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WATER STATUS, NUTRIENTS AND RADIAL INCREMENT OF PEDUNCULATE OAK (*Quercus robur* L.) IN NORTHERN SERBIA AND COMPARISON WITH SELECTED SITES IN SLOVENIA

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Abstract

Two adult oak tree groups in northern Serbia, differing in degree of decline, were studied. Measurements of pre-dawn water potential (PWP), nutrient status and radial growth were performed and compared with similar sites in Slovenia. In spite of favourable water conditions and sufficiently high groundwater table, values of PWP between groups were statistically significant, with lower values in the degraded group. Growth and nutrient analysis confirmed differences between the groups, while values of PWP did not indicate water stress. Higher values of foliar nitrogen in Serbia compared to similar sites in Slovenia may be connected with more intensive agricultural land use and, consequently, faster turnover. The different vitality status and variable nutrient content may also be due to disturbances in the functioning of the root system and impaired uptake ability.

Key words: pedunculate oak, pre-dawn water potential, growth, oak decline, nutrient status

VODNE RAZMERE, HRANILA IN DEBELINSKI PRIRASTEK DOBA (Quercus robur L.) V SEVERNI SRBIJI TER PRIMERJAVA Z IZBRANIMI RASTIŠČI V SLOVENIJI

Izvleček

Pri dveh skupinah odraslih dobov v severni Srbiji, ki sta se razlikovali po stopnji vitalnosti, so avtorji pričujočega članka preučevali razlike v vrednostih jutranjega ksilemskega vodnega potenciala (PWP) ter stanju hranil in debelinskega prirastka, potem pa vrednosti primerjali s podobnimi sestoji v Sloveniji. Kljub ugodni vodni preskrbi in globini podtalnice so bile vrednosti PWP med skupinama statistično značilne, z bolj negativnimi vrednostmi v prizadeti skupini. Tudi analiza rasti in hranil je potrdila razlike med obema skupinama, meritve PWP pa niso potrdile stresnih vrednosti. Večje koncentracije dušika v srbskih hrastih (listje) glede na vrednosti pri nas lahko povežemo z bolj intenzivno kmetijsko rabo tal. Različna vitalnost in stanje hranil sta lahko posledica motenj delovanja koreninskega sistema in zmanjšane sposobnosti prevajanja.

Ključne besede: dob, jutranji vodni potencial, rast, vitalnost, stanje hranil

UVOD
INTRODUCTION

Pedunculate oak (*Quercus robur* L.) is economically the most important and most widespread tree species among all European oaks, and it grows in various climatic conditions. In the south-eastern part of its natural range, under the influence of the Mediterranean and Pannonian climate, it occupies moist and floodplain sites (Trinajstić 1996). Owing to its floodplain character, oak forests today are among the most heavily altered forests in Europe, since their natural distribution range coincides with the most intensive agricultural land use (Batič et al. 1995). Larger pedunculate oak forest complexes are consequently limited to sites less suitable for agriculture (Wraber 1951). In alluvial regions of the Sava and Drava rivers, several hydromelioration changes have occurred in the past, which have changed the flood regime of the main river streams. Negative consequences have been intensified by mass oak exploitation since the end of the 19th century, which has also caused degradation of floodplain ecosystems in general.

Constant degradation between 1930 and 1965 caused massive oak dieback in the eighties, and the consequences can still be seen even today. The destabilized status has also been worsened by unsuitable silvicultural and technical measures in planning the optimal stand structure and in maintaining an ecophysiological balance in view of the changed environmental conditions (Rossel and Reuther 1995).The aforementioned processes, together with uneven distribution of precipitation, extreme temperatures and water pollution have disturbed the

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natural balance of biocenoses; they have been followed by diseases, pest attacks and general oak decline evident since the end of the 19th century (Manojlović 1926, Prpić 1989, Donaubauer 1998). Several theories have tried to explain the oak decline as a combined effect of several factors (Führer 1992, Rösel and Reuther 1995, Siwecki and Ufnalski 1995) and some have indicated possible causes in parts of Europe (Hartmann et al. 1989, Hämmerli and Stadler 1989, Näveke and Meyer 1990, Harapin and Androić 1996). In-depth studies concerning oaks have been performed to explain water stress induced dysfunctions (Tyree and Cochard 1996, Cochard et al. 1996, Triboulot et al. 1996), links between environmental constraints and pathogens (Brasier 1996, Rubstov 1996), effects of climate change and elevated atmospheric CO_2 (Picon et al. 1996, Vivin et al. 1996), ecological and physiological analysis of decline (Thomas and Hartmann 1996), as well as from the perspective of an improvement in silviculture of oaks (Gemmel et al. 1996, Matić 1996, Wagner and Dreyer 1997, Čater and Batič 2000, Prpić and Anić 2000, Bobinac 2000). The trend of vitality loss has been present for an extended time period and cannot be directly linked with any single factor.

In our study, differences in water status, nutrients and radial increment of adult pedunculate oak trees were compared between healthy and declining oaks at a highly productive site in Northern Serbia. The results were compared with conditions in Slovenian pedunculate oak forests.

MATERIAL AND METHODS
MATERIALI IN METODE

The studied forest stand in Northern Serbia (45⁰46'24''N, 18⁰56'22''E) is located in a former flood area of the Danube river, where watercourse regulation was carried out and a dyke against flooding built in 1883. The Danube affected the relief, pedological composition and vegetation on the inundation plain. Owing to the regular flooding, there were swamps with reeds and associations with willows and poplars, as well as associations with pedunculate oak and narrow leaved ash (*Fraxinus angustifolia* Vahl) on higher sites with less water (Herpka 1979). There was a consequent reduction of nutrients and groundwater lowering, with fragmentation of moisture sites. This caused a reduction of autochthonous poplars and willows, especially from 1890 onwards. On poplar sites (*Populetum nigro-albae* Slav. 1952) and fragmented stands of narrow-leaved ash and European white elm (*Fraxineto-Ulmetum effusae* Slav. 1952), stands of pedunculate oak, pedunculate oak with white hornbeam and pedunculate oak with narrow-leaved ash were anthropogenically introduced. Both growth and yield are very sufficient (Bobinac and Vajištanac 1990). Research was performed in an oak and hornbeam stand, at a Populetum nigro-albae Slav. 1952 site, 86 m above sea level on alluvial soil. The groundwater table drops in summer to a depth of 2.0 m. On a permanent research plot of 0.25 ha, a complete inventory (height, breast diameter) was performed in 1985 and 2003. In 2004, two groups of adult oak trees were selected: a vital one and a declining one, based on the tree crown condition, with four randomly selected dominant adult trees in each group. Crown condition assessment was done according to the ICP methodology (Anonymous 1994). In the group of healthy oaks, breast diameters ranged from 60.0 – 70.0 cm, and tree heights from 36.0 - 36.5 m, while in the degraded group, diameters were from 47.0 – 71.0 cm and tree heights ranging from 36.2 – 37.4 m.

Leaf samples were taken in August 2004 from the upper part of the crown in order to measure PWP with a water pressure chamber (Plant Moisture Vessel SKPM 1400, Skye, UK) to establish the water status. At least five repetitions were made on each tree in order to obtain a representative average value of PWP. Leaf samples for foliar analysis were taken at the same height and analyzed (Leco CNS-2000 analyzer). Leaf mass was determined before and after drying at 105°C to the constant leaf weight. Grinding was performed with Fritsch Pulverisette 5 mill. Total C, N and S were determined by CNS Leco 2000 (elemental analysis dry combustion method). Grinded material was digested with acid mixture (HNO_3/$HClO_4$: 5:1); K, Ca and Mg were determined by AAS Varian 240FS and P spectrophotometrically (UV-Vis spectrophotometer Varian Cary 50). Zn was determined by AAS Varian 240 FS (flame AAS) while Cd, Cr and Pb were established by AAS Varian 240 Z (graphite furnace AAS) (Anonymous 2005).

Tree ring samples were prepared from stem discs following the methodology described by Schweingruber (Schweingruber 1989; Schweingruber 1993; Stokes and Smiley 1996); the average sampling height was 4 m from the ground. Prepared samples were scanned with the ATRICS system (Levanič 2007), whereas tree ring width was measured with the WinDENDRO programme; synchronisation (for establishing dendrochronologies of healthy and degraded trees) and controls were done with the PAST-4 programme. Significant years were determined with the P4P programme (Levanič and Ogrinc unpublished). All analyses were carried out at the Slovenian Forestry Institute. Analyses of the frequency of appearance of both positive and negative pointer years (PY) were conducted in ten-year intervals. The criterion for a significant year (SY) was slightly modified due to the reduced number of trees and was considered to occur when 90 % of all trees in a certain year responded with increased or decreased radial increment. According to the standard method (Schweingruber et al. 1990), SY is defined as when more than 80 % of at least 13 tree rings have a different response to that of the previous year.

Results were compared with measurements performed on oaks in Slovenia, growing at comparable sites in two forest complexes: in the north-eastern part, where a drop of groundwater has caused a severe decline (Murska šuma; 46°30'27.9'' N, 16°31'5.9'' E) and in the southern part, where water supply is better and less damage has been indicated (Krakovski gozd; 45°53'0.9'' N, 15°25'3.0'' E) (Čater 2002).

RESULTS
REZULTATI

GROWTH AND INCREMENT
RAST IN PRIRASTEK

Data from the forest inventory from the stand in which measurements were performed in northern Serbia are presented in Table 1. According to data from yield and increment tables, the site is one of the best pedunculate oak sites (Špiranec 1975, Bezak et al. 1993). The forestry chronicle reports a devitalisation process since 1985; between 1985 and 2003 in the calculated area of 0.25 ha, 112 adult oaks with breast diameter ranging from 28.6 -57.2 cm and heights ranging from 27.0 – 34.3 m have been removed in salvage cut, all belonging to the upper social class in the stand. In absolute terms, trees began to lose vitality after the age of 90-108, at which 52% of all trees were removed in sanitary cuts (comparison with status from 1985).

Conditions in Slovenia (Murska šuma, Krakovski gozd) are characterized by an unbalanced proportion of development stages; degradation and dieback are increasing forest gaps, which are consequently forced into earlier regeneration. In the 1992-2000 period, 824m^3 of timber was removed at the research site in Murska šuma (36.6 ha) through salvage cut in only four years, instead of a planned 10-year cut of 780m^3 (Čater 2002). In Krakovski gozd, the proportion of salvage cut is somewhat smaller (30%), but still too high (Čater 2002).

CROWN DEFOLIATION
OSUTOST KROŠENJ

Confirmed differences between the two groups of randomly chosen adult oaks are presented in Table 2 and Fig. 1.

Table 1: Significant parameters for pedunculate oak growth within the studied stand in northern Serbia and amount of salvage cut in the 1985-2003 period

Preglednica 1: Parametri za dobovo raziskovalno ploskev v severni Srbiji in količina sanitarnega poseka v obdobju 1985-2003

Parameter *Kazalec*	*Status in 1985 Stanje 1985*	Status in 2003 Stanje 2003	Salvage cut 1985-2003[1] *Sanitarni posek 1985-2003[1]*
N (No./ha)	216	104	112
G (m^2/ha)	41.4	31.3	16.1
V (m^3/ha)	703.6	592.0	271.7
Iv (m^3/ha)	10.5[2]	8.9[3]	-
$d_{average}$ (cm)	48.4	61.2	42.4
d_{min} (cm)	28.6	44.0	28.6
d_{max} (cm)	69.1	79.2	57.2
h_s (m)	32.0	36.7	30.9
h_{min} (m)	27.0	29.5	27.0
h_{max} (m)	36.0	41.0	34.3

[1] According to status in 1985 / *glede na stanje iz leta 1985*

[2] Vol. increment derived from radial increment (Pressler drill) / *volumski prirastek, izpeljan iz debelinskega prirastka (Presslerjev sveder)*

[3] Vol. increment derived according to difference between 1985 and 2003 / *Volumski prirastek, izpeljan iz razlik med letoma 1985 in 2003*

Average values differ significantly, in spite of the relatively small number of sampling units.

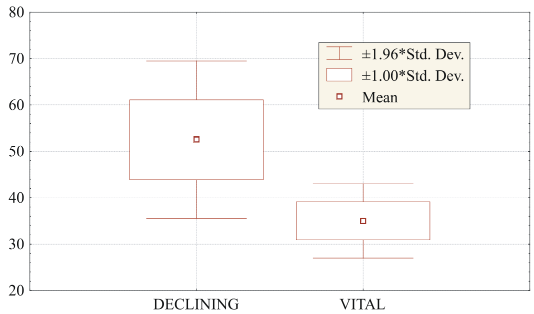

Fig. 1: Average values of crown defoliation for vital and declining groups of trees at research site in northern Serbia

Slika 1: Povprečna osutost krošenj za skupini vitalnih in prizadetih dobov v severni Srbiji

Table 2: Differences in crown defoliation between groups of vital and non-vital oaks

Preglednica 2: Statistične razlike v osutosti krošenj med skupinama vitalnih in prizadetih dobov

Crown defoliation *Osutost krošnje*	Mean (vital) *Povprečje (vitalna)*	Mean (declining) *Povprečje (prizadeta)*	t-value *t-vrednost*	df *df*	p *p*
Vital vs. declining *Vitalna - prizadeta*	35	52.5	3.656	6	0.011

WATER AND NUTRIENT STATUS

VODNE IN PREHRANSKE RAZMERE

Analysis confirmed the differences in PWP measured values between vital and non-vital pedunculate oaks (df 46; t=11.47***, table 4). Measured values in the group of degraded oaks were lower, more negative compared to the vital group, for which significant differences within the group were also confirmed (Table 3, vital trees). This means that the response of degraded trees was uniform, without confirmed differences (Table 3, degraded trees), while in the vital trees an individual response of trees was still evident. Lower (more negative) values suggest an unreliable water supply, especially since the groundwater depth was the same for both groups of trees, not exceeding 2 m below soil surface (Table 3, Fig. 2).

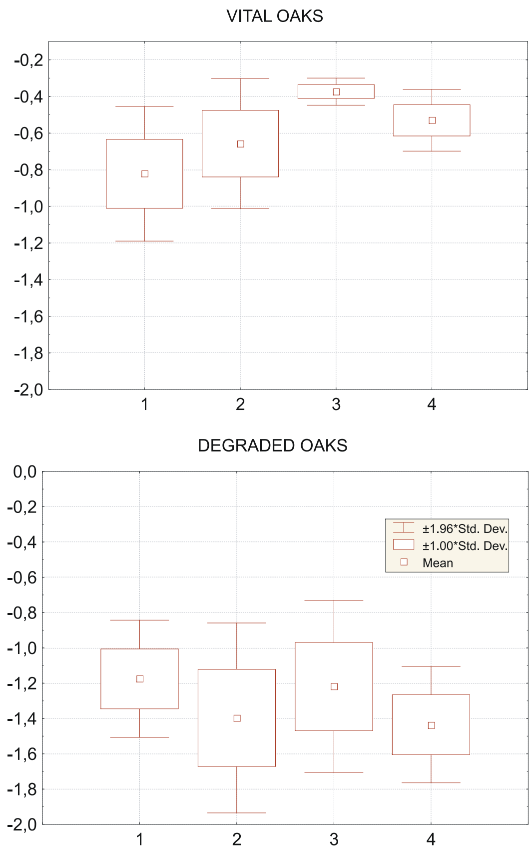

Fig. 2: PWP values in the case of vital (above) and non-vital (below) adult oaks at the research site (northern Serbia)

Slika 2: Vrednosti PWP vitalnih (zgoraj) in prizadetih (spodaj) dobov na raziskovalni ploskvi (Severna Srbija)

Table 3: Differences in PWP within the two groups of oaks (northern Serbia)

Preglednica 3: Razlike v jutranjem vodnem potencialu (PWP) med obema skupinama dobov (Severna Srbija)

Vital trees/comparison / *Vitalna drevesa / primerjava*

PWP (0.1 Mpa)	Mean 1	Mean 2	t-value	df	p
1 vs.2	-0.82	-0.66	1.411379	8	0.195802
1 vs.3	-0.82	-0.37	5.245294	8	0.000778
1 vs. 4	-0.82	-0.53	3.437563	9	0.007419
2 vs. 3	-0.66	-0.37	3.428778	8	0.008971
2 vs.4	-0.66	-0.53	1.542502	9	0.157345
3 vs. 4	-0.37	-0.53	-3.74182	9	0.004613

Degraded trees/comparison / *Prizadeta drevesa / primerjava*

PWP (0.1 Mpa)	Mean 1	Mean 2	t-value	df	p
1 vs.2	-1.15	-1.48	-2.20977	11	0.049238
1 vs.3	-1.15	-1.47	-1.09697	11	0.296086
1 vs. 4	-1.15	-1.80	-1.60741	11	0.136264
2 vs. 3	-1.48	-1.47	0.03293	12	0.974269
2 vs.4	-1.48	-1.80	-0.81182	12	0.432706
3 vs. 4	-1.47	-1.80	-0.717	12	0.487093

Table 4: Statistical differences in PWP between groups of randomly chosen adult oak trees (northern Serbia)

Preglednica 4: Statistične razlike (PWP) med skupinama naključno izbranih dobov (severna Srbija)

Group PWP (MPa) *Skupina PWP (MPa)*	Mean (vital) *Povprečje (vitalna)*	Mean (degraded) *Povprečje (prizadeta)*	t-value *t-vrednost*	df *df*	p *p*
Vital vs. degraded *Vitalni - prizadeti*	-0.593	-1.32	11.4733	46	0.000

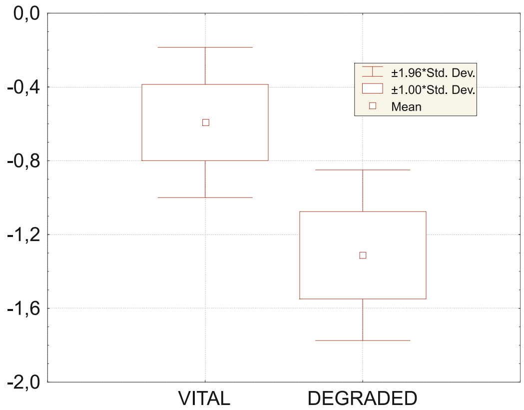

Fig. 3: Pre-dawn water potential for the groups of vital and degraded oaks (northern Serbia)

Slika 3: Jutranji vodni potencial za skupini vitalnih in prizadetih dobov (severna Srbija)

The most expressed difference between declining and vital trees in relation to the average value of dry mass was that expressed for 100 leaves. According to the critical values of nutrient content (Anonymous 2006), the status of oak trees in northern Serbia is in the optimal range; the difference between vital and degraded trees is evident in macronutrients N, S, P, K, Ca and Mg, which were higher in vital trees. The leaf mass of 100 leaves was almost twice as high for vital trees as for degraded trees (m_{vital}=18.82 g; $m_{degraded}$=10.25 g). Since the leaves in the two groups were much smaller in the degraded group, we chose to express nutritional status as contents (mass per leaf) rather than concentration (g/kg) (Table 5).

Compared to foliar analysis values for oak leaves from Slovenia (Murska šuma), we found that nitrogen concentration in northern Serbia was much higher (23.0-24.8 mg/g vs. 28.3-32.7 mg/g) (Čater et al. 1999). The pattern was the same for phosphorous but not for magnesium and calcium.

INCREMENT
PRIRASTEK

Tree ring analyses for the 1950-2005 period showed a similar pattern of growth in both groups of trees until 1950 (Fig 4). After this, differences between the two groups increased over time. The increment of degraded trees was significantly reduced and never reached the value of vital ones. In 1972 and 1979, the increment significantly dropped in all analyzed trees, while in 1988, 1996 and 1997 a positive reaction was evident in degraded/declining trees. From 1988 on, the differences between the groups were even larger; the last positive response in declining trees was in 1996, and thereafter the increment of the two groups became progressively different.

Table 5: Nutrient status of trees (leaves) in northern Serbia

Preglednica 5: Stanje hranil v listju drevja (severna Srbija)

	Tree *Drevo*	Leaf mass (100)	C	N	S	P	K	Ca	Mg	Cd	Pb	Zn	Cr
Group *Skupina*	No *Št.*	g	%	mg/leaf	mg/leaf	mg/leaf	mg/leaf	mg/leaf	mg/leaf	µg/leaf	µg/leaf	µg/leaf	µg/leaf
Vital *Vitalni*	1	20.54	51.99	6.04	0.38	0.23	2.37	1.20	0.48	0.002	0.08	4.38	0.08
	2	23.76	52.70	6.15	0.40	0.35	2.41	0.86	0.49	0.002	0.12	3.35	0.07
	3	13.37	52.65	4.30	0.28	0.18	1.19	0.70	0.23	0.001	0.06	2.97	0.04
	8	17.62	53.02	4.56	0.35	0.26	1.45	0.93	0.36	0.009	0.22	3.73	0.13
	Average *Povprečje*	18.82	52.59	5.33	0.36	0.25	1.82	0.94	0.38	0.004	0.12	3.71	0.08
Degraded *Prizadeti*	4	11.87	51.97	3.79	0.26	0.28	1.32	0.60	0.38	0.001	0.05	2.48	0.04
	5	11.78	52.26	4.23	0.28	0.30	1.13	0.92	0.35	0.002	0.06	2.60	0.23
	6	6.66	52.51	2.04	0.14	0.17	0.68	0.49	0.19	0.001	0.03	1.56	0.02
	7	10.68	52.36	3.44	0.23	0.25	1.24	0.62	0.31	0.002	0.06	2.19	0.06
	Average *Povprečje*	10.25	52.28	3.35	0.23	0.25	1.09	0.67	0.31	0.002	0.05	2.23	0.04

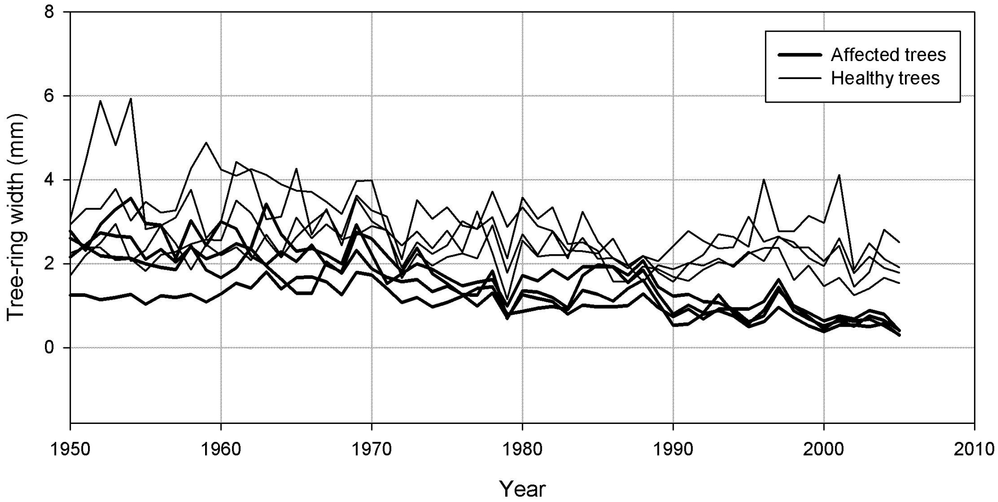

Fig. 4: Sequences of TRW for vital and degraded trees for the 1950-2005 period. There is a clear difference between the two groups from 1988 on.

Slika 4: Širine branik za vitalna in prizadeta drevesa v obdobju 1950-2005. Očitna je razlika med obema skupinama po letu 1988.

Significant years (SY) are a non-specific response to unfavourable growth conditions and biotic factors, including anthropogenic ones. Based on TRW from 1900-2006, 9 negative SY (1904, 1916, 1933, 1939, 1948, 1972, 1979, 1988 in 2002) and 7 positive (SY) were determined (1907, 1931, 1940, 1946, 1969, 1978 in 1997). The year 1997 was significant only for the group of declining trees.

DISCUSSION
RAZPRAVA

Measurements of pre-dawn water xylem potential in oaks in northern Serbia did not confirm a stress stage owing to the reduced water status in either group of trees. However, differences between vital and degraded groups were highly significant, which was also confirmed by the dendrochronologies of the same groups. Dreyer et al. (1990) proved that pedunculate oak adapted well to flooding, so that net assimilation and stomatal conductivity did not significantly differ from controls under conditions of a sufficient supply of water, while other oak species indicated a significant drop of the parameters (Dreyer et al. 1990). Changes in hydraulic conductivity occur even below -1.5 MPa (Tribolout et al. 1996, Vivin et al. 1996). Stomatal conductance decreased at PWP values of -1.5 MPa to only 10% of control values (Triboulot et al. 1996, Vivin et al, 1996). In Slovenia, a lowering of the groundwater table affected the water supply in oaks: significant reduction in stomatal conductivity (below 100 mmol/m^2s) appeared in the more damaged forest complex (Murska šuma) when PWP was lower than -1.0 MPa, whereas in Krakovski gozd, which is better supplied with water, reduction occurred when PWP was below -1.2 MPa. Complete closure of stomata was caused by PWP below -1.80 and -1.95 MPa (F=5.95 p= 0.024*), respectively (Čater 2002, Čater and Batič 2006).

Radial growth of northern Serbian oaks decreased over the 1950-2005 period, with 9 negative and 7 positive significant years; increment responses until 1980 are characterized by a rapid reduction of increment and a return to the stage prior to 1-3 years. Increment oscillations in younger oak stands may well be connected with defoliation insects (Bobinac and Andrašev 2001, 2001a). In 1979, a significant drop of increment was evident in both groups, while after 1988 there was a progressively increased reaction in both groups. Comparison with the Slovenian less favourable site in relation to water supply (Murska šuma) showed a significant drop in increment after 1974 and a severe reduction from 1980 on, when the trees no longer responded to environmental changes, while in Krakovski gozd, with better water conditions, the situation began to worsen six years later, after 1986 (Čater and Levanič 2004) (Fig. 5).

Loss of vitality in terms of absolute age evidently started in the case of Serbian oaks after 90-108 years, in Murska šuma after 70 years, and in Krakovski gozd after 100 years.

The higher values of foliar nitrogen in Serbia compared to similar sites in Slovenia may be connected with more intensive agricultural land use and, consequently, faster turnover. The different vitality status and variable nutrient content may also be due to disturbances in the functioning of the root sy-

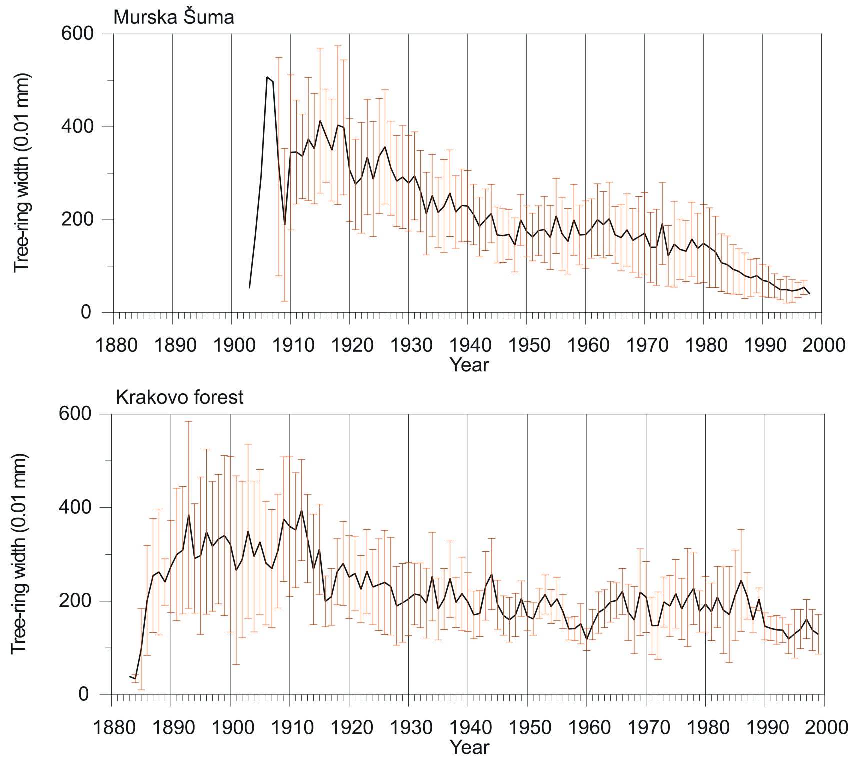

Fig. 5: TRW variability for Murska šuma and Krakovski gozd, Slovenia. Bars represent standard deviations, and the black line the average value for the tree-ring width. Variability in the juvenile period (first 20-30 years) is higher than in the adult period due to competition, thinning and elimination of trees.

Slika 5: Variabilnost debelinskega prirastka za Mursko šumo in Krakovski gozd (Slovenija). Odmiki ponazarjajo standarden odklon, osrednja linija pa povprečne vrednosti širin branik. Variabilnost v juvenilnem obdobju (prvih 20-30 let) je večja kot v odraslem obdobju zaradi redčenj in vse manjšega števila dreves.

stems and impaired uptake ability. Comparisons and studies of geomorphological, pedological and hydrological parameters in relation to decline in oaks in other countries have not confirmed any significant connections; there was only a parallel between dieback, crown diameter and the social status of trees in the stand. Trees with developed crowns and larger breast diameter were least affected. In a thinned forest stand, the proportion of affected and non-vital trees was much higher (Marcu 1987, Harapin and Androić 1996).

In spite of a favourable nutrient status, the differences between vital and declining oaks under sufficient water conditions were statistically significant in terms of water supply. Furthermore, the response of declining trees within a group did not indicate any differences in PWP, so trees responded uniformly. The same response was confirmed by dendrochronological analysis and by the period from which the response of vital and non-vital trees separated progressively. For the northern Serbian area, this period began in 1980, also characterized by massive dieback elsewhere in Europe. The last wave, beginning in 1984, differed from others in terms of extent and intensity and also coincided with a decrease in radial increment measured in this study.

On the basis of the crown defoliation status and radial increment, the group of vital oaks may still be considered to be capable of responding to environmental conditions, while the degraded group, based on the similarity of increment and other measured parameters, can no longer respond. Their questionable status was also confirmed by PWP values and the fact that groundwater table was within the optimal range during measurements. It is worth considering whether the damaged trees should be removed from the stand before complete dieback sets in. The present status is alarming, since research was performed on an optimal site for oaks, where rapid physiological weakening is still in progress. The results of annual crown defoliation assessment confirm the present situation (Čater et al.1999, Čater 2003, Levanič and Čater 2007).

There is probably no single factor causing the decline of oaks. The complexity of interactions among factors is specific to the environment. Not only the altered water regime and changed water table, but also emissions and management errors play an important role. Physiologically weakened trees become susceptible to many secondary, biotic factors, which would not be fatal in other circumstances. In contrast to the recovery of some other tree species, oaks have not improved in health, and decline is even increasing at highly productive sites (Čater 2002). The future management perspective of pedunculate oak in particular therefore remains an unanswered question. It is far from clear whether the efforts of forest managers can significantly mitigate the effects of climate change, although they can contribute to conservation, stability and diversity of endangered lowland forests and preserve the habitats of numerous species in agricultural steppe regions.

SUMMARY

In the present study, differences in water status, nutrients and radial increment of adult pedunculate oak trees were compared between healthy and declining oaks at a highly productive site in Northern Serbia. The results were compared with conditions in Slovenian pedunculate oak forests.

Analysis confirmed differences in PWP values measured between vital and non-vital pedunculate oaks. The values in the group of degraded oaks were lower, more negative compared to the vital group, for which significant differences within the group were also confirmed. This means that the response of the degraded trees was uniform, without confirmed differences, while in the vital trees an individual response of trees was still evident.

According to the critical values of nutrient content, the status of oak trees in northern Serbia is in the optimal range; the difference between vital and degraded trees is evident in macronutrients N, S, P, K, Ca and Mg, which were higher in vital trees.

Tree ring analyses for the 1950-2005 period showed a similar pattern of growth in both groups of trees until 1950. After this, differences between the two groups increased over time. The increment of degraded trees was significantly reduced and never reached the value of vital ones. From 1988 on, the differences between the groups were even greater; the last positive response in declining trees was in 1996, and thereafter the increment of the two groups became progressively different.

In spite of a favourable nutrient status, the differences between vital and declining oaks under sufficient water conditions were statistically significant in terms of water supply. Furthermore, the response of declining trees within a group did not indicate any differences in PWP, so trees responded uniformly. The same response was confirmed by dendrochronological analysis and by the period from which the response of vital and non-vital trees progressively separated. For the northern Serbian area, this period began in 1980, which is also characterized by massive dieback elsewhere in Europe. The last wave, beginning in 1984, differed from others in terms of extent and intensity and also coincided with a decrease in radial increment measured in this study.

The present status is alarming, since research was performed on an optimal site for oaks, where rapid physiological weakening is still in progress. The results of annual crown defoliation assessment confirm the present situation. In contrast to the recovery of some other tree species, oaks have not improved in health, and decline is even increasing at highly productive sites. The future management perspective of pedunculate oak in particular therefore remains an unanswered question.

POVZETEK

Med pričujočo študijo so avtorji primerjali razlike v vrednostih jutranjega vodnega potenciala (PWP), stanja hranil in debelinskega prirastka odraslih dobov med zdravimi in prizadetimi drevesi na visoko produktivnem rastišču v severni Srbiji, nato pa rezultate primerjali z razmerami na izbranih rastiščih doba v Sloveniji.

Analize so potrdile razlike v vrednostih PWP med vitalnimi in prizadetimi dobi. Izmerjene vrednosti v skupini prizadetih dobov so bile nižje, bolj negativne v primerjavi z vitalno skupino dreves, za katero pa so bile potrjene tudi pomembne razlike znotraj skupine same. To pomeni, da je bil odziv degradiranih dreves enoten, brez potrjenih razlik, medtem ko je bil v vitalnih dobih posamezen odziv dreves še vedno očiten.

Glede na kritične vrednosti vsebnosti hranil je stanje hrastovih dreves v severni Srbiji optimalno; razlika med vitalnimi in degradiranimi drevesi je očitna v makrohranilih N, S, P, K, Ca in Mg, ki so bila višja v vitalnih drevesih.

Analiza branik za obdobje 1950-2005 je razkrila podoben vzorec rasti pri obeh skupinah do leta 1950. Po tem letu pa se razlike med skupinama sčasoma začnejo večati. Prirastek prizadetih dreves se je občutno zmanjšal in nikoli ni dosegel vrednosti vitalnih dobov. Po letu 1988 pa so se razlike med skupinama celo povečale; zadnji pozitivni odziv prizadetih dreves je bil zabeležen leta, od tedaj dalje pa je prirastek obeh skupin postajal čedalje bolj različen.

Kljub ugodnemu stanju hranil so bile razlike med vitalnimi in prizadetimi dobi pod zadostnimi vodnimi pogoji statistično pomembne, kar zadeva preskrbo dreves z vodo. Poleg tega pa odziv prizadetih dreves znotraj skupine ni pokazal

nobenih razlik v PWP, kar pomeni, da so se drevesa odzvala enotno. Enak odziv sta potrdila dendokronološka analiza in obdobje, po katerem se je odziv vitalnih in nevitalnih dreves začel progresivno razlikovati. Za severno Srbijo se je to obdobje začelo leta 1984, ki ga označuje tudi množično odmiranje dreves drugod po Evropi. Zadnji val, ki se je začel leta 1984, se je razlikoval od drugih po obsegu in intenzivnosti, a se je hkrati tudi ujemal z upadanjem debelinskega prirastka, zabeleženim med to študijo.

Današnje stanje je alarmantno, saj je bila raziskava opravljena na rastišču, optimalnem za dob, kjer se naglo fiziološko slabljenje še vedno nadaljuje. Rezultati ocene letne osutosti krošenj potrjujejo današnje stanje. V nasprotju z okrevanjem nekaterih drugih drevesnih vrst se zdravstveno stanje doba ni izboljšalo, ta trend pa je zaznati celo na visoko produktivnih rastiščih. Na vprašanje, kako bomo upravljali z dobom v prihodnosti, v tem trenutku zatorej še nimamo odgovora.

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