B. Prpić: The role of climate and hydraulic operations in the stability of the pedunculate oak (*Quercus robur* L.) stands in Croatia. Glas. šum. pokuse 37: 229–239, Zagreb, 2000.

UDK 630*181+181.3+111+908 (Quercus robur L.)

THE ROLE OF CLIMATE AND HYDRAULIC OPERATIONS IN THE STABILITY OF THE PEDUNCULATE OAK (*QUERCUS ROBUR* L.) STANDS IN CROATIA

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In around 200,000 ha of lowland forests in the river valleys of Croatia, in variously moist habitats, the peduncled oak, in bigger or smaller proportions, composes forest ecosystems with other plant and animal species. Differing as to the component plant species, mainly hygrophytes, these ecosystems have in common a considerable proportion of peduncled oak.

Water is a direct ecological factor in the growth of peduncled oak. Either below the minimum, or above the maximum, it will cause the physiological weakening of the tree, frequently even its dieback. Among the lowland forest trees, the peduncled oak belongs to a very susceptible species. Today in Croatia, about 30% of all peduncled oak trees are endangered, and will die before reaching their commercial maturity.

While it successfully survives climatic excesses including drought and very humid seasons, hydraulic operations that disturb the forest areas cause its dieback in all forest ecosystems.

Key words: lowland forests of the peduncled oak, climatic excesses, hydraulic operations, changes in water regime, peduncled oak, dieback.

INTRODUCTION

The peduncled oak belongs today to the most endangered tree species in Croatia. According to the IPC Forests method, in 1988 there were 28.5% damaged trees of the species (over 25% crown damage). Since 1980, over 600,000 m^3 of peduncled oak trees have died in the lowland forests of Pokuplje, Posavina and Podravina.

This paper will offer evidence proving that anthropogenic impacts originating from the changes in the water regimes due to hydraulic or other operations in the areas of lowland forest habitats have been the major reasons for the dieback of the peduncled oak. This primarily refers to the water steps at the hydroelectric plants on the River Drava; exhaust canal dams and barriers in former natural retentions for high water protection; forest roads without drainage; deep trenches along drained agricultural areas, etc.

All these impacts change the water regimes of the forest habitats, causing either their swamping or drying, depending on the character of the operation. Deep trenches decrease the groundwater level, while hydroelectric plant accumulations turn forests into swamps. The impact of hydraulic operations depends on the microrelief, geological and pedological circumstances, and the network of natural and artificial streams in the area.

Frequent changes in the water regime caused by the infrastructure, particularly in the second half of the century, endangered the peduncled oak and other tree species through the change of the "chemical climate", while the lowland ecosystems have been under the impact of polluted waters.

At least 4 million cubic metres of trees have died since the first records of oak dieback were made in Croatia in 1909.

Climatic changes and excesses, natural changes in the river levels, phenomena causing considerable, though temporary, falls or rises in groundwater levels, together with forest tree pests and diseases, belong to the adverse factors that can be controlled. These adverse factors did not prevent the peduncled oak forests from developing normally and retaining their stability for centuries.

Man's interference in these areas in the twentieth century with the change in the "chemical climate", i.e. the activities that can be controlled, have caused higher or lesser degrees of dieback of peduncled oak and almost all other tree species. However, knowing how resistant the peduncled oak is toward the input of harmful gases, we conclude that the change of the water regime in its habitats is a major cause of its dieback.

THE EFFECTS OF FIELD ELM DIEBACK UPON THE MICROCLIMATE

The dieback of field elm in the area of Croatian lowland forests from 1930 until 1960 ended with its near extinction. The largest proportion of lowland elm was in the Slavonian peduncled oak forest (*Genisto elatae-Quercetum roboris*) where it composed the lower tree layer with such types as the hornbeam in the forest of peduncled oak and common hornbeam (*Carpino betuli-Quercetum roboris)*. The two had similar microclimates. The loss of the field elm caused the warming up of the Slavonian peduncled oak forests.

The mean maximum summer air temperature in the Slavonian forest before the elm dieback was 4 degrees C lower than in the field. With elm dieback, the difference decreased by 2 degrees (Prpić, 1975). The gradual development of the brush layer following the extinction of the elm with the formation of the canopy helped the habitat to recover, a process which lasted between 10 and 15 years, depending on the number and distribution of the dead elms in the stand. If other adverse ecological factors appear, e.g. diseases and pests, climatic excesses, or hydraulic groundwater-lowering and habitat-swamping operations, the result might be the dieback of peduncled oak.

By entirely retaining the natural relations in forest tree proportions with the hornbeam as the lower tree layer controlling the specific forest climate, peduncled oak with common hornbeam has proved to be a much more resistant ecosystem.

MICROCLIMATE CHANGES

According to Vajda 1983, in the early 20th century the climate changed in terms of frequent dry springs and summers with high air temperatures and more than average humid, cold periods. However, climate cannot be the main reason for the dieback of peduncled oak, since this species has been in these regions for thousands of years and has been well adapted to natural climatic changes.

Climatic deviations from the average, mainly in the series of dry seasons in the second half of the 20th century, have had an adverse impact on the peduncled oak, in particular when accompanied by another unfavorable ecological factor, e.g. pests or hydraulic operations changing the water regimes in the habitat, in most cases ending up with dieback of the oak at a higher or lesser intensity. If there is no additional adversity, one humid season that follows is sufficient for its recovery.

HYDRAULIC OPERATIONS IN THE LOWLAND FOREST AREA AND THEIR IMPACT ON THE PEDUNCLED OAK

The first hydraulic operation in Posavina took place in the 1930s when dams along the Sava banks were built for the protection of villages against flood, changing the rhythm of floods in the lowland forest of Spačva. The consequence was considerable dieback of peduncled oak in Spačva.

Further large-scale dieback occurred in Posavina, Pokuplje and Podravina in the following chronological order:

1. Following the disastrous flood in the city of Zagreb in 1964, water was directed to the cassette-shaped peduncled oak forests (drainless roads were built through the cuts in the square-formed sections), resulting in massive oak dieback due to the swamping of all forest ecosystems (anaerobiosis).
2. The enclosing of the Bosnian Dubica valley by dams along the rivers Sunja and Dubica in Ribasko Polje resulted in the dieback of the field ash and peduncled oak in 1966.

3. The building of the Zagreb-Karlovac road in 1972 and the Kupa-Kupa canal were reasons for swamping and a fall in the groundwater level, both resulting in considerable oak dieback in the region.
4. The disastrous oak dieback in the Kalje forest in 1984 and 1985 was caused by the flooding of the River Odra during the vegetation season, and by the fall of the groundwater level, both due to cassette-shaping operations in the area.
5. Considerable oak dieback started in 1986 in the forest of Turopoljski Lug due to the building of the outlet channel Sava-Odra, which resulted in a fall in the groundwater level. The process has continued until today.
6. Three power plants are being built on the River Drava - Varaždin, Čakovec, and Dubrava - causing the dieback of oak and other lowland forest trees due to the swamping of the areas along the accumulations and also as a result of a fall in the groundwater levels along the outlet canals. This has lasted from 1968 until today.
7. The peduncled oak was dying from 1987 until 1995 in the Repaš forest, caused by drought and a general fall in the Drava level and, consequently, by a fall in groundwater levels.

SOME OF THE RESEARCH ON THE CAUSES OF PEDUNCLED OAK DIEBACK IN CROATIA

In 1984 Klepac conducted research on the peduncled oak increment in the Lipovljani forests between 1950 and 1981. He considered the increment measured in the period 1950-1955 as normal and compared it with that of the following periods. For the period 1962-1967, he calculated a fall by 45%; 1968-1971 by 27%; 1972-1977 by 25%; 1978-1981 by 40%. Klepac points out that the oak did not show any loss of vitality in spite of the considerable fall in increment which he associated with the dry periods and absence of the regular annual floods of the River Sava.

In her dendrochronological research in 1996, Pranjić suggests that the diameter increment is the major indicator of habitat changes, hinting that all habitat factors are cumulatively registered in diameter increments. She illustrates this with research on the diameter increment in the Slavonian forest of pedunculate oak and great greenweed (*Genisto elatae-Quercetum roboris* Ht. 1938), where a powerful and short adverse impact was connected with the extremely dry season of 1983. Team research on the disastrous oak dieback in the Kalje forest (Prpić et al. 1994) revealed that the cause was an extremely dry season, a summer flood in the cassette-shaped forest area with polluted water and a fall in the groundwater level (see diagram 1).

Big hydraulic operations in the region of Kupčinske Šume connected with the building of the Zagreb-Karlovac road and the outlet canal Kupa-Kupa caused, ac-

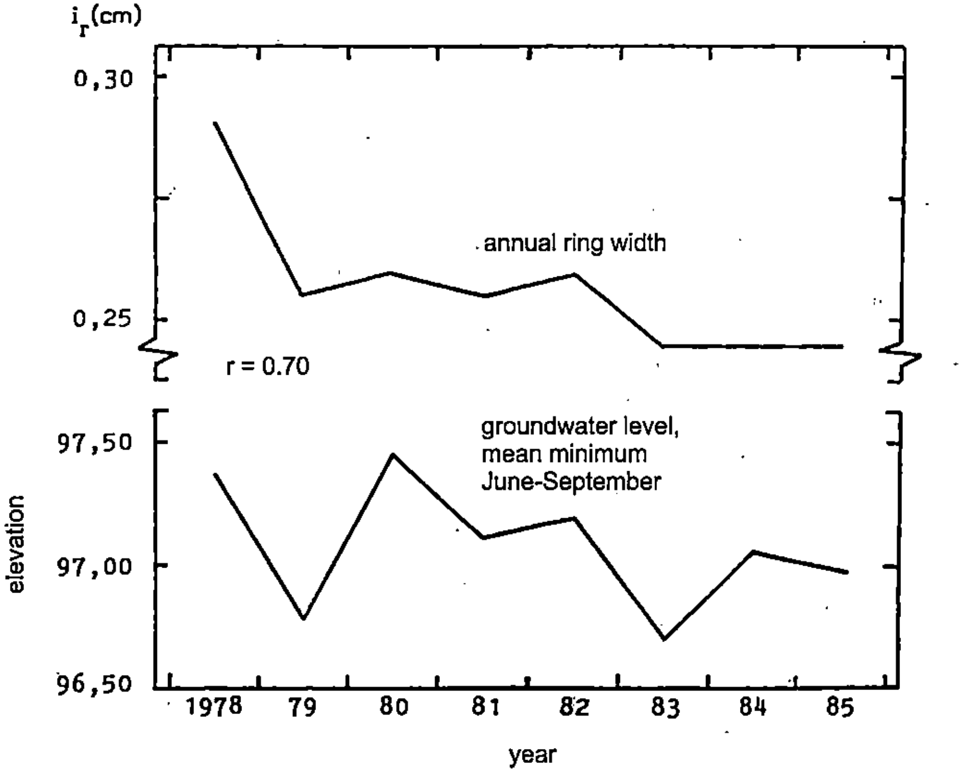

Diagram 1. The dependence of the radial increment of the peduncled oak upon the minimum groundwater level in the Kalje forest

cording to Mayer 1996, an expansion of oak dieback and the conquest of drier forest associations. The author established that the high groundwater levels advanced the increment of the peduncled oak forests.

According to Mayer 1998, following the construction of the hydroelectric power plant Varaždin on the River Drava in the area of the outlet canals, there was a fall of 1.5 to 2m in the groundwater levels in the pebbled water tank, together with flood reduction. Over large areas, groundwater became inaccessible for the roots of the flood plain forests. The trees dried, and later afforestation of these areas had no success.

Based on extensive research, Mayer concluded that in the drained forests of northwest Croatia the peduncled oak on pseudogley and eugley soils directly depended on the quantity and distribution of rainfall, since the groundwater became unreachable for the roots of the middle-aged and old stands of the lowland peduncled oak forests.

The research of Prpić 1984 and 1994 referring to the swamping of the peduncled oak habitats in the forests of Kupčine and in the Kalje forest suggests that young oak dieback took place after the artificially provoked flood during the vegetation period; the diameter increment of the peduncled oak trees also decreased in the artificially flooded stand. The content of carbon dioxide in the accumulation horizon of the soil was measured, as it becomes toxic when its values go above 50 mg/l.

Ivkov 1994 established a considerable connection between the diameter increment of the peduncled oak and the physiologically active soil moisture in the Repaš forest (diagram 2).

Prpić 1986 proved that the groundwater in the Repaš forest and the water levels of the river Drava are closely connected, and that the changes in the water regimes following the construction of the hydroelectric power plant Đurđevac were disastrous for the forest (diagram 3).

The team research on the Repaš forest (Prpić et al. 1987) revealed that the middle-aged, old and very old peduncled oak trees prolong their roots geotropically positively to the groundwater which, due to the riverbed erosion, drops yearly by 2-3 cm. This fact points to the possibility of the adaptation of the grown oaks to small falls in groundwater levels, which they need during dry summer months for transpiration and photosynthesis (Fig. 1).

According to Matić et al. 1998, the middle-aged, old and very old peduncled oak stands with decreased levels of groundwater are submitted to a less intensive dieback process. The stands with an increased level and duration of retention surface waters, i.e. in the case of swamping, die quickly.

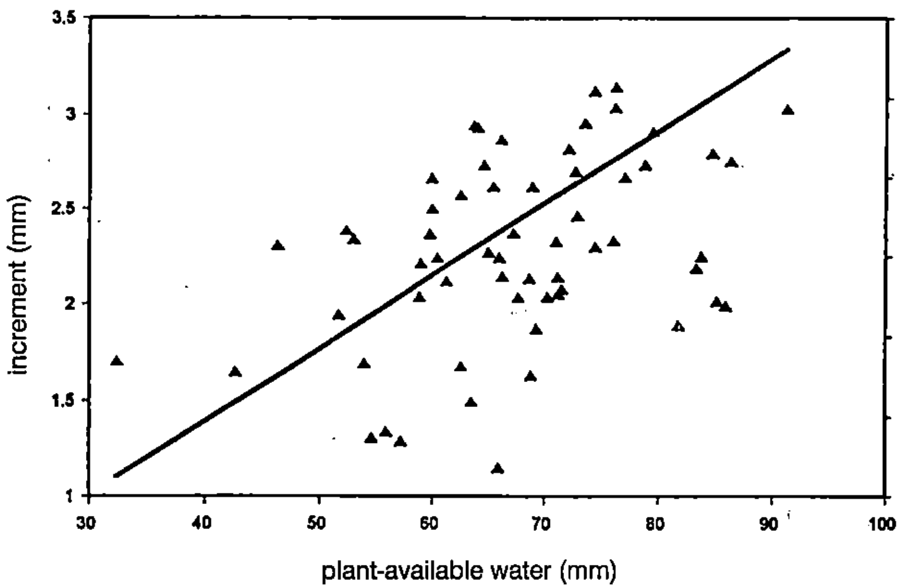

Diagram 2. Relationship between plant-available water in soil and peduncled oak radial increment in the Repaš forest (Ivkov 1994)

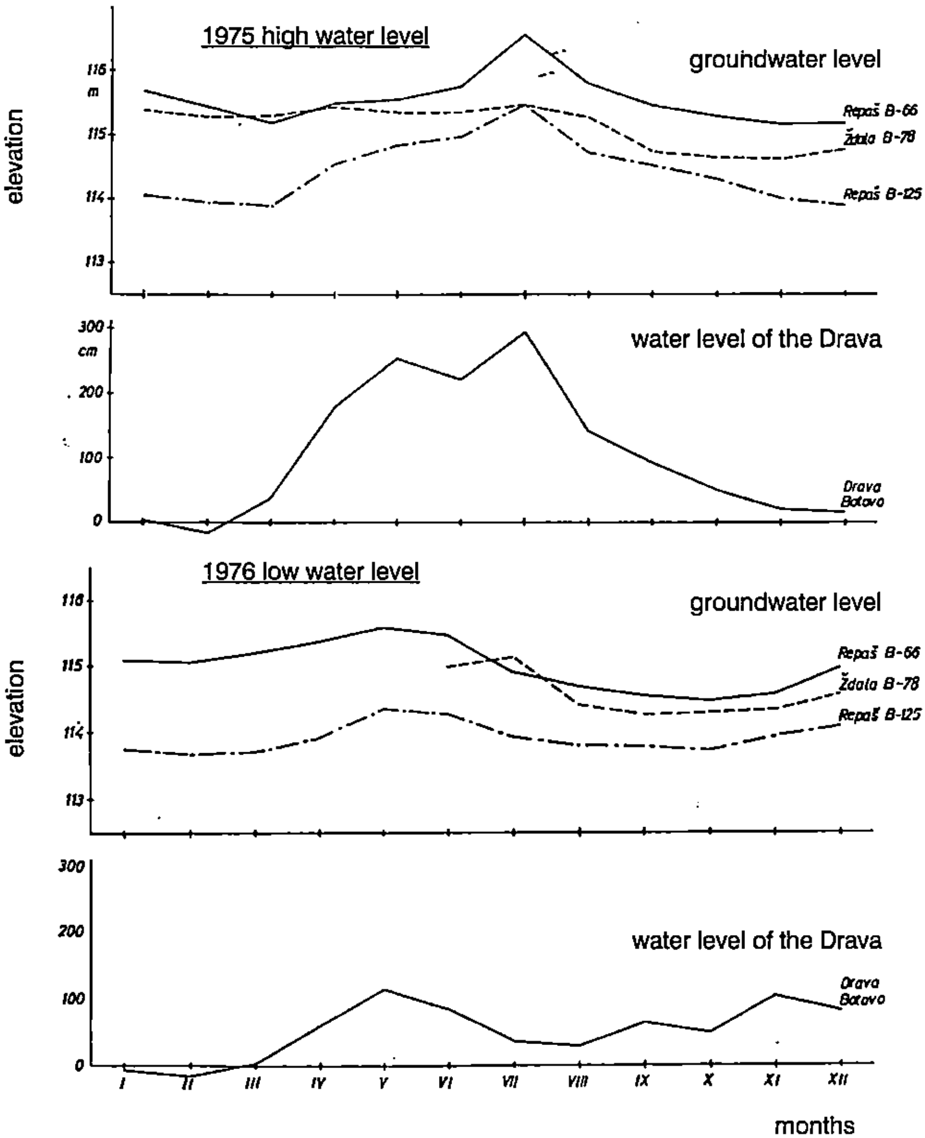

Diagram 3. Groundwater level in the Repaš forest and the water level of the river Drava at Botovo

Vukelić and Baričević 1998 completed their research on forest association successions in the areas of peduncled oak dieback in Croatia, showing the long duration of the positive succession and massive dieback of peduncled oak in the forest of Žutica.

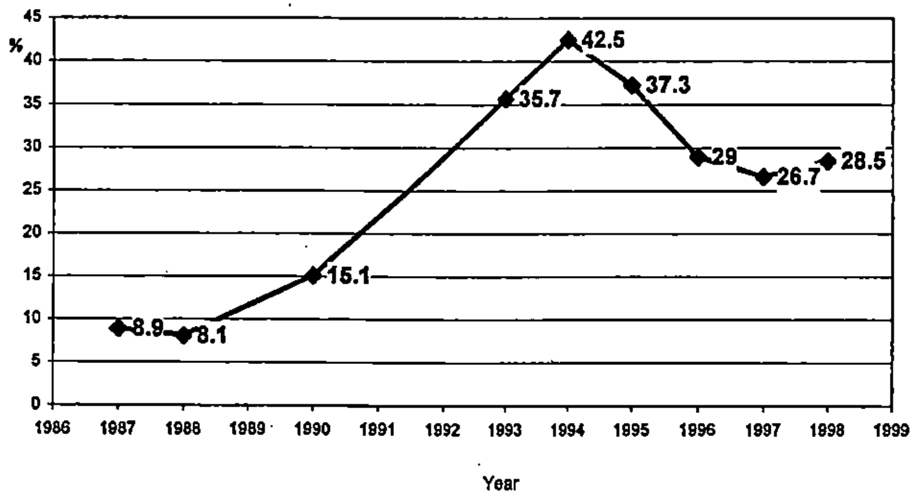

Diagram 4. The percentage of moderately to severly damaged peduncled oak trees in Croatia (Potočić-Seletković 2000)

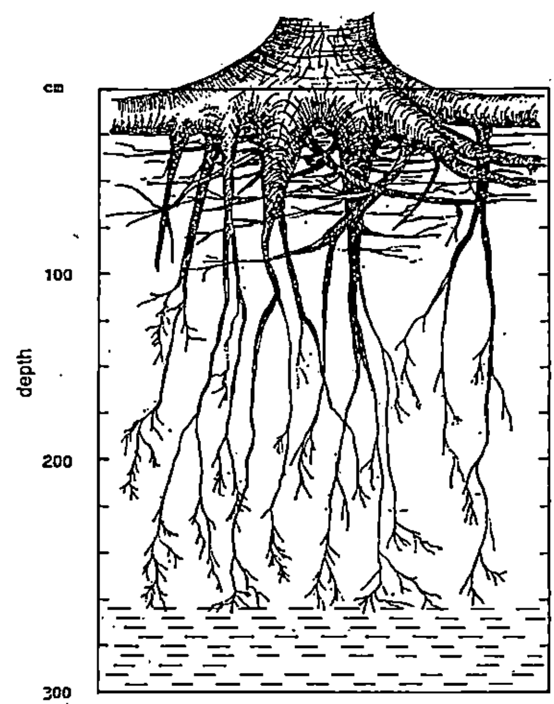

Figure 1. Root system of the peduncled oak in semigley in the peduncled oak and common hornbeam forest in the Repaš forest. The depth of rooting compared to the summer groundwater level.

Finally, there is a graphical presentation of the peduncled oak dieback situation according to Potočić and Seletković 2000, showing a relatively high percentage of considerably endangered trees after the IPC Forests method, as well as the response of the peduncled oak to the favorable climatic conditions of 1994.

CONCLUSIONS

Hydraulic operations causing habitat changes in the lowland forests of the peduncled oak lead to the physiological weakening of the species and various degrees of its dieback.

Natural climatic changes do not cause peduncled oak dieback, as the tree is adaptable to climatic excesses. If, however, these climatic excesses are linked with adverse natural biological impacts (pests and diseases), or with anthropogenic adversities (hydraulic operations; air/water/soil pollution), the peduncled oak and other lowland forest trees will die.

Any hydraulic engineering interference in the forest areas of the river valleys should be carried out so that it does not cause any changes in the water regimes within the lowland forest habitats.

A lowland forest should be considered in view of its general benefits, environmental protection, and its biological diversity - the values that must be considered in an analysis of the costs and benefits of investments and forests.

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UTJECAJ KLIME I HIDROTEHNIČKIH ZAHVATA NA STABILNOST HRASTA LUŽNJAKA (*Quercus robur* L.) U HRVATSKOJ

Hrast lužnjak, zajedno s ostalim biljnim i životinjskim vrstama, u manjem ili većem obujmu tvori šumske ekosustave na oko 200 000 ha nizinskih šuma u riječnim dolinama Hrvatske na staništima različite vlažnosti. Ti se ekosustavi razlikuju po sastavnim biljnim vrstama, uglavnom higrofitima, ali ono što im je zajedničko jest značajan udio hrasta lužnjaka.

Voda je izravan ekološki čimbenik koji utječe na rast hrasta lužnjaka. Ako je voda ispod minimuma ili iznad maksimuma, hrast lužnjak fiziološki slabi, a često se i suši. Među nizinskim šumskim vrstama hrast lužnjak pripada u vrlo osjetljive vrste. Danas je u Hrvatskoj oko 30 % svih hrastova lužnjaka ugroženo i oni će se osušiti prije nego što dosegnu svoju komercijalnu zrelost.

Premda ova vrsta uspješno podnosi klimatske ekscese, na primjer sušne i mokre godine, hidrotehnički zahvati koji ometaju šumske površine uzrokuju sušenje hrasta u svim šumskim ekosustavima.

Ključne riječi: nizinske šume hrasta lužnjaka, klimatski ekscesi, hidrotehnički zahvati, promjene u vodnom režimu, hrast lužnjak, sušenje