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THE HYDROLOGICAL REGIME CHANGES ASSESSMENT ON THE ALLUVIAL-HYGROPHILOUS FOREST HABITAT AT EAST SREM FLOOD-PROTECTED AREA

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Abstract: Intensive drying of single or group *Q. robur* L. trees at flood-protected area are connected with decreasing groundwater (GW) level and high atmospheric deficits. The study objectives are estimating GW capillary rising, amount of available water for pendunculate oak and atmospheric deficit values in enclosure hunt area “Crni lug”, at East Srem, the natural habitat of alluvial – hygrophilous forest. Data were collected from the observation stations of Republic Hydro-Meteorological Service of Serbia (RHMS) for period 1992-2024 with special analysis of changes for period 2020-2024. The results reveal that all GW seasonal levels and during the vegetational period are below an average but still on favorable depth for heighest capillary rising. Soil moisture deficits indicate larger aridity in summer, and monthly, atmospheric deficits could be excessive for vegetation. Contribution of those analysis is current evaluation of available water and climatic conditions for the alluvial-hygrophilous forest at flood-protected area.

Keywords: pedunculate oak, groundwater, Sava, capillary rising, East Srem.

PROCENA PROMENE HIDROLOŠKOG REŽIMA NA STANIŠTU ALUVIJALNO-HIGROFILNIH ŠUMA U BRANJENOJ ZONI OD POPLAVA U ISTOČNOM SREMU

Sažetak: Intenzivno sušenje pojedinačnih ili grupe stabala *Q. robur* L. u zoni odbrane od poplava povezuje se sa opadanjem nivoa podzemne vode (PV) i visokim atmosferskim deficitima. Cilj rada je procena kapilarnog izdizanja PV, dostupne količina vode za lužnjak i određivanje vrednosti atmosferskih deficita na primeru ograđenog lovišta “Crni lug” u istočnom Sremu koje predstavlja prirodno stanište aluvijalnih-higrofilnih šuma. Podaci su preuzeti sa osmatračnih stanica koje pripadaju Republičkom Hidro-Meteorološkom Zavodu Srbije (RHMZS) za period 1992-2024. g. sa posebnom analizom promena tokom perioda 2020-2024. g. Rezultati pokazuju da je nivo PV svih sezona i tokom vegetacionog perioda ispod prosečnih vrednosti ali još uvek na povoljnoj dubini za najveće kapilarno izdizanje. Deficit vlage u zemljištu ukazuje na veću aridnost tokom leta, a mesečno, atmosferski deficiti mogu biti ekscesivnih vrednosti za vegetaciju. Doprinos ovih analiza je trenutna procena dostupne vode i klimatskih uslova za aluvijalno-higrofilna šumska staništa u zonama koje su branjene od poplava.

Ključne reči: lužnjak, podzemne vode, Sava, kapilarno izdizanje, istočni Srem.

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1. INTRODUCTION

The Pleistocene fluvial deposits of southeastern Srem, known as “Beds with *Corbicula fluminalis*” and “Makiš Deposits” by Laskarev (1938) and Stevanović (1977) are lithologically made of cyclical alternation of typical riverbed deposits (sands, gravels) and sediments of flood phase (silts and partly clays) that could be observed in many places. In some cycles flood deposits are missing and regular multi-phase gradation of material has been formed, with coarser material in the lower, and finer in the upper parts (Nenadić et al., 2015). Sandy-gravel deposits ($k_f=10^{-1} \text{ cm}\cdot\text{s}^{-1}$) have larger and silts and clays ($k_f=10^{-3}\text{-}10^{-4}\text{-}10^{-5} \text{ cm}\cdot\text{s}^{-1}$) lower filtration values (Filipović, 2005) which affects on capillary rising. Due to an embankment construction along the river Sava, the direct wetlands-river hydraulic connection was interrupted during period of high water. The drainage canals and wells construction next to the Sava for the needs of Belgrade’s water supply probably contributed to the piezometric groundwater level decrease (Nikić, 2003).

Within the alluvial-hygrophilous complex forest types, Banković and Medarević (2003) (in: National forest inventory of Republic Serbia, 2008) indicates that penduculate oak is present in a large number of forest types whether it occurs alone as edificator or builds up two or polydominant communities, and the most common followers are narrow-leaved ash and hornbeam in various combinations. The second important specie, narrow-leaved ash in penduculate oak and narrow-leaved forest in Srem on flooded area habitat (*Fraxino – Quercetum roboris* subss. *subinundatum* Jov.et. Tom. 1980) shows a great capacity for revitalisation after an embankment has been constructed (Bobinac&Vučković, 1999). Penduculate oak and narrow-leaved ash forest at East Srem represents the most hygrophilous forest variant (Tomić, 2004). In this area hetero lithological environment influences on unevenly groundwater distribution (Nikić et al., 2010). Evapotranspiration from forest is considerably larger than from any other crop or grassland and the amount of water left for groundwater recharge is relatively low (Moricz, 2010). These parameters are specially significant during high evapotranspiration demands.

Main objective of the study is the hydrological and atmospheric conditions analysis on an example forest unit located in enclose hunt area “Crni lug” at East Srem for period 1992-2024 and 2020-2024 by using data from the observation stations of RHMSS. Reserves is replenished with high level of river Sava and low evapotranspiration, and decrease with high evapotranspiration. The results provide a contribution in more precisely perception of atmospheric and groundwater participation for hygrophilous species when the largest deficits occur.

2. MATERIAL AND METHOD

2.1. Study area and data

The East part of Srem is located between two major rivers, Sava and Danube, through which passes important Europe railways, which gives this area special importance in terms of economic development or great possibility for natural resources utilization (Vujović&Rašteggorac, 2002). Forest unit (FU) „Progarska ada – Crni lug – Zidine – Drenska“ (located between 44°39'00"-44°44'00"N and

20°08'00"-20°19'00"E) stretches along the left bank of the river Sava, between villages Progar and Boljevci, at a distance of 40 km from city of Belgrade. Most of the FU (Crni lug and Zidine) is behind an embankment or flood-defended area (Dražić, 2019).

FU formes several separate forest complexes or according to the vertical distribution forest vegetation belongs to I complex forest types (72-74 m a.s.l.) which are divided on ceno-ecological forest type (white willows and poplar forest and penduculate oak and alder forest) and further on ceno-ecological units: white willows forests, white willow and black poplar forest and penduculate oak and narrow-leaved ash forest. Of the total territory, 85% is covered with forest, 15% is bare land. In this regulatory period reforestation will achive optimal forest cover, 86% of FU (Dražić, 2019).

2.2 Materials and Methods

Calculations has been conducted for period 1992-2024.yr. with special analysis of 2020-2024.yr. Selected observation station are part of RHMSS (2026) network:

1. Hidrological analysis at investigation site (values are shown as absolute):

- **Surface water (SW)** level of river Sava: h.st. Šabac (72,61 m a.s.l.).
- **Groundwater (GW)** level: Obrež (137), (78,44 m a.s.l.). Piezometric construction are represented in study of author Anđelić (2021).

2. Atmospheric analysis at investigation site: m.st. Sručín (99 m. a.s.l.; 44°49' 20°17') and Sremska Mitrovica (81 m a.s.l.; 45°01' 19° 33') - data between those two stations are present as average:

- **ETp Thornthwite** - corrected with coefficient (Tab. 1), (Đorović, 2001):

$$ET_p = 1,6 \cdot (10 \cdot \frac{T}{I})^a; I = (\frac{T}{5})^{1,514}$$

$$a = 0,000000675 \cdot I^3 - 0,000077 \cdot I^2 + 0,01792 \cdot I + 0,492$$

ETp – potential evapotranspiration (mm); T- temperature (°C); I- index; a-index.

Table 1. Correction coefficient of duration day (Đorović, 2001)

g.latitude	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
44	0.81	0.82	1.02	1.13	1.27	1.29	1.30	1.20	1.04	0.95	0.80	0.76
45	0.80	0.81	1.02	1.13	1.28	1.29	1.31	1.21	1.04	0.94	0.79	0.75

- **Precipitation deficit (P-ETp):** arid >200 mm (Čermak&Prax, 2001).
- **Water-limited conditions (P-ETp⁻¹):** arid ≤0,75 (Newman et al., 2006):
- **Atmosphere humidity (Mayer qvotient):** arid NS<200 (Unkašević, 2005):

$$NS = \frac{H}{E - e}$$

H-precipitation (mm); E-max. vapor pressure (kPa); e – actual vapor pressure (kPa).

- **Vapor pressure deficit –VPD** – excessive >3kPa (Tendayi, 2010):

$$e_a = e_s \cdot \left(\frac{RH}{100}\right); e_s = 0,6108 \exp\left(\frac{17,27+T_a}{T_a+237,3}\right)$$

e_s –max.vapor pressure (kPa); T_a -temperature (°C); e_a – actual vapour deficit (kPa), RH – relative air humidity (%).

3. RESULTS

NS aridity values (Fig. 1) for a period 1992-2024.yr. are in summer (163), monthly in April (124), Jun (112) and July (45). NS seasonal aridity for 2020-2024.yr. are: spring (160) 2020.yr., summer (178) 2021.yr., spring (137) 2022.yr. and summer (188) 2024.yr. Summer 2020.yr. (405), 2022.yr. (230), 2023.yr. (284) has more humid conditions. Monthly arid conditions for 2020-2024.yr. are: March (154), April (18), July (139), September (129), November (170) 2020.yr.; March (189), April (199), Jun (56), August (125) and September (35) 2021.yr.; January (172), February (145), March (27), May (73), Jun (174), July (122) and October (82) 2022.yr.; March (144), August (145), September (179), October (75) 2023.yr.; February (21), March (115), April (77) and August (10) 2024.yr. Excessive humidity is calculated for September 2022.yr.

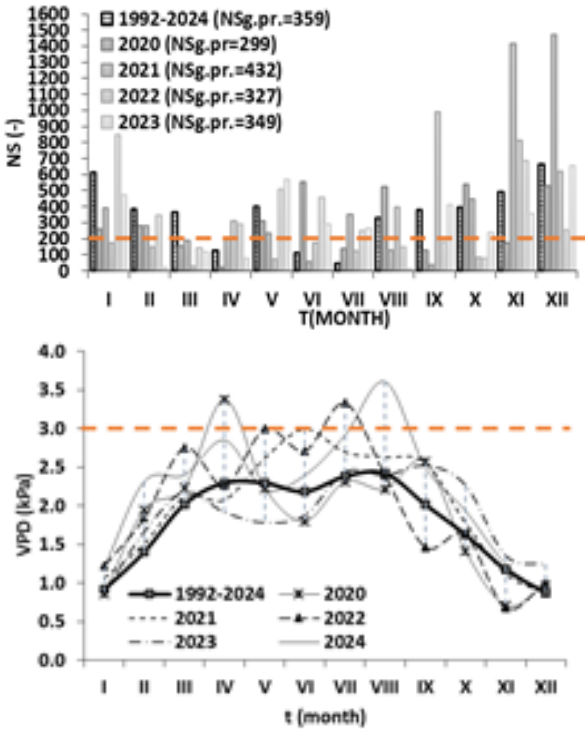


Figure 1. Comparative review NS and VPD values. Note: colored dashed line are aridity limit ($NS \leq 200$; $VPD > 3kPa$)

VPD largest value (Fig.1) for 1992-2024.yr. occurs in spring (2,2 kPa) and summer (2,3 kPa), monthly April (2,3 kPa), May (2,3 kPa), July (2,4 kPa) and August (2,4 kPa). VPD seasonal largest values for 2020-2024.yr. are: spring (2,6 kPa), summer (2,1 kPa) 2020.yr.; summer (2,8 kPa), spring (2,3 kPa) 2021.yr.; summer (2,8 kPa), spring (2,7 kPa) 2022.yr.; summer (2,2 kPa), spring, autumn (2 kPa) 2023.yr.; summer (3 kPa), spring (2,5 kPa) 2024.yr. Monthly VPD largest values are: April 2020.yr. (3,4 kPa), Jun 2021.yr. (3 kPa), July 2022.yr. (3,3 kPa), September 2023.yr. (2,5 kPa) and August 2024.yr. (3,6 kPa).

Annual soil moisture (SM) deficit for 1992-2024.yr. (Fig. 2) is -120,7 mm, the largest value occurs in summer (-222,7 mm), monthly in July (-87,5 mm). Spring's deficits are lower (-25,8 mm), and surplus occurs in winter (115,5 mm) and autumn (12,3 mm). SM deficit for 2020-2024.yr. (Fig.2) are: -145 mm (2020.yr.); -6,2 mm (2021.yr.); -172,5 mm (2022.yr.), -103,8 mm (2023.yr.), -210,6 mm (2024.yr.) SM seasonal deficit for 2020-2024.yr. is predominantly spring: 2020.yr. (-59,6 mm), 2021.yr. (-5,5 mm), 2022.yr. (-69,4 mm), 2024.yr. (-22,9 mm), (2023.yr. surplus 23,2 mm); and summer: 2020.yr. (-151,6 mm), 2021.yr. (-293 mm), 2022.yr. (-257,3 mm), 2023.yr. (-237 mm), 2024.yr. (-332,4 mm). Monthly SM largest deficits for 2020-2024.yr. are: -108,3 mm July 2020.yr., -127,9 mm Jun 2021.yr., -114,9 mm July 2022.yr., -102,6 mm August 2023.yr., -160,9 mm August 2024.yr.

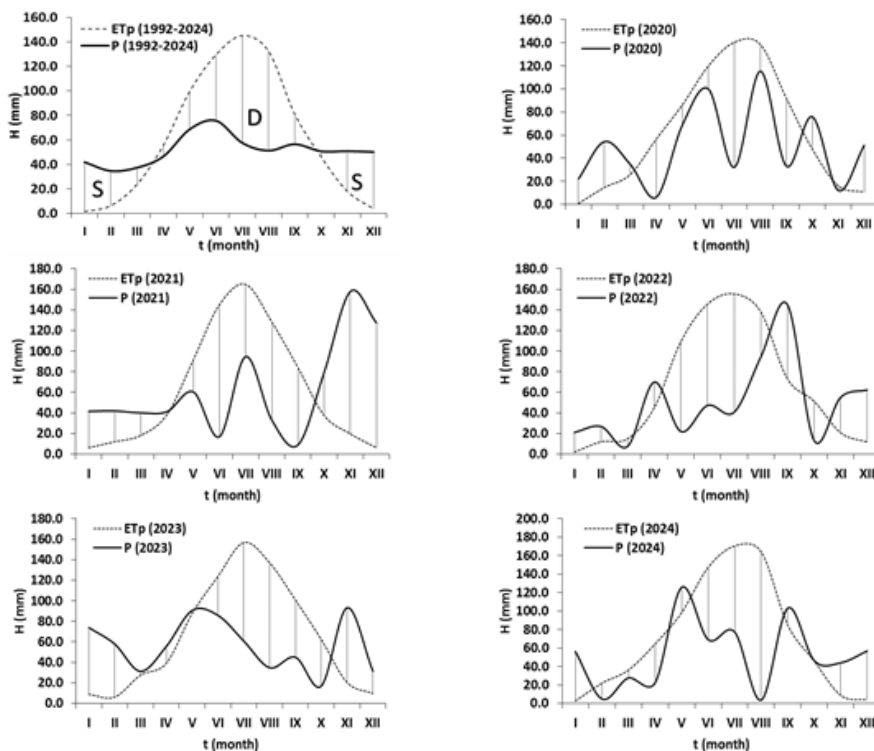


Figure 2. Comparable review SM deficits. Note: S-surplus, D – deficit

Water-limited conditions (WLC) lowest values ($P \cdot ET^{-1} \leq 0,75$) for 1992-2024.yr. (Fig. 2) are in summer (0,45) and April-September period (July and August

has lowest values 0,4). WLC seasonal lowest values for 2020-2024.yr. are: spring (0,65) and summer (0,62) 2020.yr.; only summer (0,33) 2021.yr.; spring (0,59) and summer (0,41) 2022.yr.; only summer (0,43) 2023.yr.; only summer (0,31) 2024.yr. Monthly WCL lowest values for 2020-2024.yr. are: April (0,11) 2020.yr.; September (0,11) 2021.yr.; May (0,20) 2022.yr.; August (0,25) 2023.yr.; August (0,02) 2024.yr.

Annual highest and lowest surface-water (SW) level of river Sava for 1992-2024.yr. (Fig.3) is 75,12 m a.s.l. (April) and 72,36 m a.s.l. (August), respectively, and those two parameters difference value are 2,76 m. SW seasonal highest level occurs in spring (74,84 m a.s.l.), and lowest in summer (72,94 m a.s.l.). Highest and lowest groundwater (GW) level is 74,55 m a.s.l. (May) and 74,13 m a.s.l. (November) respectively and difference value is 0,43 m. GW seasonal highest and lowest level is spring (74,47 m a.s.l.) and autumn (74,19 m a.s.l.). Annual precipitation is 622,2 mm, the largest amount is summer (184,6 mm), Jun 75,7 mm.

Annual highest and lowest SW level for 2020-2024.yr. (Fig.3) are: 74,25 m a.s.l. (October) and 72,10 m a.s.l. (September), 2020.yr. (difference 2,15 m); 76,48 m a.s.l. (February) and 71,75 m n.m. (September) 2021.yr. (difference 4,73 m); 75,80 m a.s.l. (December) and 71,65 m a.s.l. (August) 2022.yr. (difference 4,15 m); 75,86 m a.s.l. (May) and 72,22 m a.s.l. (October) 2023.yr. (difference 3,64 m); 74,69 m a.s.l. (January) and 71,85 m a.s.l. (August) 2024.yr. (difference 2,84 m). SW seasonal highest and lowest levels are: winter (73,36 m a.s.l.) – summer (72,87 m a.s.l.) 2020.yr.; winter (75,84 m a.s.l.) – autumn (72,47 m a.s.l.) 2021.yr.; winter (74,46 m a.s.l.) – summer (72,10 m a.s.l.) 2022.yr.; spring (75,62 m a.s.l.) – autumn (73,17 m a.s.l.) 2023.yr.; winter (74,24 m a.s.l.) – summer (72,55 m a.s.l.) 2024.yr.

Annual highest and lowest GW level for 2020-2024.yr. (Fig.3) are : 73,32 m a.s.l. (July) and 73,01 m a.s.l. (April and December) 2020.yr. (difference 0,31 m); 73,56 m a.s.l. (Decembar) and 72,92 m a.s.l. (July) 2021.yr. (difference 0,64 m); 73,84 m a.s.l. (January and April) and 73,59 m a.s.l. (December) 2022.yr. (difference 0,25 m); 74,27 m a.s.l. (July) and 73,61 m a.s.l. (January) 2023.yr. (difference 0,66 m) - GW data for Nov. and Dec. 2023.yr. are missing in annual books of RHMS; 73,77 m a.s.l. (April) and 73,32 m a.s.l. (December) 2024.yr. (difference 0,45 m). GW seasonal highest and lowest level are: summer (73,28 m a.s.l.) – spring (73,05 m a.s.l.) 2020.yr.; winter (73,19 m a.s.l.) – summer (72,96 m a.s.l.) 2021.yr.; spring (73,80 m a.s.l.) – summer (73,65 m a.s.l.) 2022.yr.; summer (74,23 m a.s.l.) – winter (73,65 m a.s.l.) 2023.yr.; spring (73,72 m a.s.l.) – winter and autumn (73,49 m a.s.l.) 2024.yr.

Annual precipitation for 2020-2024.yr. (Fig.3) are: 605,5 mm (2020.yr.); 743,5 mm (2021.yr.); 605,6 mm (2022.yr.); 676,6 mm (2023.yr.); 636,0 mm (2024.yr.). Seasonal largest amount is: summer 2020.yr. (247,5 mm), autumn 2021.yr. (246,2 mm), autumn 2022.yr. (213,7 mm), summer 2023.yr. (181,2 mm), autumn 2024.yr. (193,3 mm). Monthly largest amount is: August 2020.yr. (115,4 mm), November 2021.yr. (157,9 mm), September 2022.yr. (145,2 mm), November 2023.yr. (93,2 mm), May 2024.yr. (125,6 mm).

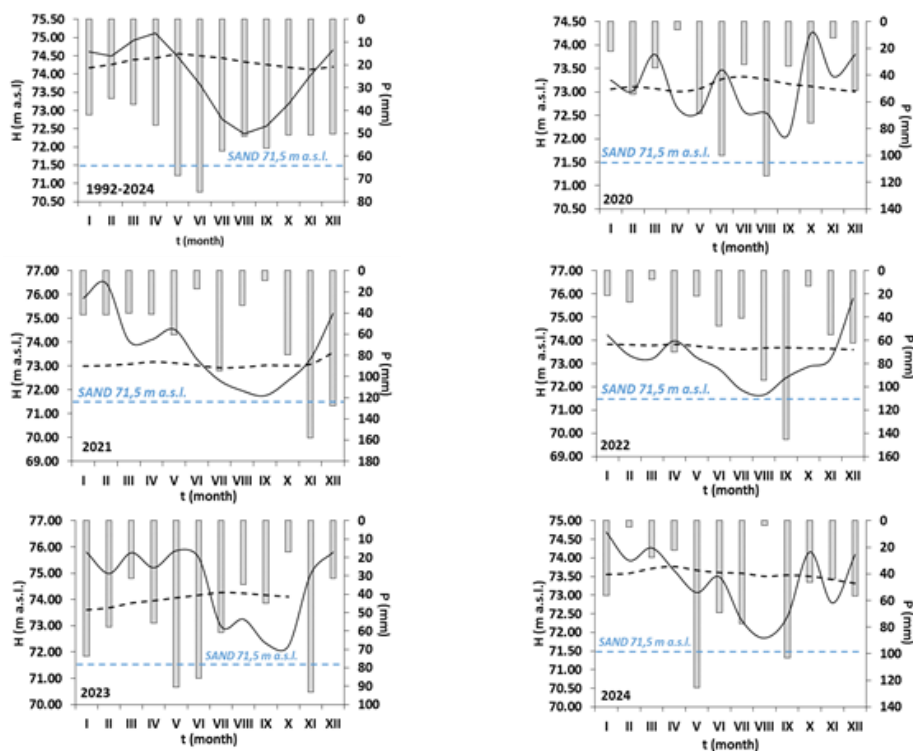


Figure 3. *Comparable review GW, SW level and precipitations (P): Legend: - - GW; █ P; — SW; Note: colored dashed line is a sand layer in Obrež (137) according to Anđelić (2021)*

4. DISCUSSION

According to Chi et al. (2018) (in: Liu et al., 2024) ensuring the necessary water demand to support normal vegetation growth is crucial for maintaining an ecosystem's functions, rational allocation of water resources, and coordinated development between ecological and economic water demand in river basins. A well-constructed database should accommodate identification of critical climate thresholds at which, under a given set of vegetation conditions, episodic recharge would occur (Newman et al. 2006). Süßel&Brüggemann (2021) highlight consideration of various authors that older penduculate oak trees cannot adopt their root system to changing GW supply and floodplain forests are especially prone to damage by combinations of decreased GW levels and increasing heat and drought waves (a major factor so-called “acute oak decline”). This multi-factorial phenomenon have accompany effects of abiotic and biotic stressors.

SM an average renewal occurs at the beginning (January-March) and end (October-December) of the year. SM renewal for 2020-2024.yr. are: January-March and October-December (with a November decrease) 2020.yr.; January-April and October-December (with significant increase at the end of the year) 2021.yr.; January-April (with a March decrease) and September-November (with a October

decrease) 2022.yr.; January-May and November-December 2023.yr.; January and May (deficits are in February, March, April) and September-December 2024.yr.

SM annual largest decrease compared with an average (-120,7 mm) is 2024.yr. (-210,6 mm), and 2022.yr. (-172,5 mm). Favorable conditions for vegetation are 2021.yr. with the smallest annual deficit (-6,2 mm) compared to a both periods. SM spring largest values compared to an average (-25,8 mm) is 2020.yr. (-59,6 mm) and 2022.yr. (-69,4 mm), and 2023.yr. (23,2 mm) have surplus. SM summer largest values compared to an average (-222,7 mm) is 2024.yr. (-332,4 mm), 2021.yr. (-293 mm), 2022.yr. (-257,3 mm) and 2023.yr. (-237 mm), and below an average is 2020.yr. (-151,6 mm). SM autumn deficits are lower 2020.yr. (-35,2 mm) and 2023.yr. (-28,6 mm), and the largest surplus is 2021.yr. (105,3 mm). The largest SM monthly deficits for 2020-2024.yr. overcome an average (July -87,5 mm): July 2020.yr. (-108,3 mm), Jun 2021.yr. (-127,9 mm), July 2022.yr. (-114,9 mm), August 2023.yr. (-102,6 mm) and 2024.yr. (-160,9 mm).

Newman et al. (2006) reveal that arid, semiarid, and subhumid regions (sometimes collectively called drylands) are considered water limited because precipitation is typically less than ET_p, such that the ratio of this variables ranges from about 0,03 to 0,75, and because extreme temporal variability results in extended periods with little to no precipitation. These environments are often sensitive and prone to change because of limitations in water and/or nutrients, which dictate fluxes and transport in the critical zone.

WLC an average spring (0,86) and summer (0,45) values indicates decrease in spring 2020.yr. (0,65) and 2022.yr. (0,59); summer 2021-2024.yr. (0,33, 0,41, 0,43, 0,31) and increase 2020.yr. (0,62) – still indicate arid conditions; autumn are below an average (1,08) in 2020.yr. (0,77) and 2023.yr. (0,84) but above the limit for aridity. Monthly lowest value WCL for period for 2020-2024.yr. indicate excessive aridity: April (0,11), July (0,23), August (0,36) 2020.yr.; May – September (0,66; 0,12; 0,58; 0,26; 0,11) 2021.yr.; March (0,51) and May-August (0,20; 0,32; 0,26, 0,68) and October (0,26) 2022.yr., Jun-October (0,69; 0,39; 0,25; 0,45; 0,27) 2023.yr., February (0,22), April (0,34), Jun-August (0,47; 0,45; 0,02), 2024.yr.

VPD serves as a critical indicator for measuring the evaporative capacity of water in the atmosphere and will increase with future temperature rise (Wang et al., 2025). Wang et al. (2025) represented other authors view that high VPD levels have high influence on plant closure stomata (minimizing water loss) consequently limiting photosynthesis and carbon uptake.

VPD spring value for 1992-2024.yr. (2,2 kPa) increased 2020.yr. (2,6 kPa), 2021.yr. (2,3 kPa), 2022.yr. (2,7 kPa), and 2024.yr. (2,5 kPa) except 2023.yr. (2 kPa). VPD summer value increased 2021.yr. and 2022.yr. (2,8 kPa) and 2024.yr. (3 kPa) until values of 2020.yr. and 2023.yr. are near to an average. VPD largest autumn increase is 2024.yr. (1,9 kPa) and 2023.yr. (2 kPa). Monthly excessive VPD values has been reached and far above an average: April (3,4 kPa) and September (2,6 kPa) 2020.yr., May – September (2,6 kPa; 3 kPa; 2,7 kPa; 2,6 kPa; 2,6 kPa) 2021.yr., March (2,8 kPa) and May-August (3 kPa; 2,7 kPa; 3,3 kPa; 2,4 kPa) 2022.yr., September (2,5 kPa) 2023.yr., April (2,9 kPa), July (2,9 kPa), August (3,6 kPa) and September (2,5 kPa) 2024.yr.

NS spring values decreased 2020.yr. (160), 2021.yr. (206), 2022.yr. (137), and 2024.yr. (253), except 2023.yr. (314) compared to an average (296). NS summer

values all years (2020.yr. 405; 2021.yr. 178; 2022.yr. 230; 2023.yr. 284; 2024.yr. 188) are increased compared to an average (163), but certain years (2021.yr. and 2024.yr.) are still below the aridity limit ($NS \leq 200$). Compared to an average (422) NS autumn value all years (except 2021-22.yr.), decreased but still above the aridity limit. NS excessive monthly values for 2020-2024.yr.: April (18) 2020.yr., Jun (56) and September (35) 2021.yr., March (27) 2022.yr., October (75) 2023.yr. and February (21) and August (10) 2024.yr.

According to Jović et al. (1989/1990) (in: Tomić&Jović, 2002) the detailed study of the forest ecosystems in Srem, forest phytoseneses succession is defined in depending on the wetting intensity or GW level and flood water from flowing to stagnant water to zonal vegetation: willow and poplar → narrow-leafed ash → penduculate oak and narrow-leafed ash → penduculate oak → penduculate oak, narrow-leafed ash and hornbeam → penduculate oak and hornbeam → zonal vegetation.

SW highest level are above an average (75,12 m a.s.l.) 2021.yr. (76,48 m a.s.l.), 2022.yr. (75,80 m a.s.l.), 2023.yr. (75,86 m a.s.l.), and below an average 2020.yr. (74,25 m a.s.l.) and 2024.yr. (74,69 m a.s.l.). SW lowest level are below an average (72,36 m a.s.l.) during all years (2020.yr. 72,10 m a.s.l.; 2021.yr. 71,75 m a.s.l.; 2022.yr. 71,65 m a.s.l.; 2023.yr. 72,22 m a.s.l.; 2024.yr. 71,85 m a.s.l.). Difference of highest and lowest SW level is above an average (2,76 m) all years (2021.yr. 4,73 m; 2022.yr. 4,15 m; 2023.yr. 3,64 m; 2024.yr. 2,84 m) except 2020.yr. (2,15 m).

SW spring level are below an average (74,84 m a.s.l.) all years (2020.yr. 73,01 m a.s.l.; 2021.yr. 74,23 m a.s.l.; 2022.yr. 73,48 m a.s.l.; 2024.yr. 73,67 m a.s.l.) except 2023.yr. (75,62 m a.s.l.). Also SW summer level are below an average (72,94 m a.s.l.) all years (2020.yr. 72,87 m a.s.l.; 2021.yr. 72,55 m a.s.l.; 2022.yr. 72,10 m a.s.l.; 2024.yr. 72,55 m a.s.l.) except again 2023.yr. (73,94 m a.s.l.). SW autumn level are below an average (73,24 m a.s.l.) all years (2020.yr. 73,23 m a.s.l.; 2021.yr. 72,47 m a.s.l.; 2022.yr. 72,83 m a.s.l.; 2023.yr. 73,17 m a.s.l.; 2024.yr. 73,12 m a.s.l.).

GW highest level is below an average (74,55 m a.s.l.) all years (2020.yr. 73,32 m a.s.l.; 2021.yr. 73,56 m a.s.l., 2022.yr. 73,84 m a.s.l.; 2023.yr. 74,27 m a.s.l., 2024.yr. 73,77 m a.s.l.). As well GW lowest level is below an average (74,13 m a.s.l.) all years (2020.yr. 73,01 m a.s.l.; 2021.yr. 72,92 m a.s.l.; 2022.yr. 73,59 m a.s.l.; 2023.yr. 73,61 m a.s.l.; 2024.yr. 73,32 m a.s.l.). GW highest and lowest level difference value are greater 2024.yr. (0,45 m), 2021.yr. (0,64 m) and 2023.yr. (0,66 m), and lower 2020.yr. (0,31 m), 2022.yr. (0,25 m).

GW level for 2020-2024.yr. compared to an average spring (74,47 m a.s.l.), summer (74,43 m a.s.l.) and autumn (74,19 m a.s.l.) are below: spring – all years (2020.yr. 73,05 m a.s.l.; 2021.yr. 73,12 m a.s.l.; 2022.yr. 73,80 m a.s.l.; 2023.yr. 73,97 m a.s.l.; 2024.yr. 73,72 m a.s.l.); summer – all years (2020.yr. 73,28 m a.s.l.; 2021.yr. 72,96 m a.s.l.; 2022.yr. 73,65 m a.s.l.; 2023.yr. 74,23 m a.s.l.; 2024.yr. 73,57 m a.s.l.); autumn – all years (2020.yr. 73,12 m a.s.l.; 2021.yr. 73,03 m a.s.l.; 2022.yr. 73,66 m a.s.l.; 2023.yr. 74,14 m a.s.l.; 2024.yr. 73,49 m a.s.l.).

5. CONCLUSION

At the East Srem area, on natural alluvial-hygrophilous forest habitat in enclosure hunt area “Crni lug” hydro-technical works changed hydrological regime and research aim is atmospheric conditions and hydrology regime review during two periods 1992-2024.yr. and 2020-2024.yr.:

- Annual atmospheric deficit (NS) indicate more humid 2021.yr. (432), more arid 2024.yr. (290) and 2020.yr. (299) and in an average (359) conditions 2022.yr. (327) and 2023.yr. (349). Vegetational period – VP (April-September) are with low values: April and August 2024.yr., at the end of VP 2023.yr., during May and summer (except August’s surplus) 2022.yr, more frequent deficit presence 2021.yr., evenly distributed (April, Jun, September) deficits in VP 2020.yr. Excessive NS values are April (18) 2020.yr., Jun (56) and September (35) 2021.yr., and August (10) 2024.yr. Extreme low NS value is spring 2022.yr. (137) and 2020.yr. (160); and summer 2021.yr. (178) and 2024.yr. (188).
- VPD monthly deficits 2022.yr. are more frequent. High VPD values are specially present: 2024.yr. – during entire VP, 2023.yr. – July, August and September, 2022.yr. – entire VP except September, 2021.yr. – entire VP, 2020.yr. – entire VP except Jun. Excessive values are April (3,4 kPa) 2020.yr., Jun (3 kPa) 2021.yr., July (3,3 kPa) 2022.yr, August (3,6 kPa) 2024.yr. Summer deficits are highest 2024.yr. (3 kPa), 2022. yr. and 2021.yr. (2,8 kPa).
- SM largest annual deficit are 2024.yr. (-210,6 mm), 2022.yr. (-172,5 mm) and 2020.yr. (-145 mm), and 2021.yr. (-6,2 mm) are lower under the influence of precipitation at the end of the year. SM VP deficits are present: 2024.yr. – except May and September; 2023.yr. – except beginning of VP; 2022.yr. – except April and September; 2021.yr. - except April; 2020.yr. – entire VP. Excessive values are August 2024.yr. (-160,9 mm) and 2023.yr. (-102,6 mm), July (-114,9 mm) 2022.yr., Jun (-127,9 mm) 2021.yr., July (-108,3 mm) 2020.yr. Summer deficits are highest: 2024.yr. (-332,4 mm), 2023.yr. (-237 mm), 2022.yr. (-257,3 mm), 2021.yr. (-293 mm)-excessive aridity.
- WLC for VP are: 2024.yr. - except May and September; 2023.yr. – except April and May; 2022.yr. – except April and September; 2021.yr. – except April; 2020.yr. – except May, Jun and August. Lowest excessive values are: August (0,02) 2024.yr., August (0,25) 2023.yr., May (0,20) 2022.yr., September (0,11) 2021.yr., April (0,11) 2020.yr. WLC occurs in spring 2020.yr (0,65) and 2022.yr. (0,59) and summer all years (2020.yr 0,62, 2021.yr. 0,33, 2022.yr. 0,41, 2023.yr. 0,43, 2024.yr. 0,31).
- SW spring and summer level are below an average all years of the comparable period except 2023.yr. SW autumn levels for period 2020-2024.yr. are below an average. Annual SW highest and lowest difference level value is greater than an average (2,76 m) during all years (2021.yr. 4,73 m; 2022.yr. 4,15 m; 2023.yr. 3,64 m; 2024.yr. 2,84 m) except 2020.yr. (2,15 m).
- GW spring, summer and autumn levels are below an average all years of the comparable period. Annual GW highest and lowest level difference value are

greater 2024.yr. (0,45 m), 2021.yr. (0,64 m) and 2023.yr. (0,66 m), and lower 2020.yr. (0,31 m), 2022.yr. (0,25 m) compared to an average (0,43).

- GW level is all the time in clay layer which is semi-permeable or non-permeable, with highest capillary rising and longest soil moisture capturmment.

Generally larger recharge soil moisture reserves are at the end of 2021.yr.; highest autumn deficits in 2020.yr.; variable increase in 2022.yr. with higher deficient annual values; above an average recharge till May 2023.yr. with lower annual deficits than an average; lower recharge 2024.yr. with highest annual deficits.

REFERENCES

- Andelić, M. (2021). *Comparable analysis atmosperic deficits and water regime during different season on alluvial flood forest habitat at East Srem*. Fresenius Enviromental Bulletin. Vol. 30.
- Bobinac, M., Vučković, M. (1999). *Relationship of some exogenous factors to the variability of diameter increment of narrow-leaved ash (Fraxinus angustifolia Vahl.) future trees on an ecologically optimal site*. Ekologia No. 18 (1): 31-38.
- Čermak, J., Prax, A. (2001). *Water balance of a Southern Moravian foodplain forest under natural and modified soil water regimes and its ecological consequences*. Ann.For.Sci.58.
- Dražić, G. (2019). *Special forest management basis for unit „Progarska ada – Crni lug – Zidine – Drenska“ for period 2020-2029.yr*. Ministry of Agriculture, Forestry and Water Management Serbia - Forest Service.
- Filipović, B., Krunić, O., Lazić, M. (2005). *Regyonal hydrology of Republic Serbia*. Faculty of Mining and Geology. University of Belgrade. 1-403.
- Liu, X., Alifujiang, Y., Abliz, A., Asaiduli, H., Ye, P., Nurahmat, B. (2024). *Estimation of Water demand for riparian forest vegetation based on sentinel-2 data: A case study of the Kokyar river basin*. Forests, 15, 1749.
- Moricz, N. (2010). *Water balance study of a groundwater-dependent oak forest*. Acta Silv.Lign.Hung., Vol. 6. 49-66.
- National forest inventory of Republic Serbia (2008). Forestry faculty, Belgrade, Ministry of Agriculture, Forestry and Water Management Serbia – Forest Service.
- Newman, B.D., Wilcox, B.P., Archer, S.R., Breshears, D.D., Dahm, C.N., Duffy, C.J., McDowell, N.G., Phillips, F.M., Scanlon, B.R., Vivoni, E.R. (2006). *Ecohydrology of water-limited enviroments: A scientifiic vision*. Water resources research, Vol. 42, No.1-15.
- Nenadić, D., Gaudenyi, T., Bogičević, K., Ganić, M. (2015). *Stratigraphical position of pleistocene fluvial deposits of Southeastern Srem and the Danube terraces in Eastern Srem*. Bulletin of the Natural History Museum No. 8: 7-19.
- Nikic, Z. (2003). *Condition and possibilities of providing quality water for needs of hunt area “Crni lug”*. Yugoslav Water Pollution Control Society. Conference Proceedings (32).
- Nikić, Z., Letić, Lj., Nikolić, V., Filipović, V. (2010). *Procedure for underground water calculation regime of Pedunculata oak habitat in Plain Srem*. Bulletin of the Faculty of Forestry Vol. 101, No 125-138.

RHMSS. Republic Hydro-meteorological Service Serbia (2026). Annual books. Web: office@hidmet.gov.rs.

Süßel, F., Brüggemann, W. (2021). *Tree water relations of mature oaks in southwest Germany under extreme drought stress in summer 2018*. Plant Stress 1.

Tomić, Z. (2004). *Forest phytocenology*. University of Belgrade. Forestry faculty. Book.

Tomić, Z., Jović, N. (2002). *Recent succession of the penduculate oak and narrow-leaved ash forest in the unflooded part of Gornji Srem*. Bulletin of the Faculty of Forestry. Vol. 85, No 101-112.

Tendayi, R. (2010). *Evapotranspiration in water limited enviroments: up-scaling from the crown canopy to the eddy flux footprint*. Thesis. International institute for geo-information science and earth observation Enschede, The Netherlands. 1-81.

Unkašević, M. (2005). *Forest ecoclimatology*. University of Belgrade. Forestry faculty Belgrade. Book. 1-231.

Vujović, M., Raštegorac, Z. (2002). *Cooperative for the drying of southeastern Srem 1902-2002*. Monography. Water management company „Galovica“ Zemun.

Wang, M., Hu, Z., Liu, X., Hou, W. (2025). *Vapor pressure deficit (VPD) downscaling based on multi-source remote sensing, in-situ observation, and machine learning in China*. Journal of Hydrology: Regional Studies 57.

THE HYDROLOGICAL REGIME CHANGES ASSESSMENT ON THE ALLUVIAL-HYGROPHILOUS FOREST HABITAT AT EAST SREM FLOOD-PROTECTED AREA

Milena ANĐELIĆ

Summary

At the alluvial – hygrophilous forest habitat at East Srem lithological environment is represented as a multi-phase gradation of material, with coarser material in the lower, and finer in the upper parts which affects on high of cappillary rising. At this area the direct wetlands-river hydraulic connection is interrupted during period of high water by embankment construction; drainage canals and wells contribute to the piezometric groundwater level decrease. Moisture reserves is replenished with high level of river Sava and low evapotranspiration, and decrease with high evapotranspiration. Study objective is hydrological and atmospheric conditions analyses for alluvial – higrophilous forest at East Srem during different seasons of two comparable periods 1992-2024.yr. and 2020-2024.yr., with data collected from observation station of the RHMSS network.

Results indicate that surface water (SW) spring, summer and autumn level are below an average (1992-2024.yr.) all years of the comparable period (2020-2024.yr.) except 2023.yr. (spring and summer levels). Also groundwater (GW) spring, summer and autumn levels are below an average all years of the comparable period. According to piezometric construction of Obrež (137) RHMSS, GW level is all the time in clay layer with highest cappillary rising and longest soil moisture capturment. Annual SW highest and lowest difference level value is greater than an average during all years except 2020.yr. GW highest and lowest difference level value is greater during 2021.yr., 2023.yr. and 2024.yr. and lower 2020.yr. and 2022.yr. compared to an average. Atmospheric aridity indicate increase and occurance excessive values. Extreme low NS value (<200) is spring 2020.yr., 2022.yr.; and

summer 2021.yr., 2024.yr. VPD ($>3\text{kPa}$) summer deficits are highest 2021.yr. and 2022. yr. and 2024.yr. SM ($>200\text{ mm}$) summer deficits are highest during 2021-2024.yr. WLC ($\leq 0,75$) occurs in spring 2020.yr. and 2022.yr. and summer 2020-2024.yr.

During vegetation period, high evapotranspiration demands and groundwater capillary rising have direct impact on adaptation mechanism of higrophilous species. Precisely perception of atmospheric and groundwater participation for hygrophilous species is important when the largest deficits occurs for better planning water resources.

PROCENA PROMENE HIDROLOŠKOG REŽIMA NA STANIŠTU ALUVIJALNO-HIGROFILNIH ŠUMA U BRANJENOJ ZONI OD POPLAVA U ISTOČNOM SREMU

Milena ANĐELIĆ

Rezime

Na staništu aluvijalno-higrofilnih šuma u Istočnom Sremu litološka sredina predstavljena je kao više-fazna gradacija materijala, sa krupnozrnim materijalom u dubljim slojevima i materijalima finije granulacije u gornjim slojevima koji imaju uticaj na visinu kapilarnog izdizanja podzemnih voda. Na ovom području prekinuta je direkta veza između vlažnih terena i reke Save tokom perioda visoke vode izgradnjom nasipa; drenažni kanali i bunari doprinose opadanju pijezometarskog nivoa podzemnih voda. Rezerve vlage se obnavljaju tokom visokog nivoa reke Save i niske evapotranspiracije, a smanjuju se pod uticajem visoke evapotranspiracije. Cilj rada je analiza hidroloških i atmosferskih uslova za aluvijalno-higrofilne šume u Istočnom Sremu tokom različitih sezona dva uporedna perioda 1992-2024.g. i 2020-2024.g. na osnovu preuzetih podataka sa osmatračkih stanica RHMZS.

Rezultati ukazuju da je vodostaj (PV) reke Save tokom proleća, leta i jeseni ispod proseka (1992-2024.g.) tokom svih godina uporednog perioda (2020-2024.g.) osim 2023.g. (proleće i leto). Takođe nivo podzemnih voda (NPV) tokom proleća, leta i jeseni je ispod proseka tokom svih godina uporednog perioda. Prema pijezometarskoj konstrukciji Obrež (137) RHMZS, NPV je sve vreme u sloju gline sa najvećom visinom kapilarnog izdizanja i najdužim kapacitetom za zadržavanje vlage. Godišnja razlika najveće i najmanje PV vrednosti je veća od proseka tokom svih godina osim 2020.g. Razlika najvećeg i najmanjeg NPV je veća od proseka tokom 2021.g., 2023.g., 2024.g., a manja 2020.g. i 2022.g. Atmosferska aridnost ukazuje na povećanje i prisustvo ekcesivnih vrednosti. Ekstremno niske NS (<200) vrednosti su tokom proleća 2020.g., 2022.g.; i leta 2021.g., 2024.g. VPD ($>3\text{kPa}$) vrednosti su tokom leta najveće 2021.g. i 2022. g. i 2024.g. SM ($>200\text{ mm}$) letnji deficit su najveći tokom 2021-2024.yr. WLC ($\leq 0,75$) je zastupljen tokom proleća 2020.g. i 2022.g. i leta 2020-2024.yr.

Tokom vegetacionog perioda visoki evapotranspiracioni zahtevi i visina kapilarnog izdizanja podzemnih voda ima direktan uticaj na adaptacione mehanizme higrofilnih vrsta. Precizan uvid u učešće atmosferskih i podzemnih voda kod higrofilnih vrsta je važna kada se najveći deficit dešavaju zbog boljeg planiranja vodnih resursa.

