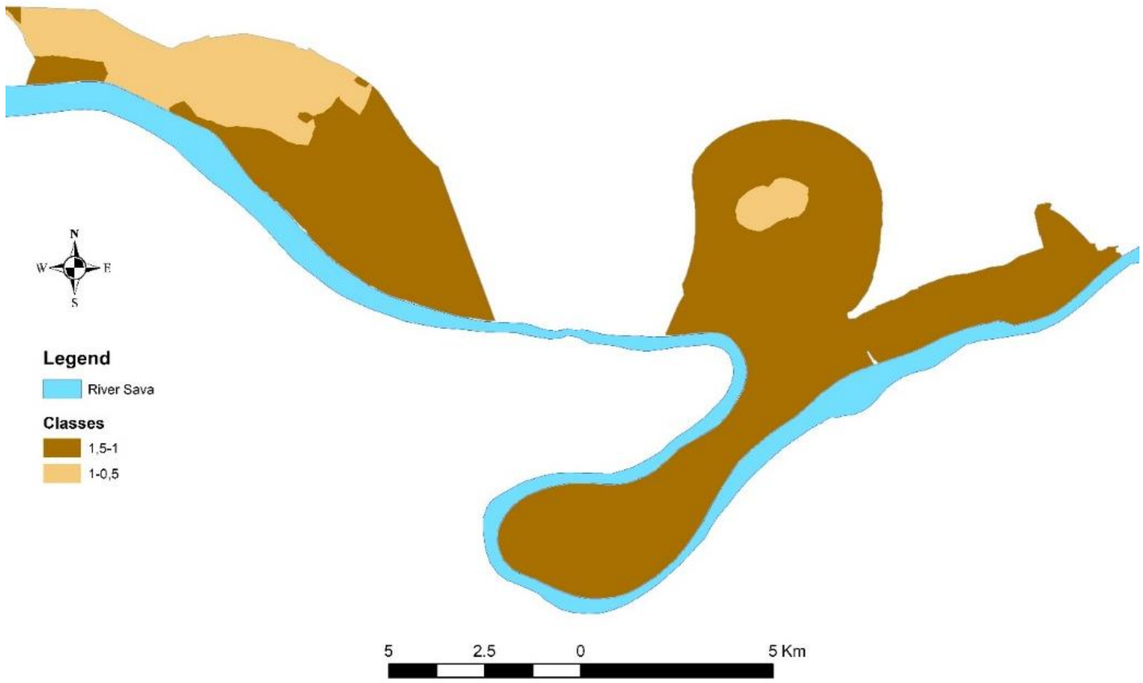

Figure 7. Height deviation of an average from reference groundwater level during growing season of the dry year.

4 Discussion

Nikolić (2017) found that decreasing of groundwater level compared to reference level at non-flooded area during the dry year negatively affects watering regime, because it has a direct influence on quantity of available water. On the other side, obtained results in our paper, where reference level is much closer to the surface, showed that increasing of groundwater level above reference level has a negative influence on environmental conditions (lack of oxygen). Some authors (Nikolić et al. 2023 b) noted that the most suitable site conditions for *Q.robur* growth are present on soils with greater proportion of groundwater. Some papers (Matić and Skenderović 1993; Prpić and Anić 2000; Vrbek 2003) dealt with a link between radial increment and minimal groundwater level during growing season by pedunculate oak. Monitoring of surface water (Jokanović et al. 2023 b) and groundwater (Mayer 1994) showed that both extreme scenarios caused by global climate changes make undesirable site conditions for hygrophilous species. Prpić (1976) emphasized that flooding affects negatively development and growth of oak pedunculate due to longer stagnation of flooding water which contributes to lack of oxygen. This coincides with our results related to groundwater level increasing in the area of Donji Srem. Prpić (1987) recorded reduced radial increment during increased humidity that occured when stagnation of flooding water lasts for a long time, and it also can be linked with our results.

During wet year at non-flooded area (Nikolić Jokanović et al. 2019), it was recorded an average rising of groundwater level of 1 m compared to reference level, while in dry year, it was established reducing of an average groundwater level of 1.6 m compared to the reference level. In our paper, for flooded area, the same tendencies occurred, but the values are a bit different – in wet year, it was recorded an average increasing of 0.9 m, while during dry year, it was established an average decreasing of 1 m compared to reference level. Based on obtained results for non-flooded area (Nikolić Jokanović et al. 2019) we can deduce that decreasing of groundwater level compared to reference level negatively affects watering regime, because it has a direct impact to the quantity of available water. On the other side, in our paper conducted at the flooded area, where reference level is much closer to the ground level (1.5-2.0 m dominant depth), increasing of groundwater above reference level has a negative influence to oxygen uptake by the plants, so the site conditions at non-flooded area (Gornji Srem) are much more suitable for pedunculate oak growth compared to flooded area of Donji Srem where desirable environmental conditions are for some hygrophilous species such as ash, willow, poplar, etc. (Nikolić Jokanović et al. 2019). Pilaš et al. (2007) observed dependence between variations of radial growth and groundwater table at pedunculate oak sites and concluded that the most intensive radial growth occurs at the beginning of the growing season when groundwater is closest to the ground surface, while radial growth decreased as it comes to the end of the growing season.

5 Conclusions

In the paper groundwater level fluctuations was monitored at flooded area of lowland forests in Donji Srem. The investigated area is under direct influence of the Sava River whose water level correlates with groundwater level. The level of groundwater largely determines the ecological conditions in the zone of lowland, floodplain forests, and the survival of the aforementioned ecosystems depends a lot on it. The main characteristics of the water regime of the aquifers of the investigated area can be observed through the features related to physical-geographical and anthropogenic factors, i.e. their influence on the amount of inflow and outflow (filling and emptying) of water from the aquifers. These processes are largely determined by climate conditions, firstly precipitation and air temperature. However, between the atmosphere, in which meteorological phenomena and processes take place on one hand, and the aquifers from the other, there are other elements such as: surface hydrography, pedological layer, and vegetation cover. Surface water in its immediate environment significantly affects the water regime of the unconfined aquifers, while the amount of water that will reach the aquifer zone largely depends on the pedological and vegetation characteristics, and they affect the modifying of the water regime. For the studied area of Donji Srem significant deviations of groundwater level were recorded compared to reference level during wet and dry year. These deviations suggest existing of potential risk zones where pedunculate oak trees may be endangered. Defining the risk zones may contribute a lot to the application of adequate management and silvicultural measures in studied ecosystems.

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