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GLASNIK
ZA ŠUMSKE POKUSE

ANNALES
EXPERIMENTIS SILVARUM CULTURAE PROVEHENDIS

34

SVEUČILIŠTE U ZAGREBU
ŠUMARSKI FAKULTET
UNIVERSITAS STUDIORUM ZAGRABIENSIS
FACULTAS FORESTALIS

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This Volume is in commemoration of Prof. Dr. Đuro Rauš, Editor–in–Chief for many years of *Glasnik za šumske pokuse* (Vol. 21–32). Prof. Dr. Đuro Rauš (1930–1997) was a great scientist, colleague and friend.

Ovaj broj objavljujemo kao spomen na dugogodišnjega glavnoga urednika Glasnika za šumske pokuse *(vol. 21–32), našega velikoga znanstvenika, profesora, kolegu i prijatelja – prof. dr. Đuru Rauša (1930–1997).*

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UDK: 630*231:630*232

Original scientific paper
Izvorni znanstveni članak

REGENERATION OF NARROW-LEAVED ASH STANDS (*Fraxinus angustifolia* Vahl) IN CENTRAL CROATIA

POMLAĐIVANJE SASTOJINA POLJSKOGA JASENA (*Fraxinus angustifolia* Vahl) U SREDIŠNJOJ HRVATSKOJ

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The research was conducted in lowland forests of Central Croatia, in the forest basin of Česma. Methods of regenerating narrow-leaved ash stands were studied, and the classification of young growth was made in terms of micro-relief, site, and regeneration methods. Narrow-leaved ash was found to regenerate in three groups of sites. The first group are micro-depressions, the second are micro-depressions in transition into micro-elevations, and the third are micro-elevations. Two regeneration methods were applied: the shelterwood method and the clearcutting method. The shelterwood method proved successful in regenerating narrow-leaved ash stands growing in the sites of the first group, as well as in those stages of the second group in which pedunculate oak cannot regenerate. Narrow-leaved ash stands growing in the sites of the third group and in those of the second group where the rejuvenation of pedunculate oak is possible were regenerated with shelterwood fellings followed by the artificial regeneration of pedunculate oak. It is unwise to regenerate ash stands of any group with the clearcutting method, because the ensuing results are poor and lead to site degradation. Clearcutting is a treatment which inhibits the progressive, and enhances the regressive, succession processes in narrow-leaved ash eco-systems.

Key words: narrow-leaved ash (*Fraxinus angustifolia* Vahl), natural regeneration, artificial regeneration, micro-relief, site, shelterwood method, clearcutting method

INTRODUCTION
UVOD

Narrow-leaved ash forests make up over 27,296 ha of lowland forests in Croatia. Their growing stock amounts to 6,245,000 m^3, and the annual increment is 210,485 m^3. Forests of narrow-leaved ash are mainly distributed in the Posavina region between Sisak and Spačva. The largest and the most beautiful tracts are found in the Posavina forests of Lipovljani, in Javička Greda near Jasenovac, and in Kamare near Novska. Going eastward, the areas under these forests decrease considerably (Matić 1971, Glavač 1959).

The economic, ecological, biological, social and other characteristics of narrow-leaved ash stands depend primarily on the properties of their sites. In Croatia, these lowland sites fall into three categories, called wet micro-depressions, unsoaked micro-depressions and micro-elevations. Their local names (*bara, niza* and *greda*) in fact reflect the water regime and the micro-relief with minimal relative height differences of occasionally only 10 cm (Dekanić 1962). Wet micro-depressions, the most important of the three, are those depressions which are frequently inundated with stagnant flood or precipitation water for longer periods of time, with average levels of groundwater in the growing period ranging between 50 and 100 cm. Unsoaked micro-depressions are drier than wet ones owing to the fact that precipitation water and, less frequently, flood water remain there for shorter periods. Average groundwater levels are about 150 cm in the vegetation period. Micro-elevations are the driest sites. They are mildly raised elevations out of reach of flood water. The average levels of groundwater in the growing period are about 200 cm (Mayer 1996, Dekanić 1962).

Between wet micro-depressions, unsoaked micro-depressions and micro-elevations there are transitional stages, such as, for example, a wet micro-depression gradually turning into a proper swamp, a wet micro-depression turning into an unsoaked micro-depression, a swampy hollow in an unsoaked micro-depression, a raised micro-depression, a transition from a micro-depression towards a micro-elevation, a low terrace, a low micro-elevation, and a micro-elevation in a micro-depression, etc.

In terms of principal tree species, the sites in Posavina can be divided into oak and ash sites. It is of primary importance for forestry practice to differentiate between the two, but also to take into account the transitional sites. In the course of forest tending, it is the properties of a site which determine the goals of forest management, the methods of regeneration, and the regulation of species composition. Narrow-leaved ash grows successfully in all the above-mentioned sites. In a wet micro-depression it forms pure stands, while in an unsoaked micro-depression it thrives in mixed stands with pedunculate oak and black alder, where its participation in the mixture can be between 20% to 26% of the stand's growing stock (Dekanić 1962). On a micro-elevation, it is mixed with pedunculate oak and common hornbeam, and participates in the composition in a proportion of up to 20% of the growing stock.

The least favourable site conditions for the growth of forest trees are found in wet micro-depressions, slightly better conditions are in unsoaked micro-depressions, while the most favourable ones exist on micro-elevations. Due to its ecological characteristics and biological properties, narrow-leaved ash is capable of tolerating various site conditions, including highly unfavourable swampy conditions. This is the reason that wet micro-depressions are inhabited by pure ash stands. In other sites, more favourable conditions allow the growth of other tree species, in particular the pedunculate oak, which results in the establishment of mixed stands. Stands of narrow-leaved ash growing in wet micro-depressions have very low economic value compared to the other stands in which it occurs (Matić 1971, Dekanić 1962). However, their ecological and social value is high.

According to Glavač (1959), Prpić (1971) and Dekanić (1971, 1970), the ecological optimum of narrow-leaved ash differs from the physiological one. The ecological requirements and biological properties enable it to reach its ecological optimum, that is, the largest participation in the mixture, in a wet micro-depression. Its biological stability and fast growth help it to suppress other water-tolerant tree species, such as black alder and willow. In contrast, narrow-leaved ash achieves its physiological optimum or its growth optimum in better-quality sites: unsoaked micro-depressions and micro-elevations. This means that, although the participation of narrow-leaved ash is dominant in a wet micro-depression, its production potential is very poor. Because of the competition, its participation in a stand mixture is lower in a micro-depression or a micro-elevation, but the quality of trees is much better (Plavšić 1965, 1960, 1956; Plavšić and Klepac 1960).

Recent research into the ecological, biological and silvicultural properties of narrow-leaved ash has shown that its characteristics as a pioneering tree species stem from its wide ecological valency in relation to the most important ecological factors in lowland forests. An abundant and frequent crop of light and slightly winged seed allows it to regenerate naturally and to inhabit wet and unsoaked micro-depressions and micro-elevations (Matić 1971). The trees fructify very early, at the age of between 20 and 30 years. As narrow-leaved ash grows very fast when young, it avoids the negative impacts of flood water, ice and frost, thus taking a dominant position in and above the soil and suppressing other tree species. Since its requirement for soil oxygen is very modest, it successfully invades wet micro-depressions, wet clearings and fields, and forms the so-called swampy borderline between a forest and a swamp.

According to Seletković (1984) and Prpić (1971), in the seedling and sapling stage, narrow-leaved ash can tolerate a kind of shade with less than 3% of full sun. However, the need for light increases with age. At the young-tree stage, terminal leaves develop only when the share of available light exceeds 6% of full sunlight. At the age of about thirty, narrow-leaved ash becomes a distinct heliophyte. At the age of about thirty, narrow-leaved ash becomes a distinct heliophyte. It is susceptible to late frost and spring colds.

Large-scale fellings of old pedunculate oak stands in the past gave rise to the problem of regenerating lowland forests as early as the last century. If a site was not abundantly seeded with acorns after the final cut, narrow-leaved ash and lowland elm, then seen as tree species of little economic value, were instantly established and spread (Matić 1971).

In connection with this problem, Kozarac (1895, 1886, 1886a) wrote papers describing the laws in mixed stands of pedunculate oak, narrow-leaved ash and lowland elm. Based on the fact that narrow-leaved ash had a wide ecological valency with regard to its occurrence in lowland forests, he divided the forests in Posavina into four groups.

- oak stands with a participation of 10% of other species in dry, unflooded sites;
- stands in which narrow-leaved ash participated at 30 to 40% of the growing stock in the composition, while the remaining proportion was made up of pedunculate oak. Both species succeeded equally, and the humidity of the site satisfied both species equally;
- stands in which narrow-leaved ash and pedunculate oak were either equally represented or where there was more ash than oak. Both species were of poorer quality, and the soil was mostly humid;
- pure ash stands on permanently humid sites.

This classification, based on the stand species composition ratio and on hydrological and pedological properties of a site, was the forerunner of the present classification of lowland forests and sites. According to Kozarac, oak and ash are two species whose regular occurrence is more or less dependent on site humidity. In a more humid site ashes suppress oaks, while in the stands of the third type, where both species participate equally in the mixture, the very high transpiration of narrow-leaved ash and its bio-draining role enhances the growth of oak (Fukarek 1955).

In recent times, the problem of regenerating narrow-leaved ash in Croatia has been dealt with by Dekanić (1970, 1961), and Matić (1971). In the cited papers, the authors state the basic principles of regenerating pure stands of narrow-leaved ash in wet micro-depressions, and mixed stands of pedunculate oak and narrow-leaved ash in unsoaked micro-depressions and micro-elevations. They focus on the relationship between these two species in the course of regeneration and on the necessary silvicultural measures to be taken for each stand.

According to these authors, narrow-leaved ash growing in wet micro-depressions should be regenerated naturally with the shelterwood method in two steps: the seed cut and the final cut. In places threatened by ice and excess water, an additional cut should be carried out between the seed and the final cut. In such cases, the trees left over for the final cut take the role of a water pump, prevent excessive bogging, and take on themselves the burden of ice, thus enabling the young seedlings and saplings to survive and develop more easily. The rotation of such stands should last up to 80 years. After this period, certain undesirable changes take place: the increment decreases, crowns desiccate, fructification becomes weaker, and dark heartwood occurs as a result of reduced crowns (Benić 1956).

Natural regeneration of narrow-leaved ash is successful in sites with narrow-leaved ash and summer snowflake, provided that stands are intensively tended from their early period (Dekanić 1962, 1962a, 1962b). If they are not, then the short, narrow and partially desiccated crowns are responsible for poor fructification. According to Matić (1971), this phenomenon is confined to smaller, isolated ash stands in depressions within a complex of pedunculate oak stands. The reason for this lies in extensive management practices in which silvicultural treatments, instead of being directed individually towards smaller groups of trees or sections, are applied uniformly to different tree species.

Shelterwood cuts in pedunculate oak and narrow-leaved ash stands in unsoaked micro-depressions should be accomplished in such a way as to favour the regeneration of the weaker species: the pedunculate oak (Dekanić 1961). Shelterwood cuts are done in two steps - the seed and the final cut. In the seed cut, all the trees competing with pedunculate oak are removed. Later on, in the course of tending the young growth sprouting after the final cuts, attention should focus on pedunculate oak. Otherwise, the biologically stronger narrow-leaved ash might assume dominance in the stand, suppress the oak and turn the stand into a pure ash stand. If there is a dominance of narrow-leaved ash over pedunculate oak in the mixture, then the shelterwood method should be accompanied by artificial regeneration involving the introduction of acorns or pedunculate oak seedlings.

Matić (1993) considers the quantity of the young growth of a principal species to be the basic prerequisite for the successful regeneration, establishment and tending of a forest. He points out that each regeneration and reforestation activity should be aimed at forming a young stand in as short a period as possible. Its composition should stop the processes of site degradation and turn the processes of regression into those of progression. In order to achieve this aim, it is very important to obtain the optimal amount of growth of the principal tree species, which should neither be too high nor too low. He recommends the use of 7 - 10 kilograms of seeds, or 5,000 to 10,000 seedlings per hectare for artificial regeneration with narrow-leaved ash (Matić 1994).

Research into the natural regeneration and growth of narrow-leaved ash in sites of pedunculate oak is of particular importance in desiccated and decline-afflicted pedunculate oak stands. Such degraded lowland ecosystems are best regenerated with narrow-leaved ash. The procedure of "biological preparation and/or site improvement" is based on the artificial regeneration of stands with the shelterwood method, and on the introduction of narrow-leaved ash and other pioneer tree species (Matić 1996, 1989, Matić *et al.* 1996, Matić *et al.* 1996, Matić *et al.* 1994, Matić and Skenderović 1993).

The successful management of a lowland forest depends on a thorough knowledge of the ecological and biological properties of forest trees, the structures of forest stands, and the conditions in a site. Narrow-leaved ash has wide ecological valency with regard to the ecological factors important for its growth and regeneration, and good elasticity with regard to site conditions. Therefore, silvicultural treatments should satisfy different stand and site conditions; hence the choice of different regeneration methods.

This paper discusses two methods of regenerating narrow-leaved ash stands: the method of shelterwood cutting and the method of clearcutting in strips. In the former method, regeneration was analyzed after the seed and the final cut. In both methods, regeneration was analyzed in terms of the proliferation of young growth, its structural characteristics and site conditions. Site conditions were observed by establishing a series of experimental plots along a levelled land profile on which wet and unsoaked micro-depressions and micro-elevations were sighted. An additional study of pedological relations and climate was made, as well as the description of hydrological and geological features of the area.

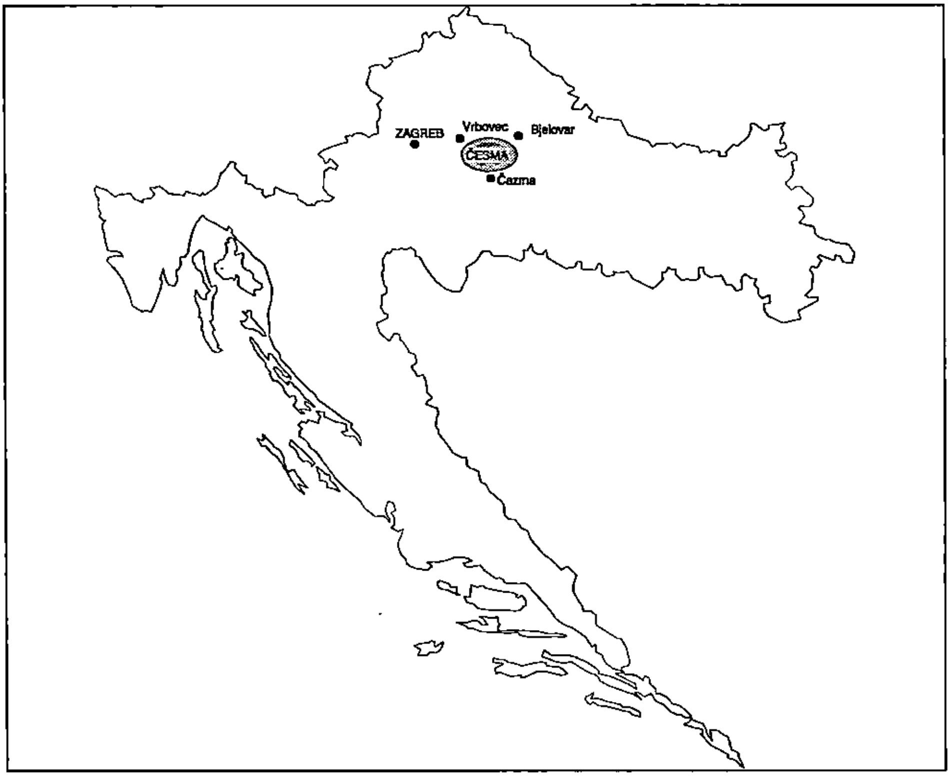
RESEARCH AREA
PODRUČJE ISTRAŽIVANJA

TOPOGRAPHIC, HYDROGRAPHIC AND GEOMORPHOLOGIC FEATURES
TOPOGRAFSKA, HIDROGRAFSKA I GEOMORFOLOŠKA OBILJEŽJA

The research was conducted in a part of the forest basin "Česma", managed by the Forest Enterprise Vrbovec (Map 1). The forest basin "Česma" is a constituent part of the Bjelovar plain which, together with upper and a part of central Posavina, belongs to a wider geographic unit of Central Croatia. The relief of the region is characterized by the denudation-accumulation, and the accumulation-tectonic type (Bognar 1979). This region contains the majority of narrow-leaved ash forests in Croatia. The northern edge of the basin runs along the southern slopes of the mountain Bilogora, and the southern one along the slopes of Moslavačka Gora. The basin of "Česma" is the area of the lowest elevation and an accumulation point of the water running down the southern slopes of Bilogora and the northern slopes of Moslavačka Gora.

The studied Management Unit of "Česma" covers an area of 1,750 ha. It is located between 103 and 107 m above sea level (Mayer *et al.* 1996), sloping in the north-south and west-east direction. The approximate coordinates encircling the basin extend from 16^0 36' to 16^0 49' of eastern longitude, and from 45^0 49' to 45^0 52' of northern latitude.

Map 1. Location of the "Česma" basin
Karta 1. Položaj bazena "Česma"



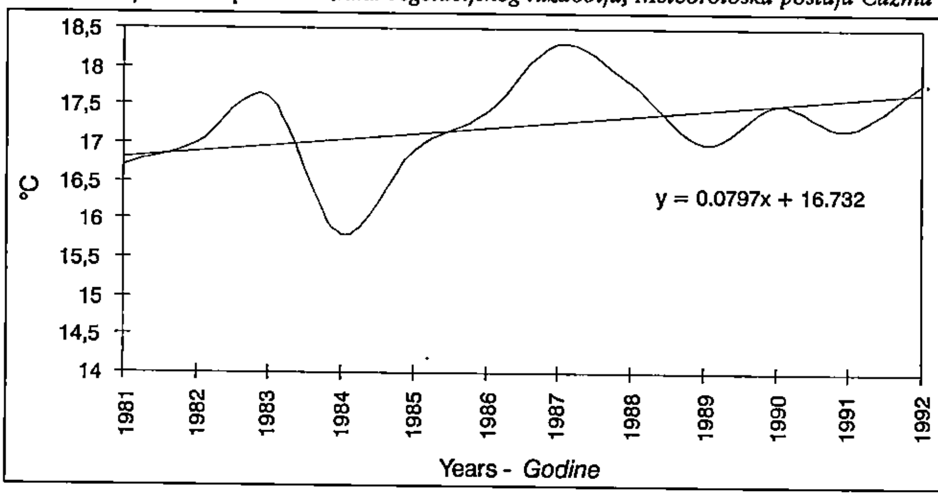
CLIMATE OF THE REGION
OBILJEŽJA PODNEBLJA

The area of Česma belongs to climatic category C, which is characterized by a temperate rainy climate without dry periods. Rainfall is evenly distributed over the whole year, with the driest part of the year falling in the cold season. The warm half of the year is marked by two precipitation maximums. The first maximum occurs in spring (May), and the second in late summer (July or August), with a dry period between them. The temperatures in the coldest month are above -3 ^{0}C, the summers are fresh with a mean monthly temperature in the warmest month under 22 ^{0}C. This type of climate belongs to the Cfwbx" type (Seletković and Katušin 1992).

The mean annual air temperature for the observed period is 10.7 ^{0}C. The marginal values of the mean air temperature range are 0.0 ^{0}C (January) and 21.0 ^{0}C (July). From a silvicultural and ecological-phytocoenological standpoint, extreme air temperatures are very important because they indicate the least favourable temperatures to which the vegetation cover, and particularly the sensitive seedlings and saplings, are exposed. The absolute minimal air temperatures are below zero in all months except for the June-September period. The values range from -22.3 ^{0}C (January) to 6.8 ^{0}C (July). The highest absolute maximum air temperatures were recorded in July and August, and their bordering values range between 16.9 ^{0}C (January) and 36.0 ^{0}C (August).

In the last ten years, mean air temperatures have risen considerably in the vegetation period (Figure 1).

Figure 1. Average vegetative air temperature, Meteorological station Čazma
Slika 1. Prosječna temperatura zraka vegetacijskog razdoblja, Meteorološka postaja Čazma

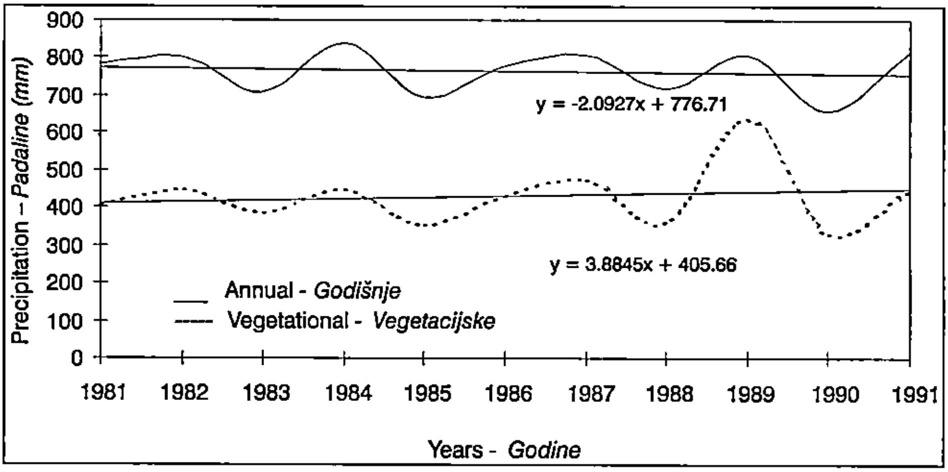


Minimal daily air temperatures of less than 0 ^{0}C (cold days) occur 89 times a year on average. Such days can occur in the vegetation period as well (April).

The average annual rainfall for the period 1981 to 1991 is 771.2 mm. A downward trend in the quantity of annual and vegetation precipitation has been noted in the last ten years (Figure 2). The average precipitation in the growth period is 428.9 mm, which is 56% of the total annual precipitation. Maximum quantities occur in June, and minimum ones in January. Another precipitation maximum occurs in the October-November period. A sudden increase in the quantity of rainfall at the beginning of the vegetation period from April to June should be pointed out.

On average, there are 26 frost days per year. The highest number of frost days occurs in the autumn. Frost is very rare in April, and completely absent in May. Days with a snow cover thicker than 1 cm (38 days a year on average) follow a similar pattern. Although not very likely, snow may also occur in April (Bertović 1971).

Figure 2. Annual and vegetational totals of rainfall, Meteorological station Čazma
Slika 2. Godišnje i vegetacijske padaline, Meteorološka postaja Čazma



GEOLOGICAL FEATURES
GEOLOŠKA OBILJEŽJA

The appearance of Quaternary deposits marks a significant point in the geological history of the Česma basin and the edges of Bilogora and Moslavačka Gora. The higher terrace parts of the basin and the mountain slopes are formed of Pleistocene deposits of typical loess, where periglacial features display manifold invasions of the glaciers into these regions. Loess is predominantly non-carbonate and of a lighter mechanical composition (loam and clayey loam), except in relief depressions where loess has retained its carbonate content due to permanent humidity and the absence of descendent water flows (Bogunović 1979).

The lowest water valleys were formed by deposits of the Holocene period. These are (Mayer 1996):

- alluvial deposits of the floodplains and old flows formed when river beds shifted,
- organogenic swampy sediments of flooded and non-flooded areas consisting of dark green and dark grey clay, clayey silt and fine-particle sand,
- deposits in disused river beds, with the sediments composed of silt, swampy clay and plant material.

The sediments of the Holocene period have a predominantly heavier mechanical composition in which clays of montmorillonite type dominate. These exhibit considerable properties of expansion, thereby causing soils to swell when wet, and to crack when dry.

PEDOLOGICAL FEATURES
PEDOLOŠKA OBILJEŽJA

Pedological characteristics of the studied plots were determined by field analyses of the three basic pedological profiles and by chemical and mechanical analyses of soil samples (18 samples) (Table 1).

The pedological profile 1/96 is located in Plot 4, on the eastern edge of the Management Unit "Česma", Compartment 66c. It lies directly along the Velika stream, with a mean elevation point of 104.69 m above sea level. The plot is situated in a wet micro-depression. The geological base consists of tightly compacted and poorly permeable organogenic - swampy sediments of mainly green and dark grey clay, clayey silt (dust) and fine-particle sands.

The profile 1/96 belongs to the type of partially drained swampy amphigley humic non-carbonate vertic soil with a stratigraphic formula Aa - Gr - Gso - Gso,r - Gr.

The humic-accumulative layer is 7 cm thick and is marked with blue-grey hydromorphous humus formed under the conditions of stagnation and saturation with surface water. The gleyic reduction horizon (Gr) reaches a depth of up to 30 cm. Due to its heavy mechanical composition (clay participates of up to 71.5 per cent) and poor permeability, surface water stagnates and reduction processes prevail in the first two horizons.

The gleyic oxidation horizon (Gso) occurs between 30 and 50 cm. It differs morphologically from the overlying horizons by the presence of yellowish-orange concretions of oxidized iron. The occurrence of three-valency iron indicates the presence of oxidation conditions in this soil horizon and the absence of contact between the surface and ground water.

The oxidation layer is followed by a transitional oxidation-reduction layer (Gso,r) to a depth of 70 cm. The gleyic reduction horizon (Gr) occurs at a depth between 70 and 95 cm, where this part of the profile is saturated with high groundwater. The groundwater table measured on 5th October 1995 was -30 cm.

The studied area is located in the wet micro-depression of the lowest terrace along the Velika stream. Before the water courses of the rivers Velika and Česma were regulated with hydro-engineering operations, the area had frequently suffered from floods. Part of the flood water was contributed by the downslope water arriving from some elevated agricultural areas located to the north-west of the plot. High embankments were built along the banks of the Velika and the Česma, and their flows were directed into canals in order to stop them from frequently flooding over. A major change in the water regime of the Česma lowland forests took place when a canal network was built along the forest road, by which the lateral influx of surface water from nearby farms was re-directed into the Česma.

Today, a large part of the lowland Česma forests is flooded in the late autumn or early spring periods (Mayer *et al.* 1996). Vegetational floods take place only during very wet vegetational periods. Mayer *et al.* (1996) cite that the average vege-

Table 1. Results of chemical and mechanical analyses of soil in the Management unit "Česma"
Tablica 1. Rezultati kemijskih i mehaničkih analiza tla u gospodarskoj jedinici "Česma"

Character code-*Oznaka uzorka*			Chemical properties of soil - *Kemijska svojstva tla*								Mechanical composition of soil determined in Na-pyrophosphate-*Mehanički sastav tla odredivan u Na-pirofosfatu*				
Compt. *Odsjek*	No. of profile *Broj profila*	Depth - *Dubina*	$CaCO_3$	pH		P_2O_5	K_2O	Humus	Total N- *Ukupni N*	C : N	2.0 - 0.2	0.2 - 0.02	0.02 - 0.002	<0.002	Texture category *Teksturna oznaka*
		cm	%	H_2O	*n*-KCl	mg/100 g of soil (AL-method)		%	%		mm				
66c	1/96	0 - 7		5.6	4.7	14.5	34.2	30.7	1.2	14.9	2.4	23.8	30.0	43.8	Light clay-*Laka glina*
		7 - 30		6.2	4.8	4.9	18.7	4.5	0.21	12.6	0.0	19.9	8.6	71.5	Heavy clay-*Teška glina*
		30 - 50	0.42	6.4	5.1	22.9	11.0	2.0	0.09	14.0	1.3	8.8	31.1	58.8	Heavy clay-*Teška glina*
		50 - 70		6.6	5.1	11.4	11.7				0.2	3.5	39.5	56.8	Heavy clay-*Teška glina*
		70 - 95		7.0	5.3	17.1	9.8				0.7	6.0	47.4	45.9	Heavy clay-*Teška glina*
72c	2/96	+3 - 0		6.8	6.4	25.4	67.2	52.2	1.85	16.4					
		0 - 25		6.2	5.3	8.2	16.3	20.5	0.71	16.8	2.1	21.5	33.7	42.7	Light clay-*Laka glina*
		25 - 60		6.7	5.1	3.7	6.1	2.1	0.10	12.2	0.2	28.7	35.1	36.0	Light clay-*Laka glina*
		60 - 80	1.25	7.4	6.0	7.7	4.7				0.1	39.1	39.3	21.5	Clayey loam-*Glin. ilov.*
		80 - 100	5.48	8.1	7.4	3.5	3.8				1.9	46.5	38.0	13.6	Loam-*Ilovača*
		100 - 135	2.53	8.0	7.3	5.4	4.8				0.9	49.1	31.8	18.2	Clayey loam-*Glin. ilov.*
71a	3/96	+3 - 0		6.7	6.3	165.4	120.0	43.9	1.51	16.9					
		0 - 17		5.8	4.8	4.1	12.1	9.1	0.49	10.8	1.1	34.9	39.9	24.1	Clayey loam-*Glin. ilov.*
		17 - 40		6.2	4.3	2.5	4.1	1.3	0.08	9.8	1.0	33.3	40.6	25.1	Light clay-*Laka glina*
		40 - 70	1.66	7.7	6.3	6.6	4.8				0.1	42.9	38.7	18.3	Clayey loam-*Glin. ilov.*
		70 - 90	1.66	8.0	7.0	10.0	4.6				0.6	46.0	35.6	17.8	Clayey loam-*Glin. ilov.*
		90 - 115	5.40	8.1	7.3	6.4	6.3				0.1	47.8	32.6	19.5	Clayey loam-*Glin. ilov.*
		115 - 135	3.74	8.1	7.4	4.1	6.3				0.2	41.7	36.0	22.1	Clayey loam-*Glin. ilov.*

tational water levels for the piezometric pipes placed at a depth of 4 m in partially drained amphigleyic soils ranged from - 69 and -130 cm in the studied period between 1988 and 1994. In the vegetational period, the duration of dry pipes was between 22 and 50% at a depth of 0.5 m. In the growing period, groundwater rarely drops below 4 m in depth.

The pedological profile 2/96 is located in Plot 2, which extends over the central part of the Česma floodplain forests, at a point where the northern elevated terraced part and the lowest southern part meet. The mean elevation of the terrain is 104.85 m above sea level, and the plot was placed in an unsoaked micro-depression which is about 1 m beneath the surrounding low terraces. The geological base is formed of loess of the Pleistocene period which is carbonate in the deeper part of the profile. The clayey loam to loamy texture makes the loess a favourable substrate with good hydro-physical properties.

The studied profile 2/96 belongs to the type of partially drained humic non-carbonate epigley with a stratigraphic formula Of - Aa - Gr - Gr,so - Gso,r - Gso.

The organic horizon consists of a decomposition-affected layer about 3cm thick, but the primary structure of plant remains is still visible.

The humic accumulative horizon (As) is found at a depth of 25 cm. This is a non-structured, bluish-grey hydromorphic humus variant. A slightly lower humus content indicates partial draining and faster decomposition of organic substance.

The gleyic reduction subhorizon (Gr) is located between 25 and 60 cm in depth. It is dominated by bluish-grey microzones. The morpho-chromatic signs are an indication of stagnant surface water in this layer.

The transitional subhorizon (Gr,so), at a depth of between 60 and 80 cm, is dominated by reduction microzones, but orange-yellow secondary oxidation zones also occur.

The transitional subhorizon (Gso,r), marked by the presence of oxidizing conditions, or brownish-red microzones, is at a depth of between 80 and 100 cm.

The depth between 100 and 135 cm is taken up by the oxidizing gleyic subhorizon (Gso). Since this part of the profile is not exposed to long-lasting saturation with groundwater, oxidizing conditions prevail.

The 25-cm thick surface layer is of a somewhat heavier mechanical composition (light clay) with 42.7% clay. A favourable soil texture and the presence of carbonates contributing to the formation of structural aggregates constitute good hydro-physical soil properties. The water-table measured on 5th October 1995 was -78cm.

Epigleyic soils are characterized by stagnant surface water in the upper layers, due to which reduction processes take place. Surface water consists of water from floods, rainfall and downslope water. The network of canals and forest roads has reduced or completely obstructed the passage of water from the upper terraces into the lower ones.

Mayer *et al.* (1996) noted that the mean vegetational levels of groundwater in epigleyic soils ranged between -141 and -206 for the period 1988 to 1994, while the duration percentage of dry pipes placed at 0.5 m in depth was between 13 and 37% in the vegetational period. The increased duration of dry pipes at a depth of 0.5 in the vegetation period was a combined result of hydrotechnical draining operations, in particular of the newly-built forest roads and canals, and a series of dry growing periods.

Plot 3 with the profile 3/96 is situated on a low micro-elevation in the central part of the Česma floodplain forests, Compartment 71a. The mean elevation is 105.22 m above sea level. The geological base consists of carbonate loess from the Pleistocene period, and has a relatively favourable clayey loamy texture.

Pedological profile 3 belongs to the partially drained pseudogley-gley type with a stratigraphic formula Of - Aa - g1 -g2 - g3 - Gr - Gr,so.

The 3 cm-thick organic horizon (Of) is made up of partially decomposed forest cover in which a primary duff structure is visible.

The humus-accumulative horizon (Aa) reaches a depth of 17 cm. It is affected by hydromorphism and mottling, and is bluish-grey in colour.

The thickly mottled pseudogleyic horizon (g1) was formed by stagnant surface water. It is characterized by an interchange of wet and dry phases and an increased clay content. It is from 17 to 40 cm deep.

The thickly mottled pseudogleyic horizons g2 and g3 have a lower clay content than the neighbouring horizons. Their depth ranges from 40 to 70 cm, or from 70 to 90 cm.

The gley horizon (Gr) is blue-grey in colour and was formed under the conditions of saturation with groundwater. Reduction processes prevail. This horizon is from 90 to 115 cm deep.

The transitional gley horizon (Gr,so), 115 to 135 cm deep, is characterized by occasional oxidizing conditions.

The entire depth of the profile has very favourable textural properties (clayey loam to light clay) and good hydric soil properties. The water-table measured in the profile on 2nd October 1995 was -85 cm.

The rhizospheric humidity of pseudogley-gleyic soils is composed of precipitation, downflows and groundwater. Surface water comes in the form of flood and downflows. The regulation of the Česma and Velika waterflows (Mayer 1996, Rauš *et al.* 1996) and the construction of a network of forest roads and canals has tipped the balance towards a dry condition. As a result of shorter-lasting and less frequent floods, the surface is now covered with water only for short periods during maximum autumn-winter floods.

A much lower evapotranspiration rate and ample rainfall is the reason for a high water-table in the autumn-winter period. According to the research by Mayer (1996, 1995), the mean vegetational water levels in the piezometers placed at a depth of 4 m for the period from 1988 to 1994 in the pseudogley-gleyic soils of the Česma range between -208 to -247 cm. The lowest water levels in the vegetation season fall below 4 m in depth. Due to a drop in groundwater in the vegetation period deep below the rhizospheric layer, there is no contact between the root systems of forest trees and groundwater, nor is there any contact with the capillary uptake layer.

All the water needed for the life of forest trees in the vegetation period, especially in its second part, is provided by rainfall, so that the availability of water for vegetation plays a fundamental role in the vitality of a stand. The rate of the duration of dry pipes at 0.5 m in depth on pseudogley soils is between 49 and 80%. In very dry years, the values reach as much as 100% .

HYDROLOGICAL CHARACTERISTICS
HIDROLOŠKA OBILJEŽJA

The construction of powerful flood defence systems with retentions and accumulations, the extensive hydromeliorative operations on agricultural and forest land, and the building of a dense road network, accompanied by a rapid worsening in the quality of water, have caused major changes in the water regimes of soils and in the regimes of groundwater, floodwater and other surface water.

Observing the forest basin Česma, Mayer *et al.* (1996) note that "since the sixties, all the surrounding agricultural land has been gradually consolidated, hydromeliorated and protected from the floods coming from the river Česma and the rivulet Glogovnica, so much so that the water regimes of the forests of Varoški lug, Česma and Bolčanski lug have undergone various changes. In the first phase, the water courses of the Česma, the Velika and the Glogovnica were directed into straight deep beds cutting across the meanders of the formerly natural flows. In the second phase, embankments were built in order to stop the polluted water from entering the forests. As a result, the forest of Varoški lug found itself completely out of reach of floods, while the forest of Česma was turned into a retention area. At the same time, economic considerations forced forestry experts to agree to the construction of a network of communications and drainage canals, so that easier access could be given to these flood forests. Surface water was directed from one section to another by a system of different-sized culverts. Doubts surrounding the ecological effectiveness of all these water-regulating solutions were only increased when dieback of trees set in at the beginning of the eighties."

Infrastructural facilities and the regulation of the Česma and the Velika water courses have significantly disrupted the natural hydrological regime of the forest Česma (Rauš *et al.* 1996). The same authors state that the course of the river Česma was considerably changed after being regulated. The old curving flows, only traces of which have remained in the forest and in the clearings in the form of a water-storage meander, have been replaced by long and straight river beds. Despite being regulated, the river Česma still floods the forests. The first to be flooded are the lowest parts inhabited by the forest of black alder and narrow-leaved ash. Then, as the water level rises, floods reach the forest of pedunculate oak and greenweed. However, the forest of pedunculate oak and common hornbeam is flooded only occasionally.

Mayer (1995) monitored the water level from 1988 and found that the ground and surface water dynamics was under a strong draining influence of the canal network. Since the river beds of the Česma and the Velika were deepened and regulated, floods have been reduced in frequency and in duration. The Česma basin is flooded during late autumn and in early spring (Mayer *et al.* 1996), while in the growing period floods are absent. From an ecological standpoint, late winter floods are very important because they ensure the presence of groundwater, so that the forest can make use of the necessary water at the beginning of the growing period.

In general, the hydro-technical operations in the Česma floodplain forests have caused the basin to dry, but also to bog locally. This, combined with a series of dry vegetation periods, has resulted in an increased desiccation of lowland forests and in a transition of the forest vegetation towards drier associations.

FOREST VEGETATION
ŠUMSKA VEGETACIJA

According to Rauš (1993, 1980), and Rauš *et al.* (1996), there are seven phytocoenoses (associations and subassociations), representing seven different ecosystems, in the studied area of the Management Unit "Česma". These are:

- typical forest of pedunculate oak and common hornbeam (*Carpino betuli-Quercetum roboris typicum* Rauš 1971),
- forest of pedunculate oak and common hornbeam with beech (*Carpino betuli-Quercetum roboris fagetosum* Rauš 1971),
- forest of pedunculate oak with greenweed and remote sedge (*Genisto elatae-Quercetum roboris caricetosum remotae* Ht. 1938),
- forest of pedunculate oak and greenweed with quaking sedge (*Genisto elatae-Quercetum roboris caricetosum brizoides* Ht. 1938)
- typical forest of narrow-leaved ash and summer snowflake (*Leucoio-Fraxinetum angustifoliae typicum* Glav. 1959),
- typical forest of black alder with buckthorn (*Frangulo-Alnetum glutinosae typicum* Rauš 1971),
- forest of black alder, elm, and narrow-leaved ash (*Frangulo-Alnetum glutinosae ulmetosum laevis* Rauš 1971).

The phytocoenology of the stands of narrow-leaved ash in Croatia was first described by Glavač (1959) under the name "forest of narrow-leaved ash and summer snowflake" (*Leucoio-Fraxinetum angustifoliae*). The same author differentiates between two associations (Glavač 1962).

The first association is a typical forest of narrow-leaved ash and summer snowflake (*Leucoio-Fraxinetum angustifoliae typicum*). It grows in wet micro-depressions and is therefore exposed to long-lasting floods and high levels of groundwater (Fukarek 1962, 1956; Rauš 1993, 1975, 1975a; Rauš *et al.* 1996, 1992).

The second association is the forest of narrow-leaved ash with summer snowflake and black alder (*Leucoio-Fraxinetum angustifoliae alnetosum glutinosae*). It inhabits the border of a flood zone, that is, a transitional area between a wet and an unsoaked micro-depression. It is also influenced by high levels of groundwater. The hydrological properties of this subassociation are more favourable than those of the first one, and so the trees are taller and of much better form (Glavač 1962).

The initial, optimal and terminal stages in the development of ash forests are determined by the degrees of humidity and the floral compositions (Glavač 1959). The initial phase is found in extremely wet, boggy micro-depressions, where narrow-leaved ash has a very poor appearance. The tree bases are wide, the stems are crooked, and the bottom parts are bent under the impact of ice. The canopy is not complete and the trees are stunted in growth. Regeneration is difficult because in winter periods the young growth is exposed to long-standing water and ice. The optimal stage is found in a wet micro-depression in which water stagnates for shorter periods. This is the habitat of a typical ash forest. The stems are straighter and the trees are much taller. The canopy is closed, while the bases of the trees are still quite prominent. The terminal stage is found in a transitional zone between a wet and an unsoaked micro-depression and in various water-logged hollows in a depression. Apart from ash, stands are also inhabited by black alder and pedunculate oak. Some species in the shrub and ground layers indicate that the conditions might be favourable for the growth of pedunculate oak.

In forest communities growing in micro-depressions, narrow-leaved ash is represented in a forest of pedunculate oak with greenweed and remote sedge (*Genisto elatae-Quercetum roboris caricetosum remotae* Ht. 1938) and in a forest association of pedunculate oak and greenweed with quaking sedge (*Genisto elatae-Quercetum roboris caricetosum brizoides* Ht. 1938). In these ecosystems, narrow-leaved ash has an important economic, ecological and social role.

Narrow-leaved ash is present on micro-elevations, although only to a lesser degree because of strong competition from other tree species, in particular from pedunculate oak. This kind of site supports the forest of pedunculate oak and common hornbeam (*Carpino betuli-Quercetum roboris* /Anić 1959/ emend. Rauš 1969).

PLAN OF RESEARCH
PLAN ISTRAŽIVANJA

After inspecting the Management Unit "Česma" in the Vrbovec Forest Office, suitable compartments were chosen and experimental plots established. The compartments included a wet micro-depression, an unsoaked micro-depression, and a micro-elevation. The regeneration methods used were the shelterwood and the clearcut method.

Four experimental plots were established in the compartments. The success of regeneration with the shelterwood method was observed in Plot 1 and Plot 2, which were placed in Compartment 72c containing stands where seed cuts were carried out.

The success of regeneration in terms of the quantity and structure of the young growth, as well as of site conditions, was explored in Plots 3 and 4. Plot 3 was set up in Compartment 71a, containing the early stage of a young growth which was raised with the shelterwood method. Plot 4 was placed in Compartment 66c, in a stand of an early young growth established by the clearcutting method in strips.

The research plan included several stages during and after regeneration. This is the reason that experimental plots were placed into several compartments with similar structural and site properties. Field work was carried out during 1995 and 1996.

MEASUREMENTS
IZMJERE

Plots 1 and 2 were 0.25 ha (50 x 50 m) in size. Plot 1 was located in a wet micro-depression, and Plot 2 in an unsoaked micro-depression. The diameters and heights of the trees left over from the old stand were measured. The young growth was measured in strips of 100 m^2 (2 x 50 m). Four strips were placed in each plot. The young growth was classified according to the tree species and the height classes of 25 cm.

Plot 3 and Plot 4 were strips of 10 m in width and 100 and 200 m in length. Plot 3 was 1,000 m^2 (10 x 100 m), and Plot 4 is 2,000 m^2 (10 x 200 m) in size. The micro-relief and the sites of the plots were determined by way of terrain levelling. The levelling was done with a level line in the direction of the slope (from micro-elevations towards unsoaked and wet micro-depressions). The distance between the points was 20 m. Measurements were carried out in the subplots arranged linearly along the levelled terrain profile. Each subplot was 200 m^2 in area. The sides were 20 m long (the distance between two points of the level line), and 10 m wide (5 m from the left and the right point of the level line). Plots 3 and 4 were the sums of surface areas of the subplots.

Five subplots, labelled 3/1, 3/2, 3/3, 3/4, and 3/5, were placed in Plot 3. Ten subplots, labelled 4/1, 4/2, ..., 4/9, and 4/10, were established in Plot 4. In both terrain profiles, the subplots were labelled in the following way: the first plot was placed on the highest micro-relief position (micro-elevation), that is, the highest elevation. The difference in height between the first point 3/1 and the last point 3/5 was 67 cm. As shown in Table 2 and Figures 5 and 7, all the characteristic micro-relief forms and sites of lowland forests were represented in the profiles of 100 and

200 m in length. The young growth of the principal tree species growing in the subplots along the profile was measured and categorized into height classes.

Table 2. Micro-relief and sites on plots 3 and 4
Tablica 2. Mikroreljef i staništa na plohama 3 i 4

Plot *Ploha*	Subplot *Podploha*	Distance *Udaljenost (m)*	Average elevation of terrain *Srednja kota terena* m n.m.	Topography *Topografija*
3	3/1	- 20	104.83	Lower micro-elevation - *Niska greda*
	3/2	20 - 40	104.83	Lower micro-elevation - *Niska greda*
	3/3	40 - 60	104.83	Transition lower micro-elevation/unsoaked micro-depression - *Prijelaz niska greda/niza*
	3/4	60 - 80	104.66	Unsoaked micro-depression - *Niza*
	3/5	80 - 100	104.36	Wet micro-depression - *Bara*
4	4/1	- 20	105.22	Lower micro-elevation - *Niska greda*
	4/2	20 - 40	105.43	Transition lower micro-elevation/micro-elevation - *Prijelaz niska greda/greda*
	4/3	40 - 60	105.42	Transition micro-elevation/lower micro-elevation - *Prijelaz greda/niska greda*
	4/4	60 - 80	105.27	Unsoaked micro-depression - *Niza*
	4/5	80 - 100	105.09	Depression in unsoaked micro-depression - *Udubina u nizi*
	4/6	100 - 120	105.50	Wet micro-depression - *Bara*
	4/7	120 - 140	104.82	Wet micro-depression - *Bara*
	4/8	140 - 160	104.70	Wet micro-depression - *Bara*
	4/9	160 - 180	104.62	Wet micro-depression - *Bara*
	4/10	180 - 200	104.50	Wet micro-depression, basin bed, lowest elevation - *Bara, dno bazena, najniže kote*

Soil samples for chemical and mechanical analyses were taken from characteristic sites of the studied localities. Data on hydro-relations in the Management Unit "Česma" were obtained by monitoring the regimes of ground and surface water in the period 1988 to 1994 (Mayer *et al.* 1996).

DATA ANALYSIS
OBRADA PODATAKA

Based on the measurements in the experimental plots, a structural analysis of the stands and the sites was made. The following factors were analyzed: the structural characteristics of the stands before the shelterwood and clearcutting treatments, the old stand and the young growth after the seed cut in a wet micro-depression, the old stand and the young growth after the seed cut in an unsoaked micro-depression, and the young growth after the shelterwood cut and the clearcut on different sites.

The prevailing site conditions in the Management Unit "Česma" are described in the section "Research area". The pedological and hydrological relationships in the studied localities are analyzed in more detail in the subsections "Pedological characteristics" and "Hydrological characteristics". The sites of experimental plots were defined on the basis of their position in the micro-relief, and on the basis of pedological, hydrological and phytocoenological conditions. The Vegetation and Pedological Maps of the Management Unit "Česma" on a scale of 1 : 10,000 were used, as well as the Hydro-pedological Overview Map on a scale of 1 : 50,000, and the Flood Map of the area.

The data was processed and presented on a PC 386/80 using the programmes Word for Windows 6.0, Excel 5.0 and Corel Draw 4.0.

RESULTS OF THE RESEARCH
REZULTATI ISTRAŽIVANJA

REGENERATION METHODS
METODE POMLAĐIVANJA

Regeneration with the shelterwood method
Pomlađivanje oplodnim sječama

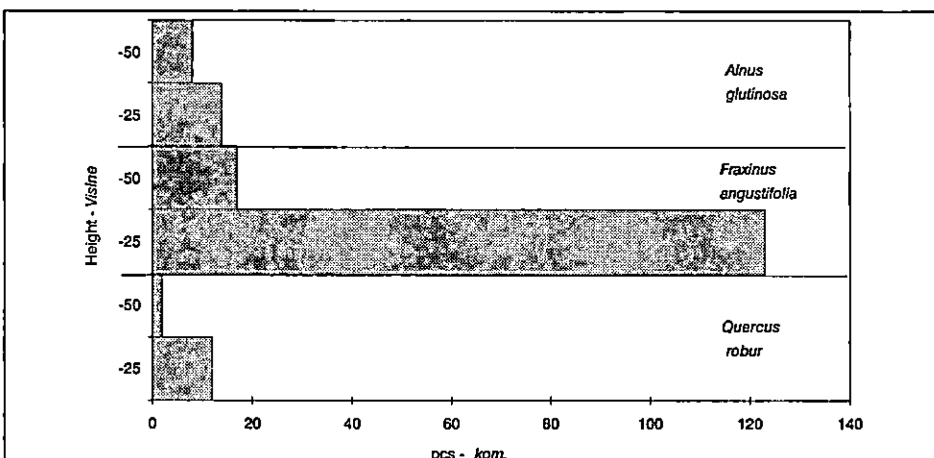
The shelterwood method will be described using the example of Plots 1 and 2. Plot 1 is located in a wet micro-depression containing a pure stand of narrow-leaved ash with some individual black alders in the lower storey. Before the regeneration, the growing stock was 375 m^3/ha at an age of 95 years. Plot 2 is situated in an unsoaked micro-depression. Before the regeneration, it contained a mixed stand of narrow-leaved ash and pedunculate oak, with lowland elm and maple in the lower storey and the understorey. The stand was 95 years old, and the growing stock was 410 m^3/ha.

In Plot 1, the preparatory cut was accomplished in 1990. The intensity of the cut was 16% of the stand's growing stock before the cut. Three years after the initial cut, the site was prepared (the shrubs and undergrowth were removed) for sowing 800 kg/ha of pedunculate oak acorns. That same year, a seed cut was carried out, removing 13% of the growing stock left over after the initial cut. 80 trees per hectare and a growing stock of 274 m^3/ha remained in the stand after the seed cut. The final cut was made in the winter of 1995. Table 3 shows the state of regeneration after the seed cut. Narrow-leaved ash was the most numerous (3,500 seedlings per hectare): in contrast, there were only 350 seedlings of pedunculate oak per hectare. There were 550 seedlings of black alder per hectare. At this stage, the majority of the seedlings of narrow-leaved ash were 25 cm high at the most (Figure 3). The young growth of narrow-leaved ash and black alder was regenerated naturally from the seeds of old trees left over in the regeneration area after the preparatory cut. The seedlings of pedunculate oak originated from the acorns sown artificially.

Table 3. Number of young growths after seeding cut, plot 1, area 400 m^2
Tablica 3. Brojnost pomlatka nakon naplodnog sjeka, ploha 1, površina 400 m^2

Plot - *Ploha: 1,* Subplot area - *Površina repeticije:* 100 m^2, Compartment - *Odsjek:* 72c, Management unit - *Gospodarska jedinica:* Česma, Forest enterprise - *Šumarija:* Vrbovec				
Subplot - *Repeticija*	*Quercus robur*	*Fraxinus angustifolia*	*Alnus glutinosa*	Total - *Ukupno*
I	2	52	2	56
II	3	17	5	25
III	8	33	7	48
IV	1	38	8	47
Total - *Ukupno*	14	140	22	176
Per ha	350	3500	550	4400

Figure 3. Number of young growths by heights after seeding cut, plot 1, area 400 m^2
Slika 3. Brojnost pomlatka u odnosu na visine nakon naplodnog sjeka, ploha 1, površina 400 m^2

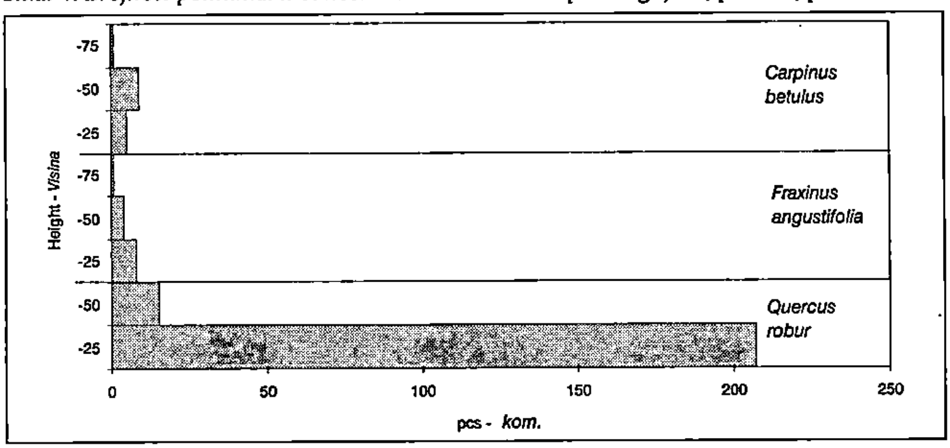


In Plot 2, regeneration was carried out similarly to that in Plot 1. A preparatory cut was made in 1990. The intensity of the cut was 16% of the stand's growing stock before the cut. In 1993, the site was prepared (the shrubs and undergrowth were removed) and 1,000 kg/ha of pedunculate oak acorns were sown. That same year, a seed cut removing 19% of the growing stock left after the preparatory cut was made. 93 trees per hectare and 280 m^3/ha of the growing stock remained in the stand after the seed cut. The final cut was accomplished in the winter of 1995. Table 4 shows the state of regeneration of the stand after the seed cut. Pedunculate oak was the most numerous (5,550 seedlings per hectare) and narrow-leaved ash the least (325 seedlings per hectare). There were 375 seedlings of common hornbeam per hectare, but no seedlings of black alder. The majority of pedunculate oak seedlings belonged to the height class of up to 25 cm (Figure 4). The seedlings of narrow-leaved ash originated from the seeds of the old trees that had remained in the regeneration area after the preparatory cut. The young growth of common hornbeam was also of natural origin, stemming from the seed of the trees growing in the neighbouring strips. The pedunculate oak seedlings were grown artificially by sowing acorns, although some naturally-grown seedlings were also found (advance regeneration in the height class of up to 75 cm).

Table 4. Number of young growths after seeding cut, plot 2, area 400 m^2
Tablica 4. Brojnost pomlatka nakon naplodnog sjeka, ploha 2, površina 400 m^2

Plot - *Ploha:* 2, Subplot area - *Površina repeticije:* 100 m^2, Compartment - *Odsjek:* 72c, Management unit - *Gospodarska jedinica:* Česma, Forest enterprise - *Šumarija:* Vrbovec				
Subplot - *Repeticija*	*Quercus robur*	*Fraxinus angustifolia*	*Carpinus betulus*	Total - *Ukupno*
I	67	6	2	75
II	52	3	6	61
III	41	1	5	47
IV	62	3	2	67
Total - *Ukupno*	222	13	15	250
Per ha	5550	325	375	6250

Figure 4. Number of young growths by heights after seeding cut, plot 2, area 400 m^2
Slika 4. Brojnost pomlatka u odnosu na visine nakon naplodnog sjeka, ploha 2, površina 400



Regeneration with the clearcutting method
Pomlađivanje čistom sječom

Regeneration with the clearcutting method will be shown in the example of regeneration in Compartment 66c containing Plot 4. The compartment is situated immediately along the river Velika, so the site is predominantly boggy and exposed to flooding and high groundwater levels. Going away from the river, the micro-relief gradually rises. The sites alternate from a wet micro-depression to an unsoaked micro-depression to a micro-elevation. Accordingly, the composition ratio of species also changes. A pure narrow-leaved ash stand inhabiting the wet micro-depression gradually transforms into a mixed stand of narrow-leaved ash, black alder and pedunculate oak in the micro-depression, while a stand of narrow-leaved ash and pedunculate oak with some examples of common hornbeam grows on the micro-elevation.

At the end of the rotation period, at 91 years of age, the growing stock was 334 m^3/ha. Narrow-leaved ash was the main producer in the stand structure, since it constituted the dominant storey both in the wet and unsoaked micro-depression and in the micro-elevation. Pedunculate oak made up the dominant storey in the micro-depression and on the micro-elevation. Black alder developed in the lower storey of the stand in the wet micro-depression. Lowland elm and maple thrived in the lower storey and the understorey of the stand in the unsoaked micro-depression, while common hornbeam grew on the micro-elevation.

The stand was regenerated with a combination of natural and artificial regeneration using clearcuts in the form of strips. The strips were about 50 cm wide. The sum of two mean heights of the seedlings was also 50 cm. The strips were cut vertically to the terrain gradient on three occasions: in 1987, 1992, and 1994. After the cut, the site in each strip was prepared and pedunculate oak seedlings were planted. A total of 155,700 seedlings of pedunculate oak, or 8,300 pieces per hectare, were planted in the 18.75-hectare area in the period between 1987 and 1994. At the same time, weeds were removed with machines each year, and the seedlings were protected against mildew. The success of this regeneration method is described in the section "Structure and development of the young growth after the clearcuts".

SUCCESS OF REGENERATION
USPJEH POMLAĐIVANJA

Structure of young growth after the shelterwood cuts
Struktura pomlatka nakon oplodnih sječa

The structure of the young growth after the shelterwood cuts is shown in Table 5 and in Figures 5 and 6. They refer to Plot 3 in Compartment 71a containing the early stage of a young stand. The stand was formed with the shelterwood method, in the manner described in the section "Regeneration with the shelterwood method".

At the end of the rotation period, at 95 years of age, the stand's growing stock was 470,00 m^3/ha. The dominant storey of the stand in the wet micro-depression was made up of narrow-leaved ash, while in the unsoaked micro-depression and on the micro-elevation it consisted of narrow-leaved ash and pedunculate oak. In the wet micro-depression, the lower storey was made up of black alder, in the micro-depression it consisted of maple and lowland elm, and on the micro-elevation it contained common hornbeam. In the wet micro-depression the understorey did not develop, while in the unsoaked micro-depression it consisted of lowland elm and maple, and on the micro-elevation, of common hornbeam. The preparatory cut was accomplished in 1990 with an intensity of 30% of the growing stock before the cut. The following year, the site was prepared (the weeds and shrubs were removed), and 500 kg/ha of acorns were sown. A seed cut was made in 1992. About half of the growing stock left on the regeneration area after the preparatory cut was felled. The final cut was made in 1994.

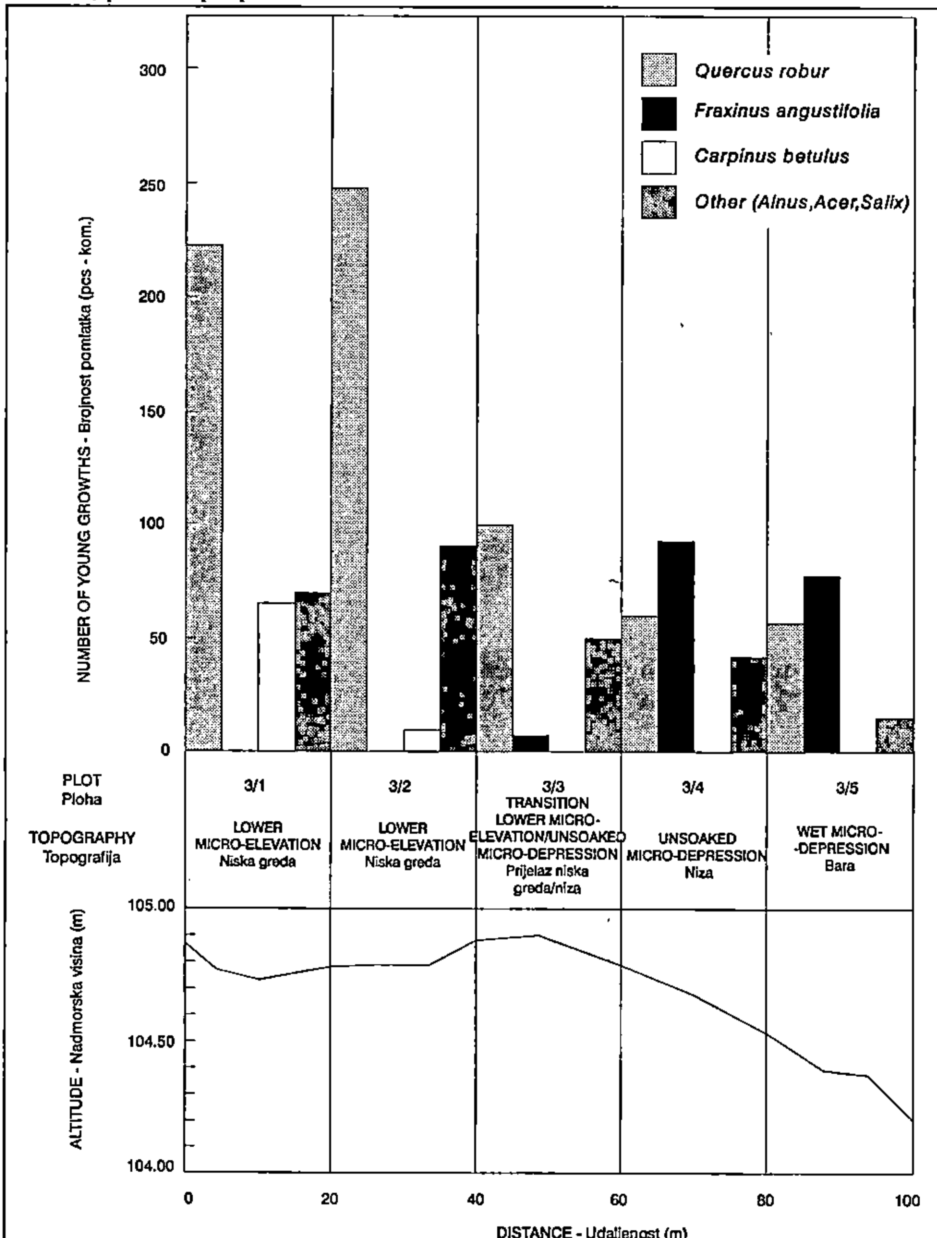
Table 5 shows the results of regeneration in relation to the micro-relief, site and tree species. In the developmental stage of a younger stand, there were 12,040 plants of the main tree species per hectare. Of this, 6,870 plants per hectare, or 57%, were pedunculate oaks, 1,770 plants per hectare, or 15%, were narrow-leaved ashes, 740 plants per hectare, or 6%, were common hornbeams, while 2,660 plants per hectare, or 22%, were other tree species (black alders, maples and willows). Except for pedunculate oak, the young growth of all the other tree species were of natural origin. Pedunculate oak seedlings originated from sown acorns and were only partially of natural origin. On average, the seedlings of pedunculate oak and narrow-leaved ash were the most numerous per hectare, while those of common hornbeam and other tree species were the least numerous. The distribution of the young growth in individual plots on the levelled terrain profile indicates the manner in which seedlings occurred in relation to the micro-relief and site conditions (Figure 5).

Table 5. Number of young growths by plots on the profile after final cut, plot 3, area 1000 m^2
Tablica 5. Brojnost pomlatka po plohama na profilu nakon dovršnog sjeka, ploha 3, površina 1000 m^2

Plot - *Ploha:* 3, Total area - *Ukupna površina:* 0.1 ha, Compartment - *Odsjek:* 71a, Management unit - *Gospodarska jedinica:* Česma, Forest enterprise - *Šumarija:* Vrbovec					
Plot number - *Oznaka plohe*	*Quercus robur*	*Fraxinus angustifolia*	*Carpinus betulus*	*Other (Alnus glutinosa, Acer campestre, Salix sp.)*	Total - *Ukupno*
3/1	223	-	66	69	358
3/2	248	-	8	91	347
3/3	99	6	-	50	155
3/4	60	93	-	41	194
3/5	57	78	-	15	150
Total - *Ukupno*	687	177	74	266	1204
Per ha	6870	1770	740	2660	12040

Figure 5. Number of young growths by micro-relief after shelterwood method, plot 3, area 1000 m^2, subplot area 200 m^2

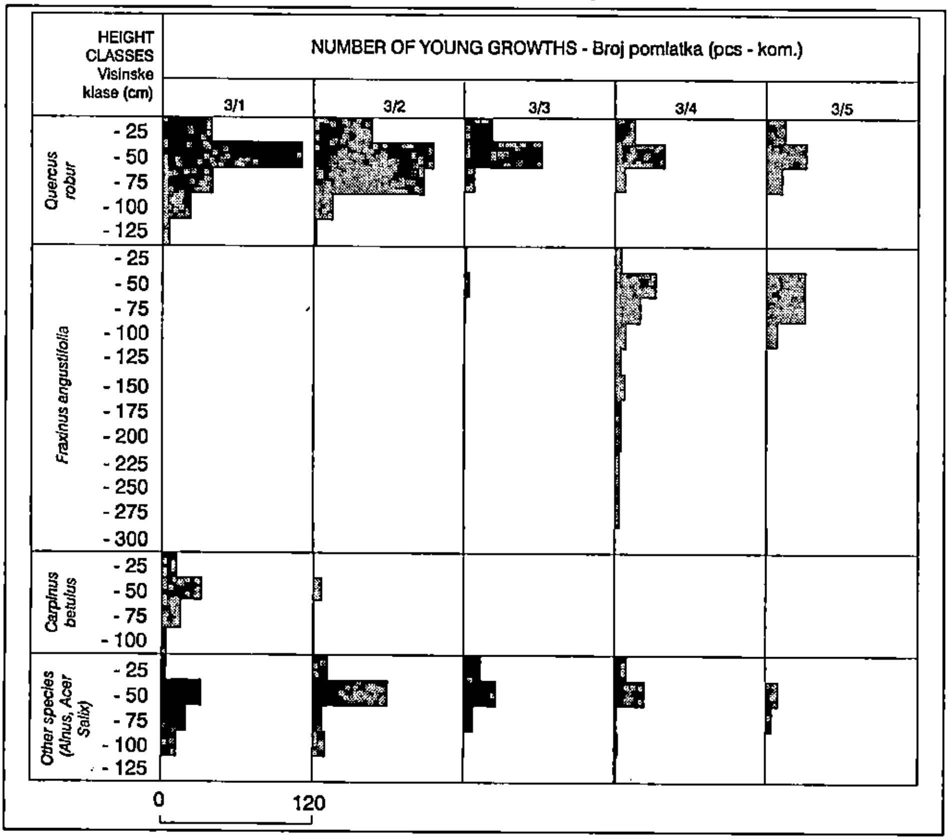
Slika 5. Brojnost pomlatka u odnosu na mikroreljef nakon oplodnih sječa, ploha 3, površina plohe 1000 m^2, površina podplohe 200 m^2



The analysis of the presence of pedunculate oak seedlings in the entire terrain profile shows that they occur most frequently in Plots 3/1 and 3/2, or on the lower micro-elevation. Although the location of Plot 3/3, situated on a transition from a micro-elevation to a micro-depression, is favourable for oak, the number of plants decreases. In Plots 3/4 and 3/5, which are micro-depressions, oak seedlings are very rare. Oak plants reach 125 cm in height on micro-elevations, and 75 cm in micro-depressions (Figure 6). The majority of the plants, stemming from artificially sown acorns, are about 50 cm tall. Plants taller than 50 cm in micro-depressions, or 75 cm in micro-elevations, have grown naturally from the acorns of old trees growing in the regeneration area.

The second most represented tree species is narrow-leaved ash. Its seedlings are present to a large extent only in wet micro-depressions and hollows. It participates at a rate of 48% in plot 3/4, and at 53% in Plot 3/5. The seedlings of narrow-leaved ash are of natural origin. Ash bears seeds almost every year. The light,

Figure 6. Height distribution of young growths by subplots on plot 3
Slika 6. Razdioba pomlatka po visinama na podplohama plohe 3



winged seeds with a high germination power regenerate easily throughout the regeneration period. In addition, young plants are shade-tolerant in their early years and grow very fast. This is the reason that the young growth ranges in height between 25 and 300 cm.

Common hornbeam occurs only on micro-elevations. Other species (maple, black alder, willow) are represented equally in all plot profiles, with maple growing on micro-elevations and willow and alder in micro-depressions. These species also bear frequent and abundant light seeds and are easily regenerated in favourable sites.

Strucutre of young growth after the clearcutting method
Struktura pomlatka nakon čiste sječe

The structure of the young growth after the clearcutting method is shown in Table 6 and in Figures 7 and 8. The figures refer to Plot 4, located in Compartment 66c, in a younger stage of a young stand. The formation of the stand was described in the section "Regeneration with the clearcutting method".

Table 6 presents the results of the applied regeneration method in terms of micro-relief, site and tree species. The stand in the early stage of young growth contains 10,630 plants of the principal tree species per hectare. Of this, 150 plants per hectare, or 2%, are pedunculate oaks, 8,650 plants per hectare, or 81%, are narrow-leaved ashes, 875 plants per hectare, or 8%, are black alders, and the remaining 955 plants per hectare, or 9%, are made up of willows, maples, and common hornbeams. On average, the best represented seedlings per plot are narrow-leaved ash, while common hornbeam and other tree species are the least numerous.

Table 6. Number of young growths by plots on the profile after clearcut, plot 4, area 2000 m^2
Tablica 6. Brojnost pomlatka po plohama na profilu nakon čiste sječe, ploha 4, površina 2000 m^2

Plot - *Ploha:* 4, Total area - *Ukupna površina:* 0.2 ha, Compartment - *Odsjek:* 66c, Management unit - *Gospodarska jedinica:* Česma, Forest enterprise - *Šumarija:* Vrbovec					
Plot number *Oznaka plohe*	*Quercus robur*	*Fraxinus angustifolia*	*Alnus glutinosa*	*Other (Acer campestre, Salix sp., Carpinus betulus)*	Total *Ukupno*
4/1	16	5	14	31	66
4/2	0	13	18	61	92
4/3	3	4	14	14	35
4/4	0	93	36	22	151
4/5	7	41	42	6	96
4/6	0	620	13	12	645
4/7	2	566	17	16	601
4/8	0	89	2	7	98
4/9	0	72	11	0	83
4/10	2	227	8	22	259
Total - *Ukupno*	30	1730	175	191	2126
Per ha	150	8650	875	955	10630

Figure 7. Number of young growths by micro-relief after clearcut method, plot 4, area 2000 m^2, subplot area 200 m^2

Slika 7. Brojnost pomlatka u odnosu na mikroreljef nakon čiste sječe, ploha 4 površina plohe 2000 m^2, površina podplohe 200 m^2

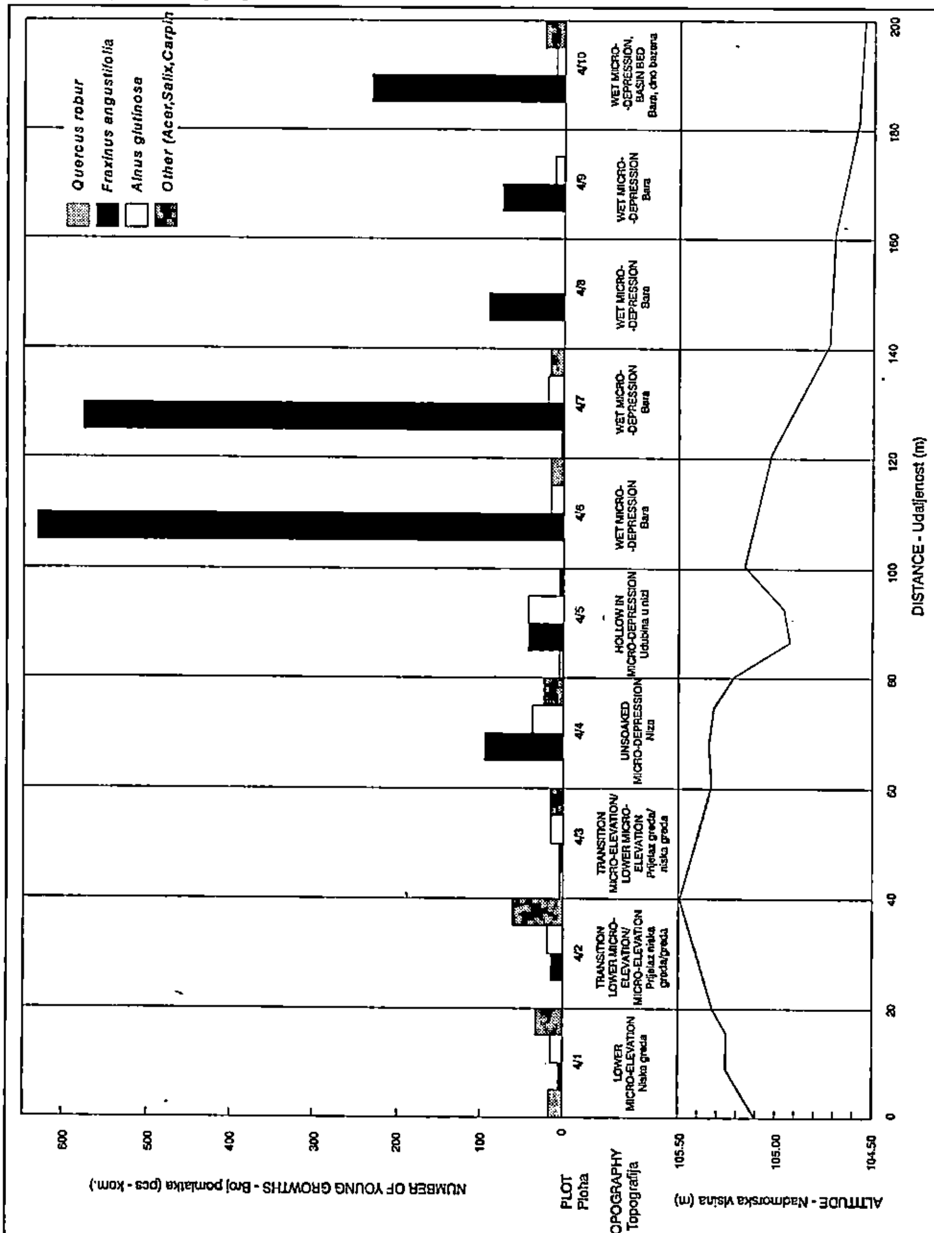
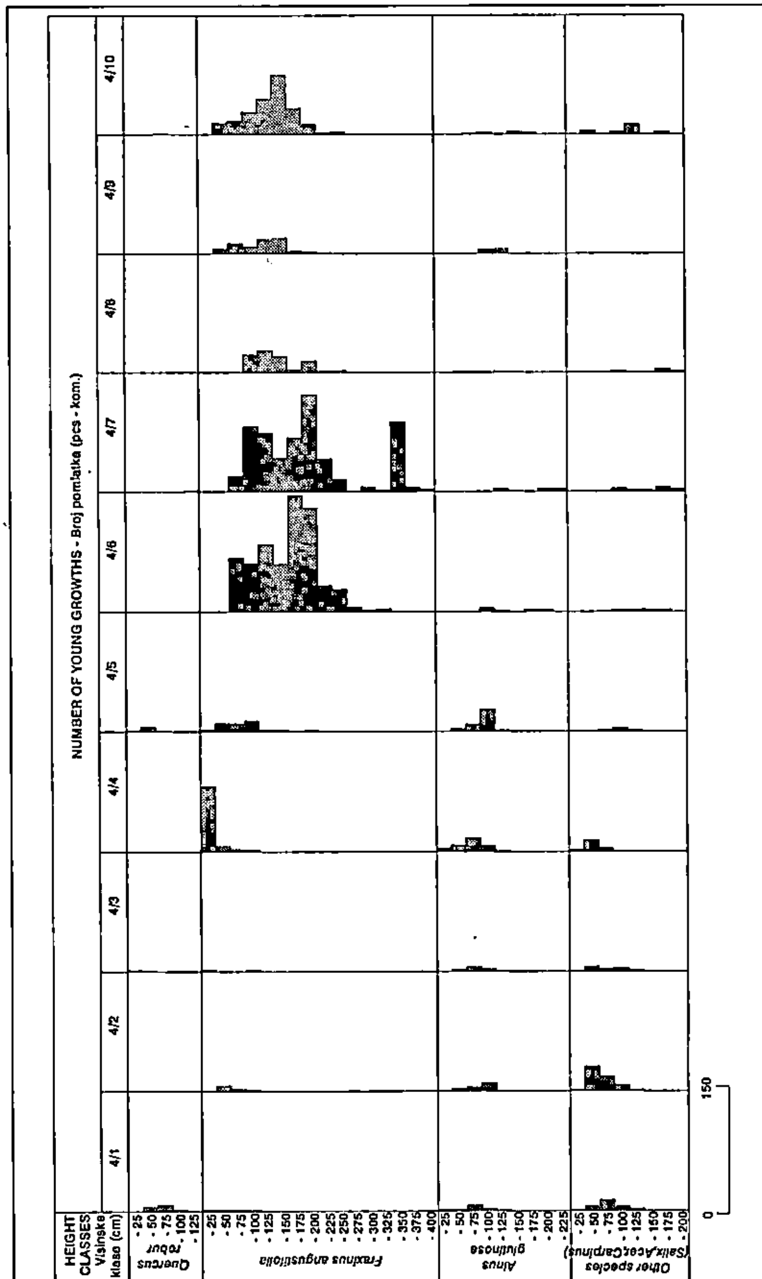


Figure 8. Height distribution of young growths by subplots on plot 4
Slika 8. Razdioba pomlatka po visinama na podplohama plohe 4



The distribution of seedlings of the above-mentioned species in the plots shows that their arrangement depends on the micro-relief and site conditions (Figure 7). Pedunculate oak was not successfully regenerated. On the whole, 150 oaks per hectare in the regeneration area is a negligible quantity in view of the fact that 8,300 seedlings per hectare were used to regenerate this stand.

8,650 narrow-leaved ash trees per hectare are found in the studied profile. This species is best regenerated in the wet micro-depression (Plots 4/6 - 4/10) and in the unsoaked micro-depression (Plots 4/4 and 4/6). It is not so well represented in the plots placed on the micro-elevation. The widest height range of the young growth of narrow-leaved ash is displayed in the wet micro-depression, then in the unsoakead micro-depression, and finally on the micro-elevation.

The seedlings of black alder are found in equal numbers in all the sites. Of other tree species, common hornbeam and maple regenerated well on micro-elevations and willow in micro-depressions.

The young growth of all the mentioned tree species is of natural origin, except pedunculate oak, which was regenerated artificially.

DISCUSSION
RASPRAVA

SITES OF NARROW-LEAVED ASH
STANIŠTA POLJSKOGA JASENA

In the forest basin "Česma", narrow-leaved ash occurs in three groups of sites. The first group consists of wet micro-depressions, the second of micro-depressions in transiton towards micro-elevations (micro-depression, a transition from a lower depression to micro-depression), and the third of micro-elevations (micro-elevation, low micro-elevation, transition from a lower micro-elevation towards micro-elevation). For the purpose of managing lowland forests in Croatia, sites were determined according to the meso-relief where landforms differ in height by some 20 m. The maps used are on a scale of 1 : 5,000 and 1 : 25,000. Our research has shown that sites of narrow-leaved ash should be differentiated at the micro-relief level. Micro-relief creates landforms less than 1 m in height which are cartographically presented on a scale of 1 : 500 to 1 : 5,000. Apart from wet micro-depressions, unsoaked micro-depressions and micro-elevations, micro-relief also allows the detection of transitional sites which influence the success of regeneration. Plots 3 and 4 are examples of relatively small areas (the length of profiles is 100 and 200 m) within the same compartment containing three groups of lowland forest sites (Table 2, Figures 5 and 7). In these areas, the old stands of narrow-leaved ash were replaced by mixed stands of narrow-leaved ash and pedunculate oak after regeneration. The differences in the micro-relief and in the sites, combined with the regenerating methods used, have resulted in the growth of new stands developed on the principles of tree growth in lowland forests. A practising forester should take into account these principles, increase the intensity of management, and avoid the application of uniform silvicultural treatments over larger areas.

The sites are determined by their position in the micro-relief (Figures 5 and 7), and by the pedological, hydrographic and phytocoenological conditions. Their characteristics depend on the water regime, which has been considerably disrupted by the construction of infrastructural facilities and the regulation of the water courses in the study area. As a result of hydro-technical operations in the lowland forests of the Česma and the Velika, the basin has generally become much drier, with scattered swampy patches. The dynamics of ground and surface water is strongly influenced by the network of draining canals. The frequency and the duration of floods has been reduced after the Česma and the Velika beds were regulated and made deeper. The Česma basin is flooded from late autumn to early spring, but floods are completely absent in the growing period. The draining of the basin, combined with a series of dry vegetation periods, has resulted in increased dieback, disturbances in stand structures and a succession of forest vegetation towards some drier associations. In such changed ecological and economic conditions, it is of utmost importance to carry out regeneration treatments properly.

REGENERATION OF NARROW-LEAVED ASH STANDS WITH THE SHELTERWOOD METHOD
POMLAĐIVANJE SASTOJINA POLJSKOGA JASENA OPLODNIM SJEČAMA

Regeneration with the shelterwood method in three cuts (preparatory, seeding and final cut) has given rise to successful natural regeneration of narrow-leaved ash in the wet micro-depression, a partially successful one in the unsoaked micro-depression, and an unsuccessful one on the micro-elevation, as shown by the results of regeneration (Table 5, Figure 5), but also by the course of seed cuts (Tables 3 and 4). As the regeneration area may be seeded with numerous light seeds of narrow-leaved ash even before the regeneration period, the height of the young growth can vary considerably (Figure 6). During the seeding cut, most young plants reach 25 cm in height, and represent the nucleus of a future stand. Some young plants may reach heights of over 75 cm during and after the cuts, and may be individually distributed across the regeneration area, thus becoming examples of advance regeneration (Figures 3 and 4). These will have to be removed in the first years of the rotation because their height will obstruct the growth and development of the new growth.

With time, the sites of old stands of narrow-leaved ash may be affected by increased desiccation for the reasons described in the sections "Pedological conditions", "Hydrological conditions", and "Site conditions of narrow-leaved ash". This refers particularly to the stands growing in wet hollows and micro-depressions. Such sites gradually turn into oak sites, which is indicated by the presence of the plants characteristic of drier sites: oak and hornbeam seedlings, shrubs and herbaceous plants (Figure 4). This justifies the use of artificial regeneration in the form of sowing seeds and planting acorns of pedunculate oak. In doing so, stand forms change from pure ash stands to mixed stands of pedunculate oak and narrow-leaved ash (Tables 4 and 5). Still, even in new stands, the young growth of different species follows the basic principles of growth in appropriate sites. So, narrow-leaved ash grows more abundantly in micro-depressions, and pedunculate oak on micro-elevations (Figure 5). If site conditions in narrow-leaved ash stands are unchanged, then all attempts to introduce pedunculate oak artificially will be unsuccessful (Figure 3). A site that is a typical ash one is indicated by the occurrence of naturally regenerated young growth and undergrowth of black alder, narrow-leaved ash and the herbaceous plants of ash sites. In this case, narrow-leaved ash should be naturally regenerated (Table 3, Figure 3).

The examples described above show that narrow-leaved ash can be successfully regenerated in a natural way with shelterwood cuts. The conditions in the site, in particular the hydropedological and phytocoenological ones, and the structure of undergrowth and young growth sprouting during shelterwood cuts, determine the possibility of artificial regeneration with oak.

The preparatory cut creates suitable conditions for regeneration in a stand. When poor-quality and superfluous trees are removed, the crowns receive more space and light and trees of good quality are distributed evenly over the regenerated area. In our examples, a preparatory cut removing 16% of the stand's growing stock proved successful (Plots 1 and 2). As the stand in Plot 3 had a larger growing stock, the intensity of the cut was 30%. In general, the intensity of the preparatory cut depends on several factors, such as the structure of the stand, the state of the growing stock, the vertical and horizontal distribution of trees in the stand, and the state of the soil, etc. Ash stands have a poorly developed lower storey and no understorey. This is the reason that trees from the lower storey and some from the dominant storey should be marked for the preparatory cut. The stands we selected for artificial regeneration had a prominent understorey and abundant undergrowth. In the course of the seed cut, some of the trees in the understorey and some undergrowth were left standing because of their role in regulating the microclimate in the stand before the seed cut and in preventing excessive weeds.

It is not necessary to conduct a preparatory cut in properly tended stands, as their structure has adapted to future regeneration procedures during the rotation period. Likewise, preparatory cuts are not carried out in stands with a reduced growing stock, since the procedure would open the canopy too much and thus expose the sensitive ash site to weeds and excess water.

The seeding cut is accomplished 2-3 years after the preparatory cut. The examples (Plot 1 and 2) show that the intensity should not exceed 20% of the growing stock left in the stand after the preparatory cut. If there is a larger amount of growing stock, then the cutting intensity could be 50% (Plot 3). The seeding cut brings abundant light to the soil for the seeds to germinate and the seedlings to develop. In choosing trees for the seed cut, it is important to ensure that the remaining trees are evenly distributed for the final cut. At this stage, all the residual intermediate and co-dominant trees should be removed. The crowns of the remaining trees protect the new seedlings against adverse ecological factors, such as frost, hail or heat. In floods or freezing conditions, their stems bear the load of ice and thus shelter the young growth from the damage incurred when floods retreat but when hanging ice remains.

A stand is seeded in the period between the preparatory and the seed cut (the seeding period). Narrow-leaved ash stands are naturally regenerated with ash seeds and artificially regenerated with sown or planted acorns. Forestry regulations of the Republic of Croatia relating to artificial regeneration prescribe that 700 -1,000 kg of acorns per hectare be sown, and 400 - 600 kg of acorns per hectare be planted. Artificial regeneration can also be accomplished by planting 10,000 - 15,000 oak seedlings per hectare. During the seeding period in our study, the site was adequately prepared to enable a good establishment and germination of seeds. The preparations involved removing shrubs and weeds (Plots 1,2,3) and, in some cases, using a machine to loosen the soil to 19 cm in depth, surface draining, erecting fences to protect the seedlings from game and cattle, controlling rodents, etc.

As a rule, the final cut is carried out when the young growth is so firmly established that it does not need the protection of the old trees. In our examples, the final cut was accomplished two year after the seeding cut. The length of the period between the seeding cut and the final cut depends primarily on the regime of floods and on climatic conditions. If floods are frequent, abundant and long-lasting, and if frost and ice remain on the old trees for long periods, the seedlings need the prolonged protection of old trees. With regard to the climatic and hydrological conditions in the Management Unit "Česma", such long-term protection of the young growth was not necessary. Therefore, the stands were successfully regenerated within the regeneration period of 5 years.

In conclusion, we should point out that the described examples of regenerating stands of narrow-leaved ash should take into account the general influence of the hydro-technical operations undertaken in their vicinity. A changed regime of floods and a general drop in the water-table in the basin have led to partial desiccation in the sites and have directed regeneration towards the formation of stands more suitable for drier sites. In this sense, the amount of narrow-leaved ash in the new stands corresponds to the altered conditions. The shelterwood method has enabled narrow-leaved ash to regenerate naturally in the sites which optimally satisfy its ecological requirements and biological properties, that is, in the sites where it can reach its ecological optimum and where competition from pedunculate oak and other tree species is minimal.

REGENERATION OF NARROW-LEAVED ASH STANDS WITH THE CLEARCUTTING METHOD
POMLAĐIVANJE SASTOJINA POLJSKOGA JASENA ČISTOM SJEČOM

The clearcutting system of regenerating stands of narrow-leaved ash proved unsatisfactory because it resulted in poor regeneration both in terms of the quantity and the structure of the young growth (Table 6, Figure 8). This refers particularly to the attempts to regenerate the site artificially with pedunculate oak. After planting 8,300 oak seedlings per hectare, only 150 individuals per hectare were found in the stand. The others gave way to weeds spreading vigorously over the regeneration area after the clearcut, despite several removal operations. The weeds developed in all micro-relief forms, from micro-elevations to micro-depressions. Additionally, as the regeneration area was suddenly exposed to the sun, precipitation and wind, the site conditions became unsuitable for a successful development of young oak plants.

After the clearcut, the barren regeneration area was promptly invaded by pioneer tree species (Figure 7). Micro-depressions became dominated by narrow-leaved ash, sporadically interspersed with willows, while micro-elevations were regenerated with common hornbeam and maple. Black alder regenerated equally poorly in all sites. The mentioned species are characterized by abundant yearly crops of light, winged, wind-borne seeds. As the rate of seed germination is very high and the fast-growing plants tolerate unfavourable site conditions, they belong to pioneer tree species.

The structure of the young growth in the areas regenerated with the clearcutting method shows that the applied silvicultural treatments have disrupted the progressive development of the stand and the site and have led to site regression. The bare areas left after the clearcut were gradually invaded by pioneer species. Despite the introduction of pedunculate oak seedlings, there is very little oak in the area.

CONCLUSIONS
ZAKLJUČCI

The following conclusions are based on the data involving the structural properties of the stands, the structural properties of young growth, and the site characteristics and ecological conditions in the studied area:

1. Narrow-leaved ash is regenerated in three groups of sites in the forest basin of "Česma". The first group of sites are micro-depressions (wet micro-depressions, hollows in micro-depressions). The second group are micro-depressions in transition towards micro-elevations (unsoaked micro-depression, transition from a low micro-elevation to an unsoaked micro-depression). The third group of sites are micro-elevations (micro-elevation, low micro-elevation, transition from a low micro-elevation to a micro-ele-

vation). The success of regeneration depends on the group of sites to which a regeneration area belongs and on the method of regeneration.

2. Shelterwood cuts (preparatory, seeding, and final cut) proved successful in regenerating stands of narrow-leaved ash growing in the sites of the first group and in the sites of the second group in which the developmental stage of the site did not allow pedunculate oak to regenerate. Stands of narrow-leaved ash thriving in the sites of the third group and in those of the second group in which pedunculate oak can be regenerated, were regenerated with shelterwood cuts in combination with the artificial regeneration of pedunculate oak.
3. Regenerating stands of narrow-leaved ash with the clearcutting method resulted in poor regeneration and site degradation. The clearcutting method is a treatment which stops progressive changes and starts regressive changes in the ecosystem, thus making ineffective all simultaneous attempts to alter stand forms.
4. In regenerating stands of narrow-leaved ash, sites should be differenced at the micro-relief level. Micro-relief creates landforms less than 1 m in height, which are presented in maps on a scale of 1 : 500 and 1 : 5,000. Apart from wet and unsoaked micro-depressions and micro-elevations, other transitional stages responsible for the success of regeneration are also present in the micro-relief.

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POMLAĐIVANJE SASTOJINA POLJSKOGA JASENA (*Fraxinus angustifolia* Vahl) U SREDIŠNJOJ HRVATSKOJ

SAŽETAK

Poljski jasen u šumskom bazenu Česma uspijeva na trima skupinama staništa. Prvu skupinu staništa čine mikroudubine (bara, udubina u nizi), drugu mikroudubine na prijelazu prema mikrouzvisinama (niza, prijelaz niske grede prema nizi), a treću skupinu staništa čine mikrouzvisine (greda, niska greda, prijelaz niske grede prema gredi). U gospodarenju nizinskim šumama u Hrvatskoj staništa se razlučuju na razini mezoreljefa kojega čine visinske razlike do 20 m, a kartografski se prikazuje u mjerilu od 1 : 5000 do 1 : 25000. Naša istraživanja pokazuju kako je u slučaju pomlađivanja sastojina poljskoga jasena potrebno razlikovati staništa na razini mikroreljefa. Mikroreljef čine visinske razlike do 1 m, a kartografski se prikazuje u mjerilu od 1 : 500 do 1 : 5000. Osim bare, nize i grede na razini je mikroreljefa moguće razlikovati i prijelazna staništa, koja također utječu na uspjeh pomlađivanja. Plohe 3 i 4 pokazuju kako se na relativno maloj površini (profili duljina 100 i 200 m), u istom odsjeku, nalaze tri skupine staništa nizinskih šuma (tablica 2, slike 5 i 7). Stare su sastojine na tim površinama bile sastojine poljskoga jasena, a nakon pomlađivanja nastale su mješovite sastojine poljskoga jasena i hrasta lužnjaka. Razlike u mikroreljefu i staništima, osim načina pomlađivanja, uvjetovale su ustrojstvo novih sastojina prema načelima pridolaska vrsta drveća u nizinskim šumama. Šumar praktičar trebao bi uzeti u obzir te zakonitosti, intenzivirati gospodarenje i izbjegavati ujednačenost gospodarskih zahvata na većim površinama.

Staništa su određena položajem u mikroreljefu (slike 5 i 7), te pedološkim, hidrografskim i fitocenološkim prilikama. Njihova svojstva ovise o režimu voda, koji je u istraživanom području većinom narušen izgradnjom infrastrukturnih objekata i regulacijom vodotoka. Izvedeni hidrotehnički zahvati u nizinskim šumama Česme i Velike uzrokovali su pojačanu isušenost šumskoga bazena, a samo lokalno zabarivanje. Dinamika je podzemnih i površinskih voda pod jakim utjecajem drenažne kanalske mreže. Poplave su zbog produbljivanja i kanaliziranja korita Česme i Velike smanjene po učestalosti i duljini trajanja. Česmanske su šume plavljene od kasne jeseni do ranoga proljeća, dok u vegetaciji poplave izostaju. Odvodnjenost bazena uz pojavu niza sušnih vegetacija uzrokuje pojačano sušenje, poremećaje u strukturi sastojina i sukcesiju šumske vegetacije u smjeru suših zajednica. U takvim promijenjenim ekološkim i gospodarskim uvjetima značajno je pravilno pomlađivanje sastojina.

Metoda pomlađivanja oplodnim sječama u tri sijeka (pripremni, naplodni, dovršni sijek) omogućila je uspješno prirodno pomlađivanje poljskoga jasena u bari, djelimice uspješno u nizi, a neuspješno na gredi. To pokazuju rezultati nakon pomlađivanja (tablica 5, slika 5), ali se uočava i u tijeku oplodnih sječa (tablice 3 i 4). Pomladna se površina naplođuje laganim i brojnim sjemenom poljskoga jasena i

prije pomladnoga razdoblja, pa razdioba visina pomlatka poljskoga jasena može imati širok raspon (slika 6). U tijeku oplodnih sječa najveći dio pomlatka postigne visinu do 25 cm. S tim pomlatkom treba računati kao s budućom sastojinom. Pojedine biljke koje svojom visinom dominiraju postati će predrast (slike 3 i 4).

S vremenom se stare sastojine poljskoga jasena mogu naći u uvjetima povećane isušenosti staništa zbog razloga koji su opisani u poglavljima "Pedološke prilike", "Hidrološke prilike" i "Staništa poljskoga jasena". To pogotovo vrijedi za sastojine koje uspijevaju u mikroudubinama - bari i nizi. Takva staništa prelaze u skupinu hrastovih, što pokazuje pojava hrastovoga podrasta, pomlatka običnoga graba, grmlja i zeljanica koje obilježavaju suše stanište (slika 4). Stoga je opravdano umjetno pomlađivanje sastojine sjetvom i sadnjom žira hrasta lužnjaka. Takvim se načinom obavlja izmjena sastojinskog oblika, jer se od čiste jasenove sastojine pomlađivanjem dobiva mješovita sastojina hrasta lužnjaka i poljskoga jasena (tablice 4 i 5). Ipak, i u toj novoj sastojini pomladak pojedinih vrsta prati temeljnu razdiobu prema staništima, pa je poljski jasen brojniji u mikroudubinama, a hrast lužnjak na mikrouzvisinama (slika 5). Ako su stanišni uvjeti u sastojinama poljskoga jasena ostali nepromijenjeni, tada će pokušaji umjetnoga pomlađivanja hrasta lužnjaka biti neuspješni (slika 3). Da je stanište ostalo jasenovo, pokazuje pojava prirodnoga pomlatka i podrasta crne johe, poljskoga jasena i zeljastih biljaka koje obilježavaju jasenovo stanište. U tom je slučaju potrebno prirodno pomladiti poljski jasen (tablica 3, slika 3).

Opisani primjeri pokazuju kako oplodne sječe omogućuju uspješno pomlađivanje poljskoga jasena, pri čemu eventualno umjetno pomlađivanje žirom određuje stanje staništa, i to ponajprije hidropedološke i fitocenološke prilike te struktura podrasta i pomlatka koji se pojave tijekom oplodnih sječa.

Pripremnim se sijekom u sastojini stvaraju povoljni uvjeti za pomlađivanje. Sječom loših i prekobrojnih stabala razmiču se krošnje, povećava se priljev svjetla, ravnomjerno se raspoređuju kvalitetna stabla po pomladnoj površini. Intenzitet pripremnoga sijeka od 16 % obujma drva u sastojini prije sječe pokazao se uspješnim u našim primjerima (plohe 1 i 2). Na plohi 3 intenzitet pripremnoga sijeka iznosio je 30 % od obujma drva u sastojini prije sječe jer je sastojina imala veći obujam. Općenito, intenzitet pripremnoga sijeka ovisi o strukturi sastojine, i to ponajprije o stanju drvne zalihe, okomitom i vodoravnom rasporedu stabala u prostoru sastojine, stanju tla i dr. U jasenovim je sastojinama slabo izražena nuzgredna etaža, a podstojne etaže nema. Zbog toga za pripremni sijek treba doznačivati stabla nuzgredne etaže i potrebna stabla iz dominantne etaže. U sastojinama koje smo odlučili pomlađivati umjetnim načinom podstojna je etaža izražena, a brojniji je i podrast. U tom slučaju pri doznaci treba za naplodni sijek ostaviti dio stabala podstojne etaže i podrast jer mogu koristiti za regulaciju mikroklime u sastojini prije naplodnoga sijeka i onemogućavati bujanja korova.

Pripremni sijek nije potreban u sastojinama koje su se pravilno njegovale, pa se njihova struktura tijekom ophodnje prilagodila budućemu postupku pomlađivanja. Isto tako pripremni se sijek ne izvodi u sastojinama sa smanjenom drvnom zalihom jer bi u tom slučaju sklop stabala bio previše otvoren, a osjetljivo bi se jasenovo stanište zakorovilo i zamočvarilo.

Naplodni se sijek izvodi 2 - 3 godine nakon pripremnoga sijeka. Na primjerima (plohe 1 i 2) pokazalo se kako intenzitet ne bi trebao biti veći od 20 % obujma koji je u sastojini ostao nakon pripremnoga sijeka. Kod povećanog obujma prije sječe intenzitet može iznositi i do 50 % (ploha 3). Naplodnim se sijekom postiže dovoljno svjetla na tlu za uspješno klijanje sjemena i razvoj pomlatka. Pri doznaci stabala u naplodnom sijeku značajno je postići ravnomjeran raspored stabala koja će ostati u sastojini za dovršni sijek. Ako je ostalo stabala iz podstojne etaže ili podrasta, tada ih treba ukloniti. Krošnje ostalih stabala štite pomladak od nepovoljnih ekoloških čimbenika, ponajprije od mraza, tuče i vrućina. Njihova debla u slučaju poplave i smrzavanja drže teret leda na sebi i tako onemogućuju oštećivanje pomlatka kada se poplavna voda povuče, a led ostane visiti.

U razdoblju između pripremnoga i naplodnog sijeka (naplodno razdoblje) sastojina se naplođuje. U slučaju prirodnoga pomlađivanja sastojina poljskoga jasena naplođuje se njegovim sjemenom, a u slučaju umjetnoga pomlađivanja sjetvom ili sadnjom žira. Prema sadašnjim propisima u šumarstvu Republike Hrvatske za umjetno pomlađivanje sjetvom potrebno je 700 - 1 000 kg žira po hektaru, a za sadnju 400 - 600 kg žira po hektaru. Umjetno pomlađivanje može se obaviti i sadnjom sadnica. Tada se koristi 10 000 - 15 000 sadnica hrasta po hektaru. Tijekom naplodnoga razdoblja pokazalo se opravdanim obaviti pripremu staništa za prihvat i uspješno klijanje sjemena. Ona obuhvaća uklanjanje grmlja, korovnih zeljanica (plohe 1, 2, 3), a u nekim slučajevima i rahljenje tla do dubine od 10 cm rotacijskom frezom, površinsku odvodnju, podizanje ograda zbog zaštite pomlatka od divljači i stoke, uništavanje glodavaca...

Dovršni se sijek najčešće izvodi kada se na pomladnoj površini pomladak razvije do mjere kada mu nije potrebna zaštita starih stabala. U našim je primjerima dovršni sijek obavljen dvije godine nakon naplodnoga sijeka. Razdoblje između naplodnoga i dovršnoga sjeka ovisi ponajprije o režimu poplava i klimatskim prilikama. Ako su poplave česte, obilne i dugotrajne, te ako su česti mrazovi i led koji se dugo zadržava na starim stablima, potrebna je duža zaštita starih stabala. U istraživanom području gospodarske jedinice Česma s obzirom na klimatske i hidrološke prilike takva dugotrajna zaštita pomlatka nije potrebna. Stoga je pomlađivanje sastojina uz pomladno razdoblje od 5 godina uspješno obavljeno.

Na kraju treba istaknuti kako opisane primjere pomlađivanja sastojina poljskoga jasena treba promatrati u sklopu općeg utjecaja hidrotehničkih radova u njihovu okolišu. Zbog izmijenjenoga režima poplava i općega pada razine podzemnih voda u Gospodarskoj jedinici djelomično je isušeno istraživano stanište pa se pomlađivanje usmjerilo prema stvaranju sastojina karakterističnih za sušnija staništa. U tom je smislu poljski jasen u strukturi novih sastojina prisutan onoliko koliko mu pripada u izmijenjenim uvjetima. Oplodna sječa omogućila je njegovo uspješno prirodno pomlađivanje na staništima koja ponajviše odgovaraju njegovim ekološkim zahtjevima i biološkim svojstvima, odnosno tamo gdje postiže svoj ekološki optimum i gdje je konkurencijska sposobnost hrasta lužnjaka i ostalih vrsta umanjena.

Čista se sječa pokazala nepovoljnim načinom pomlađivanja sastojina poljskoga jasena zbog slaboga pomlađivanja s obzirom na brojnost i strukturu pomlatka (tablica 6, slika 8). To se posebno odnosi na pokušaj umjetnoga pomlađivanja hrastom lužnjakom. Nakon sadnje 8 300 sadnica hrasta po hektaru u sastojini je pronađeno samo 150 biljaka po hektaru. Ostale su biljke propale u borbi s korovom koji se nakon čiste sječe bujno razvio na pomladnoj površini bez obzira na višekratnu žetvu. Korov se razvio na svim mikroreljefnim oblicima, od mikrouzvisina do mikroudubina. Osim toga pomladna je površina ostala naglo otvorena suncu, padalinama i vjetru, čime su stanišni uvjeti postali nepovoljni za uspješan razvoj mladih hrastovih biljaka.

Nakon čiste sječe ogoljelu pomladnu površinu počele su osvajati pionirske vrste drveća (slika 7). U mikroudubinama prevladava poljski jasen, pojavljuje se vrba, a na mikrouzvisinama se pomlađuju obični grab i klen. Crna se joha podjednako slabo pomlađuje na svim staništima. Za navedene je vrste karakteristično da gotovo svake godine urode velikim količinama laganoga, okriljenog sjemena koje vjetar lako prenosi. Klijavost je sjemena visoka, biljke brzo rastu, podnose nepovoljne stanišne uvjete, pa ih zbog svega toga ubrajamo u pionirske vrste drveća.

Iz strukture pomlatka na površini pomlađenoj čistom sječom vidljivo je kako su provedeni uzgojni zahvati prekinuli progresivni razvoj sastojine i staništa te izazvali regresiju staništa. Čistom sječom ogoljelu površinu postupno su počele osvajati pionirske vrste, dok je hrasta lužnjaka malo, iako su unošene sadnice.

Ključne riječi: poljski jasen (*Fraxinus angustifolia* Vahl), prirodno pomlađivanje, umjetno pomlađivanje, mikroreljef, stanište, oplodne sječe, čista sječa

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Izvorni znanstveni članak

THE SOIL AND FOREST VEGETATION RELATIONSHIP IN THE LIGHT OF THE ANALYSIS OF SOME PROPERTIES OF BROWN SOIL OVER LIMESTONE IN THE KARST REGION OF WESTERN CROATIA

ODNOS TLA I ŠUMSKE VEGETACIJE U SVJETLU RAŠČLAMBE NEKIH SVOJSTAVA SMEĐEGA TLA NA VAPNENCU NA KRŠU ZAPADNE HRVATSKE

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In this work the impact of vegetation on the properties of brown soil over limestone in the karst region of western Croatia has been investigated. The investigation was carried out in five dominant climazonal communities. The results suggest significant differences for some properties of brown soil over limestone (the parameters explaining relatively well the soil organic matter status) between individual forest associations. In addition, littoral the forest associations are very well discriminated from the continental ones. The specific influence of a plant species (although this was not the objective of the investigations) is recognisable in the forest associations with pure beech stands which can be attributed primarily to the influence of litter (plant tissue). The discriminating analysis proved to be very suitable for the determination of the impact of vegetation on the organic complex properties in brown soil over limestone. By including a larger number of pedophysiographical parameters, and using the discriminating analysis, their connection with vegetation characteristics could be explained in an even better way.

Key words: brown soil over limestone, soil organic matter, humus, vegetation, karst

INTRODUCTION
UVOD

The high karst of western Croatia - Gorski kotar with the massifs of Velebit and Kapela is the most valuable woodland in Croatia from the economical, social and conservation aspect. Nevertheless, when speaking of soils over karst in Croatia, including the soils in the said region, the final replies to numerous open questions, such as the origin of mineral particles, formation time and conditions, geochemical characteristics, geographical regularities, etc. have not yet been given.

For the karst region of Croatia, the relations between the soils in terms of their vertical distribution are known (Gračanin 1972, Mayer 1992). In this distribution, brown soil over limestone can be said to have the widest elevational amplitude in the western Croatian pedosphere. Bertović (1971) described in detail the relationship between the soils and the vegetation around Zavižan on northern Velebit. This description clearly indicates that brown soil over limestone is predominant in all plant communities except in the mugho pine association.

According to Martinović (1990), brown soil over limestone is the most frequent soil by far in the Croatian pedosphere, with a surface area of 9,243 km^2 or 17.55% of the pedosphere surface. Preliminary investigations have proved that its share in the western Croatia karst pedosphere is generally higher still. Consequently, when speaking of the variability and heterogeneity of the pedosphere over karst, it should be noted that brown soil over limestone is the largest participant in this variability, so it is logical that it is taken as sample to study this issue.

According to Živanov (1962), the humus accumulation horizon, primarily the organic complex parameters, reflect best the natural variability of soil parameters which can be conditioned by a number of factors. The most important of these factors are, when the same soil type is concerned, tree species, height above sea level and relief.

The heterogeneity of soils over karst proved to be very high owing to the parent substrate properties (Vranković 1971). According to Taboada et al. (1995), a very marked pedosphere heterogeneity is mainly found on limestone.

There are several reasons for this, including:

- the strata position, wearing and water permeability, a very heterogeneous parent substrate;
- uneven pedosphere thickness;
- ground relief, and consequently macroclimatic differences;
- plant species variability;
- pedofauna variability, including that of microflora and microfauna
- wind impact, etc;

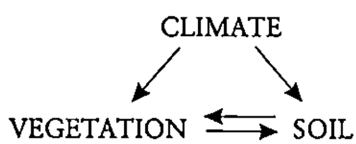
Considering the fact that the largest part of Croatia, which in terms of morphology and hydrogeology is called karst, is abundant in forests and forest soils developed on Mesozoic dolomite rocks, the importance of the issue concerning the real causes of the variability of pedophysiological properties becomes evident. Gračanin (1931) writes that the forest "wherever it occurs is an important pedological factor but hardly anywhere is its importance so decisive for soil development as on our karst."

As far as soils over limestone are concerned, it should be borne in mind that the size of the elementary soil range (Fridland 1984), the pedon, is very variable and that most often it is directly connected with the internal parent material relief.

In addition, the parent material, typical of this region, especially in its northern part (Velebit - Gorski kotar), is the sharpest climatic boundary in this part of Europe. Here, the Mediterranean climate suddenly changes into the cold continental climate type, followed by a marked vegetation change. So, the influence of the vegetation factor on the organic matter and the topsoil takes the form here of a pronounced phytobioclimatic influence. Consequently, in this area, which can be designated as the northern region of Croatian karst or the karst region western Croatia, there are, due to the climatic influence, distinct elevational vegetation zones with typical climazonal communities (Horvat 1962, Pelcer & Martinović 1990, Rauš et al. 1992, Trinajstić 1970). According to Stevenson (1994), the climate is the most important individual factor affecting the spatial distribution of plant species, the amount of produced plant matter and the intensity of soil microbiological acitivity - which means that this factor has a decisive role in the soil organic matter accumulation and transformation.

In addition to the recent, direct and indirect (through the spatial distribution of vegetation) climate influence on soil properties, the relict climatic influence in this region also can be considered. Thus, some soil properties in this part of the karst region can be explained as the consequence of specific Pleistocene climatic changes (Stritar et al. 1967).

On the basis of the extensive research carried out by Jenny (1930, 1941, 1958) in wide areas of the eastern part of the U.S., the scientific problem of the relationship of climate, soil and vegetation can be presented in the form of a triangle



which can be interpreted briefly in the following way:

1. The climate affects directly both the vegetation and the soil, so each relationship between the soil and the vegetation also includes in itself the climatic influence.

2. The soil and the vegetation interact in two directions, this relationship being controlled by the climatic influence.

3. Under the same climatic and pedogenetic conditions, the same vegetation is developed.

Wraber (1967) thinks that "the vegetation development rate as well as the soil development generally are affected by the same environmental factors - climate, ground relief, geological composition and ground hydrology - the biotic factors, but there are qualitative and quantitative differences as to the way in which these factors affect the vegetation or the soil. The vegetation also has quite a strong influence on the soil substrate which, from its part affects the vegetation, but this reciprocal action is not of equal intensity in both directions. Plant associations and the soil are developed parallelly and interdependently. For this reason between both these systems causal relationships exist, although most often the cause and the effect cannot be distinguished."

The forest vegetation affects the soil through the litter, roots and climate modifications (Kundler 1963), the most direct influence being through the litter (Jović 1969, Koegel et al. 1988).

The nitrogen and carbon concentration variability in the surface horizon in the Cascade Mountains in Oregon proved to be attributable to the vegetation influence (McNabb et al. 1986).

Using the regression analysis for 134 forest pedons, Homann et al. (1995) proved that stand characteristics explain 50% of the soil organic carbon variability.

Speaking of the influence of the forest on the soil, Zonn (1960) also mentions the specific influence of individual tree species on the soil organic matter quantity and character.

According to what is known about the geochemical role of forest trees, a different influence on soil evolution, and consequently on its physiography and on its trophicity is to be expected in different climatic conditions and where there is a different proportion of individual species.

The quality of information on forest soil and its involment in forest management or spatial planning for a certain region depends primarily on the variability of forest soil physiographical properties, especially those in the topsoil.

This surface layer of the soil is its most dynamic sphere, where most energy enters and leaves the system. When physiological functions end, and after reaching the soil, or the solum itself, the plant and animal tissue is included into a non-return substance transformation cycle in nature. Organic tissue continuously comes onto and into the soil where it is not only transformed but translocated (Kumada 1987). A large part of the reaction products leaves the soil. Research concerning the organic matter accumulation rate has shown that it is stabilised between 110 (on fine texture material) and 1500 years (on carse texture material) (Stevenson 1994).

Hayes & Swift (1978) consider humus synthesis and degradation as a dynamic process which achieves its balance under specific soil conditions. The soil organic matter is transformed much more quickly than the soil mineral particles, and besides, it is much more variable spatially.

Although many positive characteristics of soil organic matter have been studied thoroughly, it has to be remembered that the soil is a dynamically balanced multicomponent system, so soil characteristics are presented as the effect of various interactions which cannot be attributed solely to the organic matter.

The starting point in this work was a relatively high variability of physiographical properties of the brown soil over limestone, and the objective of the work was to analyse the connection between this variability and the vegetation. For this purpose, factors were selected which directly or indirectly supply information about the soil organic matter status. The task was to investigate, on the basis of the chosen soil and ecosystem status indicators, the regularities in the assumed relationships.

These indicators are as follows:

a) climazonal belongin of vegetation;
b) pedogenetic horizon thickness and soil depth;
c) A-and (B)- soil horizon reaction;
d) humus content in the soil A- and (B)- horizons;
e) total and mineral nitrogen contents in the soil A- and (B)-horizons;
f) physiologically active phosphorus and potassium content in the soil A- and (B)- horizons;
g) clay content in the soil A- and (B)- horizons.

In performing this task, special attention is given to the parameters which best explain the qualitative and quantitative properties of soil organic matter, namely to the humus and nitrogen content, which in this respect can be designated as "thematic variables".

The humus content is the main parameter of soil organic matter. The total nitrogen status is closely connected with the soil humus status because humus matters are high-molecular compounds with 1-5% of total nitrogen in their chemical composition and also because most nitrogen in forest soils is incorporated in these matters.

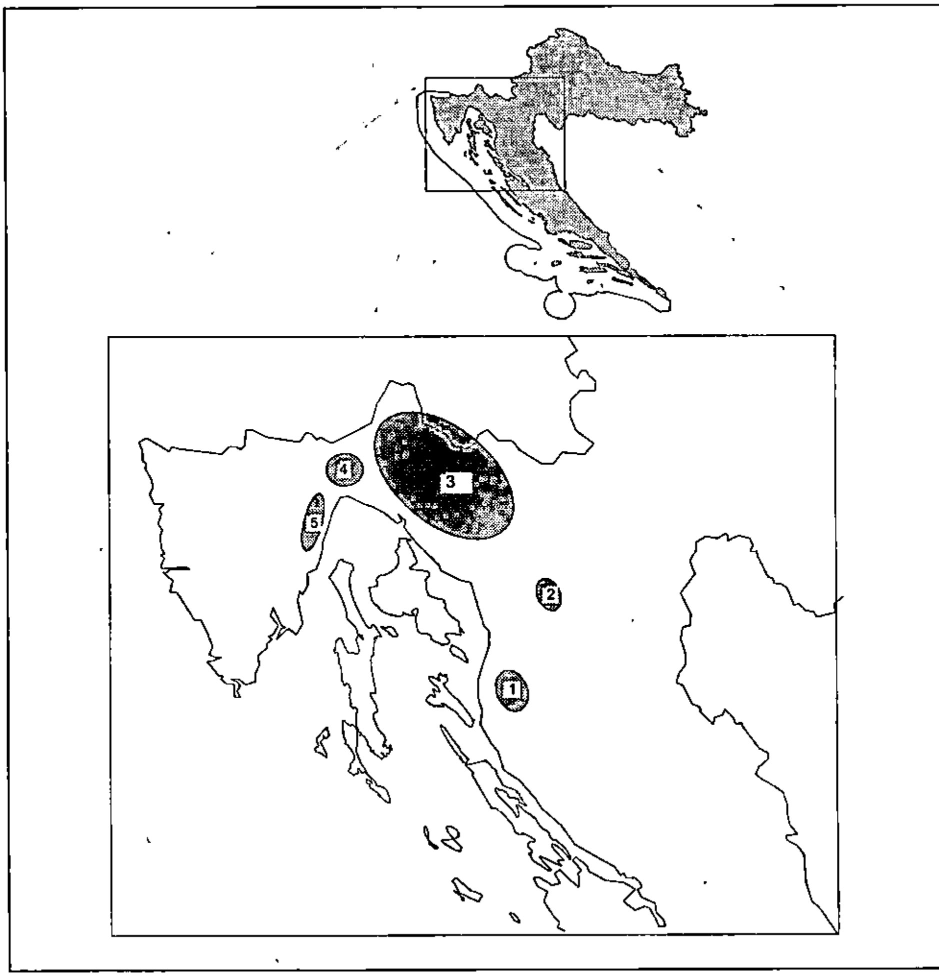
The content and shapes of soil nitrogen mineral forms are an extremely dynamic geochemical phenomenon affected by many factors. However, as it appeared to be a very sensitive indicator of forest ecosystem status, it presents an interesting parameter in the analysis of the soil organic complex status and its variability.

REGION OF INVESTIGATION AND METHODS
PODRUČJE ISTRAŽIVANJA I METODE

The region of investigation has been divided into 5 subregions (Fig. 1):

1. Northern Velebit
2. Velika Kapela
3. Gorski kotar
4. Rijeka and Opatija hinterland
5. Učka

Figure 1. Investigated area geographic position chart
Slika 1. Položaj istraživanog područja



According to Thorntwait's classification, subregions 1, 2, 3 and 5 have a perhumid climate (P/E127) and subregion 4 a humid climate (P/E=64-127). The climate characteristics are more contrasting than this statement implies, as can be seen from the review of the dominant climazonal forest associations:

1. *Ostryo-Quercetum pubescentis* /Ht./ Trinajstić 1977 (OST-QUE.)
   - mixed pubescent oak and hop hornbeam forests - subregion 4
2. *Seslerio-Fagetum sylvaticae* /Ht.1950/ M.Wraber 1960 (SES-FAG.)
   - beech and sesleria forest - subregions 3, 4 and 5
3. *Abieti-Fagetum dinaricum* Treg. 1957 (ABI-FAG.)
   - Dinaric beech-fir forests - subregions 1 and 3

4. *Homogino alpinae-Fagetum sylvaticae* /Ht.1938/ Borh.1963(HOM-FAG.)
   - sub-Alpine beech forest with homogyne - subregions 1and 3
5. *Lamio orvale-Fagetum sylvaticae* Ht. 1938 (LAM-FAG.)
   - mountain beech forest with dead nettle - subregion 2.

The geological structure of the described region consists mostly of limestone and dolomite of the Mesozoic age, with Jurassic-formation limestone dominating. In addition to these Mesozoic formations, a wider region of investigation also comprises others formations, younger or older (Herak 1960), but they are not included in the present investigation.

From both the geological and the morphological standpoint, the region of investigation belongs to the karst of the northwestern Dinaric Alps. The entire region of investigation owes its outer aspect primarily to the geotechtonical motions that occurred during its geological past, followed by the action of external factors in the form of the effects of water erosion (especially in the areas of high faults and folds), namely of glacial ice in the Pleistocene epoch (some parts of Gorski kotar and Velebit).

With regard to the type of geological-lythological stratum in the investigated region, the soils generally belong to the developement series of soils on pure, compact limestone. Such substrate with 0.2-2% of insoluble residue, is generally common for these soils, which marks strongly their genesis and properties. This area includes rocky ground, black soil, brown soil over limestone and illimerized soils. In the pedosphere, brown soil over limestone, occurs more frequently.

In the selection of control objects, namely forest stands in which field measurements and soil sampling were made, the following criteria were taken into consideration:

1. To exclude the influence of parent substrate.
2. In the respective areas, the vegetation relationships were studied from the aspect of their belonging to climazonal plant communities, typical for this part of Croatia. Five plant communities with complete ranges were chosen, which in their greatest part coincide with the range of Jurassic and Createceous limestone, and with pronounced elevational zones.
3. On the basis of the pedological-cartographic documentation, in this region ranges with the dominant presence of brown soil over limestone in the pedosphere were separated.
4. From this three-layer system, potential areas and localities were chosen in which the investigations were continued.

On the basis of knowledge concerning the variability of pedological parameters and the determination of a minimum sample size (Cline 1944, Christensen & Malmoros 1984, Starr et al. 1995, Živanov 1962), the following requirements in determining the position of pedological profiles and the composition of average soil samples for laboratory analysis were fixed:

a) the geological-lythological stratum homogeneity based on field observations;

b) quiet microrelief - exclusion of possible excessive pedoturbation caused anthropogenetically or by natural processes;
c) exclusion extreme positions of mezzorelief - peaks and downs;
d) stand canopy completeness;
e) sampling away from roots - in the outer third of dominant tree crown projection;
f) the endomorphology characteristic of medium deep, typical brown soil over limestone.

Individual samples were taken in genetical (A- and (B)rz-) horizons on the main profile dug in the outer third of the tree crown projection of the dominant tree in the stand and on another three auxiliary profiles dug under the same conditions inside the elementary soil range. Attention was paid to the fact that when soils over limestone are involved, the elementary soil range size, the polypedon (Fridland 1984), varies significantly and that most often it is directly connected with the parent material internal relief which is closely connected with the rock character. On the main profile, three samples were taken (one from the profile front and one from each of the lateral sides), from which, together with the samples from auxiliary profiles (in total, six individual samples), an average sample was made, separately for the A- and (B)rz- horizons. Sampling was made on 155 locations, distributed as follows:

OST-QUE. - 17
SES-FAG. - 26
ABI-FAG. - 47
HOM-FAG. - 40
LAM-FAG. - 25

The soil laboratory analyses were made using the following methods:

1. Soil reaction - electrometrically, with combined electrode, using soil suspension in water, namely in 0.01 $MCaCl_2$, in a ratio of 1:2.5;

2. Humus content - using the bichromate method according to Tjurin;

3. Total nitrogen content - burning according to Kjeldahl's procedure and distillation according to Bremner;

4. Nitrate nitrogen content - by spectrophotometry (436) after extraction in 0.2 M K_2SO_4 and coloration with phenoldisulphonic acid;

5. Ammonia nitrogen content - by spectrophotometry (436 mm) after extraction in 0.2 M K_2SO_4 and coloration with Nesler reagent;

6. Content of physiologically active forms of potassium and phosphorus - using the AL method;

7. Mechanical soil composition - by pipette method after deaggregate in 0.2 M $Na_4P_2O_7$.

All other pedological parameters used in further analyses were determined mathematically.

Separation of forest associations in the area of measured pedological variables (to evaluate the contribution of various phytobioclimates to the variability of the brown soil over limestone organic complex), as well as in the area of geomorphological variables (to evaluate the frequency of the geomorphological variable influence on the pedological variability through the forest associations themselves), was tested using the discriminating analysis (Mardia et al. 1982). Discrimination according to all pedological variables, as well as according to thematic variables A-, namely (B)rz- horizons (humus content, total nitrogen content and mineral nitrogen content) was made. The results presented here are given by means of: a classification matrix, a table of standardised linear coefficients for each inlet variable in each discriminatory variable (contributions of measured variables to their linear combination maximising group separation), and a dispersion diagram for classified profiles in the discriminant subarea. The canonical correlation was applied once more in linking up two sets of discriminatory variables (pedological and geomorphological discrimination criteria) to evaluate the indirect contribution of geomorphological variables in the discrimination of forest associations according to the measured pedological variables. The statistical analyses were made in the CSS-Statistica 4.3 program package.

LIST OF SYMBOLS AND ABBREVIATIONS
POPIS SIMBOLA I SKRAĆENICA

A_C - organic carbon content in A- horizon

A_C:N - relationship of content of organic carbon and total nitrogen in A- horizon

A_C_H_2SO_4 - content of organic carbon in A- horizon, extracted with 0.05 M H_2SO_4

A_C_ost - nonextracted organic carbon in A- horizon (with mixture of 0.1 M $Na_4P_2O_7$ x 10 H_20 and 0.1 M NaOH)

A_dub - depth of A- horizon

A_gli - clay content in A- horizon

A_hum - humus content in A- horizon

A_K_2O - physiologically active potassium content in A-horizon

A_N_m - mineral nitrogen content in A-horizon

A_N_m:N_uk - relationship between mineral and total nitrogen content in A-horizon

A_N_NH_4 - ammonia nitrogen content in A-horizon

A_N_NH_4:N_uk - relationship between ammonia and total nitrogen content in A-horizon

A_N_NO_3 - nitrate nitrogen content in A-horizon

A_N_NO_3:N_uk - relationship between nitrate and total nitrogen content in A-horizon

A_N_uk - total nitrogen content in A-horizon

A_P_2O_5 - physiologically active phosphorus content in A-horizon
A_pH_$CaCl_2$ - pH- value in A- horizon - measured in 0.01 M $CaCl_2$
A_pH_H_2O - pH- value in A- horizon - measured in water
ABI-FAG. (ABI-FAG.), (3) - *Abiet-Fagetum dinaricum* Treg. 1957
(B)_C:N - relationship of content of organic carbon and total nitrogen in (B)rz- horizon
(B)_dub - depth of (B)rz- horizon
(B)_gli - clay content in A- horizon (B)rz- horizon
(B)_hum - humus content in (B)rz- horizon
(B)_K_2O - physiologically active potassium content in (B)rz-horizon
(B)_N_m - mineral nitrogen content in (B)rz- horizon
(B)_N_m:N_uk - relationship between mineral and total nitrogen content in (B)rz- horizon
(B)_N_NH_4 - ammonia nitrogen content in (B)rz- horizon
(B)_N_NH_4:N_uk - relationship between ammonia and total nitrogen content in (B)rz- horizon
(B)_N_NO_3 - total nitrogen content in (B)rz- horizon
(B)_N_NO_3:N_uk - relationship between nitrate and total nitrogen content in (B)rz- horizon
(B)_N_uk - total nitrogen content in (B)rz- horizon
(B)_P_2O_5 - physiologically active phosphorus content in (B)rz- horizon
(B)_pH_$CaCl_2$ - pH- value in (B)rz- horizon - measured in 0.01 M
(B)_pH_H_2O - pH- value in (B)rz- horizon - measured in water
HOM-FAG. (HOM-FAG.), (4) - *Homogino alpinae-Fagetum sylvaticae* /Ht. 1938/Borh. 1963
LAM-FAG. (LAM-FAG.), (5) - *Lamio orvale-Fagetum sylvaticae* Ht. 1938
OKT - soil organic complex
OST-QUE. (OST-QUE.), (1) - *Ostryo-Quercetum pubescentis* /Ht./ Trinajstić 1977
OTT - soil organic matter
SES-FAG. (SES-FAG.), (2) - *Seslerio-Fagetum sylvaticae* /Ht. 1950/ M. Wraber 1960

INVESTIGATION RESULTS
REZULTATI ISTRAŽIVANJA

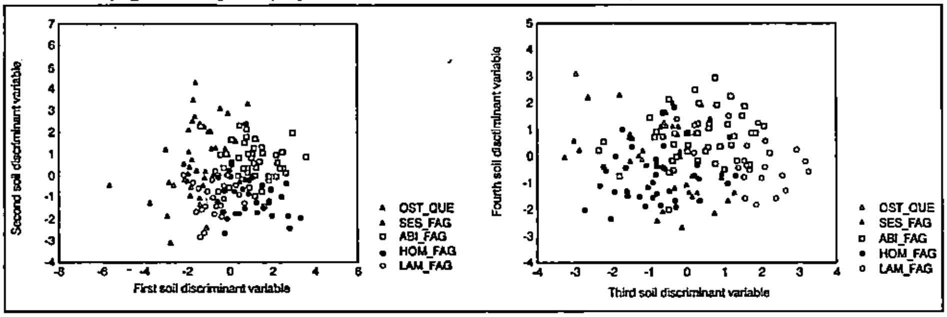
To evaluate the influence of vegetation on the organic complex variability of brown soil over limestone, the most suitable method, due to the vegetation data quality, is the forest associations discriminating analysis according to the measured pedological variables.

Forest associations discrimination based on the pedological variables is very high - 81.9% of properly classified pedological profiles (Table 1, Fig. 2), so here, with regard to the organic complex, the forest associations can be interpreted largely as separate pedological units. The continental forest associations were discriminated from the Mediterranean ones according to the measured pedological variables to an even larger extent than the individual ones, as can be seen from the classification matrix as well as in the dispersion diagram where the OST-QUE. is mixed only with the SES-FAG., while the ABI-FAG., HOM-FAG. and LAM-FAG are mixed only to a lesser extent with the Mediterranean forest associations. The additional influence of various macroclimate types, and consequently of different vegetation zone types, is evident, which obviously has an influence on pedogenesis.

Table 1. Classification matrix of forest associations according to soil variables
Tablica 1. Klasifikacijska matrica biljnih zajednica prema pedološkim varijablama

Forest associations *Biljne zajednice*	Correct *Ispravno* (%)	1:1 p=0.110	2:2 p=0.168	3:3 p=0.303	4:4 p=0.258	5:5 p=0.161
1	2	3	4	5	6	7
Ostryo-Quercetum	94.12	16	1	0	0	0
Seslerio-Fagetum	73.08	5	19	1	1	0
Abieti-Fagetum	78.72	0	1	37	5	4
Homogino-Fagetum	82.50	1	1	5	33	0
Lamio-Fagetum	88.00	1	0	1	1	22
Total - *Ukupno*	81.94	23	22	44	40	26

Figure 2. Scatterplot of soil discriminant variables
Slika 2. Dijagram raspršenja pedoloških diskriminatornih varijabli



Contributions of individual measured pedological variables to the discriminatory variables are shown in Table 2, where, from the cumulatively expressed relative property values, it is visible that not one discriminatory variable can be neglected. The specific litter influence of dominant species in the stand can be conjectured on the fourth discriminatory variable (Fig. 2), according to which the pure beech stands are not distinguished regardless of the climate (SES.-FAG., HOM.-FAG. and LAM.-FAG.), while the ABI-FAG. and OST-QUE are separated, and the macroclimates on the first discriminatory variable (Fig. 2). Presently, it can only be assumed that other discriminatory variables might present influences of ground plant cover, biomass, topoclimate, etc.

Table 2. Standardised coefficients for soil discriminant variables
Tablica 2. Standardizirani koeficijenti za pedološke diskriminatorne varijable

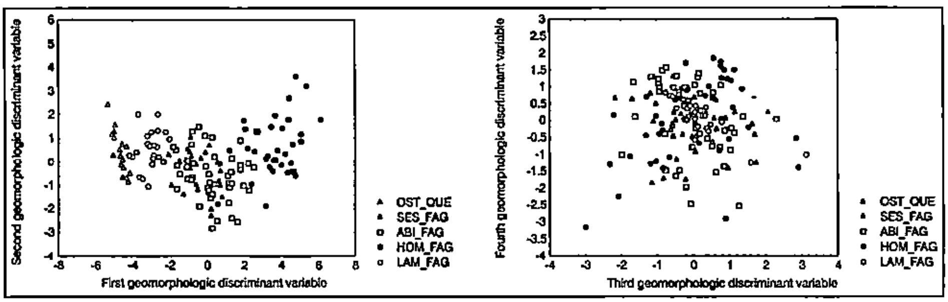
Variable *Varijabla*		Standardized coefficients for discriminant variables *Standardizirani koeficijenti za diskriminatorne varijable*			
		First variable *Prva varijabla*	Second variable *Druga varijabla*	Third variable *Treća varijabla*	Fourth variable *Četvrta varijabla*
1		2	3	4	5
A_dub		0.1754	0.5341	0.4097	-0.5519
A_pH_H_2O		-0.1782	-0.0368	0.0636	0.4574
A_hum		0.2813	1.3083	0.1790	1.2868
A_N_NO_3		-0.8247	-0.6337	-0.4570	-0.3800
A_N_NH_4		-0.0219	-1.4726	1.0724	-2.1440
A_N_NO_3:N_uk		0.5520	0.4423	0.4818	0.6529
A_N_NH_4:N_uk		0.1388	1.2441	-0.8287	1.7468
A_C:N		0.3003	-1.1235	-0.0028	-1.5710
A_P_2O_5		-0.0739	0.1190	0.1496	-0.0210
A_K_2O		-0.5187	0.2368	-0.2549	0.0592
A_gli		0.0871	0.0491	-0.4853	-0.0548
(B)_dub		-0.4839	0.2860	-0.3378	0.1236
(B)_pH_H_2O		0.2242	0.0080	0.0259	-0.0524
(B)_hum		-0.5391	1.1313	-0.9203	-0.2239
(B)_N_NO_3		0.8735	0.1896	0.0383	0.4112
(B)_N_NH_4		-0.4961	-1.2186	0.6091	0.3374
(B)_N_NO_3:N_uk		-0.3646	-0.2386	-0.2347	-0.5857
(B)_N_NH_4:N_uk		0.5563	1.0829	-0.5447	-0.0740
(B)_C:N		0.4354	-0.6078	0.4254	0.5975
(B)_P_2O_5		-0.2928	0.0301	0.0339	-0.3346
(B)_K_2O		-0.2639	-0.4535	-0.2515	0.0218
(B)_gli		0.1581	-0.0469	-0.2262	-0.1601
Eigenvalues	Single *Pojedinačno*	1.3945	0.9489	0.8853	0.5094
Svojstvene vrijednosti	Cumulative *Kumulativno*	0.3730	0.6269	0.8637	1.0000

Nevertheless, the forest associations discrimination based on the geomorphological variables is also very high - 80.6% of properly classified pedological profiles (Table 3, Fig. 3). Here, the last three discriminatory variables can practically be neglected, mostly due to the dominant influence of height above sea level, but also due to higher or lower contributions and other geomorphological variables to the first discriminatory variable (Table 4). As the total amount of shares of properly classified pedological profiles from the two described discriminating analyses considerably exceed 100%, this means that the forest associations discrimination, according to the pedological variables, as an attempt to estimate indirectly the impact of vegetation on the organic complex, also included the previously tested and proven independent evaluation factors. Accordingly, the canonical correlation of two discriminatory variable sets from two discriminating analyses is R=0.686, while other results (Table 5 and 6, Fig. 4 and 5) underline again the dominant influence of height above sea level.

Table 3. Classification matrix of forest associations according to geomorphological variables
Tablica 3. Klasifikacijska matrica biljnih zajednica prema geomorfološkim varijablama

Forest associations *Biljne zajednice*	Correct *Ispravno* (%)	1:1 p=0.110	2:2 p=0.168	3:3 p=0.303	4:4 p=0.258	5:5 p=0.161
1	2	3	4	5	6	7
Ostryo-Quercetum	100.00	17	0	0	0	0
Seslerio-Fagetum	46.15	0	12	13	0	1
Abieti-Fagetum	72.34	0	8	34	3	2
Homogino-Fagetum	95.00	0	0	2	38	0
Lamio-Fagetum	96.00	1	0	0	0	24
Total - *Ukupno*	80.65	18	20	49	41	27

Figure 3. Scatterplot of geomorphologic discriminant variables
Slika 3. Dijagram raspršenja geomorfoloških diskriminatornih varijabli



If only the thematic[1] pedological variables are taken in the discriminating analysis, the percentage of properly classified pedological profiles is lower (Table 7); in total 57.4% of properly classified profiles. This leads to the conclusion that

[1] A_hum, A_N_NO_3, A_NH_4, (B)_hum, (B)_N_NO_3, (B)_NH_4

other pedological variables contribute to a lesser extent to the forest associations discrimination; thus, from the classification matrix it can also be seen that the continental forest associations are discriminated from the sub-Mediterranean ones. According to the cumulatively expressed property values (Table 8), it is visible that the third and fourth variables can be neglected; their total contribution to the discrimination is 9%. The first variable shows as high as forest associations discrimination according to the thematic pedological variables with as 65% (Table 8), while from the dispersion diagram (Fig. 6) it can be seen that the forest associations ABI-FAG. and HOM-FAG. are separated from other forest associations. However this is very likely attributable, to the fullest extent, to the macroclimatic and topoclimatic influence, which is directly connected with height above sea level.

Table 4. Standardised coefficients for geomorphological discriminant variables
Tablica 4. Standardizirani koeficijenti za geomorfološke diskriminatorne varijable

Variable *Varijabla*		Standardised coefficients for discriminant variables *Standardizirani koeficijenti za diskriminatorne varijable*			
		First variable *Prva varijabla*	Second variable *Druga varijabla*	Third variable *Treća varijabla*	Fourth variable *Četvrta varijabla*
1		2	3	4	5
Altitude - *Nadmorska visina*		1.0201	-0.0012	0.2221	0.1298
Rockiness - *Stjenovitost*		-0.3518	0.2646	0.6321	-0.2935
Stoniness - *Kamenitost*		0.3398	0.7705	-0.5929	-0.3133
Slope - *Nagib*		0.0273	-0.2956	0.2335	-0.2650
Exposition to sun -*Izloženost suncu*		-0.6149	1.7028	1.0363	0.8046
Orientation - *Orijentacija*		0.4778	-1.6410	-1.2878	-0.2503
Eigenvalues	Single *Pojedinačno*	7.9110	0.2461	0.0261	0.0053
Svojstvene vrijednosti	Cumulative *Kumulativno*	0.9661	0.9962	0.9993	1.000

Table 5. Structure of canonical variables for soil variables
Tablica 5. Struktura kanoničkih varijabli za podskup pedoloških varijabli

Variable *Varijabla*	Canonical variables (left set) - *Kanoničke varijable (lijevi set)*			
	First - *Prva*	Second - *Druga*	Third - *Treća*	Fourth - *Četvrta*
1	2	3	4	5
First - *Prva*	0.7401	-0.1168	-0.5287	0.3989
Second - *Druga*	0.0681	-0.9666	0.1873	-0.1612
Third - *Treća*	-0.4139	-0.1532	0.1249	0.8886
Fourth - *Četvrta*	-0.5257	-0.1691	-0.8184	-0.1590

Table 6. Structure of canonical variables for geomorphological variables
Tablica 6. Struktura kanoničkih varijabli za podskup geomorfoloških varijabli

Variable *Varijabla*	Canonical variables (right set) - *Kanoničke varijable (desni set)*			
	First - *Prva*	Second - *Druga*	Third - *Treća*	Fourth - *Četvrta*
1	2	3	4	5
First - *Prva*	0.9964	0.0022	-0.0831	0.0150
Second - *Druga*	0.0105	0.9878	0.1548	0.0137
Third - *Treća*	0.0818	-0.1376	0.9070	-0.3895
Fourth - *Četvrta*	0.0182	-0.0729	0.3828	0.9208

Figure 4. Plot of canonical eigenvalues
Slika 4. Grafikon svojstvenih vrijednosti kanoničkih varijabli.

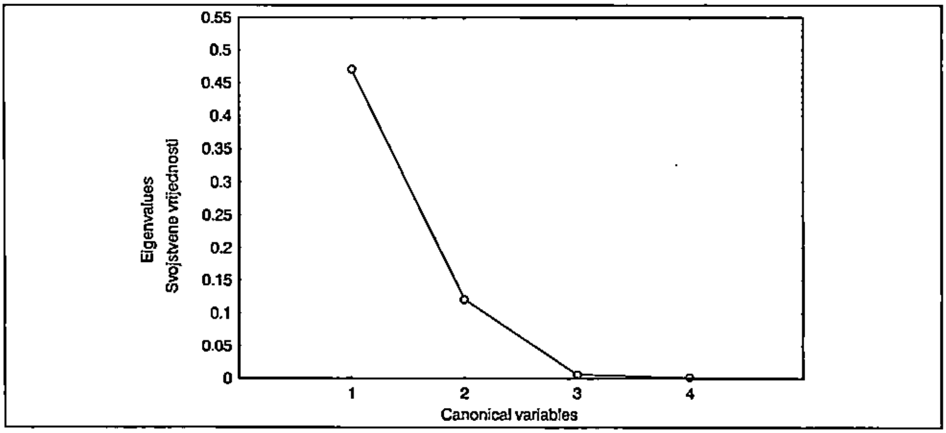


Figure 5. Plot of canonical correlations
Slika 5. Grafikon korelacija kanoničkih varijabli

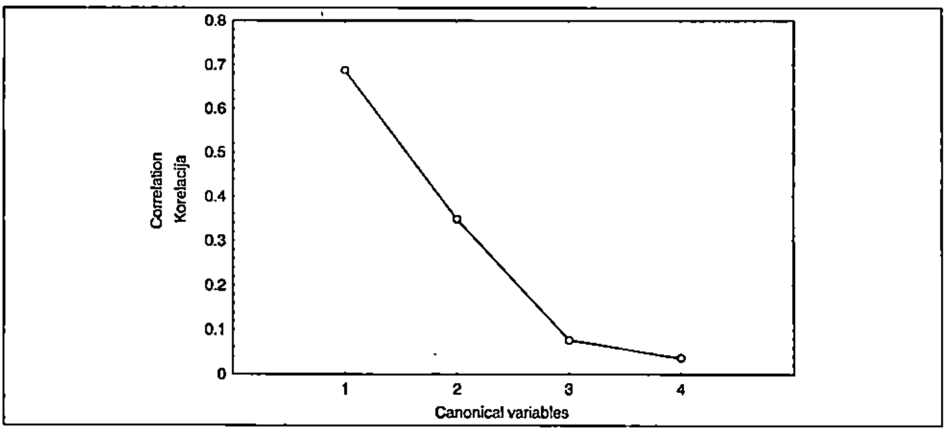


Table 7. Classification matrix of forest associations according to thematic soil variables
Tablica 7. Klasifikacijska matrica biljnih zajednica prema tematskim pedološkim varijablama

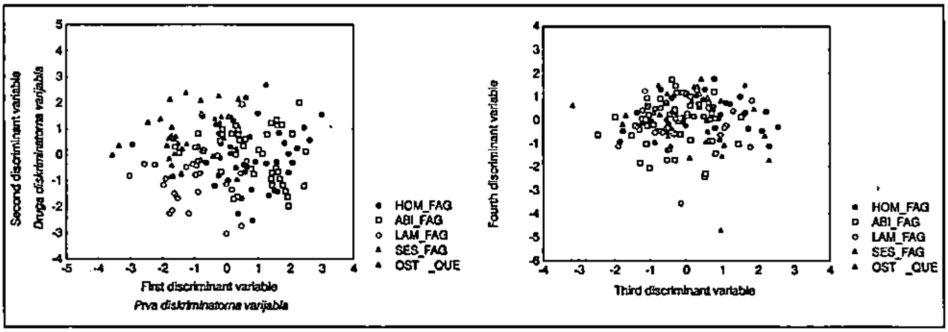
Forest associations *Biljne zajednice*	Correct *Ispravno* (%)	1:1 p=0.258	2:2 p=0.303	3:3 p=0.161	4:4 p=0.168	5:5 p=0.110
1	2	3	4	5	6	7
Ostryo-Quercetum	55.00000	22	14	2	1	1
Seslerio-Fagetum	65.95744	10	31	1	4	1
Abieti-Fagetum	68.00000	2	2	17	2	2
Homogino-Fagetum	53.84615	2	3	2	14	5
Lamio-Fagetum	29.41176	0	1	4	7	5
Total - *Ukupno*	57.41935	36	51	26	28	14

Table 8. Standardised coefficients for soil discriminant variables (according to thematic variables)
Tablica 8. Standardizirani koeficijenti za pedološke diskriminatorne varijable (prema tematskim varijablama)

Variable *Varijabla*		Standardised coefficients for discriminant variables *Standardizirani koeficijenti za diskriminatorne varijable*			
		First variable *Prva varijabla*	Second variable *Druga varijabla*	Third variable *Treća varijabla*	Fourth variable *Četvrta varijabla*
1		2	3	4	5
A_hum		.660440	-.015698	.211764	-.301591
A_N_uk		-.632466	.045263	.192146	-.433774
A_N_m		-.088606	-.306136	.458874	-.364603
(B)_hum		.212355	.734180	-.551441	-.282547
(B)_N_uk		-.808720	.061006	-.329858	.204924
(B)_N_m		.168345	-.599945	-.800576	-.178513
Eigenvalues *Svojstvene vrijednosti*	Single *Pojedinačno*	.894412	.338587	.116603	.017961
	Cumulative *Kumulativno*	.654019	.901603	.986866	1.000000

If the discriminating analysis according to the thematic variables is made separately for the A-, namely the (B)rz- horizon, the percentage of regularly classified profiles according to the A- horizon thematic variables comes off (Table 9). This refers in particular to the associations OST-QUE., SES-FAG. and HOM-FAG., where the percentage of properly classified profiles range between 17.5 and 23.5. Included here, the profiles of forest associations HOM-FAG. and SES-FAG. are mixed mostly with the forest association ABI-FAG. From the table of property values (Table 10), it can be seen that the first discriminatory variable explains the fo-

Figure 6. Scatterplot of soil discriminant variables (according to "thematic" variables)
Slika 6. Dijagram raspršenja pedoloških diskriminatornih varijabli (prema "tematskim" varijablama)



rest associations discrimination according to the A-horizon thematic variables with a percentage as high as 83%, while the other two are negligible. However, the classification matrix (Table 9) and the dispersion diagrams (Fig. 7) do not suggest any significant differences between the forest associations according to the indicated variables, with the exception, to a certain degree, of the ABI-FAG. and LAM-FAG., between which a certain discrimination exists (Fig. 7).

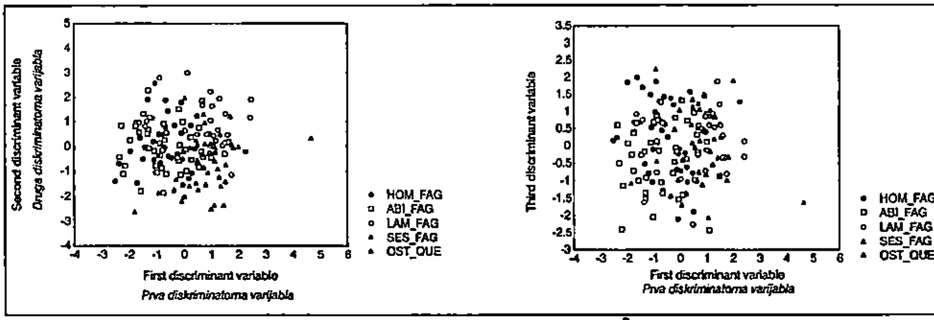
Table 9. Classification matrix of forest associations according to thematic variables of A-horizon
Tablica 9. Klasifikacijska matrica biljnih zajednica prema tematskim pedološkim varijablama A- horizonta

Forest associations *Biljne zajednice*	Correct *Ispravno* (%)	1:1 p=0.258	2:2 p=0.303	3:3 p=0.161	4:4 p=0.168	5:5 p=0.110
1	2	3	4	5	6	7
Ostryo-Quercetum	17.50000	7	29	2	1	1
Seslerio-Fagetum	65.95744	9	31	3	4	0
Abieti-Fagetum	48.00000	1	9	12	2	1
Homogino-Fagetum	19.23077	2	12	3	5	4
Lamio-Fagetum	23.52941	1	5	3	4	4
Total - *Ukupno*	38.06452	20	86	23	16	10

According to the (B)rz- horizon thematic variables, the percentage of properly classified profiles is in total the same as in the thematic variable analysis of the whole profile (Table 11). Significant here, however, is the decrease in the proper classification percentage for the forest association OST-QUE. (17.6 %) and the increase for the SES-FAG. (69.2%). The property values of the first and the second discriminatory variables are relatively high (Table 12), while the third one can be

Figure 8. Scatterplot of soil discriminant variables (according to "thematic" variables of (B)rz- horizon)

Slika 8. Dijagram raspršenja pedoloških diskriminatornih varijabli (prema "tematskim" varijablama (B)rz- horizonta)



relatively well discriminated from other forest associations, which is attributable to the macroclimatic and topoclimatic influence.

4. The forest associations discrimination according to the A- horizon thematic variables is markedly low (38% of properly classified profiles). A certain discrimination can be conjectured only between the ABI-FAG. and the LAM-FAG.

5. The phyocoenoses discrimination according to the (B)rz- horizon thematic variables is similar to that according to the thematic variables of the entire profile. There is a certain discrimination of the forest associations ABI-FAG. and HOM-FAG. from the others, as well as that of the SES-FAG. from the LAM-FAG.

DISCUSSION
RASPRAVA

In spite of the fact that the mathematical and statistical process modelling in forestry has been improved, in the investigation of certain ecosystem segments, such as soil, the problem is the large number of parameters to be included, as well as difficulties with their measurment. Experience has shown (Arrouys & Pelisser 1994, Arrouys et al. 1994, Berg 1980, Borchers & Perry 1992, Hršak 1993, Lohmyer & Zezschwitz 1982, Martinović 1972) that a reasonably acceptable solution in the investigation of such very dynamic systems consists in defining certain requirements in order to exclude uncontrolled influences (treatments). In the realisation of such a project, two basic questions arise:

1. Is the number of included parameters which can contribute significantly to the interpretation of relationships between the phenomena sufficient ?

2. Have all uncontrolled influences been excluded (namely, have the requirements been well defined) ?

The selection of variables used in this analysis and, through them, in the investigation of relationships in the soil, is based on the knowledge that the features of the soil organic matter, including those of brown soil over limestone, depend upon a number of interconnected stand conditions. With regard to the problems put forward in this work, the most important among them are: the plant tissue composition, the soil microorganism activity and soil chemical properties (Ćirić 1984, Lutz & Chandler 1962, Stevenson 1994). It is in this connection that the hypotheses on the organic complex variability in brown soil over limestone under various geomorphological and phytobioclimatic conditions of the western Croatia karst region have been presented.

With regard to the influence of forest associations, in this case of the phytobioclimates on the brown soil over limestone organic complex, the discriminating analysis has proved to be an excellent solution for the problem. The forest associations discrimination according to all measured variables is relatively high (81.95% of the properly classified pedological profiles). Nevertheless, only the pure beech stands (the forest associations SES-FAG., HOM-FAG. and LAM-FAG.) are separated well from the others, which can be attributed to the specific influence of litter. The forest associations discrimination based on the thematic pedological variables of the whole profile is less high, although the forest associations ABI-FAG. and HOM-FAG. are differentiated from the others. A likely reason for this is of the macroclimatic and topoclimatic nature and can be connected indirectly with the character of microbiological activity. A similar, though lower, discrimination is that according to the thematic (B)rz- horizon variables. If only the A-horizon thematic variables are taken into consideration, the discrimination is low (38% of properly classified profiles). The poor discrimination has been noted only between the forest associations ABI-FAG. and LAM-FAG. With regard to these findings, it can be said with certainty that in these relationships a number of factors with many interactive effects are involved.

CONCLUSIONS
ZAKLJUČCI

1. a) Discrimination of the five dominant forest associations in the karst region of western Croatia according to all measured pedological variables is relatively high (81.9% of properly classified pedological profiles). Within these, the littoral forest associations are distinguished well from the continental ones.

b) The discrimination of forest associations with pure beech stands from other forest associations has been determined and is attributable to the influence of litter.

2. In the discrimination of forest associations according to the geomorphological variables, the height above sea level dominates. This is also indicated by the canonical correlation between two sets of discriminatory variables.

3. The discrimination of forest associations according to the thematic pedological variables of the whole profile is less high than that according to all variables.

The beech and fir forest associations, as well as those of the sub-Alpine beech, are relatively well discriminated from other forest associations, which can be attributed to macroclimatic and topoclimatic influences.

4. The discrimination of forest associations according to the A- horizon thematic variables is markedly low (38% of properly classified profiles). A certain discriminati0and HOM-FAG. from the others, as well as a discrimination of the SES-FAG. from the LAM-FAG.

In general, the discriminating analysis has proved to be very suitable for the determination of the influence of vegetation on the organic complex features in brown soil over limestone. When a larger number of parameters is included, the forest associations discrimination is relatively high, owing to the pure beech stands, which can be attributed to the specific influence of litter. By reducing the number of variables, the forest associations discrimination decreases, which makes any firm conclusions difficult. In this connection, it can be assumed that these relationships include many factors with numerous interactive influences.

With the introduction of a larger number of parameters for the physiography of brown soil over limestone, the discriminating analysis would allow an even better explanation of its variability, especially in the topsoil, as well as its connection with the features of vegetation cover.

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ODNOS TLA I ŠUMSKE VEGETACIJE U SVJETLU RAŠČLAMBE NEKIH SVOJSTAVA SMEĐEGA TLA NA VAPNENCU NA KRŠU ZAPADNE HRVATSKE

SAŽETAK

U radu je istraživan utjecaj vegetacije na svojstva smeđega tla na vapnencu na kršu zapadne Hrvatske. Cilj je bio istražiti neke fiziografske značajke smeđega tla na vapnencu i provjeriti na taj način hipoteze iz dosadašnjih istraživanja slične naravi, u kojima se govori o:

- visokoj varijabilnosti fiziografskih svojstava smeđega tla na vapnencu, poglavito onih koji su u izravnoj ili posrednoj vezi s organskom tvari tla, tj. svojstava površinskoga dijela tla;
- uzročnoj povezanosti te varijabilnosti s: drugim pedofiziografskim svojstvima, klimatskim čimbenicima, vegetacijskim čimbenicima, geomorfološkim čimbenicima.

Ovdje je postavljen zadatak da se na temelju odabranih relativnih pokazatelja stanja organske tvari tla i ekosustava u cjelini istraže zakonitosti u pretpostavljenim odnosima, poglavito između svojstava smeđega tla na vapnencu i vegetacije (šumskih fitocenoza).

Riječ je o ovim pokazateljima:

a)klimatskozonska pripadnost vegetacije

b) debljina pedogenetičkih horizonata i dubina tla

c) reakcija A- i (B)- horizonta tla

d) sadržaj humusa u A- i (B)- horizontu tla

e) sadržaj ukupnoga i mineralnih oblika dušika u A- i (B)- horizontu tla

f) sadržaj fiziološki aktivnih oblika fosfora i kalija u A- i (B)- horizontu tla

g) sadržaj gline u A- i (B)- horizontu tla

h) grupni sastav humusa u A- horizontu tla.

Istraživanja su obavljena u zapadnoj Hrvatskoj, na kršu (vapnenačko-dolomitno područje), i to u sljedećim, u tom području dominantnim klimatskozonskim fitocenozama:

1. *Ostryo-Quercetum pubescentis* /Ht./ Trinajstić 1977
- mješovite šume medunca i crnoga graba

2. *Seslerio-Fagetum sylvaticae* /Ht. 1950/ M. Wraber 1960
- šuma bukve i jesenske šašike

3. *Abieti-Fagetum dinaricum* Treg. 1957
- dinarska bukovo-jelova šuma

4. *Homogino alpinae-Fagetum sylvaticae* /Ht. 1938/ Borh. 1963
- pretplaninska bukova šuma s urezicom

5. *Lamio orvale-Fagetum sylvaticae* Ht. 1938
- brdska bukova šuma s mrtvom koprivom.

U statističkom dijelu istraživanja primijenjena je diskriminantna analiza fitocenoza prema mjerenim pedološkim varijablama. Rezultati istraživanja mogu se sažeti na ovaj način:

- Prema svim mjerenim pedološkim varijablama pokazale su se vrlo značajne razlike između fitocenoza. Pritom je osobito dobro razdvojena skupina primorskih od kontinentalnih fitocenoza. Iz toga se može usvojiti zaključak o jasno prepoznatljivom, specifičnom utjecaju u istraživanja uključenih biljnih zajednica, na fiziografska svojstva tla. Što se tiče specifičnog utjecaja biljne vrste (iako istraživanja nisu bila tomu usmjerena), on se može prepoznati u fitocenozama sa čistim bukovim sastojinama (SES-FAG., HOM-FAG. i LAM-FAG.), što se može pripisati ponajprije utjecaju listinca (organskog otpada). Diskriminacija fitocenoza prema "tematskim" pedološkim varijablama cijeloga profila slabija je nego prema svim varijablama. Bukovo - jelove i pretplaninske bukove fitocenoze relativno su dobro diskriminirane od ostalih fitocenoza, što se može pripisati makroklimatskom i topoklimatskom utjecaju. Još je slabija diskriminacija fitocenoza posebno prema A-, odnosno (B)rz- horizontu. Općenito, pokazalo se da je diskriminantna analiza vrlo pogodna za determinaciju vegetacijskog utjecaja na značajke organskoga kompleksa smeđega tla na vapnencu, odnosno raščlambu varijabilnosti njegovih svojstava. Smanjenjem broja varijabli opada i diskriminacija fitocenoza, što otežava donošenje čvrstih zaključaka. U svezi s tim može se pretpostaviti da je u te odnose uključen niz čimbenika s brojnim interakcijskim utjecajima. Uključenjem većega broja pedofiziografskih parametara mogla bi se diskriminantnom analizom još bolje objasniti njihova varijabilnost, odnosno povezanost s vegetacijskim značajkama, definiranima biljnosociološkom pripadnošću.

Ključne riječi: smeđe tlo na vapnencu, organska tvar tla, humus, vegetacija, krš

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Original scientific paper
Izvorni znanstveni članak

AMELIORATION OF THE BURNT ALLEPO PINE (*Pinus halepensis* Mill.) FOREST AREA IN THE MAKARSKA COASTLINE REGION

SANACIJA POŽARIŠTA SASTOJINA ALEPSKOGA BORA (*Pinus halepensis* Mill.) U MAKARSKOM PRIMORJU

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The Aleppo Pine (*Pinus halepensis* Mill.) is an allochthonous species in the Makarska coast area, i.e. it has been planted in cultures as a pioneer species for the purpose of improving and ameliorating the karst areas. This paper presents the results of the research on the improvements to the burnt area after the devastation caused by fire on a large stretch of the Aleppo Pine forest. The research was carried out where both old stands and young growth had been successively caught by fire. Two typical problems have to be understood when dealing with the Aleppo Pine, both being encountered in the Makarska Coast region. The first refers to fire in an old stand, where fire is no obstacle to stand regeneration. On the contrary, the Aleppo Pine as a pyrophyte species supplies the soil well with seed, so that thick young growth soon covers the ground. Thus, only a decade following a fire, we can see a large area of 2 m - high Aleppo Pine young growth, often with a million plants on one hectare. Since such thick growth is a dangerous inflammable material, preventive measures are required, such as reducing the number of plants. Riding cuts and roads are a priority among silvicultural operations. A much more serious problem occurs if the fire catches a stand of young, not yet fructiferous trees, so that no regeneration can take place. On these areas the planting of the Aleppo Pine, Maritime Pine, Cypress and the Evergreen Oak was carried out. Survival differs depending on the species. It emerged that the planting of small seedlings, especially one-year-old seedlings of the Evergreen Oak, over a bare surface, like the pioneer pine species, could not meet the target, since these young plants need shade in such extreme conditions of high temperature, hot sun, little moisture in the soil, and wind. Fair results were achieved with the Cypress, which, besides a high survival rate, grew considerably more in the ten-year period. It should, therefore, be planted more than has been the case so far. On both areas, there are very few autochthonous evergreen broadleaves besides the Evergreen Oak. Thus, on Area 1 (900 m^2) there are 1 454 bushes of the *Cistus* sp., comprising 1.62 plants per 1 m^2.

Key words: fires, Aleppo Pine (*Pinus halepensis* Mill.), burnt area improvement, vegetation succession, Makarska Coastline

INTRODUCTION
UVOD

"...among the most important issues in the Mediterranean karst forest protection, forest fires are the first on the list as a constant threat to the cultures and forests of the region..." (Androić 1971).

With forests burning along the Adriatic coast and on the islands, forest fires have been a particular threat to the growing stock for the last 20 years. Enormous damage has been caused by fires started either in direct combat or deliberately by the rebellious Serbs in the areas around the cities of Zadar, Šibenik, Split and Dubrovnik.

According to the data of the Ministry of Agriculture and Forestry (1995), karst forests and forests of the islands and coastal areas of Croatia cover an area of 1,042,081 ha, or 43% of the country's forests and forestlands. On the 732,371 ha of the forested areas, 83% are degraded stands (52% coppices; 25% brushwood; 4% maquis, and 2% garigues), the remaining 17% are high forests (11% seedling forests, and 6% cultures and plantations).

As for ownership, 83% are state forests, the remaining 17% are private.

In the period from 1973 until 1993, in the 4,466 forest fires that broke out in this region, 182,360 ha of forests and forestlands disappeared. The average annual loss was thus 8,684 ha. These data do not include the fires and burnt areas in wartime from 1991 until 1995 in the recently occupied parts of Croatia.

The number of fires is rather steady - about 200 a year, while the burnt area has doubled in 15 years (from 5,500 to 11,000ha). The burnt area per fire also increased in the 15 years, from 26 to 59 ha.

Two items deserve a special attention:

a) the fire interval is about 25 years: the annual burnt area is 10,000 ha on an area of 250,000 ha (extremely fire-susceptible area);

b) in the last 20 years, the burnt area has grown by 300 ha a year.

According to the plant types, the 41,176 ha of pine forests make up as much as 22% of the total area; 36,891 are coppices (20%); 42,399 ha maquis (23%), while the remaining 61,894 ha (35%) belong to the areas covered with other vegetation. The damaged or burnt wood mass exceeds 1,421,142 m^3 (Projekt 1995).

Causing the biggest damage to the ecosystems in Croatia, particularly in the karst region, forest fires leave long-term, heavy social-economic consequences, far more serious than the loss of timber.

On the burnt, naked areas, covered in places with a few stunted bushes and grass, erosion begins, supported by rain and winds which, without the shield of vegetation, become stronger and more destructive. Eventually, naked karst emerges.

Besides the ecological destruction of the natural environment, fires are a threat to the economy of the Croatian Mediterranean, considering the tourist attraction of our coast. With its negative impact on the landscape, fire compromises many tourist destinations.

Research on forest fires in many countries shows that attention should be paid to the pedological, climatic and floral features of the areas where they appear and spread. Other subjects of research should be the resulting circulation of the bio-elements and the physical properties of the soil; overall conditions needed for forest regeneration following a fire, climatic, pedological (soil chemistry/fertility/erodibility), vegetational (progressive and regressive successions, sanative methods).

A decision on what to do in terms of forest regeneration in the aftermath of a fire will depend on a number of biological/ecological and economic factors. The first step should be an ecological and economic analysis of the utility of such regeneration, while determining the future use of the forest. As a rule, after big fires, all areas cannot be regenerated and adjusted to a particular purpose. Therefore, it is useful to know what kind of work should be done first (Španjol 1996).

"Though their floral and ecological properties may differ, certain plant associations in a zone or subzone form a whole that is syndinamically linked to a higher or lesser extent. Understanding it is extremely important for the regeneration and amelioration of the vegetation..." (Horvat 1962).

With the already known phytocenological differences, we can be certain that, individually or in groups, the natural or antropogene plant associations and cultures are the direct indices and objects that are different as to their type, quantity of inflammable materials, inflammability, speed of spreading and duration of the fire, and the consequences and conditions needed for the regeneration of the burnt areas. Therefore, the role of the plant associations is indispensable. Respecting their multiple indicative value, we confirm the crucial role and significance of the phytocenoses referring to protection and regeneration. This concerns the objective gradation and categorization of the terrain according to the natural threat from fire, expert programming and enforcement of the biological improvement of the burnt forest areas.

Fire causes a regressive vegetational succession. Burnt areas, depending on the type of vegetation beforehand and the biological-ecological conditions, start to develop a regressive vegetation succession. In burnt pine cultures, there can be strong indices about the directions to be taken in silvicultural operations.

Man influences the speed, quality and direction of the progressive succession, both positively and negatively. The positive approach begins with research on the condition and changes that have taken place, establishing the transitory plant associations, and determining the progressive and regressive directions with the main and subordinate phases of their development. The forester's tasks are to begin the biological improvements on the burnt areas, considering the pedological, climatological and vegetational conditions. The latter determines whether the improvements will continue in a natural, progressive succession, or whetter they will be achieved by planting of seedlings, or sowing the seeds, or a combination of all three methods.

In the Makarska Forest Service area, forest fires have destroyed large tracts of Aleppo Pine (*Pinus halepensis*) in the last 20 years.

GENERAL FEATURES OF THE RESEARCH AREA
OPĆA OBILJEŽJA ISTRAŽIVANOG PODRUČJA

The relief of the Adriatic hillslopes of Mount Biokovo and the wider area of Baška Voda and Brela are characterized by several morphological features. Firstly, there is the vast stretch of the Baško Polje descending toward the sea in the form of a fan ending with numerous capes that, like ribs, continue back to the foot of the Biokovo. With four types of Quaternary brezzias, this relief is a direct reflection of the geological structure of the region:

1) More resistant to wearing, these well-bound brezzias consisting of unsorted rectangular fragments bound with calcite cement stick out from the surrounding relief;

2) Semi-bound brezzia conglomerates of Baško Polje built of rectangular and partly rounded fragments bound with sandy material;

3) Weakly-bound brezzias consisting of rectangular fragments that are weakly bound by a sandy-loamy cement. They are found in the prolongation of today's "siparas";

4) Unbound brezzias, today's "sipara", consisting of rectangular, mainly loose fragments.

The genesis of the Quaternary sediments goes back to the gravitation processes on the mountain hillslope, similar to today's "siparas". A significant role in their formation was played by the torrents, especially in the warmer periods of the Quaternary "great ice age", when the climate was humid and the Biokovo snow melted into huge quantities of water (Grgasović 1995).

The pedological characteristic of the Baško Polje area is the mainly skeletal colluvium, prevailingly forming rendzinas and calcocambisols.

On the Climatic map of Croatia (Seletković & Katušin 1992), the Makarska coastline is classified as region Csa, a basic Mediterranean coastal climate, characterized by mild winters and dry summers, with a rainfall three times higher in the rainiest winter month than in the driest summer month, the latter being less than 40 mm. The summers are hot, dry and sunny. The climates Csa and Cfsax are marked as olive climates. The basic type of the Csa olive climate is on the island of Lošinj and the areas west of the line Zadar-Šibenik-Split-Imotski and the Opuzen/Dubrovnik inland area, together with all the central and south Dalmatian islands.

The chief climatic indices are shown in Walter's climatogram for the period 1982-1993 (Figure 1), and in Table 1.

Table 1. Monthly rain factor (Kfm), humidity (Hum), and thermal character (T.k.) in Makarska 1981-1993

Tablica 1. Mjesečni kišni faktor (Kfm), humidnost (Hum) i toplinski karakter (T.k.) u Makarskoj od 1981. do 1993. godine

month *mjesec*	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	yearly *godišnje*
KFm	7.1	14.6	9.4	5.7	3.8	2.8	1.2	1.0	2.6	7.9	11.3	11.4	60.9 KFg
Hum	h	h	h	sh	sa	a	a	a	a	h	h	h	sh
T.k.	ut	ut	ut	t	t	v	v	v	v	t	t	ut	t

The Martonne aridity index is 37.9

Martonneov indeks aridnosti iznosi 37,9

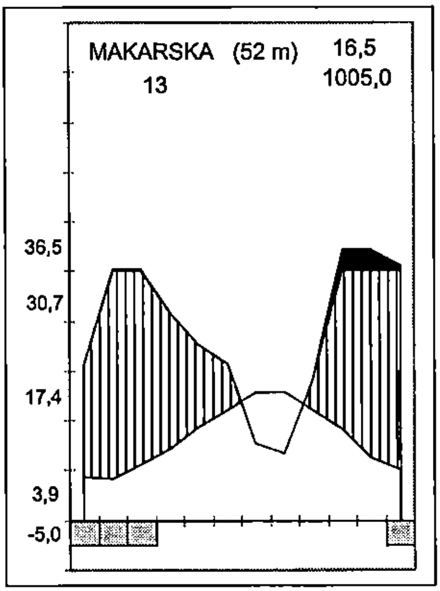

Figure 1. Climatogram according to Walter for the period 1981-1993

Slika 1. Klimadijagram prema Walteru za razdoblje od 1981. do 1993. godine

In terms of vegetation, i.e. bioclimatically, the Makarska coastal region is situated in the climatozone belt of the evergreen oak forests (*Orno-Quercetum ilicis* H-ić 1958).

THE SITUATION BEFORE THE FIRES
STANJE PRIJE POŽARA

In the last 20 years, forest fires have destroyed the largest part of the Aleppo Pine stand. Among the several test plots that were selected from this vast burnt area to monitor the ameliorative effects of vegetation within the improvement measures, the most significant are the ones in Donje Baško Polje. On August 6 1985, fire destroyed 862 ha, of which 552 ha were national (347.6 ha forests, 177 ha forestlands), and 310 ha private forests. They were mainly Aleppo Pine, while in the higher areas there was also Black Pine. The age ranged from 25 to 85 years, and the volume was 50.7 m^3/ha, or altogether 19,000 m^3. Test plot 1 (30x30) was set on an area that burnt again in 1986; test plot 2 (50x35 m) burnt in 1985 and 1988. This location is also used for monitoring the development of the Aleppo Pine upon the burnt area (plant number, heights, and diameters which, considering their age, have just begun to be measured).

SANATIVE AND REGENERATIVE MEASURES
SANACIJA I OBNOVA IZGORJELIH POVRŠINA

Afforestation was carried out in two turns, in 1987 and 1988, by planting an indefinite number of Maritime Pine seedlings (*Pinus maritima*) on test plot 1 (30 x 30 m) following the removal of the burnt wood mass. The last additions were made with the Aleppo and the Maritime Pines and Cypresses *(Cupressus sempervirens)*. All seedlings were one-year old plants with naked roots. Thus, besides the ongoing natural pine succession, we have today on this ameliorated area plants coming from three different afforestation periods.

The second test plot (2) was laid on the area that had burnt on two occasions. After the first, the old Aleppo Pine stands did not need any biological measures, since the terrain had been exceptionally well supplied with the seeds from the old pines. However, when this young growth vanished in the 1988 fire, amelioration measures had to be applied, as there was no source of seed any more. Immediately after the second fire, an indefinite number of one-year old naked-rooted seedlings of the following species were planted: Cypress *(Cupressus sempervirens)*; Aleppo Pine *(Pinus halepensis)*; Evergreen Oak (*Quercus ilex*); Maritime Pine *(Pinus pinaster)*. The results were poor, especially with the Evergreen Oak. Slightly better results were achieved with the Cypress. Such a bad outcome may be blamed on the method, the time of planting, and the quality of the seedlings.

In one part of the Makarska region, in Baško Polje, that had been devastated by a single fire (1985), no biological ameliorative measures were required, since the Aleppo Pine grew after the fire, covering the burnt area with lush new growth.

RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

PEDOLOGICAL FEATURES
PEDOLOŠKA OBILJEŽJA

The Baško Polje area is pedologically a colluvium of a strong skeletal character that has developed for the most part rendzinas and calcocambisols (Bogunović 1982). Two pedological profiles are distinguished in the upper and rear part of Baško Polje. In the lower part there are texturally somewhat heavier soils, though equally well supplied with humus and nutrients, except for the physiologically active phosphorus (Tables 2 and 3).

Table 2. Contents of the biogene elements and ashes in the O-horizon (Area: Baško Polje)
Tablica 2. Sadržaj biogenih elemenata i pepela u O-horizontu (predjel: Baško polje)

Location and soil type *Lokacija i tip tla*	Plot *Oznaka plohe*	Depth of O-horizon *Debljina O-horiz.*	Nitrogen *Dušik (N)*	Phosphorus *Fosfor (P)*	Potassium *Kalij (K)*	Calcium *Kalcij (Ca)*	Magnesium *Magnezij (Mg)*	Ash *Pepeo*
		cm	%					
Baško Polje Rendzina	P1	1.5	0.74	0.07	0.23	0.31	0.22	81.60

Legend: P1 = plot in burnt area
Legenda: P1 = ploha na požarištu;

Since the situation on both plots is identical, the O-horizon has been taken only on Plot 1.

FLORISTIC PROPERTIES OF THE TEST PLOTS
FLORISTIČKA OBILJEŽJA POKUSNIH PLOHA

With the whole area of the costal Makarska region located in an Evergreen Oak forest belt (*Orno-Qercetum ilicis* H-ić 1958), there is a flora in the cultures of the Aleppo Pine that is typical or this climatozone region. The floristic composition of Plot 1 is as follows:

I Shrub layer (35-40%)

Pinus pinaster	+	*Phillyrea latifolia*	+
Pinus halepensis	1	*Juniperus oxycedrus*	+
Cupressus sempervirens	+	*Cistus salviefolius*	3
Pistacia lentiscus	+	*Cistus incanus*	2

II Low growth layer (95%)

Brachypodium retusum	3	*Daucus major*	+
Asparagus acutifolius	+	*Plantago lanceolata*	+
Rosa sempervirens	+	*Clematis flammula*	+
Teucrium polium	1	*Carlina corymbosa*	+
Hedypnois rhagadioides	+	*Trifolium arvense*	+

Table 3. Mechanical composition and some chemical soil properties (Area: Baško Polje)
Tablica 3. Mehanički sastav i neka kemijska svojstva tla (predjel: Baško polje)

Location and soil type *Lokacija i tip tla*	Plot *Oznaka plohe*	Horizon *Horizont*		Coarse sand *Krupni pijesak*	Fine sand *Sitni pijesak*	Dust *Prah*	Loam *Glina*	Textural symbol *Teksturna oznaka*	pH		Carbonates *Karbonati* ($CaCO_3$)	Humus	Nitrogen *Dušik*	C/N	Physiologically active phosphorus and potassium *Fiziološki aktivni fosfor i kalij*	
		symbol *Oznaka*	lower border *D. granica*	0.2-2	0.02-0.2	0.002-0.02	<0.002		H_2O	0.01 M $CaCl_2$					P_2O_5	K_2O
			(cm)	(tež. %)							(%)	(%)	(%)		(mg/100g)	
Baško Polje Rendzina on skeletal colluvium	P1	A	5	8.00	21.20	31.50	39.30	l. G.	7.5	7.0	5.86	12.29	0.39	18.3	5.8	69.6
		(B)rz	18	3.40	27.10	23.40	46.10	t. G.	7.4	7.0	2.51	6.44	0.23	16.2	2.2	41.4
	P2	A	6	8.40	8.80	29.90	52.90	t. G.	7.6	6.9	5.86	12.53	0.40	18.2	5.1	100.0
		(B)rz	26	10.70	11.50	15.90	61.90	t. G.	7.6	6.9	10.77	7.16	0.26	16.0	2.9	49.7

Briza maxima	1	*Fumana ericoides*	1
Erica manipuliflora	1	*Inula varbascifolia*	+
		Seseli tomentosum	+ and others

A similar floristic composition is found on Test Plot 2 that had been devastated in the fires of 1985 and 1988.

In the brush layer covering the plot to an extent of 25-30%, there are the following plant species:

Pistacia lentiscus	1	*Paliurus spina-cristi*	+
Myrtus communis	+	*Pirus amygdaliformis*	+
Pinus halepensis	+	*Rhamnus intermedia*	+
Cupressus sempervirens	+	*Olea oleaster*	+
Quercus ilex	+	*Ficus carica*	+
Phillyrea latifolia	+	*Crategus transalpina*	+
		Colutea arborescens	+

The low growth layer covers almost 95% of the area:

Brachypodium retusum	4	*Inula verbascifolia*	+
Rosa sempervirens	+	*Sonchus sp.*	+
Rubus dalmatinus	2	*Bupleurum veronense*	+
Asparagus acutifolius	1	*Convolvulus contabricus*	+
Smilax aspera	+	*Alyssanthus sinuatus*	+
Fumana ericoides	+	*Eryngium amethustinum*	+
Consolida regalis	+	*Carlina corimbosa*	+
Trifolium angustifolium	+	*Sanguisorba muricata*	+
Scleropoa rigida	+	*Dorycnium hirsutum*	+
Arvena barbata	+	*Clematis flammula*	1
Centaurea cristata	+	*Osyris alba*	1
Petrorhogia saxifraga	+	*Convolvulus elengatissimus*	+
Euphorbia spinosa	+	*Salvia Bartolonii*	+
Caloamintha glandulosa	+	*Trifolium arvense*	+
Seseli tomementosum	+	*Verbascum thagsus*	+
Stachys slaviefolia	+	*Phleum subulatum*	+
Picris sp.	+	*Plantago lanceolata*	+
Teucrium polium	1	*Daucus major*	+
Anagillis arvensis	+	*Briza maxima*	+
		Hedypnois rhagadioides	+

On the areas where the Aleppo Pine young growth remained after the 1985 fire, the floristic composition is almost the same as the one on the areas where the dense canopy of the Aleppo Pine young trees allowed the development of other species. The following shrubs are encountered in places:

Pistacia lentiscus	*Cistus salviefolis*
Fraxinus ornus	*Cistus incanus*
Myrtus communis	*Coronila emeroides*
Erica manipuliflora	*Spartium junceum*

In the low growth layer, the dominant species is *Brachypodium retusum*, besides others found on other plots.

FLORISTIC FEATURES OF THE TEST PLOTS
FLORISTIČKA OBILJEŽJA KONTROLNIH PLOHA

A phytocenological survey has been made in the coastal region of the Aleppo Pine cultures that was spared from fire.

Area: 20 x 20 m
Inclination: 10°
Exposition: south
Date: 19.7.1993.

	I Tree layer (90%)		
Pinus halepensis	5		
	II Shrub layer (80%)		
Phyllyrea latifolia	2	*Paliurus spina-cristi*	+
Coronila emeroides	2	*Juniperus oxycedrus*	+
Pistacia lentiscus	2	*Pistacia terebinthus*	+
Spartium junceum	1	*Juniperus phoenicea*	+
Colutea arborescens	+	*Erica manipuliflora*	1
	III Low growth layer		
Brachipodium retusum	4	*Rubia peregrina*	+
Asparagus acutifolius	1	*Teucrium polium*	+
SMilax aspera	+	*Briza maxima*	+
Clematis flammula	+	*Dorycnium hirsutum*	+
Micromeria juliana	+	*Fumana ericoides*	+

STRUCTURAL FEATURES
STRUKTURNA OBILJEŽJA

The structural features are shown in Tables 4 and 5 for both test plots.

Measurements were also made in areas with dense young growth of Aleppo Pine. The density of the young growth and trees is measured along with some silvicultural thinnings. As these are tiny plants and since the data refers to a time period of only three years, they are not adequate for presentation. However, it should be said that a decade following the fire the number of plants per 1 m^2 ranged from 20 to 127, altogether 100. Or, per 1 ha there are about 1 million plants that have already reached 300 cm in height.

By comparing these data with the results of other authors, we may say that future regeneration is certain. Thanos C.A. & others (1989); Thanos & Marcon

(1991), and Daskalakon & Thanos (1993) consider a much smaller number of plants (0.15 and more per m^2) sufficient for natural regeneration.

Table 4. Distribution of measured heights
Tablica 4. Distribucija izmjerenih visina

Forest service: Makarska
Area: Donje Baško Polje - fires of 1985 and 1986
Area: 30 x 30 m = 900 m^2 = 0.09 ha

Plot: 1
Exposition: south
Inclination: level

Šumarija: Makarska
Predjel: Donje Baško Polje - požar 1985. i 1986. god.
Površina: 30 x 30 m = 900 m^2 = 0,09 ha

Ploha: 1
Ekspozicija: Južna
Nagib: ravno

Height class Visinska klasa (cm)	May 1994 svibanj 1994.							January 1996 siječanj 1996.						
	1	2	3	4	5	6	Σ	1	2	3	4	5	6	Σ
1-10		54	9				63		5	7				12
11-20		13	1				14		28	3	1			32
21-30	3			1		1	5		10				1	11
31-40	1	6		1			8	1	3					4
41-50	5	7					12							
51-60	1	7		1	1		10				1			1
61-70	1	5		1			7	1	3		1			5
71-80	2	6		1	1		10		2			1		3
81-90	2	3					5	2	1		2	1		6
91-100	3	6					9	2	1					3
101-110	2	1					3	1	7					8
111-120		2					2		7					7
121-130									5					5
131-140								2	1					3
141-150									4					4
151-160								2	1					3
161-170								2	2					4
171-180								2						2
181-190								1	2					3
191-200									6					6
201-210								1						1
211-220								1	1					2
Σ	20	110	10	5	2	1	148	18	89	10	5	2	1	125
Po ha	222	1222	111	56	22	11	1644	200	989	111	56	22	11	1389

1. Maritime Pine (*Pinus pinaster*)
2. Aleppo Pine (*Pinus halepensis*)
3. Cypress (*Cupressus sempervirens*)
4. *Pistacia lentiscus*
5. *Phillyrea latifolia*
6. Juniper (*Juniperus oxycedrus*)

1. Primorski bor (Pinus pinaster)
2. Alepski bor (Pinus halepensis)
3. Obični čempres (Cupresuss sempervirens)
4. Tršlja (Pistacia lentiscus)
5. Zelenika (Phillyrea latifolia)
6. Šmrika (Juniperus oxycedrus)

Table 5. Distribution of measured heights
Tablica 5. Distribucija izmjerenih visina

Forest service: Makarska
Area: Donje Baško Polje - fires of 1985 and 1988
Area: 50 x 35 m = 1750 m2 = 0.18 ha

Plot: 2
Exposition: south
Inclination: 3°

Šumarija: Makarska
Predjel: Donje Baško Polje - požar 1985. i 1988. god.
Površina: 50 x 35 m = 1750 m² = 0,18 ha

Ploha: 2
Ekspozicija: Južna
Nagib: 3

Height class Visinska klasa (cm)	April 1993 *travanj 1993.*												January 1996 *siječanj 1996.*											
	1	2	3	4	5	6	7	8	9	10	11	Σ	1	2	3	4	5	6	7	8	9	10	11	Σ
1-10		2	1		1							4					1							1
11-20		20							1			26		9							1			10
21-30		64			3	1	1		1		1	73		27	1						1			29
31-40	1	31		1			2		1			36		44	2		1	1	1				1	50
41-50	2	27		1	1		1		1			33	1	28	2		1				1			33
51-60	2	18		6			2			1		30	2	33	2	2	1				1			41
61-70	3	7		1			5		2			18		24		1			3		1			29
71-80	8	11		6		1	2	1	2			31	3	9	1	3			2		1			19
81-90	6	3		5		3	6					23	3	6		1			3	1	1	1		16
91-100	12	1		12		1	2					28	5	3		1			2					15
101-110	7			7			2					16	6	1		2			5					15
111-120	9	1		2			1	1				14	5			2			5					13
121-130	2			2			1					5	12			5			1					18
131-140	1			2			1					4	8			2			1					11
141-150				4								4	5			3			2					10
151-160				1								1	3			4				1				8
161-170				1								1				4			1					5
171-180															1	3								4
181-190																7								7
191-200							1					1												
201-210																3			1					4
211-220																1								1
221-230																2								2
231-240																1								1
241-250																2								2
251-260																1								1
261-270																1								1
Σ	53	185	9	51	5	6	27	2	8	1	1	348	52	184	9	51	5	6	27	2	7	1	1	346
Po ha	303	1057	51	291	29	34	154	11	46	6	6	1989	303	1051	51	291	29	34	154	11	40	6	6	1977

1. Myrtle (*Myrtus communis*)
2. *Pistacia lentiscus*
3. Aleppo PIne (*Pinus halepensis)*
4. Cypress (*Cupressus sempervirens*)
5. Evergreen Oak (*Quercus ilex*)
6. *Phillyrea latifolia*
7. *Paliurus spina-cristi*
8. *Pyrus amygdoliformis*
9. *Rhamnus intermedia*
10. Olive (*Olea oleaster)*
11. *Fig (Ficus carica)*

1. *Mirta (Myrtus communis)*
2. *Tršlja (Pistacia lentiscus)*
3. *Alepski bor (Pinus halepensis)*
4. *Obični čempres (Cupresuss sempervirens)*
5. *Crnika (Quercus ilex)*
6. *Zelenika (Phillyrea latifolia)*
7. *Drača (Paliurus spina-cristi)*
8. *Krušica (Pyrus amygdaliformis)*
9. *Trnika (Rhamnus intermedia)*
10. *Maslina (Olea oleaster)*
11. Smokva (Ficus carica)

CONCLUSION
ZAKLJUČNA DISKUSIJA

In the Makarska coastal region where fire has devastated large stretches of forests, great attention has been paid to the protection of these forests, particularly against forest fire. Intensive forest protection began in 1967 with a wide series of measures. Thus, since 1970 the Makarska region has had one the most efficient systems for forest fire protection in all the Croatian Littoral (Management Programme 1982-1991).

Tables 4 and 5 show that the afforestation on both plots has only partly succeeded. Considering the number of plants per area unit, there was more success on Plot 1, where more than 100 Stone Pines and Maritime Pines grew on 900 m^2. Unfortunately, such success was not achieved on Plot 2. On Plot 1 afforestation was carried out in three turns, while on Plot 2 only once immediately following the fire. We have already mentioned that the method and time of planting is very important in these climatic conditions. Another reason for the poor survival of the seedlings is that they were planted with naked roots instead of being grown in containers. Planting of small, particularly one-year-old seedlings of the Evergreen Oak over an unprotected area cannot be successful, since these young, tiny plants need shade in such an extreme climate with a high temperature, hot sun, and little moisture in the soil, wind, etc. Cypress was more successful for two reasons. Firstly, it showed a high rate of survival, and secondly, it grows higher in a ten-year time period. It should therefore be introduced more widely. There are surprisingly few evergreen broadleaves from the Evergreen Oak forest on either of the plots. It is also interesting that Plot 1 (900 m^2) has 1,454 brushes of *Cistus* sp., i.e 1.62 per 1 m^2.

In the Makarska Forest Service range we can speak of two typical issues concerning forest fires in the Aleppo Pine stands. The first is fire in old stands, which should not be a problem for the regeneration of these forests. A pyrophyte, the Aleppo Pine will fertilize the area well with its seeds, so that a thick young growth will readily emerge. As for further care and protection, there are several illustrations in the Makarska region. About ten years following the fire, large tracts of the Aleppo Pine young trees, 2 m in height, were threatened by repeated fire. This huge green area of almost 700 ha therefore started to be reduced. The first among the measures was the building of riding cuts as fire protection with some elements of forest roads. Another measure was the reduction of the plant number by removing the plants along lanes of a particular length (3 m or more). This was done mechanically, since manual work would have been very expensive. In 1995 the Steyr Forst 9078 tractor with a capacity of about 2 800 m^2 = 2 000 m/8h was used for these operations. The width of the blade drum was 140 cm, the wheel distance 190 cm. There were several problems with this machine on such terrain. One was the work with the circular blade on such a rocky and rather uneven surface. The blades wore or broke very fast and frequently, so that they had to be replaced, which happened every 70-75 of work hours, instead of the usual 200-250 hours. Another problem was that the blade of the circular blade saw, due to unfavourable conditions, could not be lowered down to the soil, and therefore left the side twigs, which then, receiving plenty of light, assumed the role of the tree top, and in one year's time reached almost half the height of the pines in the left-over lanes (up to 1 m). An additional problem was that the distance between the tractor wheels was 50 cm longer (25 cm at each side), whereby the tractors caused permanent damage to the young pines along the lane edges, i.e. the trees that should play the principal role in the growth and soon form the canopy over other uncompetitive specimens.

In our opinion, considering the limited success such expensive operations on such hard terrain should not be carried out. Such huge stretches of young pine growth are best protected by measures of prevention. These include in the first place a great number of forest riding cuts with forest road elements, in order to make every part of the terrain accessible for monitoring, and if necessary, fighting a forest fire. Such an area that is intersected into, say, pine oases, should be left to develop independently and spontaneously. Ten years after a fire, no silvicultural measures of cleaning are needed with 100 plants on 1 m^2. This is confirmed by a test on 10 x 10 m plots with, in turns, 100, 50, 20, and 10 plants of highest quality. With the results being monitored only for 3 years, no significant differences in the development of the thus reduced plants have been recorded. Neither has any dieback been noticed. However, we have observed that on the plots with 100 and 50 plants, there were bigger height differences than where fewer plants on 100 m^2 grew under similar conditions and without competition. These young trees, being fewer in number, are generally weaker, the number of needles is reduced and the crowns are unsubstantial. The reasons are the severe conditions of life in terms of hot sun, temperature, winds, etc., without the protection of the surrounding plants. Accordingly, spontaneous development is desired to let the natural selection work and for the best trees to be chosen to take the leading roles. The first silvicultural measures should be carried out between the age of 15 and 20, depending on plant density and vitality.

A completely different activity is required in the areas that burnt after a thick young growth covered them in the aftermath of the first fire. If this happens at an age when young plants have not yet fructified, there is no progression, and the soil remains almost naked without woody species, particularly pioneering ones such as the Aleppo Pine. Such surfaces are encroached on by a specific burnt area association with thick, low-growth vegetation, as illustrated in our plots. Then foresters must take action with biological measures of amelioration or by sowing/planting. Since there are usually specimens of the old Aleppo Pine cultures in the vicinity, the natural progressive succession on such a terrain does not stop when it comes to the Aleppo Pine, although it is present only to a lesser extent. We can always count on that. The remaining work is the routine between selecting the species and the quality of the seedling material. We believe that generally, in such circumstances, we should start with as many species as possible and later do supplements which, particularly when it comes to the autochthonous broadleaves such as the Evergreen Oak, *Phillyrea latifolia*, and myrtle, should appear when the Aleppo Pine, a pioneer species, creates sufficiently appropriate conditions after only a few years (5-10). We also consider appropriate the introduction of a smaller number of plants, 1 000 - 1 500 per hectare, but stronger, more developed and older ones, grown in adequate containers, enabling a smooth continuation when transferred into the open area. This particularly refers to the root system.

Pedological research on the average samples have confirmed the known facts about the destructive impacts of fire on the pedosphere, especially when it comes to the erosive processes, the change in the humus content, and biogene factors - nitrogen, phosphorus, carbon and potassium.

Considering a great number of factors, we can finally conclude that every fire and the following amelioration measures differ from one another. Some of them are good in one situation and bad in another. It is crucial therefore to know the local circumstances and ecological factors, as well as the biological/ecological features of the species to be used in the coming improvement measures.

The forest fires of the Mediterranean region are a historical fact, an integral part of this ecosystem and its evolution. This was scientifically confirmed by Naveh (1975). The shock combined with the impacts of fire, drought and grazing has led to a convergence in the plant forms and functions within the Mediterranean climate, favouring genetic and ecological differences. Arianoutson & Margaris (1981) and Dafis (1991) attach to the forest systems that are susceptible to fire terms such as "fire ecosystems"; "fire climax"; "fire adapted"; "fire induced", and "pyrophil".

When investigating the impact of temperature on the Aleppo Pine seed, Martinez-Sanches et al. (1995) found that the temperatures of 90°C, 110°C, 150°C, and 200°C did not affect their fertility and germination. He therefore thinks that the Aleppo Pine is not a pyrophyte, but rather a "colonizer" of the burnt areas.

Fires are not necessary for the regeneration of the mentioned species. They therefore need not be considered as simply pyrophytic, as they can be regenerated in similar conditions without a fire. An illustration of this is the forest driving cuts, clearings, and cutting areas, all encroached on by the pine.

Together with other factors of degradation and devastation in the Mediterranean, fires are a link in a dynamic process that has always been present in such forests in a perpetual interchange of regressive and progressive circles of forest vegetation.

The Mediterranean forests have vanished through cutting, grazing, browse and fire. The results are the degradation stadia in the eumediterranean and submediterranean regions. Today, the former has coppices, maquis, garigues, and naked karst, the latter coppices, brushwood, scrub forests and naked karst.

In afforestation, mixed cultures should be raised: mixed conifers, and conifers/broadleaf mixtures. Priority should be given to autochthonous vegetation, trees and brushes, and also to fire-resistant species. Dafis (1991) refers to the latter, suggesting *Arbutus* sp., *Olea* sp., *Quercus ilex, Viburnum* sp., and others. As to the ratios, the same author suggests 60% of conifers and 40% of broadleaves to reduce the risk of fire. As a fire-protection measure, he also suggests even-aged stands. This can be achieved by afforestation and succession after a forest fire. Different age, i.e. group selection, is natural.

Velez (1990) suggests *Atriplex* sp. and *Tamarix* sp., which, thanks to the salt they contain, burn slowly. *Tamarix* sp. is currently being planted along the fire-protection rails and riding cuts in Israel. Velez (1990) suggests the planting of the so-called "species mosaics", considering the inflammability and the number of the species. Dugalay (1966) suggests fire-resistent species, particularly the oaks *Q. suber, Quercus ilex, Q. pubescens,* and the sweet chestnut (*Castanea sativa)* on acid, rich and moist soils. Exotic species should be avoided, he says, as they, for reasons yet unknown, usually fail after the first promising results.

Wherever possible, natural succession should be supported by silvicultural measures, particularly over the Aleppo Pine burnt areas, where the surface has been richly sown and the progressive succession has begun richly.

As already said, the fires in old stands and those in the young ones should be distinguished. On the old stand areas, the succession is very rich in the aftermath of a forest fire. While an old tree is burning, its seeds are well protected within the cone. In the process of cooling, the cone suddenly opens and throws the seeds, which fall on the cooled ground covered with ash and, soon after the first rain, begin to grow. In good pedological conditions, a very thick young growth appears within a period of three to five years, densely covering the ground. Although such development is considered a vegetation succession, it is not so in the phytocenological sense (Trinajstić 1993).

A much more difficult case for forestry is when the fire catches and destroys a young pine stand that has not yet fructified. As a result, the first rain is followed by a lush green mass of herbs and woody plants with *Brachypodium retusum* as the dominating grass. Such areas then become ideal grazelands, which was one of the reasons for the deliberate burning of these forests in the past. From the underground organs of the woody plants, numerous sprouts emerge to cover the area entirely in the following decade. The woody garigues of *Erica arborea* and *Arbutus unedo* prevail, which develop small trees and suppress the real scrubs of the families *Cistus, Rosmarinus officinalis*, etc. "Thus a special type of maquis is formed to display an even floral composition on the large Mediterranean region and the Croatian Littoral coast" (Trinajstić 1993). Phytocenologically, these stands join the association *Erico-Arbutetum*. "It remains as a permanent phase for a long number of years and is generally well resistant to fire... The Aleppo Pine and the Evergreen Oak have great difficulties in moving into this community" (Trinajstić 1993). The same author correctly remarks that the association *Erico-Arbutetum* renders an exceptional aesthetic atmosphere in its winter flowering period. With this association being exceptionally suitable for browse, uncontrolled breeding of sheep and goats is a severe problem.

Among the protective measures, the riding cuts with forest road elements should be built as densely as possible, both in old and young cultures. Depending on the terrain configuration, forest tracts should not be bigger than 600 ha. A well-made and maintained road-cut is a recess area the inflammable plant material, both horizontally and vertically. Besides roads, other preventive measure include the erection of protective walls made of rocks and a well-organized system of surveying connected with the operations centre and the police. It is common knowledge that prevention is incomparably cheaper than afforestation of the burnt areas.

Among the preventive measures to be applied here, the most appropriate are pruning of the lower branches and thinning. As a rule, after afforestation, no silvicultural operations are done in the pine cultures, so that valuable biomass is wasted and such cultures are attractive for damaging insects and fungi, and are particularly susceptible to fire.

With the karst conifers and the pioneer cultures as possible only in the primary production of biomass while waiting for the return of the autochthonous broadleave vegetation, we should bear in mind the economic aspect: timber production. We cannot afford to waste the huge biomass. Accordingly, more attention should be paid to the better management of the available and the newly-raised stands. Our wood industry should find a challenge here in the processing of pine timber for furniture and other manufacturing. Another big consumer of the pine biomass is the pulp mill (Matić 1986).

The role of brushes and low vegetation in the Mediterranean forests at the time of a fire is a controversial issue in the literature. Some dispute, others support, the fire. Guyot (1990) recommends pine stands with lush fire-protecting low growth.

An important silvicultural method in the Mediterranean is the clearing of the vegetation along the roadways, with strips at least 10-15 (20) m wide on each side of the road. This is particularly important in the summer months, when traffic along the coastline increases due to the tourist season.

The vast areas of the eumediterranean and submediterranean coastal karst require proper valorization of forestry strategies. Conservative opinions on the issue have been overcome in certain segments. Huge tracts cannot be ameliorated in the near future in order to be turned into forest ecosystems. As this is a zone comprising major economic and urban assets, there is considerable pressure for these forests to be used for general benefits connected with the tourist trade. Accordingly, besides all biological-ecological and ameliorative aspects, these areas require the planting of other species appropriate to the aesthetic function of the areas. The biological-ecological and ameliorative group of plants will have a purely economic function. Such species of trees, brushes and low growth may be planted for fruits, medical use, etc. The idea of "agroforestry" has been frequently referred to when looking for the solutions to the burnt areas. However, Croatian forestry has as yet not shown much understanding and is missing an opportunity in finding a great source of profit.

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SANACIJA POŽARIŠTA SASTOJINA ALEPSKOGA BORA (*Pinus halepensis* Mill.) U MAKARSKOM PRIMORJU

SAŽETAK

Požari su u Republici Hrvatskoj posebna opasnost za šume, osobito za šume na jadranskoj obali i otocima posljednjih dvadesetak godina. Velike su štete izazivali požari nastali zbog ratnih djelovanja ili zbog toga što su ih namjerno podmetnuli pobunjeni Srbi tijekom Domovinskoga rata na području Zadra, Šibenika, Splita i Dubrovnika.

Prema podacima Ministarstva poljoprivrede i šumarstva (1995) šume na kršu, odnosno šume koje se nalaze na otocima i u priobalju Republike Hrvatske zauzimaju površinu od 1 042 081 ha što čini 43 % ukupne površine šuma i šumskoga zemljišta u Hrvatskoj. Na obraslim površinama, koje iznose 732 371 ha, najviše su zastupljene degradirane sastojine s 83 % (panjače 52 %, šikare 25 %, makije 4 % i garizi 2 %) dok visoke šume zauzimaju samo 17 % obraslih površina.

Prema vrsti vegetacije na opožarenim površinama udio je borovih šuma čak 22 % od ukupnih površina (41 176 ha), panjača 20 % (36 891 ha), makije 23 % (42 399 ha), dok se ostali dio od 61 894 ha (35 %) odnosi na ostale obrasle površine. Oštećeno ili izgorjelo drvo prelazi obujam od 1 421 142 m^3 (Projekt 1995).

Proučavanje šumskih požara u mnogim zemljama pokazuje da pozornost valja obratiti pedološkim, klimatskim i vegetacijskim uvjetima njihova nastanka i širenja, utjecaju na kruženje bioelemenata i na fizikalna svojstva tla, te svekolikim uvjetima obnove šuma nakon požara: klimatskim, pedološkim (kemizam tla, plodnost, erodibilnost tla i dr.), vegetacijskim (progresivna i regresivna sukcesija, metode sanacije).

Odluka o tome što učiniti u vezi s obnovom šuma koje su bile zahvaćene požarom ili njime uništene ovisi o nizu biološko-ekoloških i gospodarskih čimbenika. Prije toga valja napraviti ekološku i ekonomsku analizu svrhovitosti obnove (uz određivanje buduće namjene šume). Najčešće se nakon većih požara ne mogu odjednom sve površine obnoviti i privesti namjeni, pa je važno znati koje je radove potrebno obnoviti najprije (Španjol 1996).

Reljefni su oblici izravan odraz geološke građe ovoga terena, i to u prvom redu odraz rasprostranjenosti i tipa kvartalnih taložina. Izdvojena su četiri tipa kvartalnih breča (Grgasović 1995).

Područje Baškoga Polja obilježava u pedološkom smislu koluvijalni nanos većinom jako skeletnoga karaktera na kome su se razvile uglavnom rendzine i smeđe tlo (Bogunović 1982). Na ovom su području otvorena dva pedološka profila - u gornjem i u zadnjem dijelu Baškoga Polja. U donjem dijelu Baškoga Polja to su teksturno nešto teža tla, a podjednako su dobro opskrbljena humusom i hranivima (izuzev fiziološki aktivni fosfor).

Makarsko primorje prema karti klimatske podjele Hrvatske (Seletković i Katušin 1992) pripada klimatskom području Csa.

U vegetacijskom, odnosno bioklimatskom pogledu područje makarskog primorja nalazi se u klimatskozonskom pojasu šume hrasta crnike (*Orno-Quercetum iliricis* H-ić 1958)

Na području makarske šumarije šumski su požari posljednjih 20 godina uništili najveći dio sastojine alepskoga bora. Na tom velikom izgorenom području izdvojeno je nekoliko pokusnih ploha radi praćenja meliorativnih učinaka vegetacije na sanaciju požarišta. Najznačajnije su pokusne plohe u Donjem Baškom Polju. Tu je požar izbio 6. kolovoza 1985. godine. Tada je izgorjelo 862 ha, od toga državnih šuma 552 ha (347,6 ha šuma i 177 ha šumskoga zemljišta) i 310 ha privatnih. Pretežito je bio alepski bor, a na višim predjelima bilo je i crnoga bora. Šumska je dob bila 25 - 85 godina, obujam je bio 50,7 m^3/ha ili ukupno 19 000 m^3. Pokusna ploha 1 (30 m x 30 m) postavljena je na površinu koja je gorjela osim 1985. godine i 1986. godine, dok je pokusna ploha 2 (50 m x 35 m) postavljena na površinu koja je gorjela 1985. i 1988. godine. Na tom se području prati razvoj alepskoga bora na požarištu (broj biljaka, visine, promjeri, što je s obzirom na dob tek početak praćenja).

Na pokusnoj plohi 1 (30 m x 30 m) nakon sanacije terena vađenjem izgorenoga drva i uspostavljanjem šumskoga reda pošumljavalo se dvaput primorskim borom (*Pinus maritima*), 1987. i 1988. godine, nepoznatim brojem biljaka. Posljednji se put pošumljavalo (popunjavalo) alepskim i primorskim borom te običnim čempresom (*Cupressus sempervirens*). Sve su bile jednogodišnje sadnice gologa korijena. Danas na saniranoj površini rastu biljke osim iz prirodne sukcesije bora na požarištu, koja i dalje traje, i biljke sađene u tri navrata radi pošumljavanja i popunjavanja.

I druga je pokusna ploha (2) postavljena na požarištu koje je dvaput gorjelo. Nakon prvoga požara stare sastojine alepskoga bora nije bilo potrebno biološki sanirati jer je teren bio izuzetno naplođen sa starih borova. Međutim, kada je u požaru 1988. godine izgorio taj pomladak i ponik, morala se sanirati površina, koju ovaj put nije imalo što naploditi. Tako je neposredno nakon drugoga požara pošumljavano s nepoznatim brojem biljaka po hektaru, i to jednogodišnjim biljkama gologa korijena. Sađene su ove vrste: obični čempres (*Cupressus sempervirens*), alepski bor (*Pinus halepensis*), crnika (*Quercus ilex*), primorski bor (*Pinus pinaster*). Uspjeh pošumljavanja bio je vrlo loš pogotovo s crnikom. Nešto je bolje uspio čempres. Tako loš rezultat pošumljavanja treba tražiti u načinu i vremenu sadnje te u kakvoći sadnica.

Na dijelu makarskog područja u Baškom Polju, gdje je požar bio samo jednom, tijekom 1985. godine, nikakve biološke mjere sanacije nisu bile potrebne jer je alepski bor bujno niknuo nakon požara i potpuno prekrio izgorjelo područje.

Raščlanjujući podatke o metodama obavljene sanacije možemo uočiti da je uspjeh pošumljavanja na obje plohe djelomičan. S obzirom na broj biljaka po jedinici površine svakako je mnogo bolji rezultat postignut na plohi 1 na kojoj na 900

m^2 ima više od 100 biljaka pinije i primorskoga bora. Nažalost takav uspjeh nije postignut na plohi 2. Treba tu navesti činjenicu da se na plohi 1 pošumljavalo u tri navrata, dok se na plohi 2 samo jednom pošumljavalo neposredno nakon požara. Već je rečeno da su način i vrijeme sadnje za ovakve klimatske prilike vrlo važni. I upotreba sadnica gologa korijena, a ne kontejnerski uzgojenih sadnica djelomično je razlog slabijeg uspjeha preživljavanja biljaka. Pokazalo se da sadnja malih, posebice jednogodišnjih sadnica hrasta crnike na goloj površini poput pionirskih vrsta borova ne može polučiti uspjeh jer mlada biljčica crnike svakako treba zaklon u ovakvim ekstremnim uvjetima (visoke temperature, suncožar, mala količina vlage u tlu, vjetar i dr.). Dobar uspjeh postignut je s običnim čempresom koji, osim što je pokazao velik postotak preživljavanja postiže i znatnije visine za desetak godina. Stoga bi ga trebalo više saditi. Zanimljivo je da autohtonih vazdazelenih listača iz šume hrasta crnike ima malo na obje plohe. Zanimljiv je podatak da na plohi 1 (dakle na 900 m^2) ima 1454 grmova bušina *Cistus* sp., što je 1,62 biljke po 1 m^2.

Dakle u makarskoj su šumariji bila dva tipična požara u sastojinama alepskoga bora, ali s različitim posljedicama. Prvi požar u staroj sastojini nije bio problem za obnovu ovih šuma. Alepski bor, kao pirofit, dobro je naplodio površinu sjemenom te je niknuo gust ponik. Kako dalje provoditi zaštitu i njegu? U Makarskom primorju ima više primjera. Desetak godina nakon požara veliki kompleksi pomlatka alepskoga bora visine do 2 m opet su velika opasnost za ponovni požar. Stoga se išlo na smanjivanje te velike zelene površine od gotovo 700 ha. Prva je mjera bila izgradnja šumskih protupožarnih prosjeka s obilježjima šumskih cesta. Broj se biljaka smanjivao i odstranjivanjem biljaka u prugama određenoga razmaka (3 m ili više). Kako bi ručno to bilo vrlo skupo, radilo se strojno. Tako je početkom 1995. godine to rađeno traktorom Steyr Forst 9078 kome je prikopčan rotacijski čistač. Problem je što rotacijski sjekač zbog nepovoljnih uvjeta tla ne može spustiti sjekač do tla tako da ostaju na prerezanim borićima postrane grančice koje sada, dobivši veliku količinu svjetla, preuzimaju ulogu vrha te za jednu godinu (proljetna i jesenska vegetacija) već postignu visinu do gotovo polovice visine borova u ostavljenim trakama (do 1 m). Problem je i taj što je razmak kotača na traktoru 50 cm veći (25 cm sa svake strane) pa se pri prolazu traktora trajno oštećuju biljke borova upravo onih koji bi na rubovima ostavljenih traka preuzeli dominantnu ulogu u rastu i u dogledno vrijeme u sklapanju sklopa iznad ostalih nekonkurentnih jedinki.

Nameće se zaključak da tako skupe zahvate na ovako teškim terenima nije potrebno provoditi s obzirom na ograničeni uspjeh. Veliki kompleksi borova ponika i pomlatka najbolje se mogu zaštititi preventivnim mjerama. Riječ je u prvom redu o izgradnji što većega broja šumskih prosjeka s obilježjima ceste kako bi svaki dio terena bio dostupan radi službe opažanja i motrenja te eventualne potrebe gašenja. Tako ispresijecanu površinu u nazovimo ih zelene borove oaze treba pustiti da se razviju samostalno, spontano. Pokazalo se da 10 godina nakon požara još nije potrebno čistiti kada na 1 m^2 raste i preko 100 biljaka. Treba dakle pustiti da se spontanim razvojem i pozitivnom prirodnom selekcijom izdvoje najvrsnija i najbolja stabla koja će preuzeti vodeću ulogu i svojim visinskim prirašćivanjem potisnuti konkurenciju. Prvo čišćenje treba provesti (gdje je tako gust sklop) između 15 - 20 godine, ovisno o gustoći biljaka i njihovoj vitalnosti.

Sasvim drugačije šumarske postupke traže površine koje su nakon što su poslije prvoga požara bile gusto naplođene ponikom ili pomlatkom alepskoga bora izgorjele. Ako se to dogodilo u dobi kada mlade biljke još ne fruktificiraju, nema nove progresije, već tlo ostaje gotovo golo, bez drvenastih vrsta, posebice pionirskih kakav je alepski bor. Takve površine zaposjedne specifična zajednica požarišta, na kojemu se razvije gusta vegetacija niskoga rašća, što je vidljivo iz primjera (ploha 1 i 2). Tada šumar stručnjak mora intervenirati biološkim mjerama sanacije požarišta sjetvom ili sadnjom biljaka. Kako obično u okolici ostaju dijelovi stare kulture alepskoga bora ili pojedini primjerci, ni prirodna progresivna sukcesija alepskoga bora na takvu terenu u potpunosti ne prestaje. Iako u znatno manjoj mjeri ona je i dalje prisutna, pa na nju uvijek moramo računati. Sve je ostalo stvar operative, od izbora vrste do kakvoće sadnica. Općenito bi se u ovakvim prilikama trebalo ići sa što je moguće više vrsta već na početku ili naknadno popunjavati. To se naknadno popunjavanje posebice odnosi na autohtone listače (crnika, zelenika, mirta i dr.), koje trebaju i mogu doći kada alepski bor kao pionirska vrsta stvori kakve-takve specifične mikroklimatske uvjete već nakon nekoliko godina (5 - 10). Također bi trebalo saditi manji broj biljaka (1000 - 1500 biljaka) po hektaru, ali jačih, razvijenijih i starijih sadnica u odgovarajućim kontejnerima koji će im omogućiti razvoj. U tom slučaju biljka će nakon presađivanja nastaviti normalan razvoj, napose korijenskog sustava, bez većih šokova.

Pedološka istraživanja dobivena na prosječnim uzorcima na istraživanim plohama potvrdila su poznate rezultate o razarajućem djelovanju požara na pedosferu, posebice na eroziju i na mijenjanje sastava humusa, odnosno biogenih čimbenika: dušika, fosfora, ugljika, kalija.

Na kraju se može zaključiti da je svaki požar, a time i njegova sanacija s obzirom na velik broj čimbenika koji ga opisuju, različit jedan od drugih. Dok je za sanaciju jednih dobro, to kod drugih ne mora biti. Stoga za uspješnu sanaciju treba dobro poznavati lokalne prilike i uvjete (ekološke čimbenike) te biološko-ekološke osobine vrsta potencijalnih za sanaciju.

Arianoutson i Margaris (1981) i Dafis (1991) šumske sustave podložne vatri (*Pinus* sp., *Quercus* sp., *Cistus* sp. i dr.) nazivaju "požarni ekosustavi" ili "požarni klimaks", "na vatru adaptirani" (*fire adapted*), "od vatre inducirani" (*fire induced*), "pirofilnim".

Istražujući utjecaj temperature na plodnost i klijavost sjemena alepskoga bora, Martinez-Sanchez i dr. (1995) ustanovljuju da temperature od 90 °C, 110 °C, 150 °C i 200 °C ne utječu na njihovu plodnost i klijavost. Stoga on smatra da alepski bor nije pirofit, već "kolonizator" na opožarenim površinama (*colonizers*).

Požari nisu nužni za obnovu spomenutih vrsta i zbog toga te vrste ne treba smatrati samo "pirofitnima" jer se u sličnim uvjetima bez požara one mogu obnoviti. Dokaz tomu su šumske prosjeke, čistine, sječine koje osvaja bor.

Požari zajedno s ostalim čimbenicima degradacije i devastacije u Sredozemlju karika su jednoga dinamičnog procesa koji oduvijek postoji u takvim šumama u vječnoj izmjeni regresivnih i progresivnih tokova šumske vegetacije.

Sredozemne su šume nestale sječom, brstom, ispašom i požarima. Posljedica tih procesa na eumediteranskom i submediteranskom dijelu su degradacijski stadiji, u eumediteranu: panjača, makija, garig, goli krš, a u submediteranu: panjača, šikara, šibljak, goli krš.

Pri pošumljavanju treba podizati mješovite kulture i s obzirom na mješovitost četinjača i s obzirom na odnos četinjače : listače kako bi se što brže dobila mješovita struktura. Svakako prednost treba dati autohtonoj vegetaciji (vrstama drveća i grmlja) te vrstama otpornima na vatru. Dafis (1991) navodi ove vrste otporne na vatru: *Arbutus* sp., *Olea* sp., *Quercus ilex*, *Viburnum* sp. i dr. Što se tiče omjera vrsta pri podizanju kultura, isti autor preporučuje omjer 60 % četinjača : 40 % listača, čime se smanjuje rizik od vatre. Dafis (1991) preporučuje kao jednu od mjera zaštite od požara uzgoj jednodobnih (jednolikih) sastojina. To se može postići pošumljavanjem i nakon požara sukcesijom zbog približno istodobnoga nastajanja. Prirodna je nejednolikost: različita dob = grupno selekcionirane vrste.

Gdje je god moguće, treba maksimalno poticati uzgojnim mjerama i radovima (popunjavanje, čišćenje itd.) prirodnu sukcesiju, napose na požarištima alepskoga bora, gdje je površina obilno naplođena alepskim borom i gdje je progresivna sukcesija bujno krenula.

Od mjera zaštite šuma, napose borovih kultura, primarno treba raditi na izradi što gušće mreže protupožarnih prosjeka s obilježjima šumskih cesta. Protupožarne prosjeke treba raditi i u starim a i u mladima i u tek podignutim kulturama. Ovisno o konfiguraciji terena, ali svugdje gdje je izgradnja šumske ceste moguća, šumski kompleksi ne bi trebali prelaziti površinu od 200 ha do 600 ha. Dobro izvedena i održavana prosjeka (cesta) radi prekid zapaljivih biljnih tvari u okomitom i vodoravnom slijedu. Osim cesta važna je preventivna mjera izgradnja zaštitnih pojasa (suhozidi), promatračnica te uspostava odgovarajućega i funkcionalnog sustava veza šumskih djelatnika (promatrači, ophodnje) s operativnim centrom i MUP-om.

Od uzgojnih preventivnih mjera u obzir dolazi čišćenje, posebice potkresivanje donjih grana, te proreda radi smanjenja drvne zalihe (i broja stabala) u borovim kulturama koje se nakon pošumljavanja obično ne uzgajaju te ne samo što propada vrijedna biomasa nego takve kulture postaju pogodne za pojavu štetne entomofaune, fitopatogenih gljiva, a napose su osjetljive na zapaljenje (kulture alepskoga bora na Rabu - Matić 1986).

Autori u svojim istraživanjima nisu jedinstveni u mišljenju o ulozi grmlja i niskoga rašća u sredozemnim šumama za vrijeme požara. Neki smatraju da usporavaju, dok drugi da raspiruju vatru.

Jedan od važnijih uzgojnih zahvata u sredozemnom dijelu naše zemlje jest i čišćenje vegetacije uz prometnice. Ti bi pojasi trebali biti bar 10 - 15 (20) m široki sa svake strane ceste. Ta je preventivna mjera vrlo značajna osobito u ljetnim mjesecima kada je zbog dolaska turista višestruko povećan promet našim primorskim prometnicama.

Velika prostranstva primorskoga krša (eumediteran i submediteran) traže u strategiji razvoja šumarstva na ovim prostorima potpuno i pravilno njegovo vrednovanje. U nekim su segmentima prevladana konzervativna mišljenja o ovoj problematici. Tako velika prostranstva nije moguće u skoro vrijeme meliorirati i privesti šumskim ekosustavima. Kako se upravo u toj zoni naše zemlje nalazi vrlo velik dio našega gospodarskog i urbanog potencijala, veliki su pritisci, i prostorni i ekološki, na ova područja. Stoga se sve više teži da zelenilo, tj. šumski kompleksi na našem primorju obavljaju općekorisne funkcije ponajprije u sklopu turističke gospodarske djelatnosti. S tim u vezi takvi prostori zahtijevaju da se na mnogo mjesta, osim primarnoga biološko-ekološkog i meliorativnog aspekta, posveti i estetsko-pejzažnoj strani sadnje biljaka. To traži da se prema specifičnim pojedinim potrebama i težnjama sade i mnoge druge vrste. Drugu skupinu biljaka činile bi one koje osim biološko-ekološke i meliorativne te često i estetsko-pejzažne imaju i gospodarsku zadaću. To su one vrste drveća, grmlja i niskog rašća koje se mogu saditi radi dobivanja plodova, ljekovitih svojstava i sl. U šumarskoj terminologiji sve se više govori o pojmu *agroforestry* koji djelomice definira i pronalazi rješenje i za mnoge opožarene površine. Napose se to odnosi na zemlje istočnoga Sredozemlja u kojemu mnoge opožarene površine postaju gospodarski vrednovane zbog iskorištavanja vrsta iz prirodne sukcesije (medonosno i ljekovite biljke) ili zbog podizanja kultura isplativih vrsta. Tu šumarstvo u nas nije dosada našlo smisao ni interes, što je potpuno krivo shvaćanje i olako propuštanje dobiti.

Ključne riječi: požari, alepski bor (*Pinus halepensis* Mill.), sanacija požarišta, sukcesija vegetacije, Makarsko primorje

Photo 3. A thick young growth of Aleppo Pine (*Pinus halepensis* Mill.) a decade after the fire - Baško Polje (Photo: Ž. Španjol)
Fotografija 3. Gusti pomladak alepskoga bora (Pinus halepensis Mill.) desetak godina nakon požara - Baško polje (snimka: Ž. Španjol)

Photo 4. Removing strips of young Aleppo Pine trees (*Pinus halepensis* Mill.) with a circular blade saw in Baško Polje (Photo: Ž. Španjol)
Fotografija 4. Odstranjivanje pomlatka alepskoga bora (Pinus halepensis Mill.) u prugama rotacijskim čistačem - Baško polje (snimka: Ž. Španjol)

Photo 1. Test Plot 2 in Baško Polje - Fires in 1985 and 1988 (Photo: Ž. Španjol)
Fotografija 1. Pokusna ploha u Baškom polju - požar 1985. i 1988. godine (snimka: Ž. Španjol)

Photo 2. Circular blade saw Steyer Forst 9078 on the site in Baško Polje (March 3 1995) (Photo: Ž. Španjol)
Fotografija 2. Rotacijski čistač STEYR FORST 9078 u radu u Baškom polju (6.3.1995.) (snimka: Ž. Španjol)

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THE INFLUENCE OF NATURAL AND ECONOMIC FACTORS ON THE QUALITY OF GAME HABITATS

UTJECAJ PRIRODNIH I GOSPODARKIH ČIMBENIKA NA KAKVOĆU STANIŠTA DIVLJAČI

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Determining economic potentials of hunting activities is a very important operation in the realistic planning of game management. Since game management and game are affected by a variety of natural and economic factors, it is necessary to analyse them and determine their conditions in the field. Methods used in data collecting are costly and time-consuming, and the final results are dependent on their quality. It is advisable to use two data collecting methods: a) sample plots, and b) linear area estimation, depending on the size of the area under study. Data can generally be divided into three broad groups: food, water, and peace in the hunting ground. The collected data are processed, and realistic conditions for game management in an area are calculated mathematically. The graphic models based on several samples are intended to give the final results on the habitat quality for individual game species.

Key words: hunting area, game, natural factors, economic factors, hunting-economic potentials, evaluating site quality, hunting ground cadaster

INTRODUCTION
UVOD

Determining economic potentials of hunting activities has for many years been in the focus of interest of scientists, experts and hunting professionals. To establish realistic game management and hunting potentials is a very complex procedure, because game and their habitats are influenced by many factors.

Game husbandry is not influenced only by natural factors. In recent times, it has been man with his activities who has played a crucial role in exerting both direct and indirect influences on game habitats and game itself. In discussing the economic potentials of hunting activities in an area, two groups of factors determining the future of game management should be borne in mind. These are: ***natural factors*** / *economic factors.*

Natural factors are all those concerning habitat elements, natural phenomena, and natural features such as the relief, climate, vegetation and animal world (flora and fauna), and relationships between and within species.

Economic factors comprise influences resulting from man's activities. These activities can have a positive or a negative effect on wildlife and on game management. Each effect is either directly or indirectly reflected on game management.

Nature undergoes permanent dynamic processes which cause changes in habitats. As these are often initiated and accelerated by man, it is necessary to keep constant watch on and to analyse the existing state of natural factors and the degree of anthropogenic influences.

The level of hunting potentials and the possibility of their utilisation depend on natural and economic factors: therefore, it is of primary importance to determine the factual state in the field and to evaluate it properly.

Despite numerous methods which have been used or are being used to determine the economic hunting potentials of an area, very little space and time have been allocated to gathering field data, the starting point for all further calculations.

THE AIM OF THE RESEARCH
CILJ RADA

The problem of finding the best solutions or models for game planning has not yet been satisfactorily solved either in the world or in Croatia. Difficulties arising from each attempt to address the questions of optimal game management are caused by a large number of interacting, complementing or excluding factors which influence both habitats and game. With the added problems of the conflicting wishes and interests of those wanting to obtain goals other than game management in a hunting ground, the matter is made even more complex.

Highly diverse geographical features in Croatia are responsible for very specific game management methods. It is difficult, and often undesirable, to make general rules about which management operations to use in all regions. In Croatia, luckily, a larger area is usually composed of smaller tracts covered with varied vegetation which provide diverse food and shelter. Human settlements are usually surrounded with farmland forming a specific, heterogeneous vegetative belt. Each vegetation, whether natural or artificially grown, represents a different food source.

The condition of a site and its potentials for game management and for breeding certain game species are obtained from the careful study of details, and measurements and analyses of the factors acting integrally on game.

In order to rank all the different factors influencing game management in different-sized areas called hunting grounds, it is necessary to measure as many elements as possible. After each individual factor is measured, comparisons are made, that is, the empiric equation is drawn, and the suitability of breeding individual game species is established. The aim of this research is to draw a measuring scale for individual site factors, to observe their influence on the game, and in this way to provide a model for evaluating the economic potentials of a hunting site.

Since forestry and hunting share a number of elements, one of the most important being that both activities overlap in space, game management planning should follow the principles of forestry planning, which takes into account a large number of measurable elements.

Today, planning in game management in the Republic of Croatia is based on two data sources:

1. A cadaster of a hunting ground obtained from a competent cadastral-surveying office, outlining the boundaries of a hunting ground and a total surface area under different cultures.
2. Data on the number of game obtained from a game count.

However, these data, and specially the one concerning the size, cannot give us an accurate picture of an area. We cannot see whether the area is evenly covered with one kind of vegetation, or whether it consists of smaller units under different vegetation.

By comparing the method of drawing up a basis for forestry management with one for game management, we see that the former relies on data which are directly measured and established in the field, such as:

* compartments and sections
* surface area of each unit
* number of trees per surface unit
* basal area
* tree heights
* wood mass (with experimental plots or with total dbh measurements)
* increment
* site quality

The basis of game management was drawn up virtually without any field measurements and collected data, so that, theoretically speaking, it was drawn up without knowing the terrain and the situation in hunting grounds.

Apart from the fact that a basis for game management both small and large hunting areas, there is also a need to draw up a global game management plan for larger areas located within the present administrative district boundaries.

The reason for this lies in the vegetation composition, relief, climate, and distribution of different kinds of game. All these factors call for large areas to be divided into smaller ones, while on the other hand, it is necessary to standardise game management within a habitat range of a certain species.

Different guidelines and management goals in several smaller adjacent hunting grounds with practically identical game populations have frequently had negative impacts on these populations. The result has been the decline of trophy structure, a inbalance in sex and age structure, and a decrease in parent stock. Examples of this are large game such as deer, wild boar and bear.

Game management depends primarily on natural conditions (site), but also on a variety of economic factors. Therefore, it is difficult to find a simple solution or a universal formula for such a complex problem. The goal of this research is to find a method for establishing, measuring and recording elements in the field (in a hunting ground) which will serve as a basis for a quantitative and qualitative comparison, and for evaluating the suitability of of a hunting area for breeding certain game species. Determining a method of collecting data from a site and recording a degree of economic influence may provide a new approach to planning in hunting and to game management practices.

RESEARCH SO FAR
DOSADAŠNJA ISTRAŽIVANJA

Hunting is one of man's oldest activities. A pre-historic caveman is believed to have fed mostly on plants (180,000 - 150,000 years B.C.). Later, when his mental faculties advanced sufficiently to make tools, he started hunting animals around him both for food and for their fur, which he used as clothes, cover and bed. The period of the primeval hunter goes back to the distant past, to some 140,000 - 100,000 years before Christ.

Later on, when man started cultivating land, hunting gradually lost its original importance, but continued to be a valuable source of food.

Ancient Greeks and Romans put high value on hunting and hunting skills. With the beginning of the new age, that is, with the abolition of serfdom, hunting slowly took on the elements of economic activity (Čeović, 1953).

In the feudal system, lords allowed local people a limited use of timber from their forests, but hunting remained their exclusive prerogative. Forests were managed in such as way as to accommodate the needs of game and hunting. Feudal lords went so far as to establish new forests, and cut rides and ditches in order to increase their pleasure and success in hunting. The first drawn maps were intended to facilitate orientation in forests and to serve as a basis for hunting arrangements. The first maps made for the purpose of hunting date back to 1716 in France (Panić, 1965).

The turn of the 20th century saw a more significant development of game management in Europe, and an almost simultaneous one in Croatia, since it was a constituent part of European culture. The paper "Viestnik" (News) - published by the First General Croatian Hunting and Fishing Society" first appeared in 1892. It was the third of its kind in Europe. The first hunting manual in the Croatian language was published as early as 1896 (Kesterčanek, 1896). Hunting and game management were gaining importance, and hunting associations were founded, regulations written, and game numbers and bags recorded.

The results brought about by this enthusiasm for hunting and game management were being published, and the economic importance of hunting and its contribution to the overall economic development highlighted (Marinović, 1930).

Game management activities were particularly successful in promoting elite hunting tourism, because it was noticed that a tourist - as a hunter spent on average about 10 times more per day than an ordinary foreign tourist (Car, 1964, Žukina, 1965).

The possibility of game farming in accordance with natural conditions was examined, as well as the negative impacts on game by numerous factors stemming from technical and technological progress (Car, Rohr, 1967).

Many scientists dealing with environmental issues are very concerned about the changes in the ecosystems, of which some have turned into full-scale ecological disasters. Needless to say, some changes have had highly negative effects on the fauna, and on the animal species of special interest to us, game (Seattle 1854, Turina 1991, Gec 1991, Matas et al. 1992, Getz 1995, Springer, Prpić 1994, Komlenović 1995).

Another present-day problem with a very negative effect on animals is the modern road network crisscrossing almost all ecosystems, and disrupting normal communication and contacts among animals.

There are numerous studies on the problem of game passage and contacts between two or more isolated parts of an ecosystem (Georgii 1985, Wittkamp 1985, Wolfel 1995, Kovačić 1993).

Undoubtedly, problems occurring in the forest - game relationship have been the subject of study by a number of renowned scientists. In the middle of this century, some of the most eminent Croatian experts gave their contribution to solving the issue of priorities in the management of areas of common interest to forestry, hunting, and even agriculture (Čeović 1950, Car 1961, 1964).

Despite this, debates on the place and number of game in a unit area continued. Almost in parallel, there were very conflicting claims: one urging a reduction in the number of large game (Hanzi, 1964), and the other claiming that the numbers of all game should be considerably increased (Dragišić, 1965).

Recently, there have been numerous studies on the influence of game on stand regeneration (Viličić 1992, Liović 1993). These studies and debates are permanently concerned with the problem of site quality and the capacity of a site to support individual game species.

Research concerning the products of agriculture which can be used as food for game was carried out by experts in this field (Maceljski 1985, Šoštarić - Pisačić 1968, 1974, Wurttenberg 1956/60, Štafa 1993, 1994). Their findings were used to determine the quality of individual products in feeding or raising game.

The quantity and quality of the green mass in forest associations, and their potential as food for the game living there were also studied (Katreniak 1992, Medvedović 1994).

A key element in assessing the quality of a site for individual game comes with the insights into site conditions, and the suitability of some elements to support certain game species. In order to carry out the task, it is essential to know the biology and ecology of the species in question, that is, its demands on the habitat.

In practice, the potential of a site is usually expressed as a combination of two elements: *sitequality* and the *capacity* of a hunting area. These two terms have been in use since the 1960s.

Capacity is defined as the number of game per productive hunting ground unit of a certain class, although there are discordant opinions as to the actual number of animals per surface unit (Andrašić 1982, Ueckermann, 1956).

The term *site quality* is far more controversial.

One group of experts believes that site quality relates to a certain type of hunting ground. In this way, an association of sites with the same life conditions is formed (Petrov 1963, Danilov *et al.* 1966).

Another group bases the method of evaluating site quality on evaluating life conditions for individual game species in a defined area (Ueckermann 1960, Car 1961).

Apart from these two widely applied methods which determine the site quality analytically, that is, by evaluating certain conditions, there are other, so-called synthetic methods, in which site quality is assessed indirectly (Malinovski 1964, Krasni 1963, Rykovski 1964, Jović 1968, Jurgenson 1963).

One of the most frequently used methods of evaluating site quality is based on measuring the body weight of game (mostly roedeer and deer), and to relate this with several previously selected site factors. In this way certain site quality categories were obtained (Ueckermann 1956, 1957, 1960). The method was later expanded and updated.

This method provided the foundations for developing site evaluation in Croatian hunting grounds (Srdić *et al.* 1955, Car 1961, Novaković 1987). It has been complemented and adapted to suit present-day needs.

Very detailed guidelines on planning in game management and evaluating site conditions were presented in a hunting manual published in 1967, in which the chapter "Management of a hunting ground" was written by the then eminent game management experts Dr Zvonko Car and Dr Otto Rohr.

The quality of site for small game was assessed by adhering to the same principle for all game species included in the group. The method involved grading the most important factors in a hunting area from 1 to 5, depending on the quality of individual factors in relation to the demands of the game species in question (Car and Rohr 1967).

Site quality for large game was determined following a different principle. Site quality was established for each individual game species, and a point scale was made for each individual factor in the hunting area. In the case of large game, there are only five basic factors: food and water, vegetation, soil quality, peace in the hunting area, and the general suitability of the area.

There have been attempts to develop and apply other methods of determining site classes and planning in game management. One of the research tasks undertaken by the experts at the Forestry Institute in Jastrebarsko involves the application of the results of research on the forest types in game management (Bezak *et al*, 1988).

The latest directions and guidelines used in drawing up the basis of game management have been made by the Ministry of Agriculture and Forestry. They are based on the choice of the best working methods, which have been tested in practice and have proved to be the most efficient.

STUDY AREA
PODRUČJE ISTRAŽIVANJA

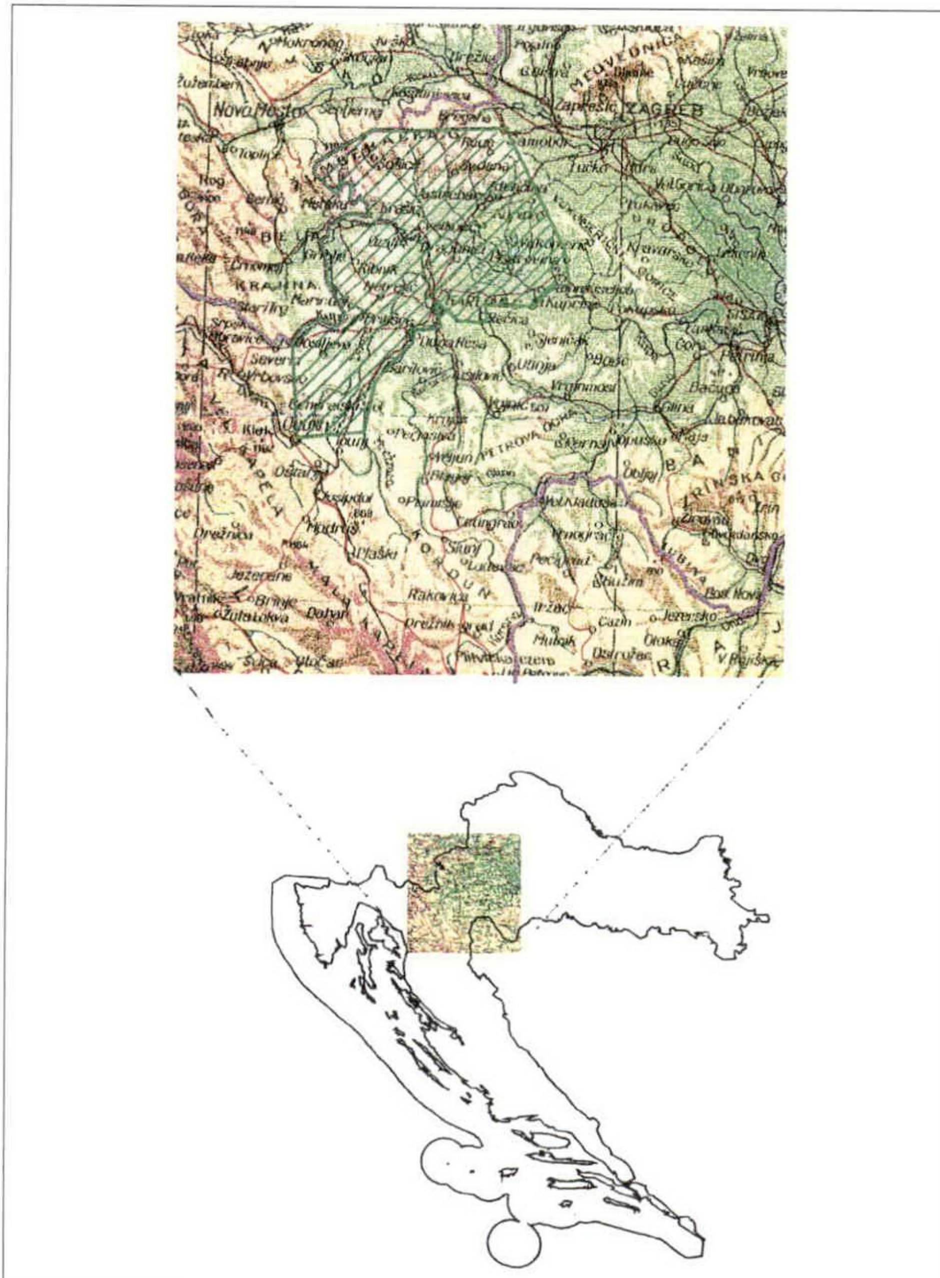
The area where the research was conducted belongs to north-west Croatia (Map 1). The selected area is managed by the Forest Office of Karlovac. The field data were collected from the autumn of 1994 to the spring of 1995.

The observed area is a link between lowland (the Pannonian Plain) and montane Croatia. The town of Karlovac is situated on the edge of lowland Croatia. The northernmost part of the area is taken by Žumberačka gora, stretching between the valley of the river Kupa on the Croatian side and the valley of the river Krka on the Slovenian side. The Žumberačka gora follows the south-west - north-east direction to a length of 40 km. The relief of the mountain abounds in ditches, valleys and conspicuous tops. The dominant tops are Sveta Gera, 1181 m Pleš, 981 m, Ječmenište, 979 m, and Japetić, 871 m above sea level.

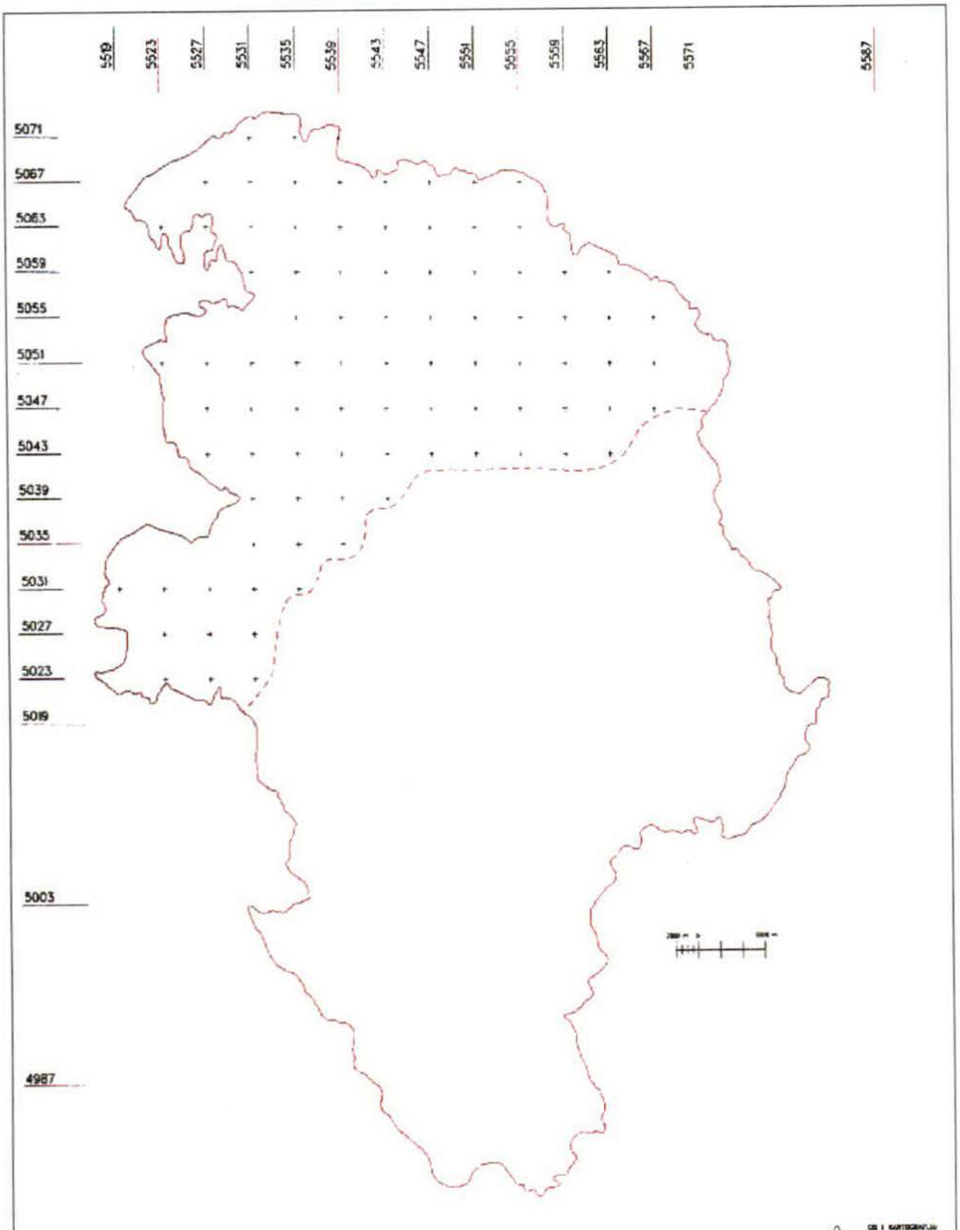
West of the river Kupa which borders the Žumberačko gorje there is a characteristic region of potholes and less well-defined tops. This is a typical karst terrain on a limestone base.

The Pokupsko basin is a specific region, being the westernmost part of the Pannonian Plain, the former Pannonian Sea. The acti onof the river Kupa and its tributaries running down the slopes of Žumberačko gorje and Plješivica has formed a specific geological, pedological and vegetation oasis.

Map 1. Geographical position of the studied area
Karta 1. Zemljopisni položaj istraživanog područja



Map 2.: Area managed by forest office of Karlovac
Karta 2.: Prikaz područja U. Š. Karlovac



The soils developed in the observed area are conditioned primarily by the parent base, climate, relief and anthropogenic influences. A combined action over longer or shorter periods has influenced the formation of the following pedosystematic units, or soils types in the area:

1. Limestone-dolomite humus (Calcomelanosol)
2. Rendzina
3. Brown soil on limestone and dolomites (Calcocambisol)
4. Dystric brown or acid brown soil (Dystric Cambisol)
5. Luvisol or illimerized soil (Luvisol)
6. Colluvial (Diluvial) soils (Colluvium)
7. Pseudogley
8. Swampy-gley soil (Eugley)

The most important hydrographic feature of the observed area is the river Kupa, whose larger part borders the area and a smaller one intersects it. Other important rivers are the Dobra, the Mrežnica (proclaimed the Nature Park), the Dobra tributary of the Globornica, and the Kupčina. The whole observed area also abounds in permanent or temporary water sources of different sizes, and in numerous streams with clean drinking water.

The data from the meteorological stations in Karlovac (112 m) and Jastrebarsko (138 m) present the climatic picture of the area.

Monthly air temperatures were taken in the station over a ten-year period between 1983 and 1992. The recorded data per month and their mean values for the observed period are given.

Table 1. Climatic data for meteorological station Karlovac for the period 1983-1992
Tablica 1. Klimatski podaci za meteorološku stanicu Karlovac za razdoblje 1983 - 1992

Month - *Mjesec*	Ts	SM	Sm	AM	Am	O	V
I	0.3	4.0	-2.8	18.1	-24.6	64.1	88
II	1.6	6.3	-2.3	22.6	-20.6	68.5	84
III	6.8	11.2	2.0	27.2	-10.9	74.4	78
IV	11.6	17.3	6.2	29.0	-3.7	70.7	75
V	16.2	22.0	10.5	32.1	0.5	85.1	76
VI	18.9	24.8	13.3	33.9	4.6	105.0	76
VII	21.9	28.2	15.8	37.0	6.5	79.3	75
VIII	21.2	27.8	15.4	37.0	7.1	78.6	77
IX	17.0	23.6	11.5	34.8	3.7	87.2	81
X	11.1	16.7	6.8	29.6	-3.3	101.5	85
XI	4.9	8.7	1.7	21.6	-14.2	98.9	88
XII	1.4	4.7	-1.2	23.4	-13.5	51.6	88
Anually - *Godišnje*	11.1	16.4	6.4	37	-24.6	964.7	81

Table 2. Climatic data for meteorological station Jastrebarsko for the period 1983-1992
Tablica 2. Klimatski podaci za meteorološku stanicu Jastrebarsko za razdoblje 1983-1992

Month - *Mjesec*	Ts	SM	Sm	AM	Am	O	V
I	-0.4	3.5	-3.9	17.2	-25.5	60.3	92
II	0.6	5.6	-3.5	21.0	-24.0	61.7	87
III	5.7	11.5	0.9	26.0	-13.0	68.2	79
IV	105.0	16.5	5.1	27.0	-4.5	59.1	75
V	15.1	21.0	9.5	30.0	0.0	76.5	76
VI	17.8	23.6	12.3	32.5	3.5	109.7	78
VII	20.5	27.0	14.6	35.5	5.5	74.5	77
VIII	19.9	26.9	14.2	35.5	6.0	82.5	77
IX	15.6	22.7	10.2	33.5	1.8	87.1	82
X	10.2	16.0	5.8	28.0	-4.0	86.3	86
XI	4.2	8.3	0.8	20.0	-14.5	86.8	90
XII	0.8	4.3	-2.1	22.5	-15.4	47.5	91
Anually- *Godišnje*	10	15.6	5.3	35.5	-25.5	900.3	82

Tm (Ts) - mean monthly and annual air temperature
MMax (SM) - mean monthly and annual maximal air temperature
MMin (Sm) - mean monthly and annual minimal air temperature
AM - absolute maximal air temperature over the observed period
Am - absolute minimal air temperature over the observed period
P (O) - average monthly and annual precipitation
H (V) - average monthly and annual relative humidity

The average precipitation and temperature values for the observed area, that is, for the meteorological stations, were used to compute the Lang rain factor (Rf = annual precipitation/mean annual temperature) and to determine the climatic region.

The Lang rain factor (Rf) is:
– Karlovac 86.9
– Jastrebarsko 90.0

According to Koppen's classification, the region belongs to the temperate rainy climate zone of the C type, or more precisely, of the "Cfwbx" type.

Both of these stations are located in the plain and thus record the features of the lowlands. Unfortunately, there are no meteorological data for higher areas; the only indicator of certain climatic changes and particularities is the composition of the vegetation.

Snow is a common winter occurrence in this region. As snow is an important climatic factor, especially as regards hunting and game management, it is necessary to record the date of its beginning and end, its duration on the soil, and its height.

On average, the first snow falls in Karlovac on 20 November, and the last on 18th March. The mean duration of snow cover is 119 days.

In Jastrebarsko, the average date of the first snowfall is 27 November, and of the last is 12 March, while the mean duration of snow cover is 106 days.

Maximal height of snow ranges between 58 and 65 cm.

On average, strong winds occur 1.3 - 3.8 days in a year, while hurricane winds appear in Jastrebarsko on average 0.4 days in a year, while in Karlovac they were not recorded.

Generally, the vegetation cover can be divided into the following groups:

- Forests
- Pastures
- Meadows
- Plouland and other arable land

Forests are spread throughout the studied area, and a forest type, or a plant association growing in individual parts, is determined by the climate, relief and soil type.

Pastures are a well-represented land and vegetation category, ranging from mountain pastures occurring on the topmost parts of the Žumberak and Plješivica mountain, bracken and heather in the hilly parts, to flooded pastures in the Pokupsko basin.

Meadows take up a considerable share of the total studied area, but they are mostly former ploughland turned into hay-producing grassland. Some of these hay meadows have gradually been turned into pastures, and even forests.

Different-sized ploughland are usually placed around inhabited places. The cultures can be classified as follows: maize is grown on as much as 70% of all arable land, and the rest is taken up by wheat, potatoes and other crops. Clover and other grass cultures are sown in smaller areas for the purpose of culture rotation, nitrogen soil enrichment, or respite for the soil.

ANIMAL WORLD
ŽIVOTINJSKI SVIJET

Of animal species (mammals and birds) classified as game under the Hunting Act, the studied area is permanently or temporarily inhabited by 13 kinds of hair-covered animals and 14 kinds of fowl.

The area abounds in a variety of protected mammals and birds not classified as game by law. Still, they are very important because they serve as indicators of ecosystem stability, and enhance the beauty of hunting areas.

SETTLEMENTS
NASELJA

The town of Karlovac is the largest urban centre of the studied area, and has also recently become the district seat.

The observed area covers most parts of the former communes of Duga Resa, Jastrebarsko, Karlovac and Ozalj. Under the new political-territorial administration, there are two towns (Karlovac and Duga Resa), and 11 communes (Bosiljevo, Draganići, Generalski Stol, Netretić, Ozalj, Žakanje, Jastrebarsko, Klinča Selo, Pisarovina, Sošice and Žumberak), of which 6 belong to Karlovac district and 5 to Zagreb district.

According to statistics (The 1993 Annual Statistics) for the 4 former communes, the 1991 census showed that there were 159,013 inhabitants in the total area of 210,800 ha.

ROADS AND RAILWAYS
PROMETNICE

On the whole, the observed area is relatively densely covered with roads and other transport networks. Karlovac, the largest town, is located at the crossroads of important roads and railways. Within the studied area there are 25 km of the Zagreb -Karlovac motorway, then the old Zagreb - Karlovac mein road, the roads Karlovac - Ozalj - Jurovski Brod, Karlovac - Netretić - Jurovski Brod, Karlovac -Rijeka, Karlovac - Senj, and a number of regional and local roads connecting small settlements. Apart from the roads, the area is also crossed by the main railway lines Zagreb - Karlovac - Rijeka, and Karlovac - Ozalj - Metlika.

We should also mention an ever-expanding network of lanes and tracks, which serve for the needs of agriculture and forestry.

From a vegetational and relief point of view, the area encompasses several important and interesting belts ranging from the lowland part of the Pokupsko basin 100 m above sea level to the tops of Plješivica and Žumberak, with the highest points of Japetić, 880 m, and Sveta Gera, 1178 m above sea level. All types of hunting grounds are included in the spectrum; the lowlands, hills, and mountains.

METHODS OF WORK
METODE RADA

WORKING PLAN
PLAN RADA

In order to conduct research on and study natural units, in our areas of study covering one or more hunting grounds, it was necessary to obtain concrete field data. This was done by recording conditions in the field.

One of the ideas on how to set up plots, which was later adopted, involved the use of a point grid (network). This kind of network is currently being used in the ongoing project "Decline of forests", started in 1986.

Every method has its advantages and disadvantages, so another variant was proposed. The aim was to obtain a linear picture of the terrain and determine the position and density of sample lines which would give the most realistic picture of the state in the field.

DATA COLLECTING METHODS
METODE PRIKUPLJANJA PODATAKA

Sample plots
Pokusne plohe

A method of collecting data in sample plots involves the use of coordinates set up for the observation of forest health. These are placed horizontally and vertically at a distance of 4 kilometres from each other. Each of the plots covers 16 km^2, or 1,600 ha.

The distance between the points makes the size of a sample plot rather too large for use in game management.

The smallest surface unit used in game management is the hunting unit (HU), which is 100 ha or 1 km^2. Therefore, the size of a sample plot should be identical to the size of a hunting unit.

The plots arranged in this way more or less cover the area of a district or a large hunting ground, and provide numerous concrete data, while at the same time they do not obstruct the work in terms of time, workforce, or finance.

This is where smaller-sized hunting grounds, which are in fact the most common in Croatia, are at a disadvantage.

As each 100 ha plot in fact represents an area of 1,600 ha, (that is, the experiment covers 6.25% of the total area), it means that our average hunting grounds of 3,000 to 4,000 ha would only be represented by 2 - 3 plots.

This is the reason that, at the initial planning stage, another working method based on a different concept was decided on. This method would yield sufficient data and give a realistic picture of smaller-sized areas.

The method in question was the method of so-called linear surface estimation.

Linear surface estimation
Linearna taksacijska površina

This method has been used successfully in practice. Between 1923 and 1929, the linear estimation method was used to make the national forest inventory of Sweden (Tomašegović 1961, 1972).

Planning and game management also makes use of the data obtained from aerial or satellite photographs. The ability to draw maps of nutrition potentials, and to determine habitats for individual species has been a subject of study especially in Western Europe and America (Ormsby and Lunetta 1987, Anon 1987, Kalafadi_ and Kušan 1993, Lampek and Kušan 1994). The same data can also be collected with any terrestrial measurement methods, but aerial photographs take less time, cover a larger area, and are less costly. In our work we limited ourselves to terrestrial measurements, because our aim was to establish models for evaluating site conditions.

PREPARATIONS FOR FIELD WORK
PRIPREMA ZA RAD NA TERENU

After deciding to set up a 1x1 km plot every 4 kilometres, a field form was drawn up for each plot listing all the most important factors used in game management.

The form took account of numerous site conditions vital for the game, and direct or indirect, harmful or useful anthropogenic influences, so that it included the following elements:

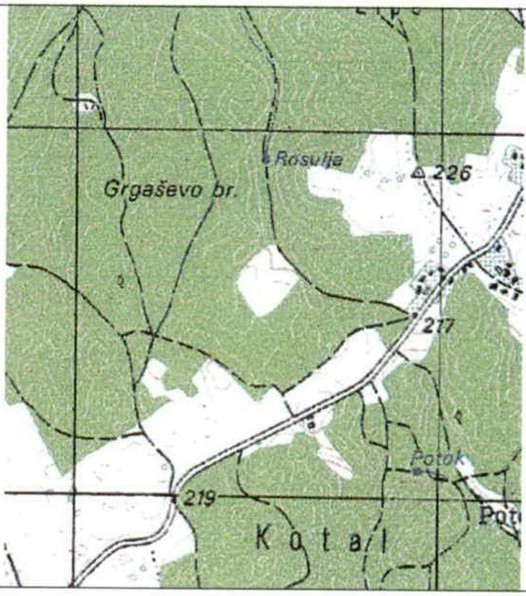
- administrative district
- place name (locality)
- plot coordinates x, y, z
- lowest and highest altitude
- exposure
- inclination
- vegetation composition (cadaster)
- settlement per category
- thoroughfares per category and length
- water per category
- chart giving a rough site estimate for individual game
- date of recording

The form was a component part of the map of the area.

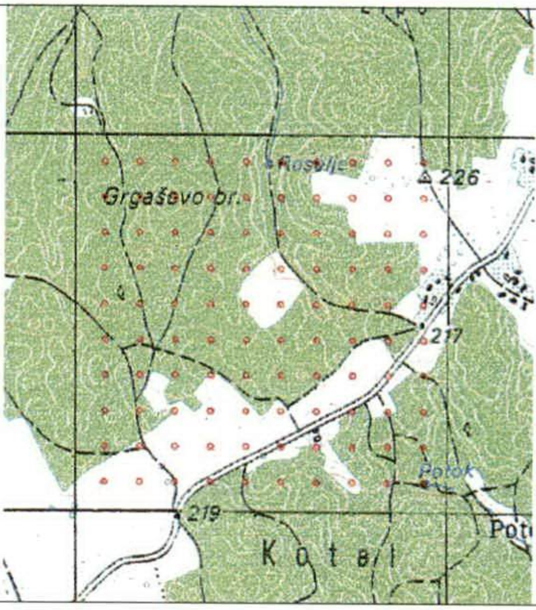
To begin with, the starting points and boundaries of a plot were marked on the map. Since the plot coordinates had been determined earlier, and the plots were 1x1 km in size, the best maps to be used in field work were those at a scale of 1 : 25,000, better known as "special maps". It was also agreed that the point with determined coordinates would represent the bottom left corner of the square, or the plot.

The preparations for the second method of collecting field data, that is, for linear estimation, were similar to the first one. For this method it was necessary to obtain large-scale maps with clearly marked plots so that a concrete situation in the field, that is, the situation at the moment of recording, could be determined more easily and accurately. Some of the collected data were written or drawn into the field maps. The maps were complemented with a form giving additional data. The following data were filled in on the form:

Map 3. A detail of a map with a sample plot
Karta 3. Detalj karte s primjernom plohom



Map 3a. Determining a share of cultures in sample plots using a dot grid
Karta 3a. Utvrđivanje zastupljenosti kultura zemljišta na primjernim plohama pomoću mreže točaka



- hunting ground
- area
- line of recording
- total length of recording line
- line altitude, its lowest and highest point
- inclination
- exposure
- thoroughfares per category
- settlements per category
- water per category
- land structure, size and distribution of plots

Just before starting with the actual field work, a recording plan was made. In other words, lines were drawn in to facilitate the recording and to present the actual state in the field. In order to make optimal recording lines, the lines were drawn in the following manner: after studying the appearance and the shape of the outer boundary of each hunting ground, the two furthest points were identified and joined with a line. In this way we obtained the longest line, a sort of diagonal line through the hunting ground. The next step was to place perpendicular lines on the horizontal one, and to join points two by two on the hunting ground boundary. The lines, set vertically on the horizontal axis, were parallel.

The density of the lines vertical to the horizontal one was defined by the homogeneity of the area under research, and the desired reliability of the collected data.

In our case, the perpendicular lines were set at one kilometre each, and the first one was placed 500 m from the starting point of the diagonal line. In order to get the sample intensity needed for the desired degree of reliability, additional perpendicular lines were later placed on the diagonal line every 500 m between the already existing lines.

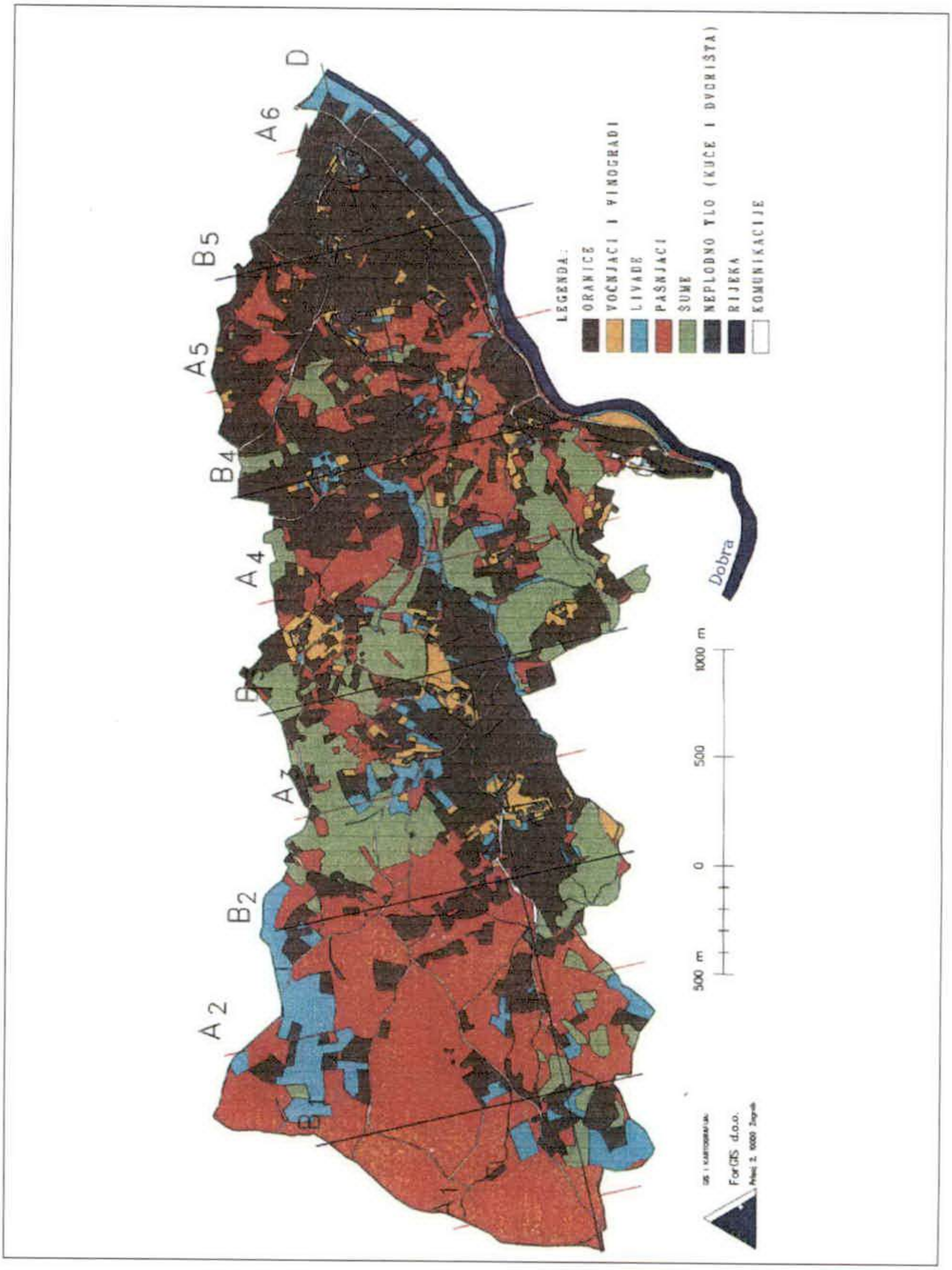
Apart from field maps and forms, other equipment needed for field work included a compass, a measuring tape, and a set of binoculars to facilitate the estimation of the soil and vegetation in adjacent areas.

RECORDINGS MADE IN SAMPLE PLOTS
TERENSKA SNIMANJA NA PRIMJERNIM PLOHAMA

After establishing the number of sample plots and marking their position on the working map, the sample plots were then inspected and their state recorded. The basic data for each plot were filled in on apropriate forms, which were later processed.

The coordinates of each point were marked on the map following the Gauss-Kruger system for easier computer processing and storing.

Map 4. The position of surveying lines in linear land measurement
Katra 4. Položaj linija snimanja kod linijske taksacije površina



It is easier to manipulate x and y coordinates in a computer data bank than place names. Apart from x and y coordinates, the altitude of the identifying point (the bottom left point in the plot under study) was also filled in.

This z-coordinate helps to place the plot and the area it represents into its appropriate altitudinal zone, which is of prime importance in game management.

The lowest and highest points (altitude) inside the plots were also recorded on the form. All these data are easily read from the 1:25,000 scale military-topographic maps which we used in our work. Altitudinal values obtained with instruments placed at certain elevations were tested and possibly corrected with direct field measurements. The elevations are given on the working map, and therefore it is advisable to use topographical maps.

The dominant exposure is established with a compass. The inclination is measured with a clinometer and is expressed in degrees. It is best to record data at the highest inclination. The average inclination can be arrived at by using the difference in altitudes within a plot.

Establishing the composition of vegetation in a plot and outlining the cadaster are the most difficult tasks, because the situation in an area should match the one in official cadastral records.

The following categories are recorded:

- ploughlend
- meadows
- pastures
- forests
- orchards and vineyards
- areas under water
- rocky ground
- unfarmed land (settlements, roads and others)

In the course of filling in the forms and using the 1:25,000 scale maps we came across a problem - how to determine with accuracy the share of each culture in a sample plot. The tast would have been easier if we had had a cadastral map with marked lots. However, that was not the case with our small-scale maps. Luckily, the size of each plot is 100 ha, so the composition of the vegetation or the percentage of individual cultures could be expressed in hectares or in relative (percentage) amounts. After the first plots were thoroughly inspected and the factual state recorded, a sketch was made of each culture and the share of individual cultures in the total plot area was estimated. This procedure yielded relatively good results, but they were not absolutely accurate.

As we have already pointed out in the planning section, as many elements should be measured as possible. The following solution was found: 4 x 4 cm squares were copied on a transparent plastic sheet (the number corresponded to that in a sample plot on a 1:25,000 scale map), within which 100 dots were evenly arranged (10x10). After the state in the field was recorded and marked on the field map, the corresponding square was covered with the dotted sheet, and the percentage or the hectares of each land category was accurately determined.

If there were fully or partially inhabited places in a studied plot, they were recorded by their size, but also by the influence they had on game management. The following code was used:

Category	Factor/Code
Town	1
Village	2
Hamlet	3
Individual houses	4
Uninhabited	5

When the data are processed, certain attributes can be assigned to each category reflecting its suitability for game management. As uninhabited areas are the most suitable, they are marked with value factor 5. On the other hand, towns and their populations have very negative impacts on the remaining natural sites, so their influence is marked with factor 1, which means that this area is excluded from game management.

Thoroughfares are placed into 5 categories, and their share per plot or per 1 km^2 is marked.

Areas under water are marked on the following 7-category basis: spring, stream, river, canal, fishpond, lake, and swamp.

As each of these categories plays a role in game management, it was deemed necessary to mark them individually, and even express them numerically. Since some plots contain several springs and streams, they are particularly valuable for the animal world and the game of the area.

Method of linear estimation
Metode linijske taksacije

A method giving a more detailed picture of a certain area in all its parts, that is, a method of continuous observation of the field and its details, involves observing and recording elements linearly along the very line of movement, but also recording essential details in a wider area along the observation line.

The composition of the vegetation, that is, the land cadaster, is recorded in the following manner: each lot, or a group of lots (depending on the homogeneity of the vegetation cover) is marked with its corresponding culture, that is, land category.

As in the previous method, the following land categories are marked:
- ploughlend
- meadows
- pastures

- forests
- vineyards and orchards
- areas under water
- rocky ground
- unfarmed (settlements, roads and others)

There are two ways in which corresponding cultures in a cadastral unit can be recorded: one is to write a shortened form or the first letter of a land category, and the other is to colour each category with a different colour. Field practice has shown that it is best to write in symbols of land categories, and later to colour them in the office, in the course of computer processing.

The share of each land category is not established during field work, but is arrived at later during the data processing stage. Originally, the plan was to measure the length of each individual lot, or the share of cultures in the field, but this proved impractical for two reasons.

The first is that tape measuring in the field requires at least two persons, with the additional job of recording land categories and their corresponding lengths, unlike marking on the map, which can be done by only one person. The second is that measuring in the field, and especially on sloping areas, requires making corrections due to inclination, which may lead to mistakes. In contrast, on a map all the lengths are already represented on a plane surface.

Additional data should be kept for each individual line in order to receive as many data as possible and have a more complete picture of the state in the field, especially if more than one person does the recordings.

The form for additional data in the linear estimation method includes the following data:

- hunting ground
- area
- recording line
- total length
- altitude
- inclination
- exposure
- thoroughfares
- settlements
- water
- land structure

DATA PROCESSING AND RESULTS
OBRADA PODATAKA I REZULTATI RADA

PROCESSING OF DATA COLLECTED IN SAMPLE PLOTS
OBRADA PODATAKA DOBIVENIH NA PRIMJERNIM PLOHAMA

The choice of a method of data processing depends on the desired goal. If the goal is to present the site and its potentials for game management in accordance with the economic base of the area, then the area is treated as a whole, but if the goal is to highlight individual parts of an area, then the corresponding plots are singled out and studied for the required data.

In order to obtain a clearer picture of a specific feature of some plot or hunting ground, a map of the study area was made using the GIS technology, and each plot was assigned a series of data which could later be displayed or recorded using any one of a number of computer graphics display and storage devices.

Altitude
Nadmorska visina

Values obtained in plots can be used to determine the lowest and highest points of the studied area, but the data will be more accurate if we support them with field maps. As the distance between plots is 4x4 km (and rarely less), sometimes a plot does not cover the extreme points in the field; however, other plots with these values will point to a place where the two extremes should be looked for. Using average altitudes, we can then classify the area into one of the altitudinal types (Map 5).

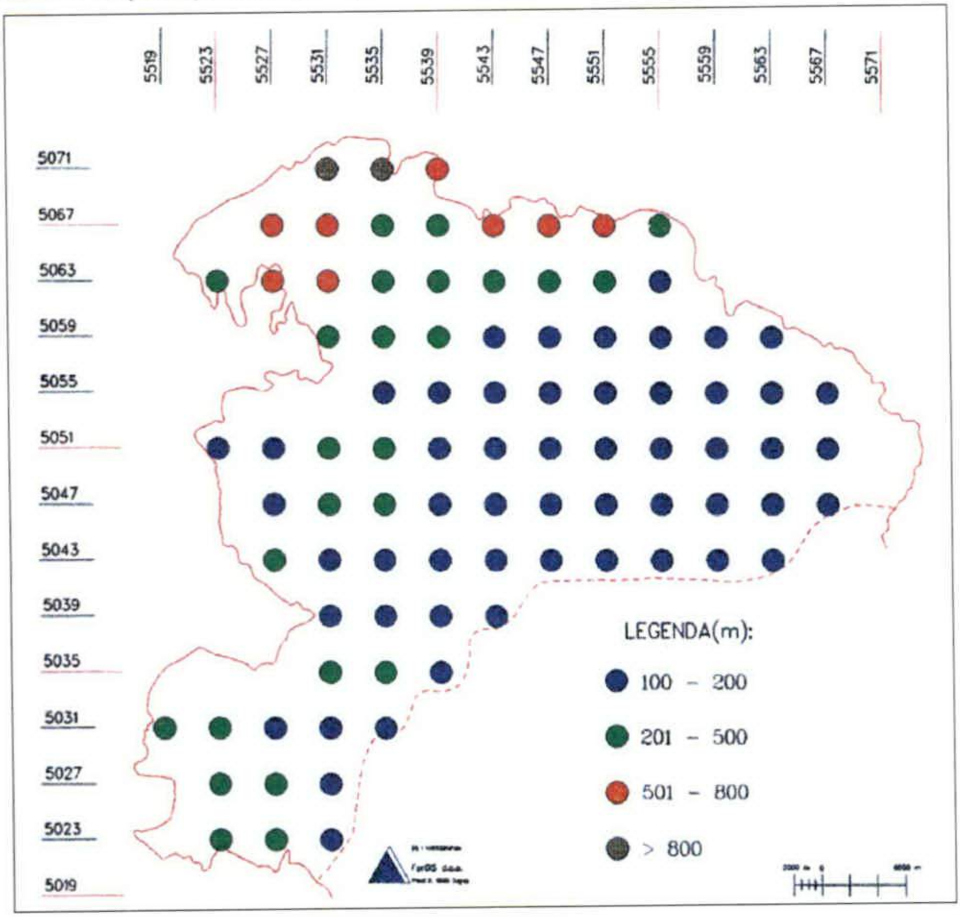
Both directly and indirectly, altitude is responsible for numerous details of importance for game and game management: climatic conditions, approximate vegetation composition, a possible natural distribution of certain animal species, and many others. It is important to establish altitudinal zones as this facilitates game management.

Exposure
Ekspozicija

A collection of data on plot exposures is used to calculate the dominant exposure, that is, the percentage of individual exposures. This type of data gives us indirect information on the possibilities of sheltering game in adverse meteorological conditions and seasons. In higher regions, this data may serve as an indicator of the floral composition in the overall site. The studied area consists of the following structure of plot exposures:

Exposure	Number of cases	Percentage
Flat	26	29.2%
Northern	12	13.5%
Eastern	8	9.0%
Southern	34.2	38.8%
Western	8.5	9.5%

Map 5. Distribution of sample plots at different altitudes
Karta 5. Raspored pokusnih ploha prema nadmorskim visinama



Inclination
Inklinacija

Terrain inclination is especially important in hilly and montane regions for reasons of passableness. Therefore, it is expressed separately for each plot.

We can calculate the mean inclination in the observed area, but it is far more important to highlight the extreme values and the frequency of very steep and craggy parts. The mean inclination of the observed area is 13.4 degrees. In the area of Žumberak and Plješivica, and in a narrow part of the Kupa canyon there are very few extremely steep and craggy points.

Land register /cadaster/
Katastar zemljišta

One of the chief aims of this work is to determine the real state of vegetation cover, that is, the distribution of different land cultures on the terrain itself. The situation recorded in sample plots should give an average land culture in the area.

It is clear that a single plot cannot represent a wider area, or provide a realistic average situation on the terrain. Since this method is intended to describe the conditions in a larger area, it is reasonable to expect that a larger number of plots will give a more realistic average state on the terrain.

Using data processing, we will abtain a mean percentage of each land category in the entire area, or in a smaller, limited area.

Average composition of land cultures in the studied area:

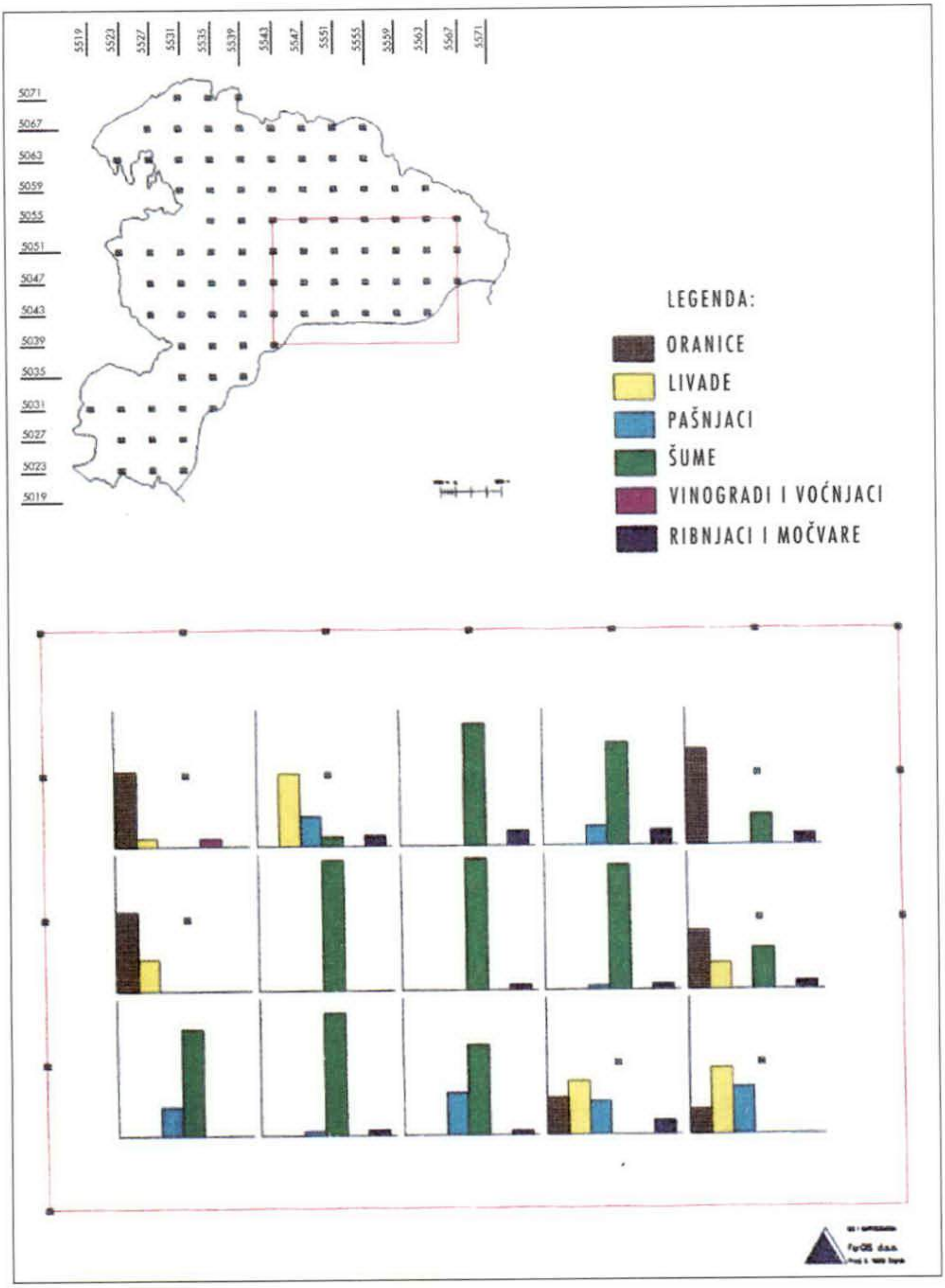
Land culture	Percentage
Ploughland	14.8%
Meadows	11.9%
Pastures	12.4%
Forests	47.5%
Orchards and vineyards	4.1%
Fishponds, canals and marshes	1.4%
Lakes, rivers and streams	0.5%
Rocky ground	0.1%
Others (settlements, roads ...)	7.3%
TOTAL	100.0%

By unifying some parts of the studied area on the basis of their vegetation composition, a foundation and a prerequisite for the formation of one or more hunting grounds was made.

A cadaster is a legally prescribed "identity card" of each hunting ground. It is a very important document because the entire task of planning in game management is based on it. A record of the real state of a land cadaster should be an integral part in making a basis for game manageme, because realistic planning can only be made with realistic data (Map 6).

Intensive cultivation of agricultural areas (ploughland, meadows, pastures) can significantly increase nutritional potentials for game, and thus indirectly influence the number of game and their physical, trophy and reproductive quality. This is why the economic aspect has a very important role in game management. In

Map 6. Soil structure in sample plots of the Pokupsko basin
Karta 6. Struktura zemljišta na pokusnim plohama pokupskog bazena



the studied area, pastures offer particularly good potentials for the improvement of game management improvement. At the moment, very small quantities of game food are produced in relatively short periods. By increasing the rate of cultivation and game food production by only 1 - 2 %, the number of game could be considerably increased, while at the same time other surrounding areas would not be threatened with game-incurred damage.

Settlements
Naselja

Any type of settlement within the area of the studied plot was registered. The settlements are categorised according to their size. The size also determines their influence on the environment and on the game, and game management.

The following categories were found in the observed area:

Type of settlement	Recorded in sample plots
Town	2
Village	19
Hamlet	25
Individual houses	8
Uninhabited	35

Settlement categories provide important information on peace in a certain area.

The distribution and size of settlements have a profound influence on the prospects of game management. Their display on the map gives an overall picture of the extend to which certain observed areas are "covered" with settlements.

Thoroughfares
Prometnice

Thoroughfares, or transport communications, are very important factors in game management owing to their numerous direct and indirect impacts on the game. They are often a limiting factor in the process of recording certain elements of game management, for example, game migration. Their most serious impact is reflected in the portion of game killed on the roads.

The processed data showed the following average structure of thoroughfares in the studied area:

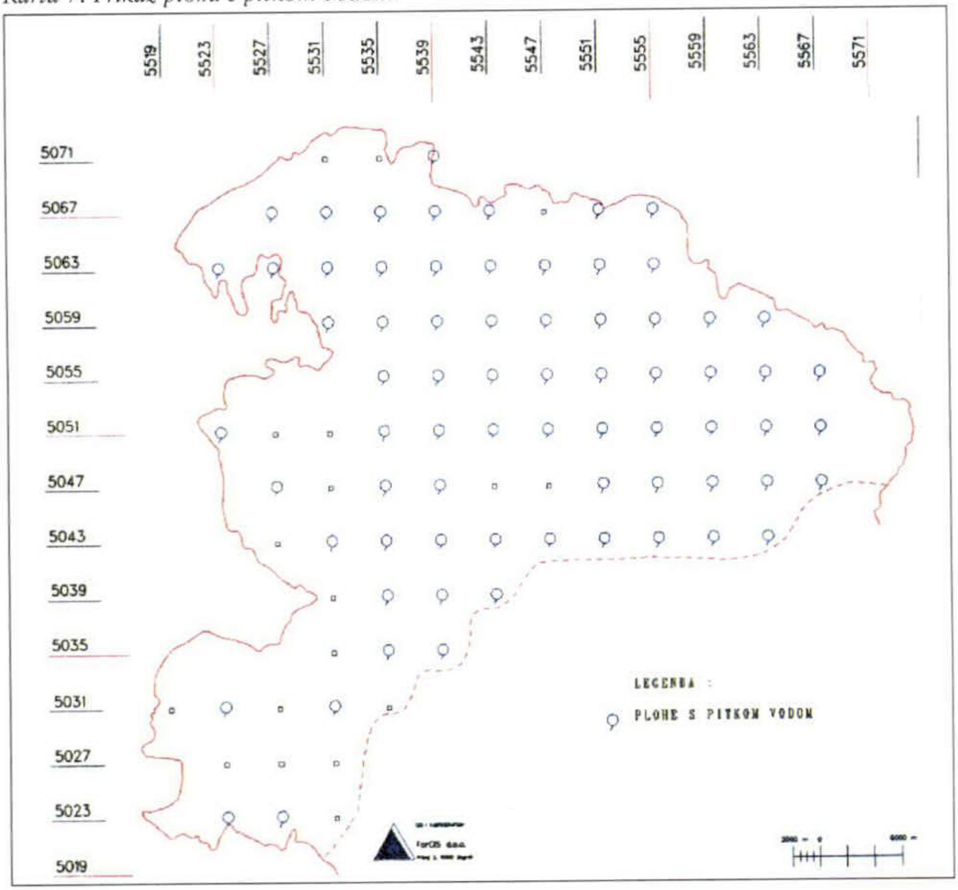
Thoroughfare category	Total factor	Degree in 100 ha
Motorway	5	0.056
Main roads	25	0.280
Regional local roads	126	1.415
Main forest and field roads	131	1.472
Side forest and field roads	227	2.550

Water
Vode

The distribution of water-covered areas and springs of accessible drinking water is a very important element in each hunting ground. Each accessible water source is a positive element. Apart from their numbers, another important factor is their spatial distribution. Evenly distributed water sources are much more important for the game than their number, or the quantity of drinking water in a small area. The distribution and number of drinking water sources are directly responsible for game staying in a certain area and their daily migration.

All water categories, except water springs and streams, (which are negligible) we01re recorded in the land register of an area during field observation activities.

Map 7. Plots with drinking water
Karta 7. Prikaz ploha s pitkom vodom



The following numbers and categories of water sources were recorded in the studied area:

Water category	Number per plots
Spring	1
Stream	140
River	11
Canal	25
Lake	1
Fishpond	1
Swamp	6

Evaluation of conditions for individual game species
Ocjena uvjeta za pojedinu divljač

Field work requires that all elements, both in studied plots and in their wider surroundings, should be taken into account. The state of the terrain, site conditions, traces of game, and all previous data on game management and game will provide a basis for determining which kinds of game actually live, or could possibly live, an the natural conditions of a given area. If conditions exist for a game species listed in the form, then realistic estimates should be made for each individual species, and their suitability graded (bad, good or very good). The concrete state will be obtained later, in the course of determining the site quality of a more narrow area for the purpose of drawing up a basis for game management. If the area provides conditions for any other more important game species apart from the 8 listed, the game should be added to the list and the conditions for their survival estimated. This refers primarily to the mouflon, chamois, capercaillie, mallard, and similar types.

PROCESSING DATA OBTAINED FROM LINEAR AREA ESTIMATION
OBRADA PODATAKA DOBIVENIH LINIJSKOM TAKSACIJOM POVRŠINA

After reading, recording and adding up the data per line, all the data are added, that is, all the lines representing one territorial unit or a hunting ground, are totalled.

After recording data from all the lines, they are totalled per cultures and in total. This provides a basis for estimating the absolute share of each individual culture. Finally, since the total surface area of the hunting ground is known, the absolute surface total of individual land cultures within the studied area is calculated using relative sums obtained from recording the states on lines.

To test the reliability of the proposed method of collecting field data, recordings in the field were done in three ways.

After the relative share of individual cultures in the observed area was established in three ways (diagonally, and with perpendiculars to the diagonal in two variants), the data were processed. First, each of the basic variants was studied separately, and then all the possible combinations of the three variants were made. In the end, we had 8 variants:

cadaster - data from official cadaster giving the real situation in a terrain
diagonal - data obtained from recording the state along the diagonal line
perpendicular A - data obtained from the lines vertical to the diagonal axis, at a distance of 1 km
perpendicular B - data obtained from the lines vertical to the diagonal between the lines in Variant A
DA - data obtained by adding diagonal and perpendicular A
DB - data obtained by adding diagonal and perpendicular B
AB - data obtained by adding perpendicular a and perpendicular B
DAB - data obtained by adding diagonal, perpendicular A and perpendicular B

Data from two KO (Maletić and Vinski vrh) were collected following the same principle. After they were processed, the percentage share of a land category was calculated for each variant.

The data were processed using the computer programme "Statistics", giving correlation values among all the variants.

Table 3. Percentages of land cultures obtained with different sample intensity
Tablica 3. Postotak zastupljenosti pojedinih kultura zemljišta dobivenih različitim intenzitetom uzoraka

Culture *Kultura*	Method *Metoda*							
	cadaster *katastar*	diagonal line *dijagonala*	vertical line A *okomica A*	vertical line B *okomica B*	*DA*	*DB*	*AB*	*DAB*
Plough-fields *oranice*	38.33	45.77	31.55	44.59	38.34	45.09	38.29	40.38
Vineyards and orchavds *vinogradi i voćnjaci*	3.07	2.07	1.52	2.84	1.79	2.51	2.20	2.17
Meadows *livade*	7.92	4.95	8.47	3.86	6.99	4.33	6.08	5.77
Pastures *pašnjaci*	33.06	24.23	39.72	33.15	33.22	29.33	36.33	32.95
Forests *šume*	13.31	13.88	15.77	10.96	15.11	12.21	13.29	13.45
Unfarmed *neplodno*	4.31	9.10	2.97	4.60	5.77	6.53	3.81	5.29

Table 4. Percentages of land cultures obtained with different sample intensity
Tablica 4. Postotak zastupljenosti pojedinih kultura zemljišta dobivenih različitim intenzitetom uzoraka

Culture *Kultura*	Method *Metoda*							
	cadaster *katastar*	diogonal line *dijagonala*	vertical line A *okomica A*	vertical line B *okomica B*	*DA*	*DB*	*AB*	*DAB*
Plough-fields *oranice*	32.95	24.06	36.55	36.79	32.97	33.07	36.67	34.55
Vineyards and orchavds *vinogradi i voćnjaci*	4.21	6.39	6.02	3.56	6.12	4.39	4.82	5.08
Meadows *livade*	7.08	3.99	11.47	3.67	9.35	3.76	7.67	7.05
Pastures *pašnjaci*	26.17	24.00	24.88	23.48	24.63	23.63	24.20	24.16
Forests *šume*	26.08	37.63	16.70	29.18	22.61	31.70	22.82	25.31
Unfarmed *neplodno*	3.51	3.93	4.38	3.23	4.26	3.51	3.82	3.84

Table 5. Correlation among methods in KO Maletić correlations significantly different from p < 0.05 are marked with*
*Tablica 5. Korelacija između metoda KO Maletić koleracije signigikantno različite od p < 0.005 su označene sa**

Metods *Metode*	Cadaster *Katastar*	Diagonal *Dijagonal*	Vert. A *Okom A*	Vert. B *Okom. B*	D_A	D_B	A_B	D_A_B
Cadaster *Katastar*	1.000 p = ---							
Diagonal *Dijagonal*	.9348* p = .006*	1.000 p = ---						
Vert. A *Okom A*	.9585* p=.003*	.8065 p=.053	1.000 p = ---					
Vert. B *Okom. B*	.9894* p=.000*	.9656* p=.002*	.9141* p=.011*	1.000 p = ---				
D_A	.9968* p=.000*	.9404* p=.005*	.9595* p=.002*	.9859* p=.000*	1.000 p = ---			
D_B	.9754* p=.001*	.9878* p=.011*	.8777* p=.022*	.9943* p=.000*	.9756* p=.001*	1.000 p = ---		
A_B	.9968* p=.000*	.9132* p=.011*	.9739* p=.001*	.9822* p=.000*	.9954* p=.000*	.9623* p=.002*	1.000 p = ---	
D_A_B	.9971* p=.000*	.9540* p=.003*	.9441* p=.005*	.9951* p=.000*	.9976* p=.000*	.9866* p=.000*	.9934* p=.000*	1.000 p = ---

Table 6. Corelation among methods in KO Vinski vrh Correlations significantly different from $p < 0.05$ are marked with*

Tablica 6. Korelacija između metoda u KO Vinski vrh Korelacije, signifikantno različite od $p < 0.05$ su označene sa *

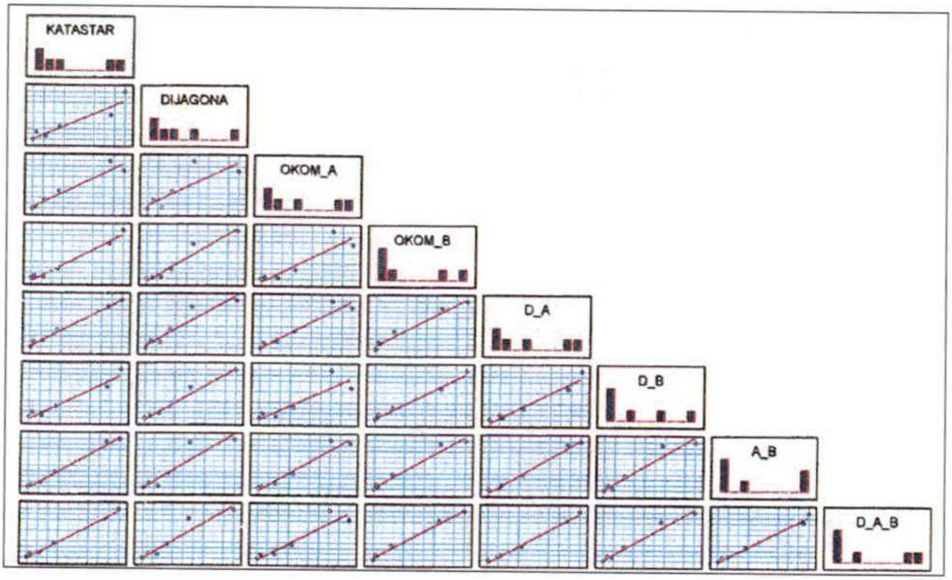
Metods *Metode*	Cadaster *Katastar*	Diagonal *Dijagonal*	Vert. A *Okom A*	Vert. B *Okom. B*	D_A	D_B	A_B	D_A_B
Cadaster *Katastar*	1.000 p = ---							
Diagonal *Dijagonal*	.8758* p = .022*	1.000 p = ---						
Vert. A *Okom A*	.9243* p=.008*	.6290 p=.181	1.000 p = ---					
Vert. B *Okom. B*	.9868* p=.000*	.8873* p=.018*	.8980* p=.015*	1.000 p = ---				
D_A	.9914* p=.000*	.8113* p=.050*	.9648* p=.002*	.9754* p=.001*	1.000 p = ---			
D_B	.9780* p=.001*	.9403* p=.005*	.8417* p=.036*	.9913* p=.000*	.9511* p=.004 *	1.000 p = ---		
A_B	.9833* p=.000*	.7887* p=.062*	.9698* p=.001*	.9782* p=.001*	.9961* p=.000 *	.9468* p=.004 *	1.000 p = ---	
D_A_B	.9954* p=.000*	.8522* p=.031*	.9392* p=.005*	.9931* p=.000*	.9945* p=.000 *	.9760* p=.001 *	.9938* p=.000 *	1.000 p = ---

The test showed that to obtain reliable results, one diagonal line per area is not sufficient. Two variants of setting perpendiculars to the diagonal, viewed separately, gave good results, but perpendiculars A in the KO Maletić displayed considerable aberrations in some cases.

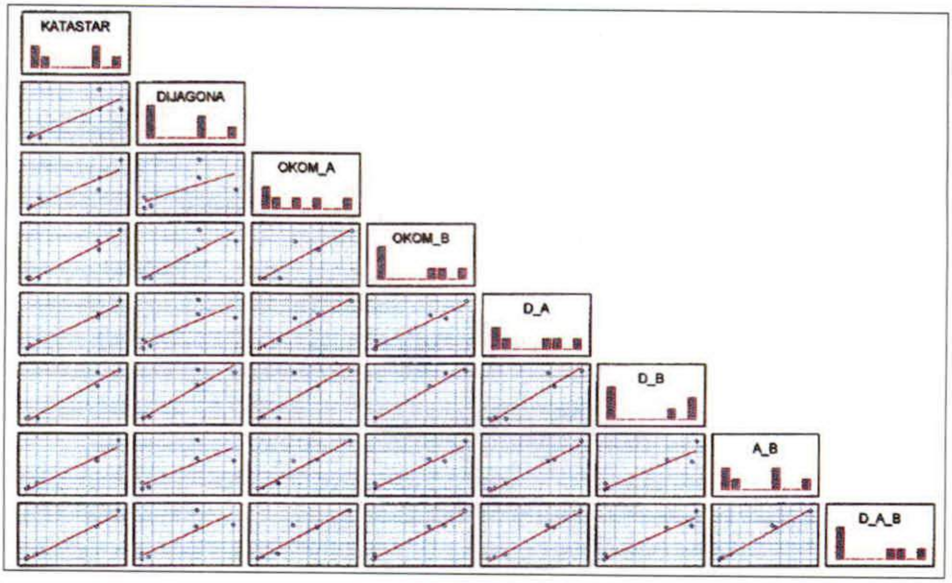
The choice of method is influenced by several factors: the size of the work to be done, costs, and data reliability. With all this in mind, we should always look for a compromise. In our case, the best results were achieved with the DAB variant, as was expected since this variant provides for the most intensive sample taking.

Variant DA (diagonal plus perpendiculars placed every kilometre) called for a much smaller intensity of sample taking, but still yielded a very high reliability coefficient. Compared to the actual state, the values obtained with this method were within 1%, which is acceptable by all statistical standards.

Graph 1. Corelation among methods in KO Maletić
Grafikon 1. Korelacija između metoda u KO Maletić



Graph 2. Corelation among methods in KO Vinski Vrh
Grafikon 2. Korelacija između metoda u KO Vinski Vrh



USING THE COLLECTED DATA MATHEMATICALLY
MATEMATIČKO KORIŠTENJE PRIKUPLJENIH PODATAKA

The evaluation of game management potentials cannot be made using only individual data. Therefore, a series of data was grouped into categories depending on its importance for, and impact on, the game. Cadastral data were placed among the factors concerned with site quality, since they are used in evaluating nutritional potentials, shelter, and overall site quality, and in deciding the suitability of the recorded vegetation elements for certain game species.

Peace is a very important factor in any hunting ground. In fact, some experts rank this factor above all others, and view it as a limiting element.

Peace in a hunting ground is basically determined by two elements - human settlements and thoroughfares. Types of settlements and their distribution have a direct and indirect impact on the game. The direct one is reflected in the fact that the area of and around a settlement directly reduces the living area of the existing game. On the other hand, man also directly influences game habitats, especially by disturbing the animals.

Man's indirect influence is seen through the activities which, among other things, reduce animals' living space, alter natural conditions, and force the game to compete for food and space with domestically-bred animals.

Thoroughfares are one of the most serious problems faced by game management today. Our way of life is unthinkable without a modern communication network; human settlements must be linked with local roads; and economic utilisation of agricultural and forest land is impossible without a good network of forest roads. All this has resulted in a significant decrease in productive areas and in the disturbance of game. Moreover, large numbers of game are run over by vehicles on modern roads, which constitutes one of the most important causes of game loss.

The following equation incorporates all the elements - factors in game management - which have a role in determining what game species to raise and in which number in a certain area.

A formula for calculating the site quality scale

$$Sq = Sc + Sw + Ss + St$$

Sq – site quality scale
Sc – points for a recorded land (culture) cadaster
Sw – points for accessibility of drinking water
Ss – points for the number and structure of settlements
St – points for a thoroughfare network

$$Ss + St = Sp$$

Sp – points determining peace in a hunting ground. They are arrived at by adding up points for settlements and points for thoroughfares. Settlements can bring a maximum of 70 points (for uninhabited areas). Any type of settlement reduces the peace factor, that is, the number of points for peace in a hunting ground. Depending on size, settlements have a constant value which serves as a ponder in estimating a settlement category and its influence on the game.

Calculating points on the basis of the land cadaster (culture):

$$Sc = 100\frac{Sf}{St} + 30\frac{Sp}{St} + 30\frac{Sm}{St} + 40\frac{Spl}{St}$$

St – total surface area of a hunting ground
Sf – forest surface area
Sp – pasture surface area
Sm – meadow surface area
Spf – plough land surface area

Calculating points for accessible drinking water

$$Sw = 10\,ns + 10\,nw - \frac{sgn0\,(ns\,nw\ -\ 5)\ +\ 1}{2}(ns + nw - 5)\,10$$

ns – number of drinking water springs in 1,000 ha

nw – number of waterflows with drinking water in 1,000 ha (streams, rivers, canals) function signum 0 is conditioned by:

sgn0(x) – 1, if x is more than 0; -1, if x is less or equal to 0

Calculating points on the basis of number and structure of settlements

$$Ss = 70 - (2\,ni + 4\,nh + 8\,nv + 16\,nt)$$

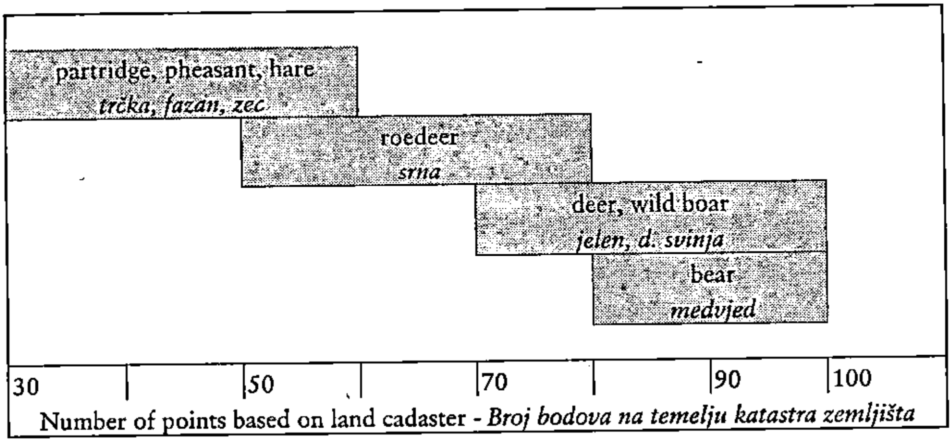
ni – number of individual houses in 1,000 ha
nh – number of hamlets in 1,000 ha
nv – number of villages in 1,000 ha
nt – number of towns in 1,000 ha

Calculating points on the basis of thoroughfare network

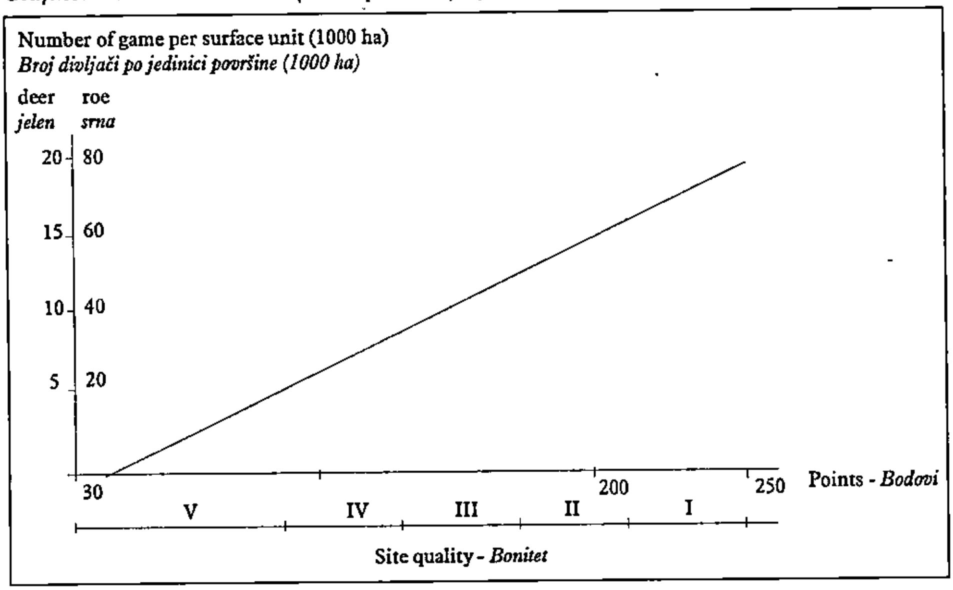
$$St = 30 \times \frac{(30\ -\ 2\,nf)\,ex\,nf\ +\ (24\ -\ 2\,nr)\,ex\,nr\ +\ (22\ -\ 4\,np)\,ex\,np\ +\ (25\ -\ 5\,nm)\,ex\,nm}{30\,(ex\,nf\ +\ ex\,nr\ +\ ex\,np\ +\ ex\,nm)}$$

nf – number (share) of main forest and field roads
nr – number (share) of regional roads
np – number (share) of principal roads
nm – number (share) of motorways
ex – existing

Graph 3. Optimal conditions for individual game species
Grafikon 3. Optimalni uvjeti za pojedinu vrstu divljači ovisno o katastru zemljišta



Graph 4. Site quality scale (For big game)
Grafikon 4. Bonitetna skala (za krupnu divljač)



DISCUSSION
RASPRAVA

This paper is primarily concerned with attempts to introduce as many measurable elements as possible into game management planning, and thus provide a basis for performing calculations for short or long-term game management.

Croatia has excellent potentials for game management. There are also good possibilities for developing hunting, increasing game numbers, and expanding the overall tourist offer and general economy with hunting tourism.

In order to meet the demands of both domestic and foreign tourist - hunters, the Croatian hunting grounds should offer a range of possibilities, in the first place their natural potentials, and an optimal number and structure of game. It is possible to increase the number of game with certain management practices, but economically speaking, the results may not bring the expected profit. The best solution is to apply the "wise use" principle to our natural potentials.

Our knowledge, experience and working methods used so far, combined with the detailed analysis of individual factors or groups of identical factors acting on the game management and game population growth, show that it is virtually impossible to single out one factor and its impact on game. The reason for this is that all factors are mutually involved in a cause-effect relationship and act integrally. It is well known that climate, soil, relief and vegetation are closely connected and interdependent. An expert in these relationships can accurately define the main features of all these factors by relying on the information on only one of them.

All the factors and elements, with their causes and consequences, create the need to keep a constant watch on the situation in the field, and to record any changes and reactions of the game.

The basic factors influencing game management and the stability of game populations are divided into natural and economic ones. Natural factors are those which have been here since time immemorial and which are a constituent part of the habitat. Economic ones are related to man's activities. In order to give a clearer picture of some factors and their influence on game management, all the important factors have been classified into three groups:

- Land cadaster (composition of land categories)
- Water (composition of areas under water and springs of accessible drinking water)
- Peace (population density and road and rail network as peace-affecting elements)

Each of these groups, and each individual element, is partially determined by nature, but unfortunately, also by man. Man's activity, especially in the 20th century, has had a profound effect on the landscape, climate, water regime, vegetation composition, and the natural pace of daily and seasonal game migrations.

Another important issue to be addressed is the question of living space, shelter and the reproduction area for animals. It goes without saying that the composition of a land category itself provides basic conditions for the support of a corresponding game species. On the other hand, game find its own living space, shelter and space for reproduction, provided the chosen areas offer peace.

The first problem we had to solve before starting our work was the choice of a method of recording the three mentioned groups of factors. Clearly, the best results are obtained by making rounds of the terrain, and by recording and mapping the whole area. However, the final goal would not justify the length of work involved and the costs. Therefore, we studied the working method based on representative samples in order to satisfy the set goal and at the same time avoid excessive cost.

Only a combination of balanced management measures and a normal number of game everywhere can guarantee successful game management in all hunting grounds. Game follows the laws of diffusion, and moves to less densely populated parts.

Our task was to determine elements of game management in a smaller area, such as a hunting ground, and a larger area, such as a district, region, or the area of the natural distribution of a game species. For this purpose it was necessary to work out the recording methods which would shit the area under observation.

The method involving 1x1 km sample plots arranged 4 km from each other was used in larger areas (larger hunting grounds, districts, areas of distribution for certain game species).

The second method, used in smaller areas (hunting grounds), was based on collecting data by means of linear area estimation. Data were recorded along the drawn line, but also in a wider "zone of responsibility".

The aim of both working methods was, first, to collect data on the concrete field conditions by means of samples, and second, to process the collected data in order to evaluate individual factors and their importance for certain game species, or for game management as a whole.

Both methods of data collecting with terrestrial measurements in the field can be done by one person only, which makes the job simpler and the costs lower.

The essential tools in field work for both methods are geographical maps of the areas under study. The most suitable are maps with a scale of 1:25,000. On these maps, each square kilometre is presented as one square, which makes it easy to define the selected plot and record the factual state.

Cadastral maps with a larger scale are more suitable for the method of linear land estimation. The cadastral lots contain signs for easier and better orientation, which allov for a more accurate estimation of land category compositions (land cadaster).

What is the advantage of the proposed method of determining natural and economic factors in game management?

It would be an illusion to expect that one pice of work will bring about revolutionary changes in game management and in methods of determining its potentials. However, even a relatively small contribution will eventually result in progress. An increase in the use of management potentials by only 1% would definitely justify the use of the new working methods in future management.

As has already been said, nature is constantly changing. In recent years, Croatia has also been going through dynamic processes.

The starting point for planning in game management so far has been the data on land categories, which were provided by a competent institution - a cadastral office, and the data on the number of game, which was obtained by a count. Both of these data are subject to errors; for example, some cadastral data may be 30 years old, and may not have taken account of the changes in the composition and structure of land categories. Establishing the number of game with a count may also be unreliable, as it depends on the time and method of counting. Errors occur mostly when counting big game; since they inhabit larger areas, the same animals can be counted several times over in different hunting grounds.

The next question is: although we had at our disposal a detailed analysis of the situation in the field, why did we classify all the factors and their categories into only three groups?

The answer is: game needs food, water and peace. All the elements recorded in the field are included in precisely these three categories.

Land structures, or land registers, were used to present basic elements for food, shelter and breeding space for a certain game species. Naturally, it is necessary to know the biology and ecology, as well as the way of life of each individual game. In the "water" section, there are 7 different water categories, so they can also be categorised according to how suitable they are for each game species.

Peace in a hunting ground, considered by many authors as the most important factor in game management, deals with two of the most significant groups of disturbers - human settlements and transport communications. The fewer settlements and roads there are, the more peace and security the animals enjoy. Predators, being a component part of the ecosystem, were not considered as sources of disturbance.

Notwithstanding the region in which a hunting ground is located, or the game living there now or possibly in the future, or the intensity of game management at present and in the future, it is necessary to carry out a detailed analysis of the habitat and establish its potentials. The collected data should be reliable, and should be stored in a database for the purpose of comparison with some future data, because each ecosystem is subjected to dynamic processes which have to be permanently monitored. Each major change sets off a series of chain reactions which eventually affect the game.

We have presented one of the proposals which involves collecting, processing and using data for a concrete goal today, and storing them for future comparison with some data collected at a later time.

The vast field of game management leaves room for additional research and detailed analyses of individual segments. Special attention should be paid to the economic moments intended to improve game management, increase food production for thè game, and advance the entire complex technology of game farming in natural conditions. Naturally, we should continue to take account of site capacity, inter and intra-species competition, and sociological behaviour of certain economic game species.

By using the new working method, several advantages can be achieved, some of the most important being: the analysis of site conditions, the database enabling calculations of realistic potentials in game management, to be made maps providing a visual analysis of available potentials, stored data to be used for comparison in subsequent analyses, and the possibility to monitor changes in an area.

CONCLUSIONS
ZAKLJUČCI

The basic aim of the work is to study and justify the new approach to recording, establishing and evaluating site elements which directly influence game and game management.

The following conclusions can be drawn:

1. Hunting and game management developed with increasing radidity at the turn of the century, while the directives and norms have been more strictly adhered to since the middle of this century.
2. Until now, the focus of attention was put on the study of site capacity, that is, game population density per surface unit, while the basic issue of the available space and its quality for game survival was addressed less frequently.
   Most research on game habitats involved forested areas, mainly for two reasons: a) forests are the home of most game species, and b), the problems concerning the forestgame relationship are most frequent there.
3. Apart from forested areas, game also makes partial or full use of agricultural land, which is a significant source of food, living space and shelter (especially for small game). It should also be adequately evaluated and used more specifically for game management.
4. The data used to describe the area and land categories in a hunting ground have so far been provided by a competent cadastral office. The real situation in the field has not actually been established, and the dynamic changes in habitats have not been adequately followed.
   On the whole, very few data have been used in drawing up a basis for game management. The data, such as the mentioned land registers and game counts, have been. In contrast, forest management uses ten measured elements as a base for future calculations and management regulations.

5. In this work we used two new methods of collecting data on the natural and economic factors influencing the quality of game habitats. The two proposed methods are - sample plots and linear land estimation.
   Both methods are intended to depict the state and structure of land categories, the distribution of drinking water springs, the arrangement and size of settlements, and the features and density of road and rail networks.
6. The research showed that the method of sample plots is more suitable for the analysis of larger areas (regions, districts), while the linear land estimation method is better adapted to smaller areas, such as hunting grounds.
7. By testing the collected field data, it was found that to establish the factual state in the field with a statistically allowed aberration ($p=0.01$), it sufficed to draw a diagonal line across the observed area (hunting ground), and perpendicular lines at a distance of 1 km from each other, and then to do the measurements of the concrete state.
8. The collected and processed data are visually presented in topographic maps, where, together with statistically processed and displayed results, they give a graphic picture of the state of each individual factor. Factors such as the land cadaster, drinking water springs, settlements and transport links are presented in such a way.
9. All the recorded data are built into a mathematical formula, which represents yet another way of obtaining the values which indicate the potentials for game management in a certain area (scale of site class, site capacity).
10. Using field data, a point scale is calculated mathematically giving an objective picture of the game management potentials of a site.
11. The new organisational hunting and game management scheme in Croatia, and the application of the new Hunting Act, require the drawing up of game management basis of an area. The aim is to standardize management guidelines in larger areas, or in several hunting grounds with similar site conditions. This is particularly important for big game, because their populations inhabit areas which go over the boundaries of the present hunting grounds. The method of sample plots and the mathematical models presented in this work are proposed for this task.
12. The research conducted so far has stressed the need to collect far more data directly in the field, and to use only factual and concrete data in calculations and planning of future game management. The present fast-changing ecosystems require constant observation and monitoring of individual factors in a hunting ground. Consequently, in the future, prior to drawing up a basis for game management, it is advisable to carry out field inventories, and to record all factors affecting the site and game at least every ten years.

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UTJECAJ PRIRODNIH I GOSPODARKIH ČIMBENIKA NA KAKVOĆU STANIŠTA DIVLJAČI

SAŽETAK

Lovstvo je kroz povijest pratilo razvoj čovjeka i ljudskoga roda te mu je u danim trenucima služilo u određene svrhe, od pračovjeka koji je lovom pribavljao hranu (meso), odjeću i prostirku za ležaj (kožu i krzno), preko srednjovjekovnoga lovca koji je lovom stjecao ratničke vještine, pa sve do današnjega lovca kojemu lov služi za sport i rekreaciju. Danas je pojedincima lov sport. Da bi se njihovim, sve brojnijim zahtjevima moglo udovoljiti, postalo je lovstvo ujedno gospodarska grana.

Od kraja 19. stoljeća, a posebno u ovom stoljeću, lovno se gospodarenje ubrzano razvijalo. Istražuju se i primjenjuju brojne metode uvrđivanja lovnogospodarskih mogućnosti staništa za život pojedinih vrsta divljači. Istraživanja su većinom tekla u smjeru utvrđivanja optimalnoga broja divljači po jedinici površine u određenim ekosustavima. Podaci o zastupljenosti pojedinih kultura na određenom zemljištu uzimani su uglavnom od službenoga katastra površina te su na osnovi njih rađeni daljnji proračuni.

U ovom je radu cilj bio istražiti metode prikupljanja terenskih podataka o čimbenicima koji utječu na lovno gospodarenje, te na osnovi konkretnih podataka izračunati kakvoću staništa za pojedine vrste divljači koje žive ili imaju uvjeta za život na promatranom prostoru. Za postizavanje zacrtanoga cilja predložene su dvije metode prikupljanja terenskih podataka o nizu čimbenika o kojima ovisi lovno gospodarenje.

Za veće površine predviđeno je postavljanje primjernih ploha na razmaku od 4 km. Svaka ploha obuhvaća 1 km^2, odnosno 100 ha. Na toj se plohi bilježi postotni odnos pojedinih kultura zemljišta, izvorišta dostupne pitke vode, broj i veličina naselja i mreža prometnica. Naselja i prometnice čimbenici su koji utječu na mir u lovištu.

Na manjim površinama, poput pojedinih lovišta, predviđa se linijska taksacija površina. Na planski postavljenim linijama, koje se postavljaju ovisno o obliku lovišta, u dijagonali i okomicama na dijagonalu, različite gustoće, na što utječe homogenost snimanoga prostora, utvrđuju se isti čimbenici kao i na primjernim plohama.

Područje istraživanja obuhvatilo je sjeverni i sjeverozapadni dio Uprave šuma Karlovac, te dvije katastarske općine koje se nalaze u sklopu cjelovitog istraživanog prostora i koje su uvjetno bile lovišta. Na većem prostoru podaci su prikupljani na primjernim plohama, dok je na manjim površinama, kao što su katastarske općine, istraživana primjenjivost i pouzdanost linijske taksacije površina.

Na osnovi prikupljenih podataka o čimbenicima koji su bitni za lovno gospodarenje, poput katastra površina, broja i strukture izvorišta pitke vode, broja i strukture naselja te zastupljenosti pojedinih kategorija prometnica uz pomoć prikladnih formula, dobiju se određeni bodovi za svaki pojedini čimbenik. Zbrajanjem bodova svih čimbenika dobije se ukupan broj bodova, odnosno skala bonitetnih razreda, čiji je raspon od 30 do 250 bodova. Unutar te skale nalazimo pet bonitetnih razreda.

Podaci o katastru zemljišta, odnosno bodovi dobiveni na osnovi tih podataka uvrštenih u formulu mogu nam načelno dati poziciju na grafikonu iz kojega se vidi za koju bi vrstu divljači promatrani prostor najviše odgovarao, tj. koja bi divljač trebala biti glavna gospodarska vrsta u određenom lovištu.

Ključne riječi: lovište, divljač, prirodni čimbenici, gospodarski čimbenici, lovnogospodarski potencijali, bonitiranje lovišta, katastar lovišta

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Izvorni znanstveni članak

APPLICATION OF RESULTS OF AERIAL PHOTOGRAPH INTERPRETATION AND GEOGRAPHICAL INFORMATION SYSTEM FOR PLANNING IN FORESTRY

PRIMJENA REZULTATA INTERPRETACIJE AEROSNIMAKA I GEOGRAFSKOG INFORMACIJSKOG SUSTAVA ZA PLANIRANJE U ŠUMARSTVU

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The main aim of this work was to find a way to link all existing data, as well as data acquired by the interpretation of aerial photographs into a unique information source, and to generate new information as a basis for planning in forestry, by using the methods of a geographical information system (GIS). The research was carred out in the NP "Risnjak".

To accomplish this aim, it was necessary:

– to process the results of the interpretation of colour infrared (CIR) aerial photographs

– to make maps with various thematic contents

– to digitalize existing maps (pedologic, geologic, phytocenologic, economic)

– to organize databases

– to assign to each acquired layer an attribute data table (numerical and descriptive) by means of which it was possible to connect digitalized maps with tabular data

– to produce a digital terrain model (DTM) and to establish new layers (slope, exposure, etc.) based on it

– to incorporate newly acquired elements into the established GIS model and to connect them with the existing elements

– to analyze all acquired data (numerical and cartographical) at the same time per individual layer or per multilayer overlap

– to process statistically-obtained dependencies (exposure, slope, plant community, taxation elements, damage stage, etc.).

According to the set aim and trough the research carried out, certain results and knowledge were obtained about both the GIS-technology, as a tool for the realisation of the given objective, and the possibilities of the use of CIR aerial photograph interpretation and GIS for planning in forestry and for environment study.

The result of the research is the established GIS model for NP "Risnjak", which can be used in all future research and planning and also for the establishment of GISs for protected and other forest areas.

Key words: colour infrared (CIR) aerial photographs (Aps), photointerpretation, geographical information system (GIS), GIS model, National Park "Risnjak", digital terrain model (DTM), planning in forestry

INTRODUCTION
UVOD

Modern techniques and possibilities of data collection, processing and interpretation have a limited use in the forestry of Croatia. Most often, data are still collected on site and the existing maps are of uneven quality and accuracy, even with obsolete content. The forest is a living being in which birth, growth, development and death processes take place continuously, which are reflected on its aspect and status. Therefore, an up-to-date collection of data about its current status as well as on the changes occurring in it is necessary.

Forest management dates back to the first activities of man. By extending the area of his reach, man expanded his activities in nature, arranging his closer and broader neighbourhood, and thus he unconsciously planned in space (Meštrović 1984). Forest management requires data which describe forests in a dynamic way with respect to their status and spatial definition (Jordan and Erdle 1980). According to modern landscaping theory (Colby 1991), from the ecological and economic aspects of future development, forests are multipurpose surfaces which should be managed in way to be of use to all living beings (Probst and Crow 1991, Jacsman et al. 1991). Meštrović (1987) points out that forests are a very important segment of nature as a whole, and especially its protected sites, so when spatial plans for such sites are prepared or legal measures for their conservation, management, improvement and utilization are enacted, forests should be given special attention.

The planning concept in forestry involves an exchange of continuous processes with up-to-date databases and applications of GIS and existing software. In a well-established space management strategy, activities of planning and establishing an adequate control and decision-making system are of the greatest importance for each environment (Jukić 1994). Nowadays, it has become almost impossible to cover, maintain, interpret and analyze by classical methods such large amounts of data relating to the condition, quantity and distribution of phenomena and objects (in this particular case of forests) on the Earth's surface within a reasonable time period. Planning in forestry, similarly to other activities associated with nature and its resources, is closely connected with general progress and with the present attitude towards the environment in which we live (Meštrović et al. 1994).

On the basis of the foregoing, it can be concluded that forestry seeks a permanent inflow of information which can be ensured by remote sensing methods which would reduce the volume of in-situ data collection and provide advantages with regard to time and efficiency. Nowadays, photographs have become an indispensable tool in the study and monitoring of environmental status and changes. This refers in particular to colour infrared (CIR) aerial photographs (APs). By using the interpretation of aerial photographs, reliable statistical data for observed phenomena and objects can be assessed.

The data collected in this way offer a large amount of information used in many scientific and economic fields. The results of (aerial and satellite) photograph interpretation are most often shown in the form of thematic maps in which the spatial distribution of observed phenomena and objects, as well as their interrelations, are presented. Making such a map by the traditional terrestrial procedure requires time, effort and financial means, and once finished cannot be modified any more. A continuous inflow of new information (sudden and unexpected changes in the forest status) requires frequent modifications.

A large amount and variety of data, changed ecological conditions and the necessity of spatial analysis call for the use of geographic information system (GIS) technology. This technology facilitates:

- electronic computer supported automatic cartography,
- receipt, storing, search, maintenance, updating, analysis, statistical processing and printing in various forms of a large number and variety of data,
- collection and storage of spatial information in the digital (quantitative) form, that makes possible objective analyses of spatial data,
- acquisition of new cartographic contents by various overlapping methods or by statistical processing of numerical and descriptive data.

In the present disturbed ecological conditions, this allows continuous monitoring of the forest status by take place, as well as timely and correct decision making in its management. It can therefore be concluded that the key position in supporting deliberate planning and decision making in forestry is occupied by GIS.

Forest management, i.e. planning in forestry involves decision making on several criteria, some of which are associated with quality and quantity data, others with weather conditions, and the third types are defined in space. A GIS has proved to be a technology which, by its possibilities, connects all three of the above-mentioned groups of criteria and, by its results, supports planning (Martinić 1993).

Planning, as one of the basic components of forest management, is the preoccupation of many specialists. There are four requirements of modern planning: technology which allows interactive work in the graphic environment, organized data thematic banks, computer equipment, and the knowledge and experience of an expert who can connect the possibilities of technology and the expected benefits.

Unlike the past planning method, GIS technology, supported by computer and remote sensing, makes possible a completely new approach in planning. This so-called "continuous" planning includes a change monitoring system which assumes permanent data updating with the changes which occur within a certain time period.

Such knowledge encourages many scientists to develop their own planning methodologies, i.e. various approaches in task accomplishment and in the use of methods and techniques within the planning system. In such an approach to the problem using GIS technology, the expert is relieved of routine work (mapping by hand, establishing new layers from the existing ones etc.), consequently leaving him more time for decision making in space management, namely planning, and offering new possibilities for research.

AIM OF RESEARCH
CILJ ISTRAŽIVANJA

INTERPRETATION OF AERIAL PHOTOGRAPHS AND GIS IN FORESTRY
INTERPRETACIJA AEROSNIMAKA I GIS U ŠUMARSTVU

Photogrammetry, namely photointerpretation as a method for the collection of necessary data on the space or geometrical characteristics of a certain area, is particularly suitable for use in a GIS. The GIS is based on the idea that every datum on the Earth's surface or its cover is to be geocoded, namely, linked up with terrestrial coordinates, which allow for faster and more precise handling of a large number of data and offer a better performance of such spatial analyses which until now has been impossible.

The results of aerial photograph interpretation can be presented in the form of maps, diagrams or tables and directly incorporated into a GIS as one of the layers (Benko et al. 1993, Kušan and Kalafadžić 1993), provided, however, that these data are previously vectorized, because vector model is more adapted to supporting the graphical mode. Most often the results of aerial photograph interpretation are presented in the form of thematic maps showing the spatial distribution of phenomena and objects on the Earth's surface, as well as their relationship.

The input of various thematic contents obtained by aerial (satellite) photointerpretation considerably increases the amount of information on forests, which eventually allows for reliable and timely decision-making. Aerial photographs are primary sources of information for many inventories and for planning in modern forest management (Reutebuch 1987).

The first application of photogrammetry in forestry, and where most experience has been gained, has been in forest management. In the last few decades, forestry photogrammetry has become a reality. According to Tomašegović (1987), it is the information system which provides basic data and methods for a fast, inexpensive and reliable synoptical identification of environment elements relevant for forestry (ground relief, vegetation, water systems, roads, etc.).

During the 1980s and in the early 1990s many papers were written dealing with the use, accuracy and efficiency of remote sensing and GIS in forestry (Kalafadžić 1984, 1987, Kušan et al. 1992a, Kalafadžić and Kušan 1993, Posarić 1993).

The ever-increasing application of GIS technology, i.e. the possibilities to use digital data, brought an important change into the process of making decisions concerning space. GIS not only created a new dimension in cartography, but opened new fields and pushed forward borders in a number of other fields, such as natural resource and infrastructure system planning and management (Smyrnew 1990).

Efficient management and planning require reliable information for forest surface mapping, growing stock inventories, assessment of forest decline and health, etc., and the collection of such information can be rationalized and made less costly by using the interpretation of aerial or satellite photographs (Kalafadžić and Kušan 1993).

In the 1980s, forest mapping based on aerial photographs became the usual operational practice in developed and developing countries (Jano 1986, Stellingwerf 1986). Most often, forest mapping is done simultaneously with a forest inventory and since aerial photographs allow for a stand data collection in which these data are spatially defined, the use of aerial photographs for forest inventory and for mapping has necessarily become a common subject in forest inventory manuals (Lötsch and Haller 1973, Kramer and Akça 1987).

In Croatia, forest mapping based on aerial photographs was investigated by Tomašegović 1956, 1965, 1987b, Vukelić 1984 and Ćurić 1986.

Until now, many experts have dealt with the application of colour infrared (CIR) aerial photographs for damage inventories in forest trees and stands (Pelz and Riedel 1973, Masumy 1984, Hildebrandt et al. 1986, Hočevar and Hladnik 1988, Voss 1989, and others). Barszcz et al. (1993) used GIS and remote sensing to study the relationship between forest damage and environment status.

The application of CIR aerial photographs in forest damage inventories on larger surfaces in Croatia started in the 1980s (Kalafadžić and Kušan 1990). Thus, in 1988, CIR aerial photographs were used for a damage inventory and for the mapping of the beech – fir forests in Gorski kotar (Kalafadžić et al. 1992, 1994).

As part of the damage inventory in the lowland forests of Posavina (the forest basin Spačva and G.J. "Josip Kozarac", as well as EEFO "Opeke") in 1989, the relationship between the damage of the stands and some biotic (honey-dew) and abiotic influences (roads, channels, meliorated marshes) on the stands and the sites were studied (Kalafadžić et al. 1993b). The photointerpretation key for the common oak (*Quercus robur* L.) was also established and the damage assessment reliability on the CIR APs was investigated (Pernar 1994). Furthermore, the photointerpretaion key for the defoliation of the common ash (*Fraxinus angustifolia* Vahl) was established, and the defoliation evaluation methodology was tested (Fliszar 1990). Research on the possible automation of some procedures in the interpretation of aerial photographs for forest damage inventories is in course (Kušan and Pernar 1996).

Research on the stand parameter assessment on aerial photographs may be divided into two groups (Kušan 1996):

1) research of stand parameter assessment reliability
2) research of the relationship between stand parameters and parameters measurable on aerial photographs.

The stand parameter assessment reliability has been dealt with by many researchers: Lukić 1981, Pavičić 1983, Kostijal 1986, Kušan 1988, 1992, Benko 1993. As for research concerning the relationship between stand parameters and parameters measurable on aerial photographs, they can be divided into several groups.

Kostijal (1986) investigated the relationship between the number of tree crowns observable on aerial photographs and the mean volume tree diameter.

Kušan and Krejči (1993) investigated, using multiple correlation, the relationship between the mean stand height, the number of trees per ha, the mean stand crown width and the stand volume per ha.

Pilaš (1994) investigated the relationship between the mean stand height, the number of trees per ha, the mean stand crown width, the mean crown surface and the mean stand age.

Benko (1995) investigated the relationship between the common oak volume (*Quercus robur* L.) and various tree parameters (tree height, tree crown diameter, crown surface, length of illuminated tree crown, etc.).

The volume of forest stands is assessed more and more economically by means of aerial photographs. By using a multiple regression analysis, regression equations have been obtained in which the relationship between photogrammetrically assessed values and terrestrially surveyed volumes of the stand is expressed with a satisfactory average error of +/-9-10%, relatively independently of the site, photograph type and interpretor (Akça and Zindel 1987).

Jakšić (1996) investigated the possible use of regression equations in volume assessment by photointerpretation.

Forest management is a very complex activity and includes several different components (biological, economic, sociological) which are interconnected into a complicated system. In this system, there are many resources (forest land, trees, people, time, money) which are in mutually restrictive relations (Buongiorno and Gilles 1986). An organized use of forests, including the achievement of economic effects and the preservation of forest stability, assumes correct decision making with regard to time, place, quantity and manner of forest resource exploitation (Čavlović 1994).

The introduction of modern technologies in natural resource management and environment quality recovery became one of the prerequisites for the improvement of status and change monitoring. For the development of this process, reliable information on current status and on realistic possibilities of change control must be made available (Kalensky 1991).

Simultaneously with the development of computer technology, research has also developed with the aim of finding a global information system for the receipt, storage, processing and analysis of a large quantity of spatially defined data, and this is the geographic information system – GIS.

The analysis of data obtained by remote sensing methods provides information on the objects and phenomena on the Earth's surface which is spatially defined (inventory taking and monitoring of interesting objects and phenomena, surveys and mapping, etc.). This information can then be directly included into a GIS to make possible the linking, processing, storage and analysis of various types of spatially defined data which, as stated above, can be presented in the form of thematic maps or mathematical models (Kalensky 1991).

Talking about forest status means such data provided by the forest inventory (Kalafadžić and Kušan 1991) which describe the type, quantity, quality, growth, physiological condition, tree and stand productivity, as well as all other details necessary for forest management and for planning in forestry.

The maintenance of forest stability with constant yields and all the important sociological aspects may be ensured under the ever-increasing demands put on the forest, by continuous and high-quality planning based on reliable forest inventories. A forest inventory supplies information on the existing plant communities, growing stock, superficies, volume increment and health. After processing, the collected data are used in many forestry disciplines, from mathematical (biometrics, dendrometry, etc.), through technical (geodesy, photogrammetry, cartography) to biological ones (silviculture, phytocenology, conservation, ecology) providing the basis for any serious planning in forestry. Moreover, knowledge obtained through a forest inventory serve in planning other segments of the national economy (tourism, infrastructure, nature preservation, etc.). For this reason, the inventory must give reliable information at as low a cost as possible and by applying all the achievements provided by the science in this field (Kalafadžić and Kušan 1991).

It is on this basis that remote sensing was introduced into forest inventory operations. Techniques of the interpretation of aerial photographs have been developed and, with time, the surveying techniques for all essential stand parameters, too. In sum, aerial photographs have become an important tool for proper inventories.

Taking a forest inventory is the sphere where a forestry specialist surveys, collects and interprets basic forestry data which then serve for primary planning in forestry (Lötsch 1968), namely for a wider planning of the national economy (Zöhrer 1974). By means of automatized and computerized graphics (digital cartography) and modern data collection methods (remote sensing), as well as with the use of computers for data processing, the speed of data preparation for planning and for performing forest management work has increased considerably. According to Lukić (1993), the application of a GIS and the ever-increasing development of computer technology present a milestone in new forest inventories within the multipurpose forest exploitation, because those who have good and timely information have the future of development, too.

Since the forest is a dynamic ecosystem with continuous changes in time and space, for any planning within this system it is necessary to survey its current state and to determine all changes taking place in it. On the basis of determined development trends, the future is anticipated. "The future is the child of the past and the present" (Neidhardt 1971). The uncertanly of the forecast regarding the future state becomes greater with the prolongation of the planning period, and the correctness of the forecast is checked by periodical inventories.

The continuity of forest development monitoring as a long-term process of the increase of biomass in space and time assumes continuous and long-term planning, the permanent conduct and constant control of all procedures regarding the forest, unified into a professionally established entity – management (Meštrović et al. 1992).

Planning is virtually to act of looking into the future prior to making any decision (Pranjić 1987). On the basis of past events, future actions can be foreseen and planned to achieve the desired aim. The fact that past events and all changes in the forest status can be properly monitored by means of photographs has helped foresters in many countries to improve forest management and to carry out planning in forestry (Mroczynski 1976, Itten et al. 1985, Buer 1987, Coleman et al. 1990, Hussin and Shaker 1995). The results of interpretation are most often linked with other data in a GIS which is used for analyses, simulations and planning.

The results of a forest inventory consist of two parts: one descriptive (text, tables, graphs) and one cartographic (topographic, forest-economic and thematic maps). In the computer era, the first part presents attributes and relationship databases and the second part provides digital cartography that allows for a rational and economic use of maps and enables them to be completed and adjusted to the real state in the field, i.e. their daily updating (Kalafadžić and Kušan 1991).

The development in the field of computer techniques and software makes it possible to link up cartographic and graphic databases with relationship bases into one unique information system for the land, thus providing an inflow of correct and fresh information on forests as an essential prerequisite for successful management. Such a system must be designed in a way that a fast flow, documentation and exchange of information is possible between all levels (Tomanić 1990) and that the data can be exchanged with other databases (Kušan et al. 1992a). The system must meet some basic criteria (Lund 1988) such as plasticity, polyfunctionality, integrity and multitemporality.

Because of the large amount and variety of data obtained by inventories for high-quality planning and decision making on the operation of forest management and forestry policy, the establishment of a unique information system for forestry is necessary (Kušan and Kalafadžić 1994). Having in view its great possibilities and fast development, a GIS can be the carrier of such a unique information system for the forestry of Croatia (Brukner et al. 1992, Kušan et al. 1993).

Lately, in much research work, the main role in planning has been given to the spatial information system with special reference to the advantages offered by the use of a GIS (Patrono 1995).

According to Nijkamp and Scholten (1993), such a spatial information system is becoming an indispensable tool in efficient planning.

GIS technology has found permanent application in many disciplines dealing with the study, exploitation and management of natural resources:

- geology (Schetselaar et al. 1990, Bocco et al. 1990, Akinyede 1990)
- geography (Lee 1991)
- hydrology (Smart and Rowland 1986, Mallants and Bodji 1992, Rasamee and Suwanwerakamtorn 1994)
- pedology (Skidmore et al. 1991)
- environmental protection (Fleet 1986, Dulaney 1987, Stendback et al. 1987, Besio and Roccatagliata 1991)
- forestry (Consoletti 1986, Sieg et al. 1987, Keefer 1989, Susilawati and Weir 1990, Lesyen and Goossens 1991, Hentschel 1996).

So far, GIS technology has been applied in the forestry of Croatia in several ways, namely:

- GIS model for EEFO "Opeke" (Kušan et al. 1992a)
- GIS model application in forest management (Kušan and Kalafadžić 1992)
- GIS model application in forest exploitation (Kušan et al. 1992b)
- GIS technology application in forest classification in Croatia for seed production purposes (Benko et al. 1993)
- GIS application in hydropedological researche (Mayer 1993).

APPLICATION OF THE DIGITAL TERRAIN MODEL IN FORESTRY
PRIMJENA DIGITALNOG MODELA RELJEFA U ŠUMARSTVU

The modern planning and management of space require the construction of an efficient GIS. A significant qualitative improvement of the GIS is achieved by the introduction of a DTM into the database, by means of which the data are geometrically and exactly located in the space with respect to both their position and their height. To construct a DTM with adequate characteristics, it is necessary to collect data containing positional and elevational information about the ground (Gajski et al. 1994).

The DTM can be one of the GIS elements. The accuracy of produced DTMs has been the preoccupation of research scientists since the very beginning of their preparation and application in 1958 (Kušan 1996). Accuracy depends on the amount and selection of points on the basis of which the DTM is constructed, on the selected interpolation points and the adjustment method (Jergović 1994).

The use of DTMs has become the usual practice in forestry (Gossard 1978), regardless of whether technical or biological disciplines are involved (Kušan 1995). As far as technical disciplines are concerned, the DTM can be used for:

- mapping from aerial photographs (Schneider and Bartl 1994)
- orthophotograph, orthophotoplan and/or orthophotomap preparation (Ecker 1992, Miller et al. 1994)
- road project engineering (Dvorscák and Hrib 1992, Becker and Jäger 1992)
- forest opening planning (Dietz et al. 1984, Shiba and Löffler 1990, Sessions 1992, Nearhood 1992, Knežević and Sever 1992, Dürrstein 1992, Pičman i Tomaz 1995, Hentschel 1996).

In biological disciplines, DTM can be used to calculate individual habitat features (terrain slope, exposure, insolation, etc.) which, as ecological variables, can then be used for:

- vegetation study (Antonić et al. 1994)
- study of ecological fauna niches (Štefanović and Wiersema 1985)
- simulations in climate and air pollution studies (Tesche and Bergstrom 1976)
- interception and transpiration evaluation (Kändler 1980)
- soil type maps (Skidmore et al. 1991)
- landscape architecture (Posavec 1993)
- park and arboretum landscaping (Repić 1995).

In the case of photographs of mountainous terrain or spatially very heterogeneous areas, in addition to the results of interpretation, it is also necessary to include additional information in the form of grid – thematic maps (pedological, vegetation, etc.) as well as maps describing terrain characteristics (slope, exposure, DTM). In this way, significant improvements in the interpretation results can be obtained (Skidmore 1988b, Lillesand and Kieffer 1994).

The advantage of DTM is the possibility to make a three dimensional projection of an interesting terrain configuration, and by simple visualisation to plan and to determine the direction of forest openings more easily, thus facilitating considerably the maintenance of the sensitive natural balance which nowadays is particularly endangered.

AIM OF THE WORK
CILJ RADA

The main aim of this work was to find a way of linking all existing data, as well as data acquired by the interpretation of aerial photographs, into a unique information source, and to generate new information as a basis for planning in forestry, by using the methods of a geographical information system (GIS).

To accomplish this aim, it was necessary:

- to process the results of interpretation of colour infrared (CIR) aerial photographs
- to make maps with various thematic contents
- to digitalize existing maps (pedologic, geologic, phytocenologic, economic)
- to organize databases
- to assign to each acquired layer an attribute data table (numerical and descriptive) by means of which it was possible to connect digitalized maps with tabular data
- to produce a digital terrain model (DTM) and to establish new layers (slope, exposure, etc.) based on it
- to incorporate new acquired elements into the established GIS model and to connect them with the existing elements
- to analyze all acquired data (numerical and cartographical) at the same time per individual layer or per multilayer overlap
- to process statistically-obtained dependences (exposure, slope, plant community, taxation elements, damage stage, etc.).

Such an approach to the problem, using GIS technology, relieves the expert of routine jobs (hand mapping, establishing new layers from existing ones, etc.) and leaves him more time for decision making in space management, i.e. planning, and opens new possibilities of research.

Research carried out will indicate the possibilities of the use of remote sensing (in this case, CIR APs) and GISs for planning in forestry and for environmental study.

The established GIS model can be used in all future research, and in addition will serve as the basis for the establishment of GISs for other protected areas in Croatia.

LIST OF SYMBOLS AND ABBREVIATIONS
POPIS SIMBOLA I SKRAĆENICA

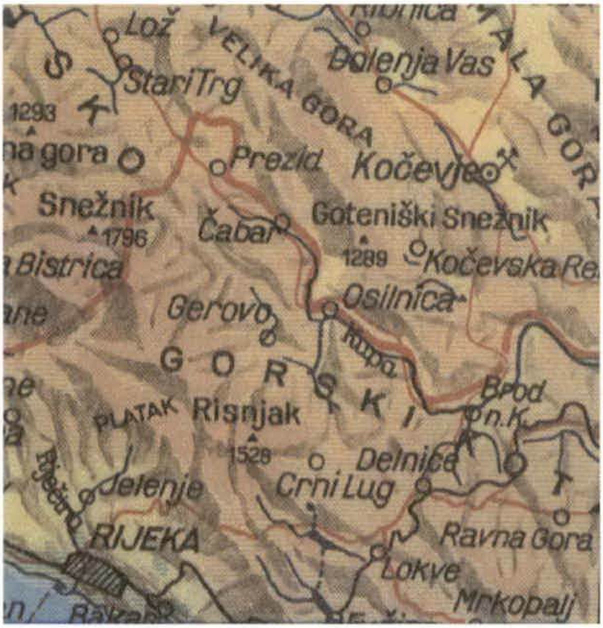
Abi – Fag –	*Abieti – Fagetum dinaricum* Treg. 1950
Arem – Pic –	*Aremonio – Picetum* Ht. 1938
B –	regression coefficient
BETA –	standardized regression coefficijent
Blech – Abi –	*Blechno – Abietetum* Ht. 1950
BUKVAIO –	beech – damage index
BUKVASO –	beech– mean damage
BUKVAUS –	beech – relative share
Cal – Abi –	*Calamagrosti – Abietetum* Ht. 1956
D1.30 –	breast diameter (photogrametric data)
DMR –	digital terrain model (DTM)

DTER –	breast diameter (field data)
EEFO–	educational experimental forest object
ftg. –	photogrammetric data
G –	base surface (photogrammetric data)
G. J. –	management unit
GEOL –	geological categories
GIS –	geographical information system
GTER –	base surface (field data)
Hom – Fag –	*Homogyno alpinae – Fagetum sylvaticae* Ht. 1938/Borh. 1963
ICK –	colour infrared (CIR) aerial photographs (Aps)
IO –	damage index
JELAIO –	fir – damage index
JELASO –	fir – mean damage
JELAUS –	fir – relative share
JSO –	unique damage stage (UDS)
List – Pic –	*Listero – Piceetum abietis* Ht. 1938/Fuk. 1969.
N-H–	number of trees (photogrametrical data)
NP –	National park
NTER –	number of trees (field data)
R –	digital terrain model (DTM)
RASP –	exposure
RFITFIN –	phytocenose, plant communities
RISPED –	pedocartographic units
RSLP –	ground slope
SMREKAIO –	spruce – damage index
SMREKASO –	spruce – mean damage
SMREKAUS –	spruce – mixture share
SO –	mean damage
Std. dev. –	standard deviation
ter. –	field data
TIN –	Triangular Irregular Network
UKUPIO –	total damage index
UKUPSO –	total mean damage
V –	volume (photogrammetrical data)
VTER –	volume (field data)

RESEARCH AREA
PODRUČJE ISTRAŽIVANJA

The National Park "Risnjak" in the western part of Croatia extends some fifteen kilometers from the sea in a straight line (Figure 1).

Figure 1.Geographical position and map of research area
Slika 1. Zemljopisni položaj područja istraživanja



The surface area of the NP "Risnjak" is 3227.90 ha with the peak Veliki Risnjak as its highest point (1528 m) and its lowest point in the Leska depression (676 m). The Park includes the central part of the Risnjak massif which extends from the Kupa river source to Gornje Jelenje and from Crni Lug to Snježnik.

When the boundary of the NP "Risnjak" was determined, care was taken to encompass into one entity over the smallest area possible the most typical natural and scientific phenomena on one hand, and all the most important esthetic elements on the other hand.

The geographical position of the Risnjak massif, as well as that of the entire Gorski kotar, makes this area very interesting because it presents a very strong climatic and vegetational barrier between continental Croatia and the Croatian littoral.

In the investigated area to which the Park gravitates, the oldest deposits, composed mostly of clastic elements, are of the Upper Carboniferous Age. A large space is occupied by the Lower and Middle Permian deposits where, in addition to clastic sediments, limestone occurs, too. In the Triassic deposits, predominant are limestone-dolomite and limestone surfaces with sporadically expressed stratification, but also with a vertical, i.e. lateral dolomite and limestone exchange. The Credaceous sediments contain deposits of limestone, limestone breccia and limestone with dolomites. The youngest – Quartenary sediments are settled in plains on mountain platforms and in river valleys.

Within the boundaries of the Park, in its southern part, the oldest geological elements are Triassic deposits composed of clay – marl – sandstone and dolomite-sandstone strata. The Triassic deposits are overlaid by the Middle Mesosoic, Jurrasic sediments of limestone and dolomites of a medium-grained to a very compact structure. The Jurrasic deposits occupy the largest part of the Park surface.

Owing to such complexity and the variability of pedogenetic factors and their influence on pedogenetic and pedoevolutionary processes, a relatively large number of soils is in this area found on all systematization levels: type, subtype, variety, form (Martinović et al. 1994).

In the NP "Risnjak", the soils found on pure limestone and dolomite are: black earth-soils (melanosol), brown soils (cambisols over limestone), loess soils (luvisols) and on softer, clastic limestone and dolomites, clay and crystalline – rendzinas as the primary stages of pedogenetic development.

On silicate supstrates (sandstone, sand clays and conglomerates), the acid brown (dystric cambisols) and brown podsolic soils (brunipodsols) were determined. On both groups of substrates, sporadically colluvial soils were determined, and on limestone and dolomites rocky tracts too.

Risnjak is located in the aera where maritime and continental influences are encountered, also with the influence of the Alps from the northwest and of the Dinaric Alps in the southeast, which causes moderately warm summers, rainy autumns, and long and severe winters (Kamenarović 1970).

In the investigated area, the moderately cold climate reigns with a large amount of precipitation, high air humidity, frequent frosts, a shorter vegetation period and high and long-lasting snow cover.

A particularly precious trait of the Risnjak massif is its vertical zoning of forest vegetation, characteristic of the western Dinaric Alps (Rauš et al. 1992). The most important and the largest by surface area is the Dinaric beech-fir forest (*Abieti-Fagetum dinaricum* Treg. 1950). It is followed by the sub-Alpine beech forest (*Homogyno alpinae-Fagetum sylvaticae* /Ht. 1938/ Borh. 1963).

On Risnjak, the vegetation of mungo pine with the honeysuckle family (*Lonicero-Pinetum mughi* /Ht. 1938/ Borh. 1963) is particularly conserved, among which rare and endangered plant species grow.

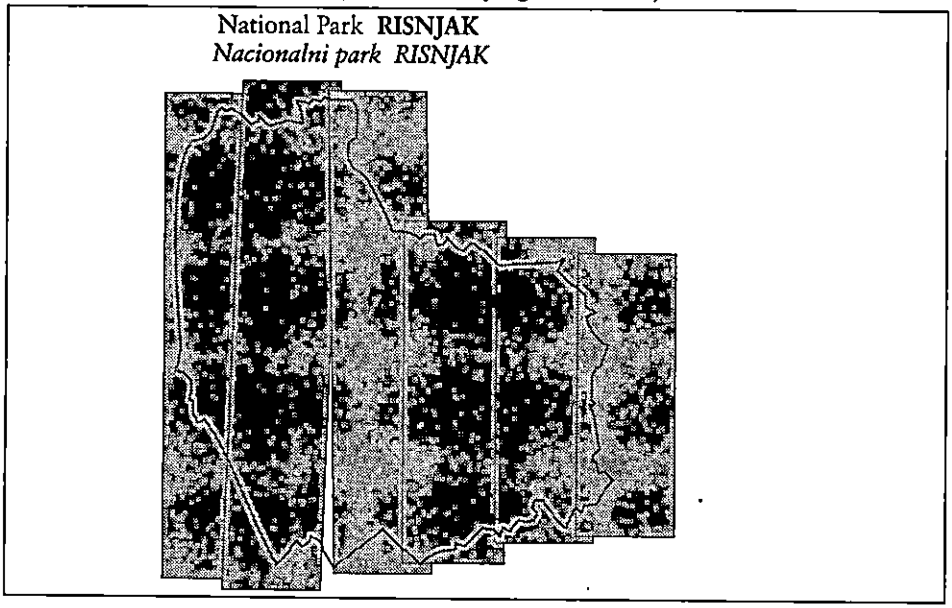
METHODS OF WORK
METODE RADA

PHOTOINTERPRETATION
FOTOINTERPRETACIJA

Delineation
Delineacija

The delineation was made on the CIR aerial photographs taken in the period from August 1 to 10, 1988, using a Zeiss Jena LMK 305/23 photogrammetric normal angle camera with Kodak Aerochrome Infrared 2443 film.

Figure 2. Photographed area map with drawn flight lines
Slika 2. Karta snimljenog područja s ucrtanim prugama snimanja



The NP "Risnjak" surface was covered with 6 strips, namely by 90 air photos in a mean scale of 1:5754 (4680 to 6820), (Figure 2).

The longitudinal overlap of adjacent photographs (in a strip) was between 55 and 70%, and the lateral (between strips) had to be between 10 and 30%. This, however, was not achieved in a short section between central strips, so a small surface in the southern part of the Park remained unphotographed.

On the CIR aerial photographs, stands were extracted by means of visible differences between individual image elements of forest stands such as: tree species, mixture proportion, stand canopy, crown size, damage stage, parent substrate appearance etc. Interpretation was made using a mirror stereoscope with a magnification of 8x.

In each extracted stand, between 20 and 60 trees were examined with respect to tree species and damage status. The number of examined trees depended on the extracted stand (stratum) surface. In total, 364 strata were extracted and 9457 trees were examined.

Damage Assessment
Određivanje oštećenosti

Trees for interpretation purposes were selected according to a randomly positioned systematic sample (grid) inside the carefully extracted, homogeneous strata. Using the grid method, a uniform distribution of interpreted tree crowns per extracted strata washas been obtained. The variability of all photogrammetrically estimated variables inside the strata is unsignificative.

On the transparent foil, a grid of lines at a distance of 5 mm was drawn. By means of linear intersections, a grid of sample points was defined. The number of interpreted trees varied according to the size of individual delineated strata. The foil was randomly placed on the delineated aerial photograph. As a sample, the tree nearest to the sample point, namely, to the grid line intersection in the top right square from the sample point, was taken. Tree examination was made in the stereomodel under a magnification of 8x.

As the basis for damage status assessment, the provisions from the "Guidelines" (1987) for inquiries on forest decline in Croatia were used. According to these "Guidelines" (Prpić et al. 1988), the stage of tree damage was assessed according to a determined percentage of assimilation organ absence (needles, leaves), the percentage of yellow needles/leaves and the percentage of branch decline.

For photointerpretation purposes, the said features had to be considered together, because they will thus be projected on the aerial photograph. According to Kalafadžić and Kušan (1990, 1993) every tree on the ground and on the aerial photograph should be estimated with a unique damage stage (UDS), as a global estimation of all said features.

During the forest damage inventory using the CIR aerial photographs (Kalafadžić and Kušan 1989), it was noted that the damage stage range (26-60%), according to the damage stage scale used in the European Community (Hildebrandt et al. 1986), was too wide. Therefore, on the basis of the investigated increment in differently damaged trees, the range was divided into two substages (2.1 and 2.2).

Such a division was also confirmed by the proposals in AFL (1988) where the same damage degree scale was suggested for spruce, and which coincided with the experiences of Hočevar, too (1988).

Trees were classified into groups/classes according to damage stages during photointerpretation of CIR APs by using a carefully established photointerpretaion key, in which the method of individual tree species and the projection of the tree damage stages on aerial photographs was shown in an illustrative and descriptive manner.

The photo interpretation key was constructed for the main tree species: fir (*Abies alba* Mill.), spruce (*Picea abies* Karst.) and beech (*Fagus sylvatica* L.) on the basis of experiences in Central Europe (Löffler et al. 1984) and field observations carried out during aerial photographing. In addition to the said species, the interpretation was also made for: mugho pine (*Pinus mugo* Turra.), mountain maple (*Acer pseudoplatanus* L.) and mountain ash (*Fraxinus excelsio*r L.), but not being predominant, these species were indicated as "other broadleaved species" (OBS).

For each stratum, damage indicators were computed. Classification of the single tree damage status (tree crowns) was made according to a completed damage stage scale of the European Community, namely the terrestrial enquiries on forest decline in Croatia (Kalafadžić and Kušan 1989, 1990b). Forest stands were classified into damage stages according to scale (Kalafadžić and Kušan 1990b), on the basis of mean damage (SO) by the formula (1). A good indicator is the damage index (IO) expressed by the formula (2):

$$SO(\%)=\frac{\sum f_i x_i}{\sum f_i}\ (1)\quad IO(\%)=\frac{\sum f_{(2-4)}}{\sum f_{(0-4)}}\,100\ (2)$$

where fi= the number of trees in i– damage stage.

xi= i– stage interval centre in the damage stage scale for single trees (x_0=5%; x_1=17,5%; $x_{2.1}$=32,5%; $x_{2.2}$=50%; x_3=80%; x_4=100%).

Strata were grouped into damage stages 20% wide. Thus obtained areas with various damage stages were mapped on a basic state map and the damage map was made.

Stand Parameter Measurements
Izmjera sastojinskih veličina

On the CIR aerial photographs, together with damage assessment, some stand parameters were also measured. These measurements were made on 36 aerial photographs, namely on 878 sample plots. A grid of points with drawn sample plots was placed on each stereopair, inside the previously delineated strata. On such a systematic sample and on each linear intersection inside the plot, tree species were determined, the tree crown diameter was measured, and all trees inside the plot were counted.

The optimal sample plot size was the plot with 20 to 30 observable tree crowns (Spurr 1960). For each photograph scale, the sample plot surface area (circle) was calculated. The surface area of a single sample plot ranged between 608 and 1,241 sqm.

The stand volume was reàd from the increment-yield tables. By means of the number of trees, the most suitable valuation rate was chosen, i.e. the one with a similar number of trees per ha. Wherever necessary, the interpolation was made. The normal volume data were reduced by means of canopy to obtain real data per ha for each stand (stratum).

For fir, the Swiss tables were used (EAfV 1966), for beech the Špiranec's tables (1975) and for spruce Wiedemann's tables 1936/42 (Meštrović and Fabijanić, 1995).

On the basis of the tree crown diameter (natural crown size) and the tree crown projection surface as measured on the aerial photographs, the fir, spruce and beech base surface and breast diameter were assessed.

The linear equations obtained by multiple regression (Kušan and Pernar 1996a) were used to assess the breast diameter and base surface of fir, spruce and beech. By correlation analysis, it was found that the relationship between these parameters was very strong for all three tree species.
For the breast diameter, the linear equation $d_{1.30}=f(D)$; $d_{1.30}=b_1D$, was used and for the base surface $g=f(Pk)$; $g=b_1Pk$.

Fir (N = 2146)
$d_{1.30} = 5.73366D$ $r=0.9534$
$g = 0.003637Pk$ $r=0.8770$

Spruce (N=2048)
$d_{1.30} = 6.798789D$ $r=0.9802$
$g = 0.004798Pk$ $r=0.9364$

Beech (N=1920)
$d_{1.30} = 5.051564D$ $r=0.9777$
$g = 0.0027{=}46$ $r=0.9417$

MAP DIGITALIZATION
DIGITALIZACIJA KARATA

To develop the graphical part of the GIS model, existing maps were digitalized:
1. contours and topographic maps 1:5000
2. topographic map of a wider area of the NP "Risnjak" 1:18000

Although the map was made as an excursion map, it contains all the important elements. To allow its use in a GIS (ARC/INFO), the vectorization was made with simultaneous attributisation in layers.

The digitalized map contains eight layers which can be used on a computer either jointly or separately. By means of a special program, transformation to other meaures (scales) or projections is possible.

The purpose of a digitalized map is to allow all other themes to be entered in a geocoded form in the same way, so that the contents can overlap for all themes in a uniform manner. Another purpose is to facilitate the introduction of modifications and additions, if any, because the map is the basis for data entry into the GIS database from all other thematic fields:

3. thematic map of forest communities – phytocenological map 1:25000
4. forest soil map – pedological map 1:50000
5. thematic hydrogeological map 1:25000
6. stand damage map 1:10000
7. management map 1:25000.

Digitalization was done using PC computers (386/40 Mhz, 8 MB RAM) to which the digitaliser (DRAWING BOARD II – CalComp) and the ver. 12 AutoCAD program were conected.. With this program, it was possible to assign to every point on the map the values of its terrestrial coordinates, which ensures easier subsequent transformation to other scales. In the ARC/INFO program, errors which occurred by digitalization were corrected using the PC ARC EDIT, CLEAN and BUILD modules. After all errors had been corrected, the heights of each contour, such as read from the analogue topographic map, were assigned graphically as attributes.

DIGITAL TERRAIN MODEL (DTM) DEVELOPMENT
IZRADA DIGITALNOG MODELA RELJEFA (DMR)

The digital terrain model (DTM) for the area of the NP "Risnjak" was developed using the program ARC/INFO – TIN modules (Triangular Irregular Network), on the basis of digital data for the contours from the topographic map.

The final DTM version was obtained in three forms:

– grid form, with shaded height for certain factors and with 3D impression
– coloured 3D form with colours per elevation class
– 2D form onto which coloured elevation classes were entered.

The purpose of the developed DTM was not only to provide a view of space, but also to provide ground slopes, exposures and visibility from single points, as well as to plot other themes under research (stand damage, taxation elements, pedological characteristics, plant communities, etc.).

RESULTS OF RESEARCH
REZULTATI ISTRAŽIVANJA

GIS-MODEL FOR THE NP "RISNJAK"
GIS-OV MODEL ZA NP "RISNJAK"

The GIS-model was established using the program package MODEL (old name GRID), developed for data use and preparation in ecological modelling (Antonić et al. 1994). This is the grid GIS program for personal computers with some elements of the vector GIS (grid overlapping with linear objects, operation with contours etc.). The program has the possibility to make DTMs on the basis of vector or point data. MODEL supports various forms of data (grid, lines and points). Grid and line data are stored as binary databanks, and point data as – dbf – databanks.

For the realisation of the GIS – model in this work, the procedures which can be presented shematically as a flow chart were used (Figure 3).

By means of the functions incorporated in the MODEL for solving more complex requirements (trigonometric functions, azimuth and Sun elevation, etc.) and usual grid functions ("neighbourhood", statistical functions, reclassification, making colour composites, colour separation, as well as surface functions – slope, hillshade, visibility), the desired modelling was developed.

Inside the GIS-model, all accessible information sources were geocoded and stored as separate layers, thus enabling easy manipulation between thematic and topographic data (Figure 4).

The established grid GIS-model for the NP "Risnjak" consists of 30 layers[1]:

1. pedocartographic unit;
2. geological categories (according to rock composition and permeability);
3. plant communities;
4. spatial distribution of mean breast diameters per ha (field data – ter.);
5. spatial distribution of mean breast diameters per ha (photogrammetric data – ftg);
6. spatial distribution of base surfaces per ha (ter.);
7. spatial distribution of base surfaces per ha (ftg.);
8. spatial distribution of volumes per ha (ter.);
9. spatial distribution of volumes per ha (ftg.);
10. spatial distribution of number of trees per ha (ter.);
11. spatial distribution of number of trees per ha (ftg.);
12. relative share of fir (ftg.) – Figure 5;
13. relative share of beech (ftg.) – Figure 6;
14. relative share of spruce (ftg.) – Figure 7;

[1] In the paper several examoles of layers are shown (Figures 5 to 12). Other established layers are given given in the author's dissertation (Pernar, 1996)

Figure 3: Procedures used in establishing a GIS-model for the NP "Risnjak"
Slika 3. Slijed postupaka za uspostavu GIS - modela NP "Risnjak"

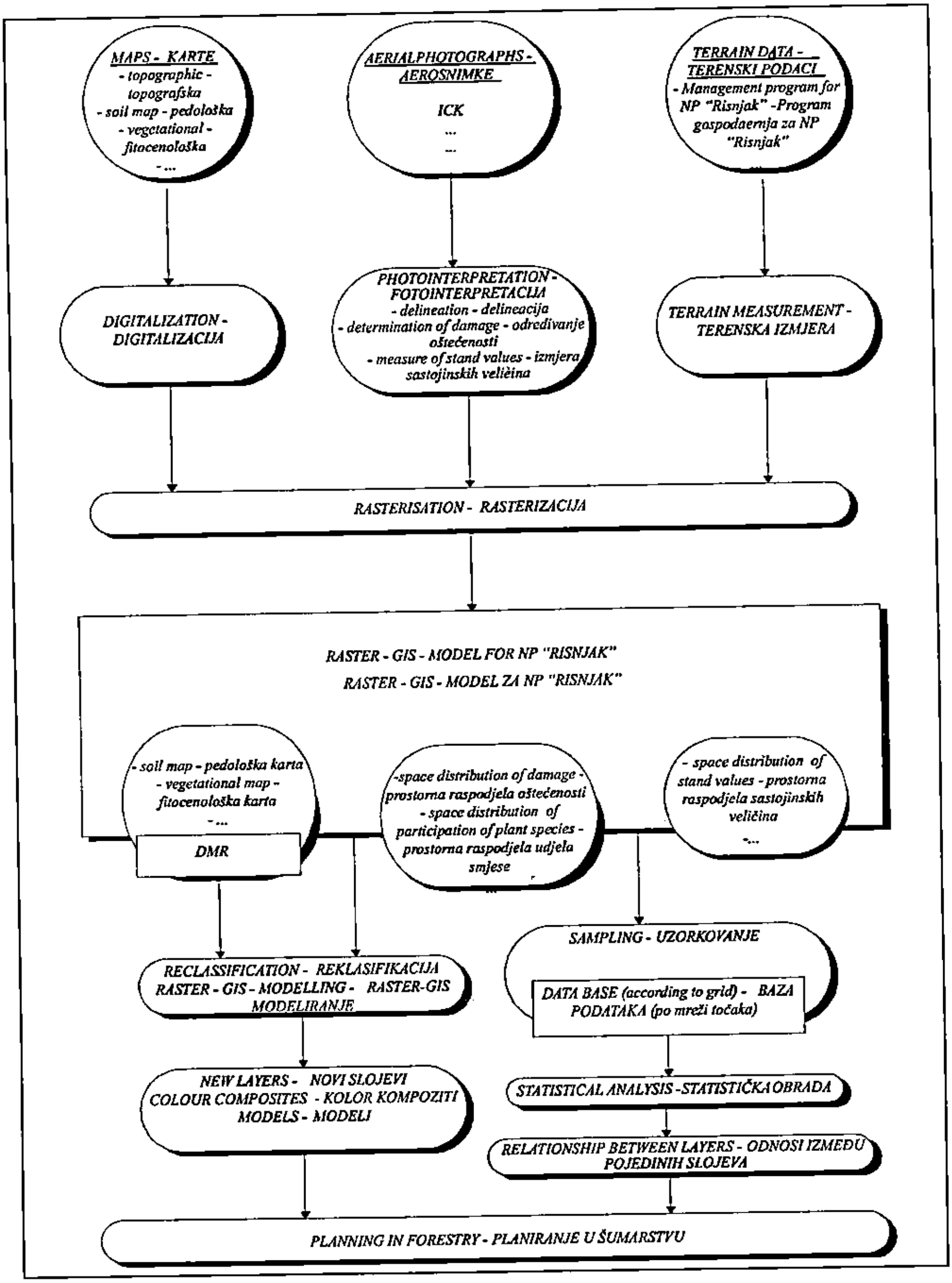


Figure 4. Schematic review of layers and thematic (attribute) data in a GIS-model
Slika 4. Shematski prikaz slojeva i tematskih (atributnih) podataka u GIS - modelu

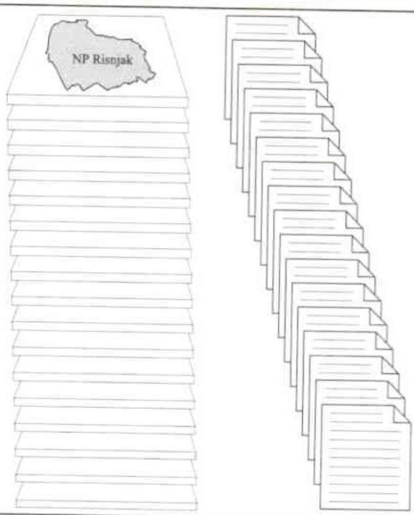


Figure 5. Relative share of fir in cover (ftg.)
Slika 5. Relativni udjel jele (ftg.)

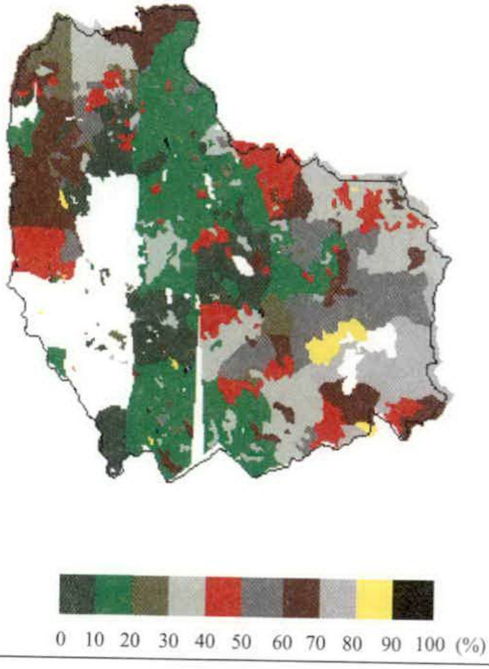


Figure 6. Relative share of beech in cover (ftg.)
Slika 6. Relativni udjel bukve (ftg.)

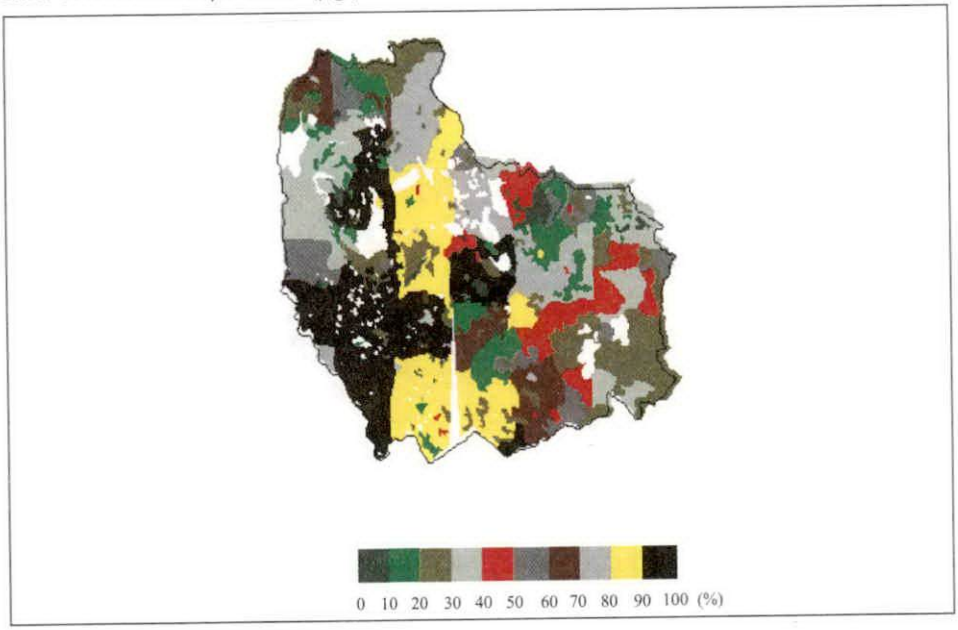


Figure 7. Relative share of spruce in cover (ftg.)
Slika 7. Relativni udjel smreke (ftg.)

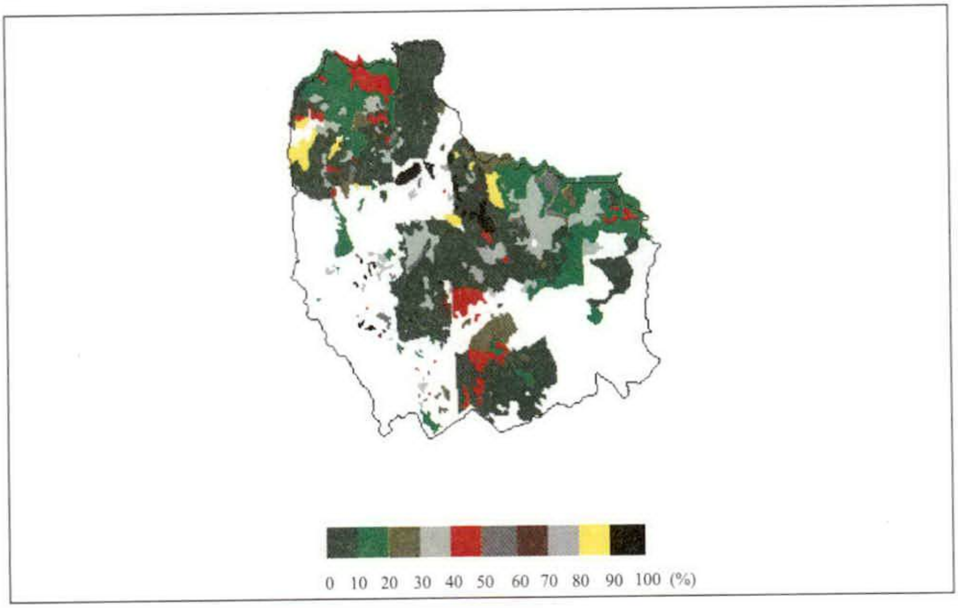


Figure 8. Spatial distribution of fir mean damage (ftg)
Slika 8. Prostorna raspodjela srednje oštećenosti jele (ftg.)

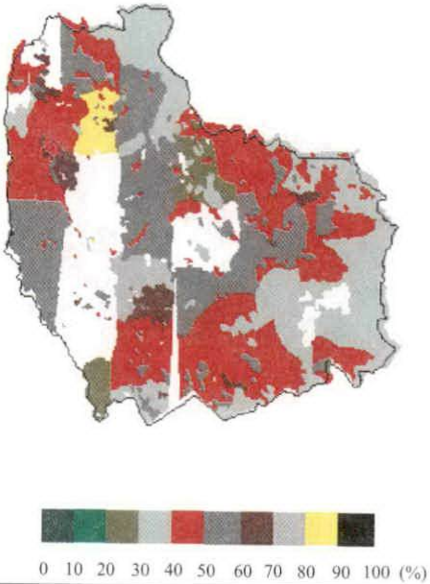


Figure 9. Spatial distribution of beech mean damage (ftg)
Slika 9. Prostorna raspodjela srednje oštećenosti bukve (ftg.)

15. spatial distribution of fir mean damage (ftg) – Figure 8;
16. spatial distribution of beech mean damage (ftg.)– Figure 9;
17. spatial distribution of spruce mean damage (ftg) – Figure 10;
18. spatial distribution of fir damage index (ftg.);
19. spatial distribution of beech damage index (ftg.);
20. spatial distribution of spruce damage index (ftg);
21. spatial distribution of conifers mean damage (ftg.);
22. spatial distribution of deciduous trees mean damage(ftg.);
23. spatial distribution of conifers damage index (ftg.);
24. spatial distribution of deciduous trees damage index(ftg.);
25. spatial distribution of total mean damage (ftg.) – Figure 11;
26. spatial distribution of total damage index (ftg.);
27. digital terrain model (DTM);
28. ground slope;
29. ground slope per class according to Löffler (1991) – Figure 12;
30. angle of deviation from the south (exposure);

The Park area is presented by the point grid with a 50 m pitch on X and a 50 m pitch on Y. The point grid was generated on the computer. Linked up to each layer are attribute data with corresponding coordinates.

Figure 10. Spatial distribution of spruce mean damage (ftg)
Slika 10. Prostorna raspodjela srednje oštećenosti smreke (ftg.)

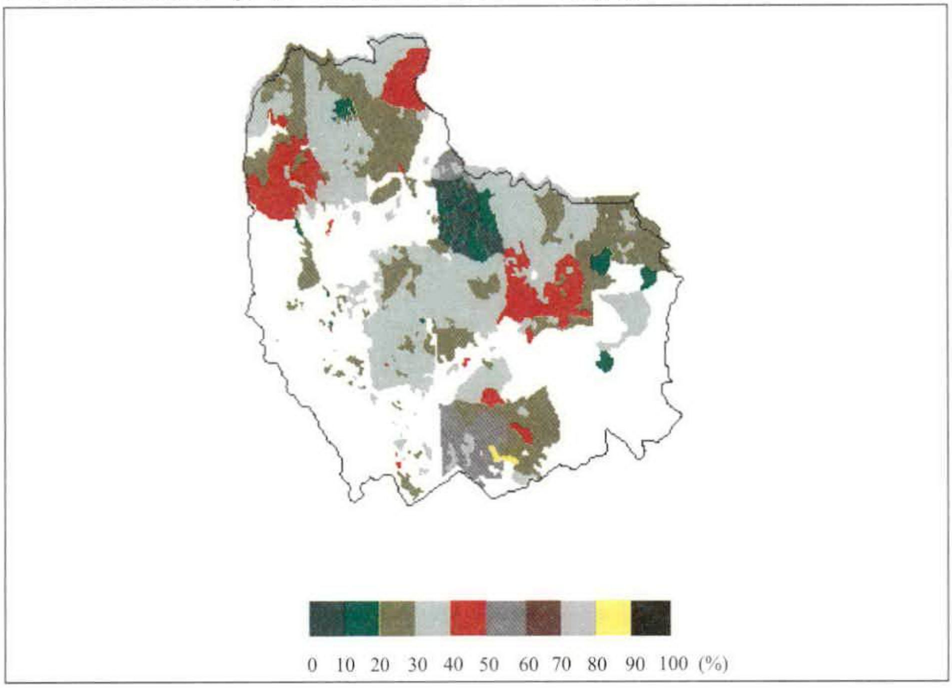


Figure 11. Spatial distribution of total mean damage (ftg.)
Slika 11. Prostorna raspodjela ukupne srednje oštećenosti (ftg.)

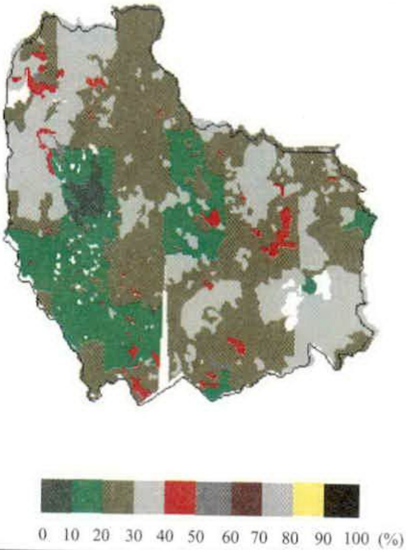
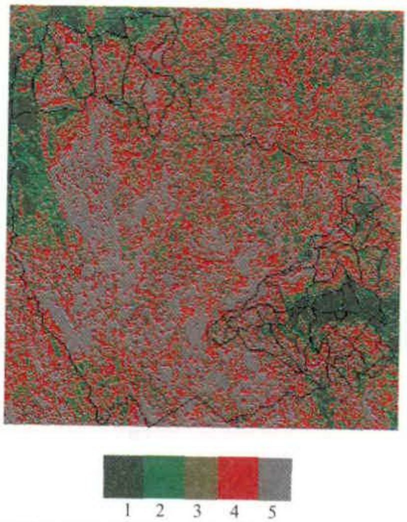


Figure 12. Ground slope per class according to Löffler (1991)
Slika 12. Nagib terena po klasama prema Löffler-u (1991)



1 (0-10%) - plain terrain - ravničarski teren
2 (10-20%) - moderate terrain - umjereni teren
3 (20-33%) - middle favorable terrain - srednje povoljni teren
4 (33-50%) - steep terrain - strmi teren
5 (>50%) - very steep terrain - vrlo strmi teren

The data used for establishing the GIS-model were obtained by the interpretation of CIR APs, map digitalization and field surveys (the data from the Management Program).

All vector themes were grid converted at a pixel size of 10 x 10, which corresponds to the square size of 2 x 2 mm on the map.

NEW LAYERS
NOVI SLOJEVI

Inside the established raster GIS – model for the NP "Risnjak", the preparation of new contents (layers) was started by using some of the procedures shown in the flow chart in Figure 3 above. In this way, on the basis of the results of the interpretation of CIR APs, the attribute data and layers for the relative share of individual tree species within the investigated stand was obtained (Figures: 5, 6, 7). Then, from the layers and damage data for individual tree species, new layers were generated and the data were obtained for the mean damage and the damage index separately for broadleaved and coniferous trees, as well as the data on total damage per strata (Figure 11).

New layers obtained in this way can be a starting point for many further analayses and are useful to researchers dealing with forest damage in planning their future research.

The layers with stand parameters measured on CIR aerial photographs which are outside the compartments where management isconducted, can indicate the condition of stands in a closer area of the Park, as well as providing an inventory of management parameters.

From the digital terrain model using raster – GIS modelling, the slope and exposure layers were obtained. Ground slope was computed for each pixel from the 3x3 neighbourhood in DTM as the highest slope of the regression plane obtained by the smallest square method through 9 points.

The exposure layerwas also obtained from the 3 x 3 neighbourhood as an angular deviation of the highest slope direction from the north. This being a cyclic variable, the lowest (0°) and highest (360°) values obtained were equal, so standardization in relation to the absolute angular distance from the given orientation was made. In this way, the values from 0° to 180° were obtained.

Since the DTM, namely the ground slope, is very important for research work in various fields, especially in the field of forest exploitation, the next step was the establishment of a new layer (Figure 12). As a karst region is involved, slope variability is very high and it did not suffice to take into account the average slope on some of the surface area.

There are several functions by means of which slope variability can be defined (variation coefficient, arithmetical volume of the given neighbourhood value, standard deviation, etc.).

The new slope layer was calculated from standard deviations of 9x9 neighbouring pixels, so on the basis of the surfaces of 0.81 ha (resolution 10x10m), the spatial slope variability was expressed (low stand.dev.-uniform slope, high stand.dev.-variable slope). The new layer obtained can serve for planning forest openings, namely for optimal forest road network project engineering.

DATA ANALYSIS
ANALIZA PODATAKA

The statistical data processing was made using the CSS – Statistical program package. The data used for statistical processing were been obtained by systematic sampling on a computer-generated 50 x 50 m point grid from all layers in the geographical database.

Damage difference tests between plant communities
Testiranje razlika oštećenosti između biljnih zajednica

Tests concerning differences in mean damage and the damage index between plant communities were carried out using t-tests for dominant tree species in plant communities.

Tests concerning differences in mean damage and the damage index for beech between the plant associations *Abieti-Fagetum* and *Homgyno-Fagetum* did not show the existence of any significant differences (Table 1, Figure 13).

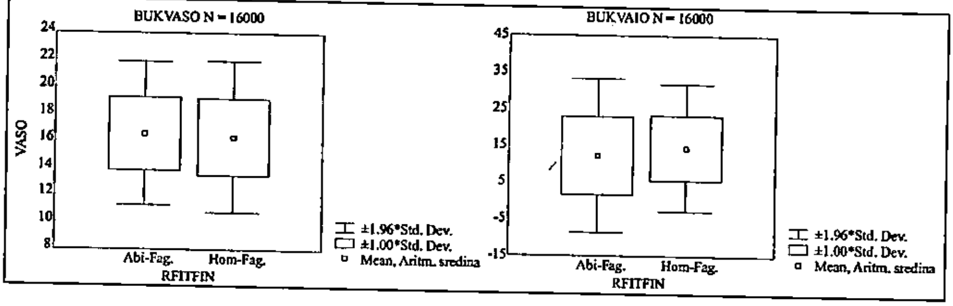
Table 1. Difference test for beech mean damage and damage index between the plant associations Abi-Fag. and Hom-Fag.

Tablica 1. Testiranje razlika srednje oštećenosti i indeksa oštećenosti bukve između fitocenoza Abi-Fag. i Hom-Fag.

Variable *Varijabla*	Unit *Jedinica*	Arith. mean *Aritmetička sredina* Abi-Fag.	Hom-Fag.	t	N	p	N - Abi-Fag.	N - Hom-Fag.	Std. dev. Abi-Fag.	Std. dev. Hom-Fag.	F	p
1	2	3	4	5	6	7	8	9	10	11	12	13
BUKVASO	(%)	16.40	16.33	.9181	10450	.3585	8456	1996	2.848	2.859	1.007	.8293
BUKVAIO	(%)	11.89	14.48	-0.32	10450	.0000	8456	1996	10.38	8.831	1.383	.0000

Figure 13. Differences test in mean damage and damage index for beech between the plant associations Abi-Fag. and Hom-Fag

Slika 13. Grafički prikaz razlika srednje oštećenosti i indeksa oštećenosti bukve između fitocenoza Abi-Fag. i Hom-Fag



In tests concerning differences in mean damage and the damage index for fir between the plant associations *Abieti-Fagetum* and *Calamagrosti-Abietum* (Table 2, Figure 14), and *Abieti-Fagetum* and *Blechno-Abietum* (Table 3, Figure 15), as well as the associations *Calamagrosti-Abietum* and *Blechno-Abietum* (Table 4, Figure 16), significant differences were noticed in all cases.

Table 2. Difference test for fir mean damage and damage index between the plant associations Abi-Fag. and Cal-Abi.
Tablica 2. Testiranje razlika srednje oštećenosti i indeksa oštećenosti jele između fitocenoza Abi-Fag. i Cal-Abi.

Variable *Varijabla*	Unit *Jedinica*	Arith. mean *Aritmetička sredina* Abi-Fag.	Cal-Abi.	t	N	p	N - Abi-Fag.	N - Cal-Abi.	Std. dev. Abi-Fag.	Std. dev. Cal-Abi.	F	p
1	2	3	4	5	6	7	8	9	10	11	12	13
JELASO	(%)	44.42	50.53	-9.27	9013	0.000	8086	929	9.058	9.960	1.209	.0001
JELAIO	(%)	91.40	93.59	-5.52	9013	.0000	8086	929	11.670	8.915	1.713	.0000

Figure 14. Differences test in mean damage and damage index for fir between the plant associations Abi-Fag. and Cal-Abi.
Slika 14. Grafički prikaz razlika srednje oštećenosti i indeksa oštećenosti jele između fitocenoza Abi-Fag. i Cal-Abi.

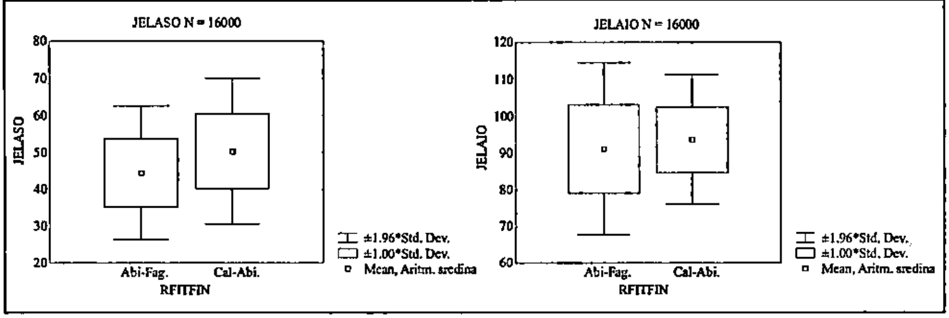


Table 3. Difference test for fir mean damage and damage index between the plant associations Abi-Fag. and Blech-Abi.
Tablica 3. Testiranje razlika srednje oštećenosti i indeksa oštećenosti jele između fitocenoza Abi-Fag. i Blech-Abi.

Variable *Varijabla*	Unit *Jedinica*	Arithm. mean *Aritmetička sredina* Abi-Fag.	Blech-Abi.	t	N	p	N - Abi-Fag.	N - Blech-Abi.	Std. dev. Abi-Fag.	Std. dev. Blech-Abi.	F	p
1	2	3	4	5	6	7	8	9	10	11	12	13
JELASO	(%)	44.42	37.50	10.22	8264	.0000	8086	180	9.057	3.110	8.478	.0000
JELAIO	(%)	91.40	81.82	10.96	8264	.0000	8086	180	11.669	6.761	2.978	.0000

Figure 15. Differences test in mean damage and damage index for fir between the plant associations Abi-Fag. and Blech-Abi.

Slika 15. Grafički prikaz razlika srednje oštećenosti i indeksa oštećenosti jele između fitocenoza Abi-Fag. i Blech-Abi.

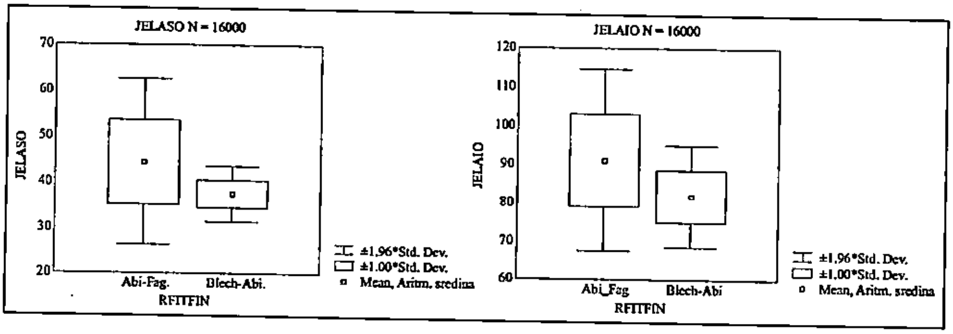


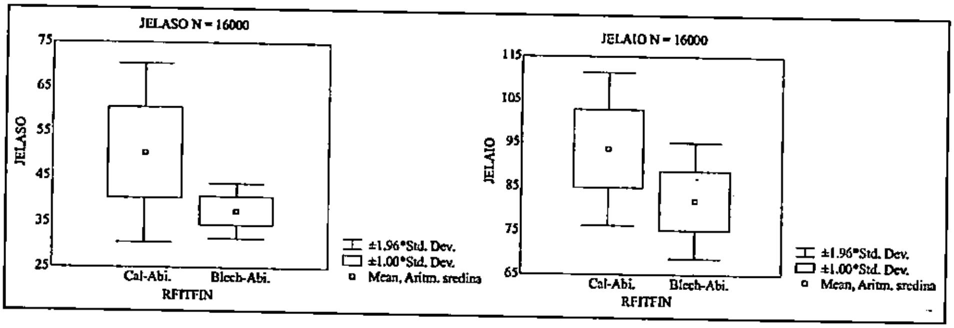
Table 4. Difference test for fir mean damage and damage index between the plant associations Cal-Abi. and Blech-Abi.

Tablica 4. Testiranje razlika srednje oštećenosti i indeksa oštećenosti jele između fitocenoza Cal-Abi. i Blech-Abi.

Variable *Varijabla*	Unit *Jedinica*	Aarithm, mean *Aritmetička sredina* Cal-Abi.	Blech-Abi.	t	N	p	nN-Cal-Abi.	nN-Blech-Abi.	Std. dev. Cal-Abi.	Std. dev. Blech-Abi.	F	p
1	2	3	4	5	6	7	8	9	10	11	12	13
JELASO	(%)	50.53	37.50	17.37	1107	0.000	929	180	9.960	3.110	10.25	.0000
JELAIO	(%)	93.58	81.82	16.78	1107	0.000	929	180	8.915	6.761	1.738	.0000

Figure 16. Differences test in mean damage and damage index for fir between the plant associations Cal-Abi. and Blech-Abi.

Slika 16. Grafički prikaz razlika srednje oštećenosti i indeksa oštećenosti jele između fitocenoza Cal-Abi. i Blech-Abi.

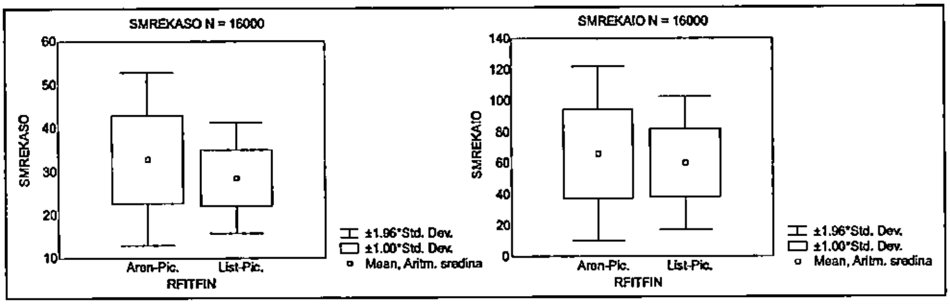


Tests concerning differences in mean damage and the damage index for spruce between plant associations *Aremonio – Piceetum* and *Listero – Picetum* also showed considerable differences (Table 5, Figure 17).

Table 5. Difference test for spruce mean damage and damage index between the plant associations Aren-Pic. and List-Pic.
Tablica 5. Testiranje razlika srednje oštećenosti i indeksa oštećenosti smreke između fitocenoza Aren-Pic. i List-Pic.

Variable *Varijabla*	Unit Jedinica	Arithm. mean *Aritmetička sredina* Aren-Pic.	List-Pic.	t	N	p	N - Aren-Pic.	N - List-Pic.	Std. dev. Aren-Pic.	Std. dev. List-Pic.	F	p
1	2	3	4	5	6	7	8	9	10	11	12	13
SMREKASO	(%)	33.07	29.13	4.19	324	.0000	70	256	9.869	5.945	2.755	.0000
SMREKAIO	(%)	68.18	61.80	2.15	324	.0315	70	256	28.632	19.675	2.117	.0000

Figure 17. Differences test in mean damage and damage index for spruce between the plant associations Aren-Pic. and List-Pic.
Slika 17. Grafički prikaz razlika srednje oštećenosti i indeksa oštećenosti smreke između fitocenoza Aren-Pic. i List-Pic.



However, due to significant differences in the variabilities of the analyzed parameters (SO, IO) between all subgroups (plant associations), the interpretability of the t-tests is questionable.

Partial linear correlations
Parcijalne linearne korelacije

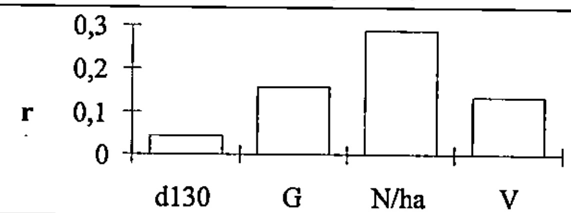
1.) By using partial linear correlations, the connection between dendrometric parameters measured on site and those obtained by measurement on CIR aerial photographs was checked.

There is a high correlation between photogrammetrical and terrestrial data ($p=0.05$) for all observed dendrometric parameters (Table 6, Figure 18).

Table 6. Correlation between photogrammetrical and terrestrial data
Tablica 6. Korelacija terenskih i fotogrametrijskih dendrometrijskih parametara

p < 0.05; N=2710	D130	G	N H	V
1	2	3	4	5
DTER	.04	-.31	-.36	-.26
GTER	.11	.16	-.03	.18
NTER	.05	.37	.29	.35
VTER	.34	.07	-.38	.14

Figure 18. Correlation between photogrammetrical and terrestrial data
Slika 18. Grafički prikaz korelacije terenskih i fotogrametrijskih dendrometrijskih parametara



Owing to the sample size (2710 trees), correlations are significant regardless of the relatively low values of correlation coefficients.

Terrestrial data are reduced to a constant inside compartments and photogrammetrical ones inside strata, which decreases the spatial variability of observed parameters inside the GIS-model.

The highest correlation was obtained between the number of trees, because this variable is least affected by measurement errors (it is observed directly), the others being loaded with the stochastic variability of regression models.

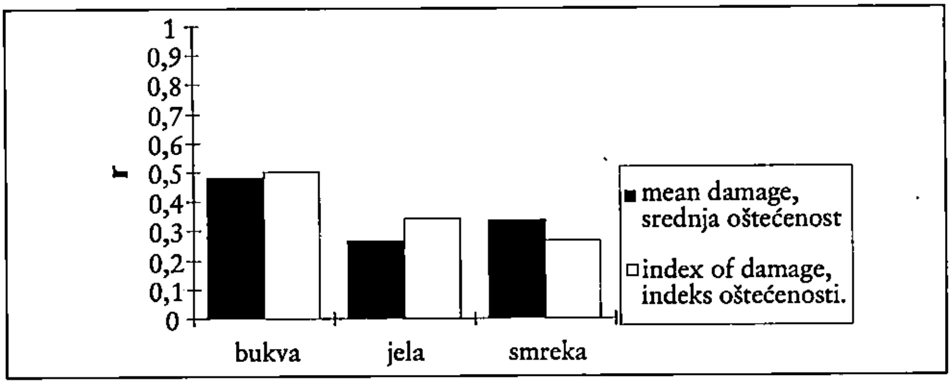
More precise conclusions about correlations between terrestrial and photogrammetrical parameters may be obtained by research on a systematic sample.

2.) The partial linear correlations were also used to study the relationship between the frequency (mixture share) and mean damage, namely the damage index for dominant tree species (Table 7, Figure 19).

Table 7. Correlations of frequency (mixture share) and mean damage for dominant tree species
Tablica 7. Korelacija zastupljenosti (udio smjese) i oštećenosti prema dominantnim vrstama

	BUKVASO	JELASO	SMREKASO	BUKVAIO	JELAIO	SMREKAIO
1	2	3	4	5	6	7
BUKVAUS	.4832	-.1185	-.1918	.5014	-.1483	-.1477
	p=0.00	p=0.00	p=0.00	p=0.00	p=0.00	p=0.00
JELAUS	.0240	.2693	.0737	-.2815	.3429	.0639
	p=.007	p=0.00	p=.000	p=0.00	p=0.00	p=.000
SMRE-KAUS	-.6022	.0576	.3346	-.3446	.0804	.2677
	p=0.00	p=.000	p=0.00	p=0.00	p=.000	p=0.00

Figure 19. Partial linear correlations, the frequency (mixture share) and mean damage, namely damage index for dominant tree species
Slika 19. Grafički prikaz korelacija zastupljenosti (udio smjese) i oštećenosti prema dominantnim vrstama



The results of the correlation analysis show that the larger the share of a certain species in the mixture, the higher the site suitability, and that the damage correlates positively with its share.

If the share of individual tree species in the mixture is interpreted as the site suitability for respective species, and if the increase of damage is interpreted as loss of physiological resistance, then from the said results it can be assumed that the physiological resistance decreases as the site suitability for the respective species increases.

3.) The total mean damage and the damage index correlated with the tree base surface and the volume. The correlation analysis was made on a sample of 6,997 trees. The obtained correlation coefficients (Table 8) lead to the suggestion that the bigger the tree base surface, i.e. the volume, the higher the total damage.

Table 8. Correlation of total damage with tree base surface and volume
Tablica 8. Korelacija ukupne oštećenosti s temeljnicom i volumenom

$p < 0.05$; N=6997	UKUPSO	UKUPIO
1	2	3
G	.74	.78
V	.76	.80

4.) The correlation analysis between the dendrometric parameters (the tree base surface and the volume) and the terrain elements (DTM, slope) shows an inverse correlation, namely that the base surface and the volume decrease when the height above sea level increases (DTM), but also that they decrease when the slope increases (Table 9).

Table 9. Correlation of tree base surface and volume with terrain elements
Tablica 9. Korelacija temeljnice i volumena s elementima reljefa

p < 0.05; N=6997	G	V
1	2	3
R	-.36	-.40
RASP	.10	.12
RSLP	-.23	-.22

5.) The existence of an inverse correlation between the total damage (SO, IO) and terrain elements was shown by the partial correlation analysis on a sample of 12,784 trees (Table 10). From the results obtained, it can be seen that the damage decreases with an increase in the height above sea level (DTM) and an increase of the slope (RSLP). Exposure and total damage do not correlate, which leads to the suggestion that the exposure (RASP), due to the fact that it is strictly locally conditioned, is an insufficiently precise indicator.

Table 10. Correlation of damage with terrain elements
Tablica 10. Korelacija oštećenosti s elementima reljefa

p < 0.05; N=12784	UKUPSO	UKUPIO
1	2	3
R	-.43	7-.51
RASP	.00	.01
RSLP	-.19	-.24

Multivariant regression
Multivarijatna regresija

1.) The multiple regression analysis was used to investigate relationships of the base surface (Table 11) and the volume (Table 12) with terrain elements (DTM, slope, exposure). The results obtained coincide with those of the partial linear correlation (the linear coefficient symbols are equal to the symbols of the regression coefficients).

Table 11. Multivariant regression of tree base surface with terrain elements
Tablica 11. Multivarijatna regresija temeljnice s elementima reljefa

R= .39980751 R^2= .15984605						
F(3.6993)=443.49 p < 0.0000 Std. Error of estimate, *Std. greška procjene*: 2.7994						
	BETA	Std. Err. of BETA *Std. pogreška od BETA*	B	Std. Err. of B *Std. pogreška od B*	t(12201)	p
1	2	3	4	5	6	7
Intercpt			18.68806	.221970	84.1919	.000000
R	-.331992	.011437	-.00612	.000211	-29.0290	.000000
RASP	.108730	.011030	.00698	.000708	9.8576	.000000
RSLP	-.126065	.011463	-.03878	.003526	-10.9975	.000000

Table 12. Multivariant regression of volume with terrain elements
Tablica 12. Multivarijatna regresija volumena s elementima reljefa

R= .43359868 R²= .18800782						
F(3.6993)=539.72 p < 0.0000 Std. Error of estimate, *Std. greška procjene*: 46.318						
	BETA	Std. Err. of BETA *Std. pogreška od BETA*	B	Std. Err. of B *Std. pogreška od B*	t(12201)	p
1	2	3	4	5	6	7
Intercpt			279.3128	3.672615	76.0528	.000000
R	-.374500	.011243	-.1161	.003487	-33.3089	.000000
RASP	.125915	.010844	.1360	.011708	11.6119	.000000
RSLP	-.108433	.011269	-.5614	.058347	-9.6220	.000000

2.) The results obtained by the regression analysis of mean damage (Table 13) and damage indices (Table 14) with terrain elements also coincide with those of the linear correlation. The linear coefficients have the same symbols as the regression coefficients.

Table 13. Multivariant regression of mean damage status with terrain elements
Tablica 13. Multivarijatna regresija srednje oštećenosti s elementima reljefa

R= .43574187 R²= .18987098						
F(3.12780)=998.42 p.0000 Std. Error of estimate, *Std. greška procjene*: 7.1472						
	BETA	Std. Err. of BETA *Std. pogreška od BETA*	B	Std. Err. of B *Std. pogreška od B*	t(12201)	p
1	2	3	4	5	6	7
Intercpt			47.70860	.413120	115.4836	.000000
R	-.411090	.008351	-.01889	.000384	-49.2278	.000000
RASP	.016842	.008051	.00280	.001337	2.0920	.036454
RSLP	-.069264	.008390	-.05386	.006524	-8.2557	.000000

Table 14. Multivariant regression of damage index with terrain elements
Tablica 14. Multivarijatna regresija indeksa oštećenosti s elementima reljefa

R= .48223411 R²= .23254973						
F(3.12543)=1266.9 p < 0.0000 Std. Error of estimate, *Std. greška procjene*: 17.752						
	BETA	Std. Err. of BETA *Std. pogreška od BETA*	B	Std. Err. of B *Std. pogreška od B*	t(12201)	p
1	2	3	4	5	6	7
Intercpt			104.2314	1.059149	98.4105	.000000
R	-.450265	.008138	-.0544	.000982	-55.3315	.000000
RASP	.032694	.007908	.0139	.003350	4.1344	.000036
RSLP	-.091375	.008177	-.1836	.016429	-11.1750	.000000

3.) The multiple regression analysis was also used to investigate relationships between the mean damage of dominant tree species and terrain elements (DTM, slope, exposure).

The regression coefficients obtained for beech (Table 15) and spruce (Table 16) are negligible, while the results obtained for fir (Table 17) show that an increase in height above sea level (DTM) is followed by an increase in damage, similar to the case of slope (RSLP), where anthe increase in slope is followed by an increase in fir damage.

Table 15. Multivariant regression of beech damage status with terrain elements
Tablica 15. Multivarijatna regresija oštećenosti bukve s elementima reljefa

R= .08315875 R^2= .00691538						
F(3.12201)=28.321 p < 00000 Std. Error of estimate, *Std.greška procjene*: 3.0730						
	BETA	Std. Err. of BETA *Std. pogreška od BETA*	B	Std. Err. of B *Std. pogreška od B*	t(12201)	p
1	2	3	4	5	6	7
Intercpt			16.82780	.181212	92.86227	.000000
R	-.029111	.009448	-.00052	.000169	-3.08102	.002068
RASP	.033378	.009119	.00215	.000587	3.66026	.000253
RSLP	-.060259	.009490	-.01826	.002876	-6.34952	.000000

Table 16. Multivariant regresion of spruce damage status with terrain elements
Tablica 16. Multivarijatna regresija oštećenosti smreke s elementima reljefa

R= .04648488 R^2= .00216084						
F(3.7485)=5.4030 p < 00104 Std. Error of estimate, *Std. greška procjene*: 10.239						
	BETA	Std. Err. of BETA *Std. pogreška od BETA*	B	Std. Err. of B *Std. pogreška od B*	t(12201)	p
1	2	3	4	5	6	7
Intercpt			30.86084	1.093272	28.22795	0.000000
R	.005823	.011832	.00050	.001018	.49209	.622672
RASP	.045667	.011642	.00992	.002529	3.92261	.000088
RSLP	.002426	.011820	.00248	.012105	.20522	.837405

Table 17. Multivariant regression of fir damage status with terrain elements
Tablica 17. Multivarijatna regresija oštećenosti jele s elementima reljefa

R= .54784497 R^2= .30013411						
F(3.10944)=1564.4 p < 0.0000 Std. Error of estimate, *Std. greška procjene*: 8.9207						
	BETA	Std. Err. of BETA *Std. pogreška od BETA*	B	Std. Err. of B *Std. pogreška od B*	t(12201)	p
1	2	3	4	5	6	7
Intercpt			8.475030	.577413	14.67758	.000000
R	.513960	.008258	.034014	.000547	62.23712	.000000
RASP	-.003692	.008105	-.000819	.001798	-.45549	.648766
RSLP	.108239	.008273	.114805	.008775	13.08295	.000000

INTERPRETATION OF RESULTS
INTERPRETACIJA DOBIVENIH REZULTATA

According to the set aim and by the research carried out, certain results and knowledge have been obtained about both GIS-technology, as a tool for the realisation of the given aim, and about numerous possibilities for its use in multidisciplinary research.

Great advantages of GIS-technology in relation to the traditional (classical) method of data collection and analysis have been noticed. These advantages are manifested in an efficient and simple use of data collected in various manners (field survey, remote sensing, etc.), in an abundance of collected data and their easy accessibility and modification, in the possibilities of cartographic presentation of data in layers and a large number of combinations as required for purposes of analysis and many other advantages.

The data used to establish the grid GIS-model for the NP "Risnjak" were obtained by the interpretation of CIR aerial photographs, field surveys (Management Program for the NP "Risnjak" 1991-2000) and the digitalization of existing maps. Strata obtained by aerial photograph delineation were also digitalized, which allowed spatial distributions from the data to be interpreted on the CIR aerial photographs (damage and stand parameters). By the digitalization of compartments, the spatial distribution of taxation parameters measured on site was obtained. All vector themes were grid converted at 10 x 10 m pixel size. Grid-converted data are suitable for the presentation of thematic subjects and for their subsequent analysis.

All information sources inside GIS-models were geocoded and stored as separate layers, which allows unlimited handling with either thematic or topographic data.

The raster GIS-model is composed of 30 layers. Data with corresponding coordinates are assigned to each layer attribute.

From such thematic contents obtained by the interpretation of aerial photographs, new layers were established using some of the procedures shown in Figure 3.

By means of raster – GIS modelling, the slope and exposure layers were obtained from DTM. Their further processing enables to present and calculate daily insolation and insolation in various seasons, stormwater flows, etc.

Having in view the importance of DTM, i.e. of the ground slope for research work in many fields, especially in the field of forest exploitation, a new layer based on ground slope classes was made (Figure 12). In this way, it is possible to plan forest openings, namely to design an optimal network of forest roads.

On the basis of earlier research, statistical analyses (correlation and multivariant ones) were carried out for some layers. The results of these analyses allow us to investigate the impact of individual environment characteristics on forest damage, stand parameters, etc. and indicate a direction for future multidisciplinary research aimed at complex analyses of all environment characteristics.

All prepared thematic contents (layers) with attribute data form the database for the NP "Risnjak", which presents a large potential for further research and planning, always open and adaptable to new data.

CONCLUSIONS
ZAKLJUČCI

The research concerning the use of the results of the interpretation of APs and the geographical information system for planning purposes in forestry was carried out using the example of the NP "Risnjak". The aim of the research was to find a way of linking all existing data on the site in one unique information source and to generate new information as a basis for planning by using geographic information system methods.

From the research carried out and the results obtained, the following conclusions can be made:

1) By using the interpretation of CIR aerial photographs, a large amount of data (tree damage, stand parameters, etc.), applicable in many fields of science and economy was collected. The results of the interpretation of aerial photographs are suitable for studying and monitoring environment status and changes and thus present a very good basis for planning.

2) By monitoring the results over a certain period of time a forecast of future conditions is possible.

3) The results of the interpretation of aerial photographs can be presented cartographically or in the form of tables and diagrams. Cartographic data are translated into digital form by digitalization. The grid conversion of these data provides a basis for the spatial presentation of tabular data. In this way, various thematic layers are obtainable which can be later used for analysis purposes.

4) The geographic information system is a suitable tool for putting together data from various sources, but all these data should be georeferenced so that their uniform overlapping is possible.

5) The established GIS-model for the NP "Risnjak" consists of 30 thematic layers based on the data from various sources: the interpretaton of CIR aerial photographs, field surveying (the data from the Management Program) and map digitalization.

6) Assigned to each layer is its respective attribute database, generated on a 50 x 50 m point grid through all layers, which is always open and adaptable to newly-received data. This database is at the same time permanently archived material which can be easily reproduced at any moment.

7) All entered data present a good basis for future research and planning with the help of GIS-technology which allows better analyses of existing data and forecasts of future conditions, which is a prerequisite for good planning.

8) These data can be used in various fields of forestry, such as forest management, ecological research, forest exploitation, etc.

9) By means of various mathematical and statistical methods, the data from the GIS-model can be analyzed and on the basis of such analyses the relationship and dependence between various parameters essential for planning in forestry can be studied.

10) The given examples of analyses show the complexity of the study of forest conditions and the impact of individual environment characteristics on these conditions. At the same time, they indicate the necessity of such analyses as well as of remote sensing and GIS technology for good planning in forestry.

11) The established GIS-model and the analyses carried out justify such an approach in the study and the performance of tasks put before specialists from various fields with regard to the planning of management and control in both protected areas and exploitation forests.

12) The establishment of such a GIS-model is not the end of this task, but the beginning of the construction of just one part of a general planning system, one of timely and correct decision making, the so-called *decision support system*.

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PRIMJENA REZULTATA INTERPRETACIJE AEROSNIMAKA I GEOGRAFSKOG INFORMACIJSKOG SUSTAVA ZA PLANIRANJE U ŠUMARSTVU

SAŽETAK

Istraživanje primjene rezultata interpretacije aerosnimaka i geografskog informacijskog sustava za planiranje u šumarstvu provedeno je na primjeru NP Risnjak. Cilj je istraživanja bio pronalaženje načina za povezivanje svih postojećih podataka o terenu i podataka dobivenih interpretacijom aerosnimaka u jedinstveni izvor informacija, te generiranje novih informacija kao podloga za planiranje primjenom metoda geografskog informacijskog sustava (GIS).

Podaci upotrijebljeni za uspostavu rasterskoga GIS modela za NP Risnjak dobiveni su interpretacijom infracrvenih kolornih (ICK) aerosnimaka, izmjerom na terenu (Program gospodarenja za NP Risnjak 1991 – 2000. god.) i digitalizacijom postojećih karata.

Na ICK aerosnimkama izlučene su sastojine (delineacija) prema vidljivim razlikama u slikovnim pojedinostima šumskih sastojina, kao što su: vrsta drveća, omjer smjese, sklopljenost sastojine, veličina krošnje, stupanj oštećenosti, pojava matičnoga supstrata itd.

Delineacijom aerosnimaka dobiveni su stratumi također digitalizirani, čime je omogućeno dobivanje prostornih raspodjela iz podataka interpretiranih na ICK aerosnimkama (oštećenost, dendrometrijski parametri). Sve vektorske teme rasterizirane su uz veličinu piksla 10 m x 10 m.

Unutar GIS modela svi su izvori informacija geokodirani i pohranjeni kao zasebni slojevi, čime je omogućeno nesmetano međusobno rukovanje, bilo tematskim, bilo topografskim podacima.

Uspostavljeni rasterski GIS model za NP Risnjak sastoji se od 30 tematskih slojeva:

1. pedokartografske jedinice
2. geološke kategorije (prema sastavu stijena i vodopropusnosti)
3. biljne zajednice
4. prostorna raspodjela srednjih prsnih promjera po ha (terenski podaci – ter.)
5. prostorna raspodjela srednjih prsnih promjera po ha (fotogrametrijski podaci – ftg.)
6. prostorna raspodjela temeljnica po ha (ter.)
7. prostorna raspodjela temeljnica po ha (ftg.)
8. prostorna raspodjela volumena po ha (ter.)
9. prostorna raspodjela volumena po ha (ftg.)
10. prostorna raspodjela broja stabala po ha (ter.)
11. prostorna raspodjela broja stabala po ha (ftg.)
12. relativni udjel jele (ftg.)

13. relativni udjel bukve (ftg.)
14. relativni udjel smreke (ftg.)
15. prostorna raspodjela srednje oštećenosti jele (ftg.)
16. prostorna raspodjela srednje oštećenosti bukve (ftg.)
17. prostorna raspodjela srednje oštećenosti smreke (ftg.)
18. prostorna raspodjela indeksa oštećenosti jele (ftg.)
19. prostorna raspodjela indeksa oštećenosti bukve (ftg.)
20. prostorna raspodjela indeksa oštećenosti smreke (ftg.)
21. prostorna raspodjela srednje oštećenosti četinjača (ftg.)
22. prostorna raspodjela srednje oštećenosti listača (ftg.)
23. prostorna raspodjela indeksa oštećenosti četinjača (ftg.)
24. prostorna raspodjela indeksa oštećenosti listača (ftg.)
25. prostorna raspodjela ukupne srednje oštećenosti (ftg.)
26. prostorna raspodjela ukupnog indeksa oštećenosti (ftg.)
27. digitalni model reljefa (DMR)
28. nagib terena
29. nagib terena po klasama
30. kutni otklon od juga (izloženost).

Uza svaki je sloj vezana atributna baza podataka, generirana na mreži točaka 50 m x 50 m kroz sve slojeve, a koja je uvijek otvorena i prilagodljiva za dopunu novim podacima. Baza je podataka ujedno trajno pohranjen materijal koji se u svako doba može vrlo lako umnožiti.

Iz tematskih sadržaja dobivenih na osnovi interpretacije aerosnimaka modeliranjem su izrađeni novi slojevi (relativni udjeli dominantnih vrsta drveća).

Rasterskim GIS modeliranjem iz digitalnoga modela reljefa (DMR) dobiveni su slojevi nagiba i izloženosti. Njihovom daljnjom obradom moguće je izračunati i prikazati osunčanost padina tijekom dana i u različita godišnja doba, tok oborinskih voda itd.

Budući da nagib terena ima značajnu ulogu za obavljanje radova u mnogim područjima istraživanja, posebno u području iskorištavanja šuma, izrađen je novi sloj po klasama nagiba terena. Time je omogućeno planiranje otvorenosti šuma, odnosno projektiranje optimalne mreže šumskih prometnica.

Na osnovi ranijih istraživanja za neke su slojeve provedene statističke analize (korelacijska i multivarijatna). Testirane su razlike u oštećenostima između biljnih zajednica. Parcijalnim linearnim korelacijama ispitana je veza između dendrometrijskih elemenata mjerenih na terenu i onih dobivenih mjerenjem na ICK aerosnimkama, a također i veza između zastupljenosti (udjela smjese) i oštećenosti dominantnih vrsta drveća. Multivarijatnom regresijskom analizom istraživan je odnos strukturnih elemenata i oštećenosti dominantnih vrsta drveća s elementima reljefa (nadmorska visina, izloženost, nagib).

Rezultati provedenih analiza omogućavaju proučavanje utjecaja pojedinih značajki okoliša na oštećenost šuma, sastojinske veličine, te upućuju na smjer budućih multidisciplinarnih istraživanja s ciljem kompleksnih analiza svih značajki okoliša.

Navedene analize upućuju na svu složenost proučavanja stanja šuma i utjecaja pojedinih značajki okoliša na to stanje.

Uneseni su podaci osnova za buduća istraživanja i planiranja uz pomoć GIS tehnologije, koja omogućuje bolje analize postojećih podataka i predviđanja budućih stanja, što je preduvjet za ispravno planiranje.

Svi izrađeni tematski sadržaji (slojevi) s atributnim podacima čine bazu podataka za NP Risnjak koja pruža velike mogućnosti za daljnja istraživanja i planiranja i koja je uvijek otvorena i prilagodljiva za izmjene ili dopunu novim podacima.

Ključne riječi: infracrveni kolorni aerosnimci (ICK), fotointerpretacija, geografski informacijski sustav (GIS), rasterski GIS model, NP "Risnjak", digitalni model reljefa (DMR), planiranje u šumarstvu

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PRIMJERI NAVOĐENJA LITERATURE:

Članak iz časopisa

Arrouays, D. & Pelissier, P., 1994: Modeling carbon storage profiles in temperate forest humic loamy soils of France. Soil Sci. 157(3): 185–192.

Matić, S., 1993: Unapređenje proizvodnje biomase šumskih ekosistema Hrvatske. Glas. šum. pokuse, pos. izd., 4: 1–6.

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Hampson, A. M. & Peterken, G. F., 1995: A Network of woodland habitats for Scotland. In: Korpilahti, E., Salonen, T. & Seppo, O. (eds.), Caring for the Forest: Research in

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Matić, S., Anić, I. & Oršanić, M., 1996: Prilog poznavanju nekih šumsko-uzgojnih svojstava pionirskih listopadnih vrsta drveća. In: Mayer, B. (ed.), Unapređenje proizvodnje biomase šumskih ekosustava, Šumarski fakultet Sveučilišta u Zagrebu & Šumarski institut, Jastrebarsko, Zagreb, pp. 181–187.

Knjiga

Burschel, P. & Huss, J., 1997: Grundriss des Waldbaus (2nd ed). Parey Buchverlag, Belin, 487 pp.

Rauš, Đ., 1987: Šumarska fitocenologija. Sveučilišna naklada Liber, Zagreb, 313 pp.

Poglavlje iz knjige, monografije, enciklopedije

Lammi, J. O., 1994: Professional ethics in forestry. In: Irland, L. C. (ed.), Ethics in forestry, Timber press, Portland, pp. 49–58.

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