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# OAK FORESTS (*Quercus* sp.) IN CROATIA

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This paper describes all oaks that occur naturally and form natural forest communities in Croatia. These are pedunculate oak (*Quercus robur* L.), sessile oak (*Quercus petraea* /Matt./ Liebl.), pubescent oak (*Quercus pubescens* Willd.), live oak (*Quercus virginiana* Ten.), Turkey oak (*Quercus cerris* L.), holm oak (*Quercus ilex* L.), Hungarian oak (*Quercus frainetto* Ten.), and kermes oak (*Quercus coccifera* L.). The most important associations where they occur are described, as well as their principal forest-silvicultural characteristics, area, growing stock, increment, and silvicultural treatments of tending and regeneration. It is emphasised that oak as a species has had a significant effect on Croatian forestry, and that its importance goes beyond the framework of forestry and penetrates all areas of life and customs of the people in Croatia.

Key words: oak, pedunculate oak, sessile oak, pubescent oak, live oak, Turkey oak, holm oak, Hungarian oak, kermes oak

## INTRODUCTION

The Republic of Croatia extends over two important vegetative-geographical regions: the Mediterranean and the Euro-Siberian-Northern-American one. Its flora is characterised by a vast diversity of species that include plant representatives ranging from sub-tropical to alpine species. The large number of relict and endemic species and families is the result of the historical development of the plant world and of geological and climatic changes from the Tertiary period up to now. Numerous diverse floral elements, the abundance of relicts and the wealth of endemic species make Croatia a very interesting country in the European framework.

Approximately 4,500 plant species and subspecies have found home in a relatively small area due to Croatia's geographical position and highly diverse synecological conditions. About 50% of them are distributed in the area of forests and their degraded forms (scrub, thickets, maquis and garrigues). Of the total number, there are about 260 autochthonous forest woody species, some sixty of which are interesting from forest-management standpoints (Rauš *et al.* 1992).

Oak forests cover about 30% or 615,000 ha of overall forested area in Croatia (2,078,289 ha) with a growing stock of 89,000,000 or 27.4% of the total growing stock (324,256,000 $m^3$). The increment is 2,400,000 $m^3$ annually or 25% of the total annual increment (9,600,000 $m^3$).

The forests of Croatia contain eight oak species, of which five form autochthonous, coherent, climatogenous forest associations providing important economic and social functions. The remaining three species occur individually or in small, locally-formed forest communities. Their economic function is less significant than their social function and is mainly reflected in the fact that they enhance the biological diversity and stability of the forests in which they occur.

The first group comprises the following oaks: pedunculate oak (*Quercus robur* L.), sessile oak (*Quercus petraea* /Matt./ Liebl.), pubescent oak (*Quercus pubescens* Willd.), live oak (*Quercus virginiana* Ten.) and holm oak (*Quercus ilex* L.).

The second group includes Turkey oak (*Quercus cerris* L.), Hungarian oak (*Quercus fraineto* Ten.) and kermes oak (*Quercus coccifera* L.).

With regard to the fact that oak forests account for 30% of all forests in Croatia, it is important to point out that they occur both in the Mediterranean region and in the Euro-Siberian - Northern-American forest region (European sub-region).

The littoral vegetation belt of the Mediterranean region features holm and kermes oak, which occur in the steno-Mediterranean and eu-Mediterranean vegetation zone. Pubescent oak, live oak, Turkey oak and Hungarian oak occur in the sub-Mediterranean vegetation belt of the same region.

Pubescent, live and Turkey oak occur in the Mediterranean-hilly vegetation belt of the Mediterranean region 400 m above sea level on the islands, 300 m in the Northern Adriatic and 600 m in the southern part.

Depending on ecological and climatic factors in particular, there are lowland areas, low hills, highlands and pre-Alpine belts in the European sub-region of the Euro-Siberian - Northern-American area. Each of these contains several vegetation zones, which contributes to the wealth of forest vegetation in Croatia. Oaks occur in the lowland, hilly and highland areas.

Pedunculate and Turkey oak occur in the lowland vegetation belt, and sessile and Turkey oak in that of the hills and highlands.

In order to obtain a comprehensive picture of all oaks present in the forests of Croatia, each important forest-silvicultural property, that is, the biological characteristics, ecological requirements and economic value of each species will be described.

## PEDUNCULATE OAK (*Quercus robur* L.)

Pedunculate oak is the most valuable and best-known economic tree species in Croatian forestry. Thanks to its mechanical, aesthetic and applicable characteristics, it is renowned and valued on all European timber markets. It is most widely

distributed in floodplain regions along the rivers Sava, Drava, Danube, Kupa and their tributaries, where, under the name of *Slavonian oak*, it forms forest associations with narrow-leaved ash, lowland elm, common hornbeam and other tree species. Floodplain forests of pedunculate oak, as well as forests on micro-elevations mixed with common hornbeam and numerous other tree species, are characterised by biological diversity, significant productivity and stability.

Pedunculate oak in Croatia covers 10% of the total forested area, or 210,000 ha, with a growing stock of 14% or 44,400,000 m³ of the total growing stock, and an annual increment of 11% or 1,050,000 m³ of the total increment.

Flood and groundwater are the main ecological factors determining the survival and growth of pedunculate oak forests in Croatia. Each disturbance in flood dynamics and groundwater levels causes physiological weakening of especially older and old pedunculate oak stands, allows secondary pest attacks and leads to dieback and degradation.

Forests of pedunculate oak appear in two basic forest associations: those of the floodplain forest of pedunculate oak and *Genisto elata* (*Genisto elatae-Quercetum roboris* Ht. 1938) and the forest of pedunculate oak and common hornbeam (*Carpino betuli-Quercutum roboris* (Anić 1959) emend. Rauš 1969), which grows on micro-elevations. Pedunculate oak is characterised by within-population flushing variability; as a result, there is an early form "*praecox*" and a late form "*tardissima*" (*Quercus robur* var. *tardissima* Sim.). The time difference in the flushing between the early and late oak is about 2-5 weeks.

Forests of pedunculate oak in Croatia form large coherent complexes, such as Spačva (40,000 ha), Lonjsko Polje (30,000 ha), Repaš (5,000 ha), and forest basins in the area of Česma, Donji Miholjac, Našice, Slatina and others.

Pedunculate oak forests are regenerated naturally and sometimes artificially with shelterwood felling in three or two separate cuts (preparatory, seeding and final cut). Tending often begins before the final cut (young growth is tended under the canopy of old trees), and finishes with the last thinning prior to the beginning of the preparatory cut. During tending, all attention is focused on pedunculate oak as the most valuable but silviculturally weakest species in relation to its principal competitors, common hornbeam, narrow-leaved ash, lowland elm and other accompanying pioneer tree species.

## SESSILE OAK (*Quercus petraea* Liebl.)

Sessile oak and pedunculate oak are extremely important tree species in Croatian forestry from both economic and social standpoints. In terms of mechanical and aesthetic properties, the value and quality of sessile oakwood is very close to that of Slavonian pedunculate oak.

Forests of sessile oak in Croatia cover the hilly vegetation belt between 150 - 500 m above sea level and the highland vegetation belt up to 700 or 900 m above

sea level, depending on the position and macroclimate of the massifs. Sessile oak forests contain a large number of other tree species and shrubs, which makes them biologically diverse and stable.

In Croatia, sessile oak is distributed over 11% or 230,000 ha of the total forested area, with a growing stock of 10% or 32,000,000 m³ and an increment of 1,000,000 m³ or 10% of the total increment.

Sessile oak is a climatogenous tree species forming five different forest communities in the Central-European vegetation zone of acidophilic forests, one forest community in the Central-European zone of thermophilic forests and two communities in the peri-Illyrian vegetation zone.

Of all sessile oak communities in Croatia, special mention should be made of the widely distributed climatic-zonal association of outstanding value - the Illyrian forest of sessile oak and common hornbeam (*Epimedio-Carpinetum betuli* Ht. 1938, Borh. 1963). This forest is characterised by rich floral composition and species that more or less mark the Illyrian floral element. This association grows on acid, loamy and sandy soils poor with lime, as well as on carbonate substrates and eutric soils.

This sessile oak association has high economic and social importance, but is endangered by anthropogenic influences. Areas of sessile oak have been taken over by human settlements, roads, vineyards and other agricultural areas. Synecological conditions of this association are much better suited to sessile oak than to beech; as a result, sessile oak is stronger and more competitive here.

Forests of sessile oak form considerable forest complexes on the hillocks and hills between the rivers Sava and Drava in the north and north-west of Croatia. Similarly, sessile oak forms forest communities in Central Croatia and on suitable positions in the mountains of the Dinaric Alps.

Regeneration of sessile oak forests is similar to that of pedunculate oak forests. Forests are regenerated with shelterwood felling in two or three cuts, depending on the state of a stand and the soil. Compared to pedunculate oak, there are fewer problems relating to natural regeneration due to the fact that changes in site conditions are less conspicuous in sessile stands than in pedunculate ones, while acorn yields are more abundant and more frequent than with the pedunculate oak.

Sessile oak forests are tended in the period of the final cut and during the whole rotation until the beginning of the preparatory or seed cut. In relation to its competitors, common hornbeam and beech, which are more aggressive and silviculturally stronger species than sessile oak, focus is laid on assisting the sessile oak at the expense of its competitors.

## PUBESCENT OAK (*Quercus pubenscens* Willd.) AND LIVE OAK (*Quercus virginiana* Ten.)

Climatozonal forests of pubescent oak and live oak occur in the sub-Mediterranean vegetation zone of thermophilic, deciduous and black pine fo-

rests. With regard to the fact that the sub-Mediterranean belt of pubescent and live oak forests is relatively high, sometimes reaching heights of 1,200 m above sea level, it is divided into warm, temperate and cold belts according to the presence of various associations.

Apart from other forest associations, the warm belt also encompasses the most widely-distributed mixed forest of pubescent oak and oriental hornbeam (*Querco-Carpinetum orientalis* H-ić 1939).

The temperate belt abounds in several associations, of which the most important is a mixed forest of pubescent oak and hop hornbeam (*Ostryo-Quercetum pubescentis* Ht, Trinajstić 1977) from the standpoint of silviculture and general benefits.

The cold belt of pubescent oak forests is inhabited by the forest of hop hornbeam with autumn rush *(Seslerio-Ostryetum* Ht. and H-ić 1950).

Live oak (*Quercus virginiana* Ten.) occurs in the sub-Mediterranean region from Knin eastwards to the Dubrovnik hinterland, and forms the forest of live oak and oriental hornbeam in the warm belt, and the forest of live oak and hop hornbeam in the temperate belt.

Live oak is more xerothermal than pubescent oak, capable of tolerating drought and heat well, and is a very resistant deciduous tree species.

Forests of pubescent oak and live oak in Croatia cover about 5% or 110,000 ha of forested area, with a growing stock of 1.3 % or 4,300,000 $m^3$ and an annual increment of 1.3 % or 130,000 $m^3$.

All the associations mentioned above occur mostly in the degraded stage of scrub and in the low silvicultural form or coppice. Only about 1,000 ha of pubescent and live oak forests are in the high silvicultural form or forest from seed. These stands are often of poor appearance due mostly to the very hard ecological conditions in which they live and to the sites of poor quality.

The main economic product of these forests is fuel wood. In its attempts to preserve these forests and transform them into a higher silvicultural form, the forestry profession is faced with the problem of goat browsing, which is otherwise banned by law. Despite this, a large share of pubescent and live oak forests is in progression. At present, they are left to spontaneous succession, which could be accelerated by providing expert forestry treatments and protection.

The tending of these forests is mostly oriented towards their protection from the negative effects of biotic and abiotic factors (people, cattle and fires). Tending in stands on good sites with favourable structural properties is geared to progressive development towards medium and high silvicultural forms.

These forests can be regenerated with natural or artificial methods with shelterwood felling in two or three cuts.

Apart from their economic importance, forests of pubescent oak and live oak provide considerable general benefits both from the ecological and social standpoints.

## TURKEY OAK (*Quercus cerris* L.)

As a species, Turkey oak appears both in sub-Mediterranean forests of pubescent oak and in continental forests of pedunculate and sessile oak. It occurs more frequently in more xerothermal site conditions where it competes with other oaks. It is less valuable than pedunculate, sessile, pubescent and live oak. However, it has a high forest-silvicultural value and importance in the structure of the forests in which it occurs as it provides biological diversity, survives the most adverse conditions, and repairs the flaws and mistakes in the structure of "parent" stands where it appears.

Its timber is not very valuable economically, at least in Croatian market conditions. It is mostly used as fuel wood, although it has value in building and in some specific products of the timber industry.

Turkey oak occurs largely in the association of pedunculate oak and common hornbeam with Turkey oak (*Carpino betuli-Quercetum roboris quercetosum cerris* Rauš 1969), which represents the most extreme variant of pedunculate-hornbeam forests (Rauš *et al.* 1992). Similarly, Turkey oak forms Hungarian-Turkey oak forests (*Quercetum frainetto-cerris* Rudski 1940, 1949), a climatogenous association that occurs in the transitional area between the steppe and the forest (Vukelić, Rauš 1998).

The growing stock of Turkey oak in the forests of Croatia is 1 % or 3,000,000 $m^3$ of total growing stock, while the annual increment amounts to 1.2 % or 120,000 $m^3$.

Silvicultural treatments in the forests in which it occurs are aimed at preserving it in smaller percentages in the interest of favoured oaks. It often yields seeds and regenerates well naturally with shelterwood felling in two or three cuts.

## HOLM OAK (*Quercus ilex* L.)

Holm oak is the most valuable and most stable species in the eu-Mediterranean forest region in Croatia. Due to centuries-long exploitation and devastation by both biotic and abiotic factors (man, cattle, fires), the areas where it occurs have decreased. Holm oak has often even disappeared from the associations it originally formed in the region. Today, it occurs mostly in the degraded form of maquis and in the low silvicultural form or coppice forest.

Its timber is highly valued in the shipbuilding industry due to good physical properties. Today, it is largely used as fuel wood.

In the eu-Mediterranean region, holm oak forms two important forest associations. The forest of holm oak with myrtle (*Myrto-Quercetum ilicis* H-ić 1956, Trinajstić 1985) is the most thermophilic forest association in which only evergreen species survive (Trinajstić 1986). The forest of holm oak and manna ash (*Fraxino orni-Quercetum ilicis* H-ić 1956, 1958) is the most widely distributed climatogenous association of the eu-Mediterranean region. It occurs in the areas from Istria

over the islands to Zadar, and then along the littoral part and the islands to Prevlaka. It grows in somewhat more favourable temperature and moisture conditions than the previously mentioned association. For this reason, it contains a large number of accompanying species of both an evergreen and deciduous nature, of which manna ash (*Fraxinus ornus* L.) is the most valuable from the forest-silvicultural standpoint.

Holm oak covers 3.5 % or 70,000 ha of the area in Croatia, with a growing stock of 1.6 % or 5,050,000 m³, and an annual increment of 1.3 % or 120,000 m³.

Silvicultural treatments in holm oak forests are divided into treatments in maquis and treatments in coppice forests. In maquis, the treatments are aimed primarily at protection from adverse impacts of biotic and abiotic factors. In the course of time, an excessive number of accompanying species is differentiated and reduced in the interest of holm oak. In this way, maquis is gradually transformed into coppice.

Silvicultural treatments in a coppice include tending and regeneration. Tending that involves cleaning and thinning operations favours holm oak over numerous accompanying species. Regeneration can be done by natural and artificial means, with shelterwood felling in coppice or high forest in two or three cuts.

## HUNGARIAN OAK (*Quercus frainetto* Ten.) AND KERMES OAK (*Quercus coccifera* L.)

Hungarian and kermes oak inhabit relatively small areas in Croatia and have no significant economic value, although they are interesting and valuable from the natural-scientific standpoint.

Hungarian oak is a deciduous tree species of the continental part of Croatia. It forms a climatogenous forest association of Hungarian-Turkey oak (*Quercetum frainetto-cerris* Rudski 1940, 1949). It occurs on the slopes of Krndija in the Kutjevo area.

Kermes oak is an evergreen Mediterranean tree species that inhabits a relatively small area of eu-Mediterranean: the islands of Lošinj, Korčula, Mljet, the Pelješac peninsula and the vicinity of Cavtat. It occurs in bush form with a maximal height of about 10m. With manna ash it forms a forest association of kermes oak and manna ash (*Fraxino orni-Quercetum cocciferae* H-ić 1958). There are frequent more of less pure stands of kermes oak in the area of Pelješac, Korčula and Cavtat (Rauš et al. 1992).

## CONCLUSION

Oaks, and pedunculate, sessile, Turkey, pubescent, live and holm oaks in particular, are characteristic tree species of Croatian forestry. As such, they have beco-

me a symbol of manifold properties appertaining to the Croatian region, people and customs. Their presence marks the living conditions represented by the properties of the soil, water regime and climate. Their influence embraces ecological, social, economic, cultural, national, religious and mythical areas, to which the Croatian man has been adapting for millennia. Oaks carry an outstanding quality of timber reflected in their physical, aesthetic and chemical properties, features belonging only to high-quality tree species.

It is not surprising that the importance of oaks has exceeded the framework of forestry alone. Oaks have become an indelible part of the living styles and customs of the people in these areas, and even feature in the lyrics of the Croatian national anthem, in which they symbolise the permanence and eternal existence of the Croatian people in these regions.

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## HRASTOVE ŠUME (*QUERCUS* SP.) U HRVATSKOJ

Članak opisuje sve vrste hrastova koje dolaze od prirode i koje tvore prirodne šumske zajednice u Hrvatskoj. To su hrast lužnjak (*Quercus robur* L.), hrast kitnjak (*Quercus petraea* /Matt./ Liebl.), hrast medunac (*Quercus pubescens* Willd.), dub (*Quercus virginiana* Ten.), cer (*Quercus cerris* L.), crnika (*Quercus ilex* L.), sladun (*Quercus frainetto* Ten.) i oštrika (*Quercus coccifera* L.). Opisane su najznačajnije šumske zajednice u kojima uspijevaju, njihove temeljne uzgojne značajke, areal, drvna zaliha, prirast i uzgojni postupci njege i pomlađivanja.

Ključne riječi: hrast, hrast lužnjak, hrast kitnjak, hrast medunac, dub, cer, crnika, sladun, oštrika