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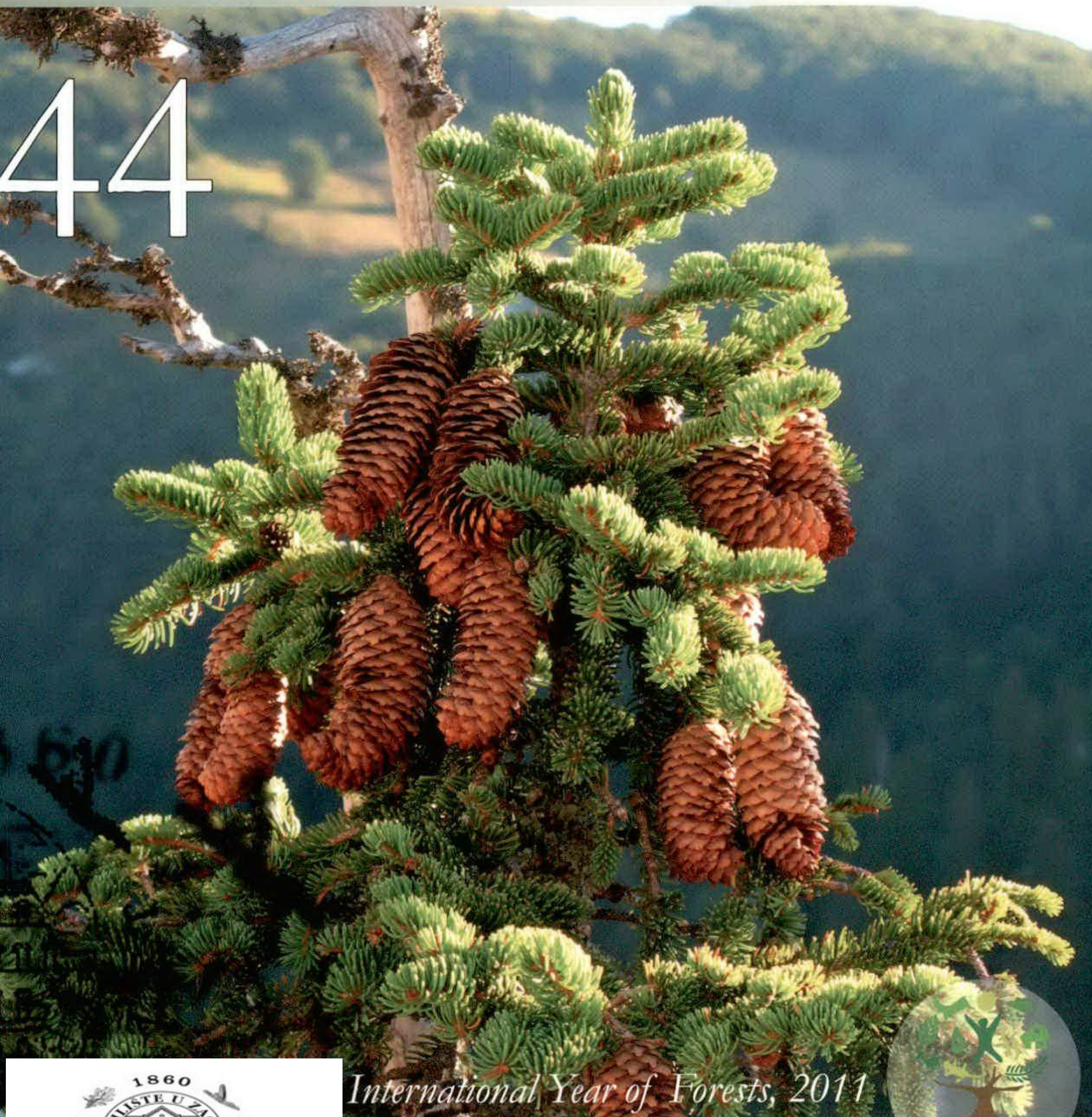

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UNIVERSITAS STUDIORUM ZAGRABIENSIS
FACULTAS FORESTALIS
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Volumen 44

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MORPHOLOGICAL-BIOLOGICAL PROPERTIES OF FRUIT AND SEED OF BEECH *(Fagus sylvatica L.)* GROWING AT DIFFERENT ALTITUDES

MORFOLOŠKO-BIOLOŠKE ZNAČAJKE PLODOVA I SJEMENA BUKVE (Fagus sylvatica L.) S RAZLIČITIH NADMORSKIH VISINA

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Abstract

The paper examines morphological-biological characteristics of beech fruit and seed growing at different altitudes. Research was conducted in seven localities in the area of Velebit at altitudes ranging from 521 to 1,535 m a.s.l. Fruits were collected and yield rates were assessed during autumn 2007. Seed analyses were performed in the seed and nursery production laboratory of the Department of Forest Ecology and Silviculture of the Faculty of Forestry of Zagreb University. All the elements of seed quality were tested in accordance with the ISTA rules (International Rules for Seed Testing, 2006). The average beechnut viability obtained with the tetrazolium method was 81.4%. A positive and significant (r= 0.69452) correlation between the altitude and empty (non-vital) beech seed was confirmed. The average weight of 1,000 seeds was 118.9 g. A correlation between altitude and weight of 1,000 seeds was negative and significant (r= -0.6315). The average beechnut weight from all the seven localities was 0.24 g. There were statistically significant differences in beechnut weight in relation to the localities under study. A statistically significant difference in beechnut length was established with regard to yield rate described as average and very good, or good and very good. The average beechnut length at average yield amounted to 14.72 mm, at good yield it was 15.05 mm, and at very good yield it was 16.03 mm. The overall laboratory beech seed germination after 17 weeks of testing in sand at a constant temperature of 5°C was the highest in the Krecelj locality (39.3%) and the lowest in the Velika Stražbenica locality (34.8%), whereas average germination was 37.3%. A correlation between altitude and laboratory seed germination was positive and significant (r= 0.48350). With a rise in the altitude of provenances, laboratory germination of beechnut increases significantly.

Key words: *Fagus sylvatica* L., altitude, seed yield, seed viability, 1,000 seed weight, laboratory germination

Sažetak

U radu se istražuju morfološko-biološke značajke plodova i sjemena bukve sa različitih nadmorskih visina. Istraživanja su provedena na sedam lokaliteta na području Velebita sa rasponom nadmorskih visina od 521-1535 m n.v. Tijekom jeseni 2007. godine sakupljeni su plodovi i obavljena je procjena stupnja uroda. Analize sjemenena obavljene su u laboratoriju za sjemenarstvo i rasadničarstvo Zavoda za ekologiju i uzgajanje šuma Šumarskog fakulteta Sveučilišta u Zagrebu. Svi elementi kvalitete sjemena

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ispitivani su u skladu sa pravilima ISTA (International Rules for Seed Testing, 2006). Prosječni vitalitet bukvice dobiven metodom tetrazola iznosio je 81,4%. Utvrđena je pozitivna i značajna (r= 0,69452) korelacija između nadmorske visine i šturog (nevitalnog) sjemena bukve. Prosječna težina 1000 sjemenki iznosila je 118,9 g. Korelacija između nadmorske visine i težine 1000 sjemenki je negativna i značajna (r= -0,6315). Prosječna težina bukvice sa svih sedam lokaliteta iznosila je 0,24 g. Težina bukvice statistički se značajno razlikovala s obzirom na istraživane lokalitete. Dobivena je statistički značajna razlika u duljini bukvice s obzirom na stupanj uroda osrednji i vrlo dobar odnosno dobar i vrlo dobar. Prosječna duljina bukvice kod osrednjeg uroda iznosila je 14,72 mm, kod dobrog uroda 15,05 mm odnosno kod vrlo dobrog 16,03 mm. Ukupna laboratorijska klijavost bukvice nakon 17 tjedana ispitivanja u pijesku na konstantnoj temperaturi od 5°C bila je najveća na lokalitetu Krecelj (39,3%) a najmanja na lokalitetu Velika stražbenica (34,8%) dok je prosječna klijavost iznosila 37,3%. Korelacija između nadmorske visine i laboratorijske klijavosti sjemena je pozitivna i značajna (r= 0,48350). S porastom nadmorske visine provenijencije značajno se povećava laboratorijska klijavost bukvice.

***Ključne riječi:** Fagus sylvatica L., nadmorska visina, urod sjemena, vitalitet sjemena, težina 1000 sjemenki, laboratorijska klijavost*

INTRODUCTION
UVOD

Common beech (*Fagus sylvatica* L.) is the most widespread tree species in the forest fund of Croatia. It occurs in different communities and in the sites with distinct vertical and horizontal distribution (Matić et al. 2003b). In Croatia, it inhabits a variety of sites and altitudes from 100 m a.s.l. in lowland Croatia to 1,500 m a.s.l. in the Dinaric range, where beech trees assume the stunted appearance (Seletković and Tikvić 2003).

Common beech is a monoecious species that is pollinated by wind. It is characterized by the possibility of self-fertilisation, but generally speaking, there is a high degree of heterosis (Merzeau et al. 1994, Müller-Starck 1996, Rossi et al. 1996).

The importance of beech seed to be used for interventions in the existing stands in the regeneration stage, whether it is the introduction of seeds or of nursery-raised seedlings, is increasing daily. Seeds or seedlings of common beech are also frequently used in selection beech-fir stands, in which intensive dieback of fir creates the space for the beech (Matić et al. 2003a).

As seen from the data on the planned and needed number of seedlings of common beech (Žgela 2002), there is an increasing need for beech seedlings, which requires the collection of sufficient quantities of good quality seed.

Knowing the morphological and biological properties of beech seed from different localities allows us to improve regeneration and viability of beech stands (Gradečki et al. 2003).

The effect of site parameters on the quantitative properties of seed is of particular importance. Altitude is one of the site features that affect morphological and biological seed properties (Farmer and Barnett 1972, Dorne 1972, Cavieres and Arroyo 2000, Oršanić et al. 2006, Oršanić et al. 2009).

There is a strong correlation between full yield of beech seed and improved biological characteristics of beechnuts (Crnković 2009). Full seed yield occurs at different time intervals, which may be 4, 6, 8 or 10 years (Šmelkova 1996). The interaction between climate and ample seed yields has been confirmed by numerous investigations (Hilton and Packham 1995, Hilton and Packham 2002, Övergaard et al. 2006).

A dormant seed is a seed which is incapable of germination under favourable conditions of temperature, moisture and air. Such a seed is blocked and is unable to germinate immediately, but must first undergo physical and psychological changes (Gradečki et al. 2003). It requires a certain period of time to pass from the stage of morphological maturity to the stage of physiological maturity. This period is overcome by the length of seed stratification (Matić et al. 2003a). Germination tests have demonstrated that, compared to seed germination at lower altitudes, unfavourable climatic conditions at higher altitudes result in a higher percentage of dormancy frequency or in special temperature requirements for germination (McDonough 1970).

Seed germination is the most important qualitative seed characteristic. It depends on several factors, such as seed maturity, health status, collection method, time of collection and seed storage. According to research by Šijačić-Nikolić et al. (2007), germination of beechnuts from different provenances in Serbia ranged between 58.33% and 88.88%. Nursery beechnut germination from 79 provenances in the Republic of Croatia in full mast year (2001) was between 1% and 37% (Gradečki et al. 2006).

The objective of this research was to (1) identify the effect of altitude on beech tree yield in 2007, (2) examine the elements of beech seed quality (absolute weight, laboratory germination or viability) in relation to altitude, (3) check if there is a time difference in overcoming beechnut seed dormancy in the laboratory with regard to altitude, and (4), establish a correlation between viability and laboratory germination of beech seed.

MATERIAL AND METHODS
MATERIJALI I METODE

In the course of autumn 2007, beechnuts (*Fagus sylvatica* L.) were collected from several localities situated at different altitudes in the area of North Velebit. The trees in the localities were selected randomly. The altitudes were determined with a GPSmap 60CSx device, and exposure with a compass.

A six-point yield classification system (none, very bad, poor, average, good and very good) was conducted according to Kapper, who is cited by Vincent (1965). The fruits were collected from different parts of the crowns of standing trees using shears with a telescopic handle or were picked manually from freshly felled trees. In the locality Pod Pogledalcem, beechnuts were collected from a nylon cover previously spread under the standing trees.

All the analyses were performed in the Seed and Nursery Production laboratory of the Department of Forest Ecology and Silviculture of the Faculty of Forestry of the University of Zagreb. A random sample of 30 fruits per tree was taken for morphometric analysis. Fruit length and width were measured with a digital calliper (0.01 mm), and fruit was weighted on the laboratory scale "Sartorius" (0.01 g). The number of beechnuts in 1 kg was counted during data processing. The absolute seed weight was determined according to the ISTA Rules (International Rules for Seed Testing 2006). Beechnut viability was examined with the tetrazolium method, and the assessment was made according to the ISTA Rules (ISTA Working Sheets on Tetrazolium Testing, Volume II, Tree and Shrub Species 2003). As set down by a standard procedure for testing laboratory germination of seeds of the genus *Fagus* L. species (ISTA, International Rules for Seed Testing, Chapter 5: The Germination Test 2006), stratification was required for the duration of 16 (12-20) weeks at a temperature of 3-5 °C. Laboratory seed germination was tested in a refrigerator at a constant temperature of 5°C. Sterile alluvial sand was used as a medium. The germinated seeds were checked and classified every week in accordance with the ISTA Rules (ISTA, International Rules for Seed Testing, Chapter 5: The Germination Test 2006). Data were statistically processed using Statistica (StatSoft, Inc. 2003) software.

RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

Table 1 provides some basic data on the investigated beech trees growing at altitudes between 393 and 1.535 m a.s.l. (an altitudinal difference of 1,142 m). With regard to the social position of the trees in the stand, all the trees were registered as boundary ones. The trees mostly grew in the NE expositions and at inclinations of 6-24°. Tree yields varied from none in the MU Senjska Draga to very good in the MU Bršljun, Lom and Senjsko Bilo.

Table 1 Data on the investigated beech trees (*Fagus sylvatica* L.) from different altitudes in the area of Velebit in 2007
Tablica 1 Podaci o istraživanim stablima bukve (Fagus sylvatica L.) sa različitih nadmorskih visina na području Velebita u 2007. godini

Forest Management Unit *Gospodarska jedinica*	Senjska Draga	Bršljun	Senjsko Bilo	Nadžak Bilo	Lom	Senjsko Bilo	Nadžak Bilo	NP Sjeverni Velebit
Forest District, section *Odjel, odsjek*	30a	19c	29b	98a	22a	48a	86a	-
Forest site *Šumski predjel*	Pizdulinova Jaruga	Pod Pogledalcem	Mala Snježnica	Velika Stražbenica	Santinova Ložnica	Snižnica	Krecelj	-
Social position of tree *Socijalni položaj stabla*	edge *rubno*	edge *rubno*	edge *rubno*	edge *rubno*	edge *rubno*	edge *rubno*	edge *rubno*	edge *rubno*
Altitude zone (m a.s.l) *Nadmorska visina (m n.v.)*	393	521	830	1091	1270	1300	1463	1535
Exposition *Ekspozicija*	SI	SZ	SI	SI	SZ	ISI	SI	SI
Inclination (°) *Inklinacija (°)*	12	6	19	10	7	12	11	24
Yield *Urod*	none *nikakav*	very good *vrlo dobar*	good *dobar*	good *dobar*	very good *vrlo dobar*	very good *vrlo dobar*	average *osrednji*	good *dobar*

Table 2 Data on viability, 1000 seed weight and laboratory germination of beech seed (*Fagus sylvatica* L.) from different altitudes in the area of Velebit in 2007
Tablica 2 Podaci o vitalitetu, težini 1000 sjemenki i laboratorijskoj klijavosti sjemena bukve (Fagus sylvatica L.) sa različitih nadmorskih visina na području Velebita u 2007. godini

Locality *Lokaliteti*	Altitude zone (m a.s.l) *Nadmorska visina (m n.v.)*	Viability (%) *Vitalno (%)*	Non stained *Neobojeno(%)*	Rotten (%) *Gnjilo (%)*	Damaged (%) *Oštećeno (%)*	Empty (%) *Šturo (%)*	1000 seed weight (g) *Težina 1000 sjemenki (g)*	Laboratory germination (%) *Laboratorijska klijavost (%)*
Pod Pogledalcem	521	90,0	4,0	1,5	1,5	3,0	150,6	36,5
Mala Snježníca	830	76,5	3,5	5,0	6,0	9,0	119,9	37,3
Velika Stražbenica	1091	80,5	1,0	0,0	9,5	9,0	99,5	34,8
Santinova Ložnica	1270	77,0	1,0	0,5	5,0	16,5	110,9	35,3
Snižnica	1300	78,0	5,0	0,0	3,5	13,5	119,2	39,0
Krecelj	1463	81,0	0,5	3,5	3,5	11,5	111,7	39,3
NP Sjeverni Velebit	1535	87,0	1,5	0,0	2,0	9,5	120,5	39,0

Data on the altitudes of the investigated localities and on some more important biological characteristics of beech (*Fagus sylvatica* L.) seed are given in Table 2.

The lowest viability (76.5%) was manifested by beechnut from the locality Mala Snježnica 830 m above the sea, and the highest (90.0%) by that from the locality Pod Pogledalcem 521 m above the sea. The average beechnut viability for all the seven investigated localities was high and amounted to 81.4%. The highest percentage of non-vital unstained seed was recorded in the locality Snižnica (5.0%). The highest quantity of decayed seed was recorded in the locality Mala Snježnica (5.0%), whereas seeds of this category were not identified in the localities Velika Stražbenica, Snižnica and NP North Velebit. An amount of 1.5% of decayed seed was registered on average. The highest percentage of insect damaged seeds was recorded in the locality Velika Stražbenica (9.5%) and the lowest in the locality Pod Pogledalcem (1.5%), with an average percentage of seeds of this category reaching 4.4%. The highest quantity of empty seeds were recorded in the locality Santinova Ložnica (16.5%), and the lowest again in the locality Pod Pogledalcem. There were on average 10.3% of empty seeds.

The weight of 1,000 seeds was the highest in the locality Pod Pogledalcem (150.6 g) and the lowest in the locality Velika Stražbenica (99.5 g). The average weight of 1,000 seeds was 118.9 g. The correlation between altitude and weight of 1,000 seeds was negative and significant (r= -0.6315).

Total laboratory seed germination was the highest in the locality Krecelj (39.3%) and the lowest in the locality Velika Stražbenica (34.8%), whereas average germination reached 37.3%. The correlation between altitude and weight of 1,000 seeds was positive and significant (r= 0.48350).

Categories of non-stained beech seed (*Fagus sylvatica* L.) obtained with the tetrazolium method are given in Table 3.

There were on average 1.0% seeds with a stained radicle and over one third of non-stained cotyledon surface. Only 0.07% of the seeds had completely non-stained radicles and cotyledons. An average of 0.57% seeds with non-stained radicles and completely stained cotyledons were also identified (most of them in the locality Pod Pogledalcem). Correlation analysis confirmed negative and significant

Table 3 Categories on non-stained beech seed (*Fagus sylvatica* L.) from different altitudes in the area of Velebit in 2007 obtained with the tetrazolium method

Tablica 3 Kategorije neobojenog sjemena bukve (Fagus sylvatica L.) sa različitih nadmorskih visina na području Velebita u 2007. godini dobivene tetrazol metodom

Category of non stained seed (%) *Kategorije neobojenog sjemena (%)*	Locality *Lokaliteti*						
	Pod Pogledalcem	Mala Snježnica	Velika Stražbenica	Santinova Ložnica	Snižnica	Krecelj	NP Sjeverni Velebit
1	0,0	0,0	0,0	0,5	0,0	0,0	0,5
2	0,5	1,0	0,0	0,5	0,0	0,0	0,5
3	0,5	1,5	0,5	0,0	4,0	0,5	0,0
4	0,0	0,0	0,5	0,0	0,5	0,0	0,5
5	3,0	0,5	0,0	0,0	0,5	0,0	0,0
6	0,0	0,5	0,0	0,0	0,0	0,0	0,0

Legend - *Legenda*:
1 - area of soft or necrotic tissue larger than 1/3 of the seed
1 - površina mekanog ili nekrotičnog tkiva veća od 1/3 sjemenke
2 - unstained radicle, more than one third of cotyledons unstained
2 - radikula neobojena, više od trećine kotiledona neobojeno
3 - radicle stained, more than one third of cotyledons unstained
3 - radikula obojena, više od trećine kotiledona neobojeno
4 - whole radicle unstained
4 - cijela radikula neobojena
5 - radicle unstained, cotyledons stained
5 - radikula neobojena, kotiledoni obojeni
6 - radicle and cotyledons completely unstained
6 - radikula i kotiledoni potpuno neobojeni

correlation between altitude and non-vital non-stained beechnut seed (r=-0.5192). Positive and significant correlation (r=0.69452) between altitude and empty (non-vital beech seed was obtained (Figure 1).

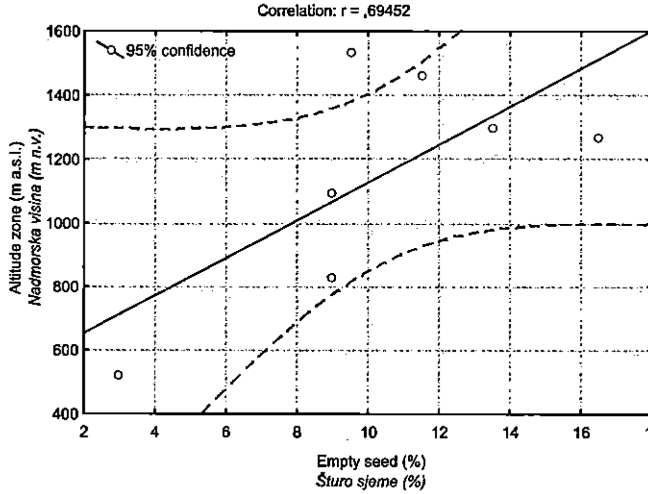

Figure 1 Correlation between altitude and empty (non-vital) beech seed.
Slika 1 Korelacija između nadmorske visine i šturog (nevitalnog) sjemena bukve

The results of descriptive statistics and weight of beech (*Fagus sylvatica* L.) seed from different altitudes in the area of Velebit in 2007 are given in Table 4.

Table 4 Descriptive statistics for weight of beechnut (*Fagus sylvatica* L.) from different altitudes in the area of Velebit in 2007
Tablica 4 Deskriptivna statistika za težinu sjemena bukve (Fagus sylvatica L.) sa različitih nadmorskih visina na području Velebita u 2007. godini

Locality-*Lokalitet*	Altitude zone (m a.s.l) *Nadmorska visina (m n.v.)*	N	Mean	Median	Minimum	Maximum	Variance	Std.Dev.
Pod Pogledalcem	521	30	0,31	0,32	0,10	0,45	0,01	0,08
Mala Snježnica	830		0,26	0,27	0,09	0,40	0,01	0,08
Velika Stražbenica	1091		0,21	0,22	0,06	0,40	0,01	0,09
Santinova Ložnica	1270		0,23	0,24	0,09	0,35	0,01	0,07
Snižnica	1300		0,23	0,24	0,05	0,36	0,01	0,09
Krecelj	1463		0,22	0,23	0,10	0,29	0,00	0,05
NP Sjeverni Velebit	1535		0,24	0,24	0,08	0,35	0,00	0,07

On average, beechnut from the locality Pod Pogledalcem was the heaviest (0.31 g), and that from the locality Velika Stražbenica was the lightest (0.21 g). The average weight of beechnut from all the seven localities amounted to 0.24 g. Variance analysis (Figure 2) yielded a statistically significant difference in beechnut weight in terms of the investigated localities (F=5.751, p=0.000015). Tukey's HSD test was used to establish statistically significant differences in beechnut weight between the local-

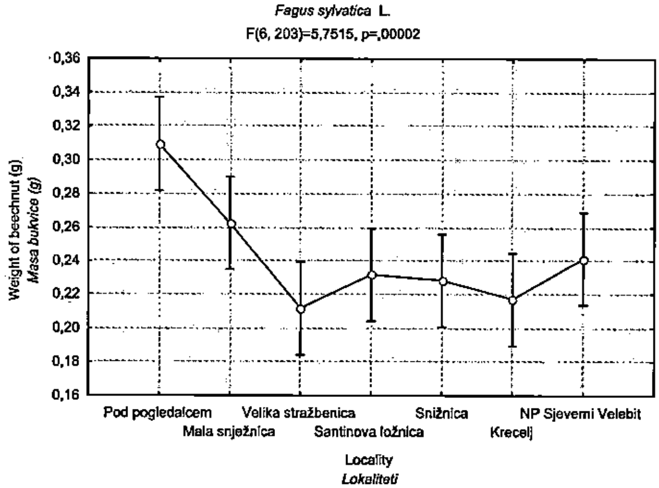

Figure 2 Weight of beechnut (*Fagus sylvatica* L.) from different altitudes in the area of Velebit in 2007
Slika 2 Težina sjemena bukve (Fagus sylvatica L.) sa različitih nadmorskih visina na području Velebita u 2007. godini

ity Pod Pogledalcem and all the other localities (p=0.000041; 0.001733; 0.000874; 0.000087; 0.010782), except Mala Snježnica (p=0.210751). Variance analysis did not confirm any statistically significant differences between beechnut weight and seed yield rate (F=2.921, p=0.056100).

The results of descriptive statistics for the length and width of beech (*Fagus sylvatica* L.) seed from different altitudes in the area of Velebit in 2007 are given in Table 5.

Table 5 Descriptive statistics for length and width of beechnut (*Fagus sylvatica* L.) from different altitudes in the area of Velebit in 2007
Tablica 5 Deskriptivna statistika za duljinu i širinu sjemena bukve (Fagus sylvatica L.) sa različitih nadmorskih visina na području Velebita u 2007. godini

Locality-*Lokalitet*	N	Lenght of beechnut (mm)-*Duljina bukvice (mm)*						Width of beechnut (mm)-*Širina bukvice (mm)*					
		Mean	Median	Minimum	Maximum	Variance	Std. Dev.	Mean	Median	Minimum	Maximum	Variance	Std. Dev.
Pod Pogledalcem	30	16,33	16,14	14,55	18,29	1,09	1,04	8,63	8,62	7,64	10,17	0,52	0,72
Mala Snježnica		15,33	15,52	10,70	16,89	1,22	1,11	8,97	9,07	6,92	10,14	0,84	0,92
Velika Stražbenica		14,50	14,58	12,05	17,40	1,61	1,27	7,47	7,57	5,24	10,20	0,96	0,98
Santinova Ložnica		16,21	16,02	13,81	18,43	1,48	1,22	8,20	8,15	7,32	9,49	0,24	0,49
Snižnica		15,54	15,85	12,00	17,74	2,34	1,53	7,87	7,94	6,38	9,06	0,53	0,73
Krecelj		14,72	14,94	11,84	16,09	0,60	0,78	7,91	8,00	6,03	8,66	0,33	0,58
NP Sjeverni Velebit		15,33	15,54	12,06	17,73	1,04	1,02	7,90	7,78	6,83	9,42	0,48	0,70

Beechnut from the locality Pod Pogledalcem was the longest (16.33 mm) and that from the locality Velika Stražbenica was the shortest (14.50 mm). The average beechnut length for the investigated localities was 15.42 mm. Beechnut from the locality Mala Snježnica was the widest (8.97 mm) and that from the locality Velika Stražbenica was the narrowest (7.47 mm). The average beechnut width for the investigated localities was 8.14 mm. Variance analysis provided a statistically significant difference in beechnut length (F=10.50; p=0.000000) and width (F=14.04; p=0.000000) in terms of the studied localities (Figure 3). Tukey's HSD test was used to establish statistically significant differences in beechnut length between the localities Pod Pogledalcem and Mala Snježnica (p=0.014191), Velika Stražbenica (p=0.000026), Krecelj (p=0.000027) and NP North Velebit (p=0.013979). Statistically significant differences were also obtained between the localities Mala Snježnica and Santinova Ložnica (p=0.049107), Velika Stražbenica and Santinova Ložnica (p=0.000026), Velika Stražbenica and Snižnica (p=0.008836), Santinova Ložnica and Krecelj (p=0.000037), and Santinova Ložnica and NP North Velebit (p=0.048478). Tukey's HSD test yielded statistically significant differences in beechnut width between the localities Pod Pogledalcem and Velika Stražbenica (p=0.000026), Snižnica (p=0.001843), Krecelj (p=0.003608) and NP North Velebit (p=0.002830). Statistically significant differences were also obtained between the localities Mala Snježnica and Velika Stražbenica (p=0.000026), Santinova Ložnica (p=0.001278), Snižnica (p=0.000026), Krecelj (p=0.000026) and NP North Velebit (p=0.000026). There was also a difference in beechnut width between the localities Velika Stražbenica and Santinova Ložnica (p=0.002811).

Variance analysis did not confirm any statistically significant difference between beechnut width and yield rate (F=1.63, p=0.198194), but a statistically significant difference was found between the variables beechnut length and yield rate (F=20.95, p=0.000000). The average beechnut width at medium yield was 7.91 mm, at good yield it was 8.11 mm, and at very good yield it was 8.23 mm. Tukey's HSD test found a statistically significant difference in beechnut length and medium and very good yield rates (p=0.000022), and between good and very good yield rate (p=0.000022). The average beechnut length at medium yield was 14.72 mm, at good yield it was 15.05 mm, and at very good yield it reached 16.03 mm (Figure 4).

Cumulative laboratory seed germination of beech (*Fagus sylvatica* L.) from different altitudes in the area of Velebit in 2007 is presented in Figure 3.

The highest germination percentage after 8 weeks of stratification was manifested by beechnuts from the locality Krecelj (9.00%), and the lowest by those from the locality Mala Snježnica (0.50%). The

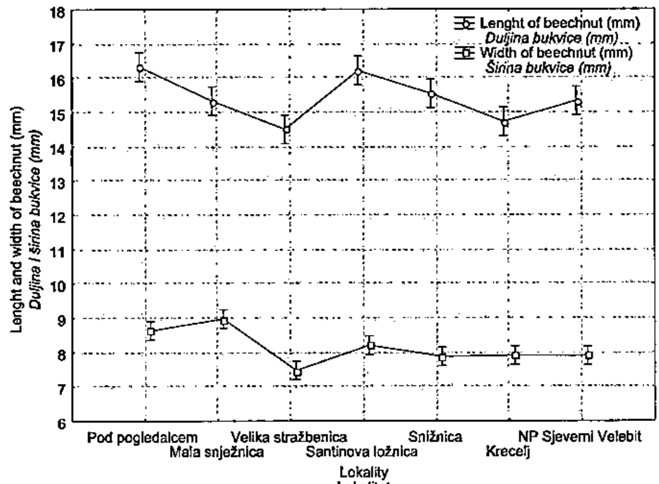

Figure 3 Length and width of beechnut (*Fagus sylvatica* L.) from different altitudes in the area of Velebit in 2007
Slika 3 Duljina i širina sjemena bukve (Fagus sylvatica L.) sa različitih nadmorskih visina na području Velebita u 2007. godini

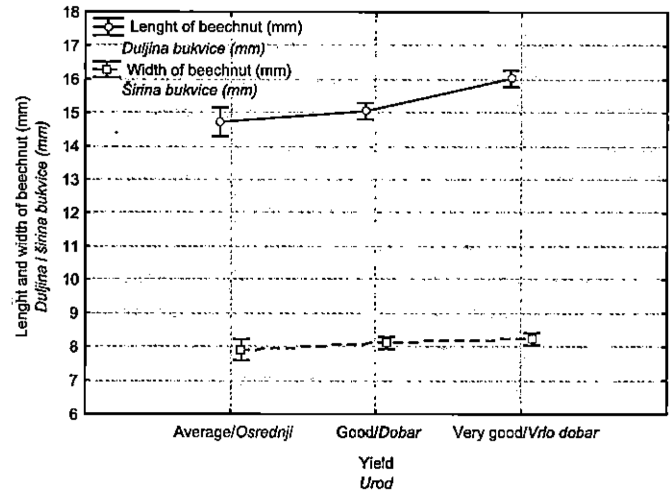

Figure 4 Length and width of beechnut (*Fagus sylvatica* L.) with regard to yield rate
Slika 4 Duljina i širina sjemena bukve (Fagus sylvatica L.) s obzirom na stupanj uroda

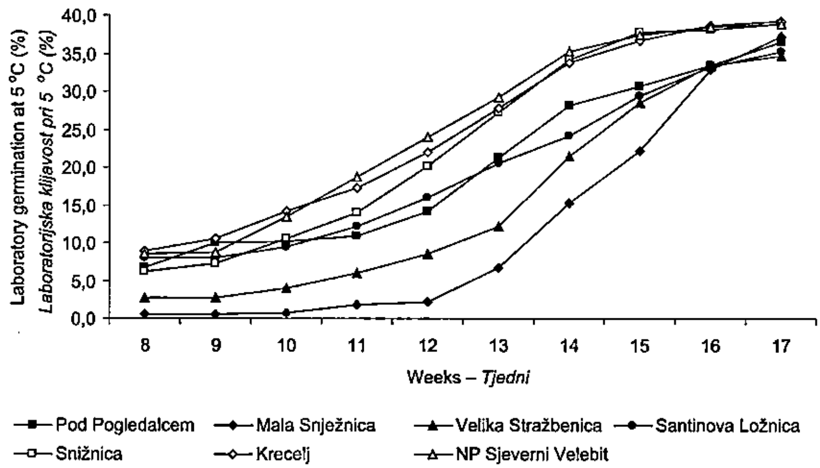

Figure 5 Cumulative presentation of laboratory seed germination of beech (*Fagus sylvatica* L.) from different altitudes in the area of Velebit in 2007
Slika 5 Kumulativni prikaz laboratorijske klijavosti sjemena bukve (Fagus sylvatica L.) sa različitih nadmorskih visina na području Velebita u 2007. godini

average beechnut germination at the end of 8-week stratification amounted to 5.96%. At the end of testing, the highest laboratory germination, equal to that in the eighth week, was exhibited by beechnut from the locality Krecelj (39.25%), and the lowest by beechnut from the locality Velika Stražbenica (34.75%) The average laboratory beechnut germination after 17 weeks of testing in sand at a constant temperature of 5°C was 37.29%. Correlation analysis showed a positive and significant correlation between beechnut viability and its germination on the eighth week in the stratifying medium (R= 0.39919). Correlation between beechnut germination on the eighth week in the stratifying medium and total laboratory germination is also positive and significant (R= 0.40364). Correlation between beechnut germination in the eighth week in the stratifying medium and the altitude of seed provenances is positive and significant (R= 0.53016), and so is correlation between total laboratory beechnut germination and the altitude of seed provenances (R= 0.47954). Accordingly, an increase in the altitude significantly increases total seed germination in the laboratory.

DISCUSSION
RASPRAVA

According to Rehder (1940), the genus *Fagus* L. comprises 10 species of medium tall trees which occur naturally in temperate zones of the northern hemisphere. Of all woody and economically important forest species in Croatian forests, common beech is the most widely spread and inhabits all the three regions (Pannonian, Dinaric and Mediterranean). It covers an area of 921,882 ha or 44.72% of the total forested area. There are no artificially raised beech forests or forest cultures in the Republic of Croatia, because natural regeneration is the only method of beech forest regeneration. Natural regeneration is the basic prerequisite for their biological diversity, productivity and stability (Matić 2003a).

Beech is a species that is currently in the optimum of its biological potential, as confirmed by the fact that it thrives on all lithological bedrock, including volcanic lava, eruptive and metamorphic silicate rocks, silicate sandstones, limestones and dolomites, etc. It colonizes all expositions, grows on a broad soil spectre ranging from distinctly acid to extremely basic and in the orographic sense occurs in all vegetation belts, from planar to subalpine one. According to Matić (2003b), beech is the only tree species in Europe that occurs naturally at altitudes from 100 m to as much as 2,000 m. Beech is found in all vegetation belts of continental Croatia in an altitudinal range from 100 to 1,500 m. In the pre-alpine belt of the Dinaric mountains, above beech-fir forests and before the belt of mugho pine, beech again builds pure stands which often form the upper boundary of forest vegetation, as is the case with the localities Bjelolasica (1.533 m a.s.l.), Risnjak (1,528 m a.s.l.), Viševica (1,428 m a.s.l.), and with numerous mountain tops of Velebit.

For this research, beech yield was registered and beech seeds were collected from 7 localities in the area of northern Velebit from altitudes ranging between 521 and 1,535 m a.s.l. According to Regent (1980), beech flowers from April to May and the fruit (beechnut) matures from September to October of the current year, to fall shortly after the first frosts. In terms of beech seed yield intervals, there are differences from author to author. Dirr and Heuser (1987) write that beech yield varies from year to year and that a good yield cannot be expected every year. Regent (1980) reports that beech bears fruit every 7-12 years, while Seletković and Tikvić (2003) state that intervals of ample seed yield occur approximately every 5-8 years. According to Young and Young (1992), common beech begins fructifying at 40-80 years of age, with intervals of 2-20 years. Oršanić et al. (2005) write that beech stands in Croatia put forth full mast every 5-10 years in warmer sites and every 8-12 years in colder ones. Övergaard (2010) states that until the end of the 17th century, the interval of full beech mast was about five years, but during the past 30 years it has been 2.5 years. Full beechnut yield is usually preceded by warm and dry July the previous year. Matthews (1955) obtained a positive correlation between beech yield rate and air temperature and the number of sunny days in July of the previous year. Among others, beech yield was investigated by Matyas (1965) and Schmidt (2006). Literature sources rarely mention seed quantities in good mast years; in other words, yield is often expressed only qualitatively. According to Henriksen (1988), it takes at least 500,000 vital seeds ha^{-1} (50 seeds m^{-2}), whereas Huss (1972) states that there should be a minimum of 20 seedlings per m^2 to ensure good quality natural regeneration. Övergaard (2010) writes that there is a big difference in beechnut quantity between good and bad mast years. During good years, beechnut yield is counted in millions or hundreds of thousands of seeds at least, whereas during bad years the quantity of seeds reaches only several thousand. Bilek et al. (2009) emphasise that a good beechnut yield in the current year negatively affects the yield of the following year. Late spring frost is the main limiting factor of seed fructification on the northern boundary of the natural distribution range of beech, while dry summers impede fructification on the southern boundary (Peters 1997). In the eastern part of the range, beech flowers more frequently from e.g. Western Europe, but this phenomenon does not affect yield frequency (Standovár and Kenderes 2003). Seed bearing and plant survival are also influenced by insects, fungi and birds. According to Suszka et al. (1996), full beech mast can be expected every 5-10 years and partial every 3-5 years. Yield periodicity depends on microclimatic conditions. In some years the yield is completely absent, even in solitary trees, while in other years only some individual trees may bear seeds; however, the seeds are generally empty. According to the same authors, beechnuts that fall off first in September are usually of very bad quality, empty or infected by insects. Šindelář (1993) also states that beechnuts begin to fall off in September and reach their maximum in the second part of October. Fructification is also affected by the phenology of individual trees (early or late flowering), the social position in a stand (height classes according to Kraft), and the position within a stand. Thus, yield quantities may vary significantly within one locality (Standovár i Kenderes 2003). Long-term investigations of beech seed yields in England revealed high variability between trees and mast years (Harmer 1994). Oddou-Muratorio et al. (2010) report on the limited capacity of beech seed dispersal to a distance of 10.4 m and pollen to a distance of 41.63 m. In their research into impacts of snow accumulations on the survival of *Fagus crenata* seed, Shimano and Masuzawa (1998) conclude that about 70% of the beechnuts are spared from mouse damage in the sites with a thicker snow cover during winter, and that about 70% of the survived seeds successfully germinate in the spring. In contrast, most beechnuts were mouse damaged in the sites with a thinner show cover, while the remaining, healthy beechnuts degenerated through desiccation during winter. This research can be correlated with our research, in which we recorded a smaller percentage of damaged seeds in the localities at higher altitudes, where there are thought to be fewer beech seed predators. In our research, the beech seed yield of 2007 ranged from none in the MU Senjska Draga to very good in the MU Bršljun, Lom and Senjsko Bilo, which coincides with claims by Harmer (1994) on high yield variability among the trees. In terms of the average yield in the study area, it can be concluded that it was between medium and good. It should be emphasised that yield rate did not drop with an increase in the altitude of the studied localities. In fact, it was completely absent at the lowest altitude.

Morphometric research by Yilmaz (2010) on 14 different provenances of oriental beech (*Fagus orientalis* Lipsky.) showed high variability within and between the populations. Beechnuts from some provenances were long and moderately heavy, whereas some others were thick, wide and heavy. Regardless of the provenances, the highest and the lowest correlations were found between the length and width (0.697), and weight and length (0.307). There is very little research into common beech seed of a similar kind. Gradečki (2003) reports the average seed length of 14.89 mm in the range of 11.31-16.20 mm, and the average width amounting to 9.53 mm in the range of 7.63 - 10.34 mm. Seed size showed good direct correlation with seed mass. In our research, beechnut length and width also differed significantly with regard to the studied localities. The average beechnut length for all the localities was 15.42 mm in the range of 14.50 - 16.33 mm, which is very similar to the results obtained by Gradečki (2003). The average width was 8.14 mm in the range of 7.47 - 8.97 mm. A statistically significant difference was obtained between beechnut length and yield rate. In other words, an increase in yield rates results in increased seed length.

Thomsen and Kjaer (2002) report on the significant difference in seed weight, germination percentage, dormancy and seed yield of beeches from different families. Seed weight was significantly correlated with the year of research, which may indicate the genetic hereditary property. Seed weight was also significantly correlated with seed germination from the yield of 1995, but not from that of 1993. According to Young and Young (1992), the average beechnut weight is 4.6 g, which is significantly more that the values obtained by our research, where beechnut weight ranged from 0.21 to 0.31 g, or 0.24 g on average.

Stjernquist (2010) reports that rain reduces endosperm mass and the total quantity of essential nutrients in the seed, but also stimulates the reduction of endosperm mass at all crown levels. Future research should include the chemical soil composition in the immediate vicinity of the trees from which the seeds are collected. According to Bonner and Leak (2008), one hl contains from 50 to 53 kg of fresh, or from 39 to 45 kg of air dried beech seed. The same source mentions that 1 kg has from 4,000 to 6,200 pieces of pure beech seed or 4,630 pieces on average. Gradečki (2003) reports that 2,000 g contains on average 4,098 seeds in the range of 6,062 – 10,000 pieces. It is reversely proportional to seed mass. According to the same author, the average seed weight in one hectolitre is 450 N in the range of 330 – 580 N. Suszka et al. (1996) write that 1 kg contains from 3,000 to 5,000 of beechnuts with a moisture content of 25%, or 3,500 to 5,800 pieces with a moisture content of 8%. According to this author, 1 hl contains about 50 kg of fresh or 39 to 45 kg of dry beechnuts. According to Šmelkova (2001), 1 kg of seeds contains an average of 4,300 beechnuts with average germination of 70%, purity of 90% and the proportion of full seeds of 90%. The WSL catalogue, Versuchsgarten (1991), lists 3,700 to 4,700 pieces of beechnut in one kg. According to Žgela (2002), there are on average 4,300 beechnuts in one kg, while Regent (1980) counted 4,600 pieces in one kg, which is slightly more than the quantity of 3,226-4,762, or 4,167 pieces on average obtained in our research. According to Šmelkova (2002), the weight of 1,000 seeds or the absolute beechnut weight is 234 g, and according to Suszka et al. (1996), the weight is between 150 and 300 g, or 250 g on average. In one of their investigations, Roth et al. (2005) found that 1,000 beech seeds weighed 237 g, whereas according to WSL h Versuchsgarten (1991), their weight varied between 210 and 270 g. Gradečki (2003) cites the average seed mass of 258 g in the range of 100.331 g. In our research, the average weight of 1,000 seeds was 118.9 g, which is much less that the data put forth by the above mentioned authors. The highest absolute weight of 1,000 seeds (150.6 g) was obtained in the locality Pod Pogledalcem at the lowest altitude, but this can be attributed to the method of seed collection in this area. A negative and significant (r= -0.6315) correlation was obtained between the altitude of a locality and the weight of 1,000 seed; in other words, an increase in the population altitude leads to a significant decrease in the weight of 1,000 seeds. This can, among others, be attributed to microclimatic features. The awareness of this pattern may be interesting from the aspect of nursery production of beech seedlings. In order to reach an accurate answer on the influence of altitude on beechnut weight, research should be repeated in several more localities. Research by Gračan et al. (2006) indicates the existence of differentiation, both between and within the provenances of common beech in Croatia.

Beech seed is characterized by deep embryo dormancy which blocks germination of a vital and mature embryo even when it is isolated from the seed and placed into optimal germination conditions (Bewley and Black 1994). Barthe et al. (2000) also report that at the moment of collection beechnut has well developed deep dormancy because of the embryo and the outer fruit structure. The fruit pericarp inhibits embryo germination because it prevents water uptake and gas exchange. Fluridone, a pyridine inhibitor of carotenoid synthesis, is important in ABA biosynthesis, which plays a key role in embryo dormancy of beech seed. According to El-Antably (1976) and Suszka et al. (1996), embryo dormancy can be overcome with cold-moist stratification at temperatures from 2-5°C, with or without a substrate. The time period required to overcome dormancy is long and lasts 5-8 weeks, and in some cases for as many as 12 weeks (Muller and Bonnet-Masimbert 1982). In our research, beechnut began germinating on week eight in the stratifier at a temperature of 5°C, which coincides with the data by Muller and Bonnet-Masimbert (1982). On the other hand, Gradečki (2003) reports that previous treatment of the seed in cold storage at a temperature of +3°C to +5°C for 60 days did not prove efficient in overcoming beech seed dormancy, because without additional moisture the seeds became too dehydrated. The key factor for successful beech seed stratification is the seed moisture content, which should not be above 30% (Muller and Bonnet-Masimbert 1983). Krawiarz and Szczotka (2008) stress that during stratification at 3°C, there is an abrupt increase in the activity of amino acid arginine (ADC) and enzyme ornithine decarboxilase (ODC) in the embryonic cavity (from week 7) and cotyledons (from week 8).

According to Kolářová et al. (2010) there is no statistically significant difference in germination capacity between non-treated dormant beechnuts, beechnuts treated with tap water and beechnuts treated with ethephon or GA_3. Ethephon and GA_3 treatment reduces germination capacity if applied to the seed previously subjected to stratification for four weeks. The effect of ethephon and GA_3 on germination rate or energy and on overcoming dormancy increases significantly if beechnuts are stratified for four weeks prior to the treatment. The effect of GA_3 on mean germination time of stratified beechnuts did not prove important in comparison with dormant non-treated beechnuts. A shorter mean germination time was achieved with seeds soaked in 1,000 mg·l^{-1} GA_3 prior to germination. Compared to the beechnut soaked in running water, the application of GA_3 shortens the period of cold stratification by three weeks. In our research, the largest amount of seeds germinated after 14 weeks in the stratifier on average, while average germination on week eight was 5.96%. On average, the smallest amount of seeds germinated in the ninth week in the stratifier (0.86%). According to ISTA (2006), beechnut germination is tested in sand and at a temperature of 3-5 °C, with a note that the duration of testing depends on dormancy and that in some exceptional cases it may last for 24 weeks. Since the seed is dormant, the ISTA rules (2006) suggest that, instead of testing germination, seed viability should be tested with the tetrazolium method. Foffová and Foff (2003) write that the tetrazolium test and the germination test of beech seed give variable results, which indicates subjectivity in the assessment of stained seed parts or regular, irregular and non-germinated seeds. In terms of drying and storage, Gosling (2007) classifies beech seed into the "*Intermediate*" group, while in terms of dormancy he places it in the group of deeply dormant species. To overcome dormancy, he proposes cold stratification of 16 (12-20) weeks at a temperature of 4°C. Young and Young (1992) report on germination of untreated beech seed of 14%. Seeds kept in cold stratification for 120 days manifested germination of 67%. The same authors write about 100%-germination of freshly collected and stored seeds, which were cold stratified for 5 months.

The key element of good seed germination is healthy seeds. The pericarp of a healthy seed is light brown in colour. Gradečki et al. (2006) report on the low average value of laboratory germination of beech seed, which was between 1 and 37%, or 12% on average. The average proportion of fresh, non-germinated seed ranged from 1-5%, or 5% on average, of diseased and rotten seed from 24-81% or 62% on average, and empty seed from 1-70% or 19% on average. Šmelkova (2001) reports on the average beechnut germination of 70%, whereas according to WSL Versuchsgarten (1991) it varies between 50 and 80%. The results of research by Rezaii et al. (2010) into the seed of *Fagus orientalis* Lipsky showed a favourable effect of stratification on germination. Significant variations were obtained between provenances and duration of seed stratification. In our research, average laboratory germination amounted to 37.3%, which coincides with the data by Regent (1980), who reports on average germination of 35%. Differences in seed germination in individual localities can be the result of varying degrees of seed dormancy. In the same locality, the degree of seed dormancy can vary from year to year or within the same year by provenances (Wang 1976, 1980). With this in mind, it would be advisable to repeat investigations in the same localities. The degree of dormancy is influenced by the nutrition status and water status of mother trees, as well as by climatic conditions during maturation. Accordingly, seeds should not be collected from several trees or one tree and the results should not be related with provenances. According to Villiers (1972), higher temperatures in the vegetation period may cause deeper dormancy than usual. In some tree species, seed dormancy may vary in relation to geographic distribution (Viliers 1972, Wang and Haddon 1978).

A positive and significant correlation was established between altitude and total laboratory seed germination (r= 0.48350), or laboratory germination on week eight (r= 0.53016), which suggests that laboratory beechnut germination increases significantly with an increase in the altitude of the populations. The trend is visible as early as the eighth week of testing. This can be explained, among others, by a lower average air temperature at higher altitudes in relation to the lower ones, and consequently, less developed seed dormancy at higher altitudes.

According to Ratajczak and Pukacka (2005) and Pukacka and Ratajczak (2007), substances that could play a key role in maintaining seed viability are phenols, α-tocopherol, sterols, ascorbic acid, glutathione and soluble proteins. Germination capacity is positively and strongly correlated with amounts of total phenolic compounds, ultraviolet (UV-) absorbing phenols and soluble proteins. According to Gradečki (2003), the average beechnut viability was 69 % (10-90 %), and the average proportion of empty seed was 19 % (1--50 %).

Procházková and Bezděčková (2008) provide data on the viability of three seed lots of beech from different altitudes. Beechnut viability of the first lot from an altitude between 601 and 700 m was 85%, of the second lot from an altitude between 551 and 600 m was 66-68%, and of the third lot from an altitude of 551-600 m was 83%. In this research, the highest viability (90%) was obtained at the lowest altitude of 521 m. Gradečki (2006) reports that beech seed viability tested with the tetrazolium method provided a higher result than that obtained with a germination test. Seed viability ranged from 10-90% or 72% on average, the proportion of empty seed was 0-50% or 15% on average, while the proportion of non-vital (diseased) seed amounted to 13% on average. Our research also confirmed the already established fact that much higher results are obtained with seed viability assessment than with germination tests. The average viability was 81.4%, which is somewhat higher than the data cited by Gradečki et al. (2006). An amount of 10.3% of empty and 4.4% of diseased seed was found on average, which is less than the results reported by Gradečki et al. (2006). According to Ratajczak and Pukacka (2005), the loss of viability in beechnuts strongly correlates with an increase in membrane permeability and the formation of lipid-hydroperoxide (LHPO) as an indicator of peroxidation of unsaturated fatty acids. During storage time, concentrations of individual phospholipids and fatty acids decrease proportionally with the loss of viability. Decreased vitamin E (α-tocopherol) and sterol concentrations were recorded, which have an important role in protecting the membrane from harmful environmental impacts. Beechnut germination capacity abruptly decreases at temperatures above 0°C and in high moisture conditions. This happens mainly because peroxidation of unsaturated fatty acids weakens the membranes.

Tylkowski (2002) writes that the majority of beech seed lots are characterized by different levels of infestation with pathogenic fungi of the genera *Fusarium, Rhizoctonia* and *Cylindrocarpon* spp. Research into beechnut mycoflora revealed the most frequent saprophytic fungi, as well as fungi causing diseases: *Alternaria alternata, Arthrobotrys superba, Botrytis cinerea, Fusarium* spp., *Penicillium* spp., *Trichotecium roseum, Mucor* sp., *Graphium* sp. and *Chaetomium* sp. (Novak Agbaba et al. 2003).

According to Wang (2003), the percentage of empty seeds from 91 trees in the same locality ranged from 4.8 to 40.9% and had the form of normal distribution. The average percentage of empty seed was 21.4%, which is much higher than the percentage obtained in our research. The percentage of repeatability of empty seeds was 43.4%. Self-pollination is an important cause of the occurrence of empty beech seeds. Our research found a positive and significant correlation between altitude and the percentage of empty seeds; with an increase in the altitude of a locality the quantity of empty seed increases significantly, which can, among others, be explained by a higher rate of self-pollination. In many forest tree species, controlled self-pollination results in a higher share of empty seed, unlike cross-pollination or wind pollination (e.g. Nielsen and Schaffalitzky De Muckadell 1954, Dieckert 1964, Sorensen 1971, Park and Fowler 1982, Kormutak and Lindgren 1996). Genetically speaking, empty seed in forest tree species can arise from incompatibility (Nielsen and Schaffalitzky De Muckadell 1954, Yazidani and Lindgren 1991) or embryo degeneration, which may be the consequence of inbreeding. Apart from genetic factors, empty seed in forest trees may also occur as the result of environmental factors, such as limited pollen quantities (Colangeli and Owens 1990) and insect damage (O'reilly and Farmer 1991). Cross-pollination in species that are wind-pollinated is positively correlated with stand size and flower density.

The average nursery germination of beech seed (Gradečki et al., 2006) is very low and reaches only 3%. The relationship between laboratory and nursery germination coincides relatively well. Future research should focus on investigating nursery germination of beechnut from different altitudes in order to gain a realistic picture of this important biological property of a seed. Insights gained by such research would be widely applicable in forest nursery production. A positive and significant correlation (R= 0.39919) was established in our research between beechnut viability and germination on week eight in the stratifier, and between beechnut germination on week eight and total laboratory germination (R= 0.40364). In other words, instead of the time-consuming procedure of testing beechnut germination in the laboratory, it is recommended to test beechnut viability. On the other hand, in the case of testing germination, a period of eight weeks can be considered a sufficiently reliable time to provide satisfactory results.

CONCLUSIONS
ZAKLJUČCI

Beechnut yield in the Velebit area in 2007 ranged from none in the MU Senjska Draga to very good in the MU Bršljun, Lom and Senjsko Bilo.

Beechnut from the locality Mala Snježnica 830 m a.s.l. demonstrated the poorest viability (76.5%) and that from the locality Pod Pogledalcem 521 m a.s.l. the highest (90.0%). The average beechnut viability for all the seven investigated localities was high and amounted to 81.4%. Correlation analysis established a negative and significant correlation between altitude and non-vital unstained beechnut seed (r=-0.5192). A correlation between altitude and empty (non-vital) beechnut seed was positive and significant (r= 0.69452).

The weight of 1,000 seeds was the highest in the locality Pod Pogledalcem (150.6 g) and the lowest in the locality Velika Stražbenica (99.5 g). The average weight of 1,000 seeds was 118.9 g. A negative and significant correlation (r= -0.6315) was established between altitude and weight of 1,000 seeds.

On average, beechnut in the locality Pod Pogledalcem was the heaviest (0.31 g), and that in the locality Velika Stražbenica was the lightest (0.21 g). The average beechnut weight from all the seven localities was 0.24 g. A statistically significant difference was confirmed in beechnut weight with regard to the studied localities.

Variance analysis did not establish any statistically significant difference between beechnut width and yield rate, whereas there was a difference between the variables beechnut length and yield rate. Tukey's HSD test revealed a statistically significant difference in beechnut length and yield rate, described as average and very good, and good and very good. The mean beechnut length at average yield was 14.72 mm, at good yield it was 15.05 mm, and at very good yield it was 16.03 mm.

Total laboratory germination of beechnut after 17 weeks of testing in sand at a constant temperature of 5°C was the highest in the locality Krecelj (39.3%) and the lowest in the locality Velika Stražbenica (34.8%), with average germination amounting to 37.3%. The correlation between altitude and laboratory seed germination was positive and significant (r= 0.48350). The correlation between beechnut germination on week eight in the stratifier and the altitude of seed provenances was positive and significant (R= 0.53016), and so was the correlation between total laboratory germination of beechnut and the altitude of seed provenances (R= 0.47954). This indicates that total seed germination in the laboratory increases with an increase in altitude.

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MODEL OF COMPENSATION PAYMENT TO THE OWNERS ON NATURE 2000 FOREST SITES

MODEL PLAĆANJA NAKNADE VLASNICIMA NA ŠUMSKIM LOKALITETIMA NATURE 2000

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Abstract

Ecological Network (Natura 2000) is a system of areas for protection of endangered species and habitats on European Union level and presents the biggest coordinated network of nature protection areas in the world.

When Croatia becomes the member of EU, its biological and landscape biodiversity will be a part of this network. According to the Regulation on habitat type categories, habitat map, endangered and rare habitat types (NN 7/06, NN 119/09) which includes National habitat classification, forest ecosystems have 104 categories (NN 7/06).

Regardless of the interpretation method, there are three evaluation methods: according to the historical costs (time of establishment), current market value, and evaluation through expected participation in future incomes and benefits. Forest evaluation needs determining of economical (wood and secondary forest products), non-wood forest functions (ecological and social), and assimilation of forest functions. For those purposes, different market and non-market evaluation methods, as well as qualitative description methods and point systems have been used.

Key words: forest economics, forest policy, value assessment, Natura 2000

Sažetak

Ekološka mreža (Natura 2000) je sustav područja za očuvanje ugroženih vrsta i staništa na razini Europske unije i predstavlja najveću koordiniranu mreža područja očuvanja prirode u svijetu. Kada Hrvatska postane članicom Europske unije svoju će biološku i krajobraznu raznolikost uključiti u tu mrežu. Prema Pravilniku o vrstama stanišnih tipova, karti staništa, ugroženim i rijetkim stanišnim tipovima (NN 7/06 , NN 119/09) koji uključuje Nacionalnu klasifikaciju staništa, na šumske ekosustave odnose se 104 kategorije (NN 7/2006). Neovisno o načinu interpretacije, postoje tri načina vrednovanja vlasništva: prema povijesnim troškovima (vremenu nastanka), sadašnjoj tržišnoj vrijednosti, i kroz očekivano sudjelovanje u budućim prihodima i koristima. Vrednovanje šuma iziskuje utvrđivanje vrijednosti gospodarskih (drvo, sporedni šumski proizvodi), općekorisnih (ekološke i socijalne funkcije) i asimilacijskih funkcija šume. U tu svrhu se koriste različite tržišne i netržišne metode procjene, ali i metode kvalitativnog opisivanja i bodovni sustavi

***Ključne riječi:** ekonomika šumarstva, šumarska politika, utvrđivanje vrijednosti, Natura 2000*

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INTRODUCTION
UVOD

It is considered that natural resources are a given and that they represent a fixed offer because in many cases they can not be quickly increased or are difficult to discover or multiply. For example, forests in some areas increase, almost always in a certain quantity; mineral resources like coal, oil, mineral iron and many others regenerate very slowly on their own and are therefore considered non-renewable. However, many basic resources can be increased or at least transformed from one into another usable form. Forest can be regenerated with caring sustainable management. Based on this, natural resources are defined as production factors – inputs (costs), which, combined with human mental, entrepreneurial and physical labour as well as with capital, produce goods and services.

Natural resources are considered unique input factors; out of which many have features that make them similar to capital factors. Foremost, in order to be used for consumption or in the production process, the majority of natural resources must be separated, dug, cut, etc.

Time is also an important precondition in analysis of natural resources use. It helps in distinguishing different types of resources. Annual adjustments can not be done in forest management. Improvements or aggravations which can arise as a result of economic, management or forest management and silvicultural interventions, become visible only after several years. For this reason, the role and possibility of implementing technological rationalizations is minor. Forest management on forest and forest land is based on the Forest management plan made by the company Croatian forests ltd, approved by the Ministry of Agriculture. Present Forest Management area plan is valid from the year 2006 to 2015 with management projections until the year 2045. The Plan represents the base for the Croatian forest policy and is revised every 10 years. According to that document the total forest land in Croatia covers 2688687 ha, out of which private forests take 22% and state forests 78%. The average growing stock according to the First National forest inventory is shown in table 1.

Table 1. Grow stock (source: First national forest inventory RH 2010)
Tablica 1. Drvna zaliha (izvor: Prva nacionalna inventura šuma RH 2010)

Ownership *Vlasništvo*	Grow stock *Drvna zaliha*						
	Total area *Ukupna površina*					Area without young stands *Bez mladih sastojina*	
	Grow stock *Drvna zaliha* (α=0,05)			*sp*	Udio *Share*	Grow stock *Drvna zaliha*	*sp*
	m^3/ha	1000 m^3		%		m^3/ha	%
State forests *Državne*	255,57	468035	458112 - 477957	2,12	84,61	278,16	2,21
Private forests *Privatne*	155,84	85143	80775 - 89511	5,13	15,39	170,26	5,36
Total *Ukupno*	232,22	552146	541103 -563189	2,00	100,00	253,45	2,09

NATURA 2000 is a basic program of European Union nature protection whose aim is to provide favourable conditions for endangered species and habitats through establishing ecological network of the most important areas for their preservation. All EU member states are obliged to proclaim this network on their territories, as well as establish a suitable management system and systematically follow the condition of preservation of each specific species and habitat stated in the annexes of Directive on protection of natural habitats and wild fauna and flora, and report regularly on the matter to the European Commission. Monitoring reports are fundamental for following the implementation success of the NATURA 2000 program. Altogether, for the needs of NATURA 2000, 241 localities of the total surface area of 41 666 ha or 2.5 % of forest in the Republic of Croatia have been suggested (Vukelić et. al. 2008). Different levels of nature protection will limit and change present activities of private forest owners and therefore decrease their income. One of the main aims of NATURA 2000 is to ensure implementation of measures necessary for preservation with the least possible limitations and with implementing appropriate remuneration and incentives for users of an area. The basis of implementing Natura 2000 network in forestry sector means respecting the principles of sustainable management (EK, 2003). Implementation of this general viewpoint shows certain regional differences – in middle and North-Western Europe the majority of Natura 2000 areas are either small or medium sized, and forests within those areas are managed according to the strict principles of nature protection. On the other hand, in South and East Europe the majority of Natura 2000 areas are vast expanses managed through supporting the traditional ways of land usage such as forestry and agriculture. Certain Natura 2000 areas contain species and habitats of priority European interest, in which all economic activities are forbidden. But, as already stated, in most forest locations within Natura 2000 network in Eastern and Southern Europe it is enough to comply with the principles of sustainability in their management (in accordance with Annex I. And Annex II. Of the second Lisbon resolution from 1998 within MCPFE process).

Before full EU membership, the applicant country is obliged to submit its proposal of Natura 2000 areas, a list of measures for managing those areas and a list of areas for which co-financing is needed in order to achieve favourable preservation conditions of species and habitats of European interest. After that, European Commission reviews the areas in need of co-financing, in which the main criteria are the representative quality of the area and availability of financing sources. For the areas recognized by the Commission as areas in need of co-financing for which there is no adequate funding, member state must ensure that there are no activities which might disturb its preserved condition. It is estimated that annual cost of implementing Natura 2000 network on the level of 25 EU countries is about 6.1 billion € (EK, 2007)

AIMS AND PROBLEM MATTERS
PROBLEMATIKA I CILJEVI RADA

Determining the total economic forest value, as well as the value of a particular function is needed for effective management of natural resources and better making of investment decisions in forestry (Figurić 1996). The classical forest evaluation methods are based on calculation of growing stock value (stand) and land value. Quantitative inventory is conducted on stand level (forest unit), due to the heterogeneous characteristics based on stand quality, coverage, tree species etc.

Some stands have different biological parameters and evaluation methods because of their different location (Posavec et. al. 2006). Received incomes depend on the transport costs and on possibility of using different working methods and assets. In practice, for assessment of forest and forest land value specific regulations are used. There is a need to define production costs for growing stock (stand establishment costs, silviculture, protection and administrative costs) which is almost impossible due to long production process. All these facts make the assessment complicated and specific individual approach is need. In cases where it is possible to calculate material incomes and costs, the yield of money will still be dependent on the insecure wood price fluctuation. Forest resources values are not constant, but are constantly changing according to the needs of the society (Karppinen 2000).

Legal regulation for financing of Natura 2000 network is the article II. Habitat directive, according to which, before making decisions about the Network, social, economic and cultural significance of the area should be taken into account. It is in line with article VII. EU Declaration on human rights, where it is defined that application of measures based on the EU regulations should accept principles of compensation for loss of income. According to the European Court of Justice (C-71/99 and C-220/99), definition of the Natura 2000 sites could be based only on the scientific knowledge. Other factors such as economic, social, cultural, regional or local could be taken in account for the development of area management plans (EK, 2006). EU funds for financing of NATURA 2000 network were closely tied to the

LIFE funds until the end of 2006. With the new joint agricultural policy from the beginning of 2007 network financing is a part of EU Cohesion and Structural Funds from the year 2007 until 2013 with the annual budget of 49.6 billion €. Access to those large sources of financing has a negative side – in comparison to LIFE funds, the currently valid calculation period demands much more significant involvement from the applicant and implies much bigger competition.

The main EU financing sources for NATURA 2000 network presently are:

- European Agricultural Fund for Rural Development –EAFRD with annual budget of 77.66 billion €.
- European Fisheries Fund (EFF), annual budget of 615 million €
- European Regional Development Fund (ERDF), annual budget of 1.9 billion €
- European Social Fund (ESF). The fund promotes social inclusion, education and training (annual budget of 10.7 billion €).
- Cohesion Fund. Fund gives support to Trans-European transport networks and to environmental project in compliance with Community environmental protection policy (annual budget of 10 billion €).
- LIFE+. Has three components: Nature and Biodiversity, Environmental Policy and Governance; Information and Communication (annual budget is 250 million €).
- 7th Research Framework Programme (FP7). The primary focus of Fund are trans-national researches related to environment (especially climate change) and to aeronautics. Research related to food, agriculture, fisheries and biotechnology are also eligible (annual budget is 7.2 billion €).

For reaching conservation goals on private forests another mechanism is introduced – Contract conservation. This instrument is meant to serve as a balance to forgone income due to implementation of the Natura 2000 network. By this scheme the landowners themselves can perform conservation measures, or they can be performed by third party (NGOs, contractors). The compensation can be in a form of direct payment, tax breaks, compensatory land-use right, etc. Direct payment are mostly decided on case-to-case basis, and can greatly vary; from 80 €/ha in Spain up to 4000 €/ha in Sweden (for the owners of agricultural and forest land).

There is no unique methodology for calculation of compensation to forest owners for discrepancy from "normal" management. The highest compensation to forest owners was 6898 €/ha/annually in Finland as a part of the METSO programme of NEWFOREX project.

Detailed theoretical analysis of different compensation models were made by Anthon et al. (2010), whose analysis discovers how such compensations often result in too high amounts considering results, because they do not take into account the moral risk of compliance with a contract and the natural variability of stand. Authors also recommend that forest owners who find it difficult to change the conditions in their forests should get contracts for low value compensations with no regard to the results of their implementation. On the other hand, active forest owners should be offered high value compensations through contracts offering a bonus if forest owner accomplishes significantly better stand conditions than with "normal" forest management.

The main forest resources in the Republic of Croatia are in state ownership. State Department for Natural Protection is responsible for implementation of NATURA 2000 network. What are the main financing instruments for NATURA 2000 network? Basically, the answer is simple, monitoring and reporting are responsibility of EU state members. Croatia will have to implement EU standards for nature protection before EU accession. Croatia has proposed NATURA 2000 sites for more than 250 species and 70 stand types.

Establishment of relevant compensation presents an important component for rural development regulated with Lisbon strategy. In article 224 of the Strategy 158 million euros are reserved for compensations. Only 5% of that amount is realised. Only 11 EU state members provide regulations for compensation payments.

In this paper, on the sample Educational and Experimental Forest Site Dotrščina, with use of modern forest evaluation methods and estimation of lower income in protected areas (such as: prohibition of management, hunting, collecting of non-wood forest product, lower annual cut, longer rotation period, care for preservation of endangered and rare wild species and continuous monitoring) possible calculation of compensation will be presented.

MATERIALS AND METHODS
MATERIJAL I METODE RADA

The object of research is Education and Experimental Forest Site Dotrščina (EWEFS), University of Zagreb, Croatia. Although the object is not included by Natura2000 proposal it is chosen because of data availability. Dotrščina was used as an example for determining the value of benefits for certain forest areas in the Republic of Croatia. EWEFS makes one management unit Dotrščina, size of 180.75 ha. The management unit is located in the northwest Croatia, Zagreb, and it is part of even-aged forests. Sub-compartment 2a is chosen as the research plot. Forest stand is size of 7.12ha, 49 years old and grows on IV site quality-class. Stand has normal canopy density, southwest exposure and it is located on altitude of 185 m. Middle age stands of sessile oak, beech, hornbeam and other hard broadleaves with a mixture ratio of 70:30 (sessile oak : beech). Sessile oak occurs in the upper canopy layer and the trees are of good quality, beech and hornbeam occur in lower layer.

Table 2. Structure of sub-compartment 2a, Management unit Dotrščina, at age of 49
Tablica 2. Strukturne značajke odsjeka 2a, Gospodarske jedinice Dotrščina u 49-toj godini starosti

Tree species *Vrsta*		Sessile Oak *Hrast kitnjak*	Beech *Obična bukva*	Hornbeam *Grab*	Other broadleaves *OB*	Total *Ukupno*
Site quality-class *Bonitet*		IV	IV	IV	IV	
Number of trees [N/ha] *Broj stabala* [N/ha]		291	251	153	10	705
Basal area [m²/ha] *Temeljnica* [m²/ha]		14,31	5,33	2,42	0,12	22,18
DBH 1,30 [cm] $d_{1,30}$ [cm]		27,50	17,50	12,50	12,50	
Height [m] Visina [m]		19,95	17,74	14,62	14,18	
Growing stock *Drvna zaliha*	[m³/ha]	149,42	46,95	17,84	0,87	215,08
	[m³/subcomp.]	1063,87	334,28	127,02	6,19	1531,36
	[%]	69,47	21,83	8,29	0,40	99,99
Current annual increment *Tečajni prirast*	[m³/ha]	5,36	1,80	0,71	0,04	7,91
	[m³/subcomp.]	38,16	12,82	5,06	0,28	56,32
	[%]	67,76	22,76	8,98	0,51	100,01

All data required for calculation were taken from Management plan Dotrščina (1994-2003).

Method
Metode

Methodology for determining of remuneration due to limited management was made according to the model made for the Republic of Finland (Leppane et. all 2005). Model adjustments were made for Croatian forest management system and legislative requirements.

The model determines the amount of compensation for the absolute prohibition of forest stands which are managed by even-aged system. It is primary to determine the current financial value of the forest sub-compartment, then a certain financial value at the end of the prescribed rotation. Payments for ecosystem services are also calculated but not considered in further calculations, because forest stand and forest land ownership does not change, only the economic functions are replaced with the protective one. From forest economics perspective the preferred payment method is a one-time fee.

The amount of one-time fee for forest plot ownership which is managed regularly is calculated by the formula (1)

$$(1)\ NPV = \frac{\dfrac{Cn}{U_{N-n}}}{\dfrac{r}{100}}$$

Where is: (*NPV*) net present value (amount of financial compensation), (*Cn*) value of forests at the end of the rotation, (*U*) time period from preservation to the end of the rotation (*N*), (*n*) current age of the stand, (*r*) interest rate.

The presented model is an adaptive model of a perpetual annul series. It is used when assessing the value of forests. Forest value should be equal to interest of amount invested in the bank perpetually. Interest rate is constant and interest stays equal perpetually, ie. $n \rightarrow \infty$ (Klemperer 2003).

According to the Ordinance of compensation establishing for the transferred and limited rights to the forest and forest land (NN 131/06) current estimate is made for researched sub-compartment.

Using data from the Management plan Dotrščina (growing stock by tree species), assortment tables Croatian Forests Ltd. Zagreb and the Price list of major forest products Croatian Forests value of growing stock on the stump is estimated.

The present cutting value method is an economic value of forest that can be calculated from selling prices of timber assortments. In this method of determining the economic value, forest is considered as a final product that can be cut and sold immediately. Consequently, this method is often recognized in literature as value of forest stand which is cut and sold at any age. To determine the value of the stand based on the amount of its assortments it is necessary to take prices of assortments. Content of assortments must be multiplied by current price. Obtained result is the market value of the stand. This value is very low for young stands and it grows with age of the stand.

Payments for ecosystem services were carried out according to the method prescribed in the Regulations establishing fees for the transferred and limited rights to the forest and forest land (NN 131/06). Also according to the same Regulations future value of growing stock was estimated of (for the end of the rotation).

$$(2)\ Cn = C_0 \cdot \left(1 + \frac{r}{100}\right)^n$$

To determine the future value of forest stand used in the formula (2), where is: (C_0) current growing value, (*r*) interest rate, (*n*) is the number of years, (*Cn*) future value.

For accurate assessment every tree species was separately investigated. According to the calculations of Croatian Forests Ltd, the reforestation cost of sessile oak stand is 6944.53 EUR / ha, which is in this case the invested equity. Costs related to the reforestation period refer to the first 20 years. It is therefore necessary that all costs are discounted to the start of the rotation using the formula (3).

$$(3)\ C_0 = \frac{C_n}{\left(1 + \dfrac{r}{100}\right)^n}$$

Interest rate determining is of great importance. The exact interest rate is the one which discounted all costs to rotation beginning and compounds them to rotation end. Computed value must be equal to estimated value using formula 2.

The interest rate was tested by Leibnitz's formula (4)

$$(4)\, r = 100\left(\sqrt[n]{\frac{C_n}{C_0}} - 1\right)$$

Where is: (r) interest rate, n time period (years), (Cn) value of forests at rotation end, (C_0) current value of growing value.

RESULTS
REZULTATI

On the basis of the above presented methodology the current stumpage value of forest is 3500.08€/ha. The growing stock in a 120 year old stand (end of rotation period) is estimated according to Increment-Yield tables and according to the Ordinance on forest management (Official gazette no. 111/2006). The researched stand falls into the management section of pedunculate oak, class IV. After determining growing stock using the sortiment tables of Croatian Forests Ltd. Zagreb, the future value of the forest on the end of rotation period was determined by application of the method of present yield value. The value of the stand at the end of rotation period is 12012,53 €/ha (Formula 2). Based on the field survey and the marking of the "ecological" functions of forest, the respective forest is marked with 31, and according to the Ordinance its value is 56375.83 €/ha.

Table 3. Value of forest sortiments for 1 ha, compartment 2a, at age of 49 years
Tablica 3. Vrijednost šumskih sortimenta za 1ha, odsjek 2a, u 49-toj godini starosti

Tree species *Vrsta*	Assortment Sortiment	Percentage[%] *Udio[%]*	Assortmentm³ *Sortiment* m³	Stumpage price [€/m³] *Vrijednost sastojine*	Price [€] TOTAL *Ukupna vrijednost*
Sessile oak *Hrast kitnjak*	t2	19	28,390	41,87	1.188,59
	t3	6	8,965	25,60	229,51
	to	5	7,471	20,53	153,40
	pd	57	85,169	12,93	1.101,52
Common beach *Obična bukva*	to	0,015	0,704	15,20	10,70
	pd	0,935	43,898	12,93	567,75
Hornbeam *Grab*	pd	0,96	17,126	13,87	237,49
Other broadleaves *OB*	pd	0,9216	0,802	13,87	11,12
					3.500,08

T2 – second class sawn wood; t- third class sawn wood; to- thin sawn wood; pd – fuel wood
t2- pilanski trupci druge klase, t3- pilanski trupci treće klase, to- tanka oblovina, pd- prostorno drvo

For the needs of calculations the percentage of wood sortiments has been taken from the current General forest management plan. For a detailed calculation the present and future distribution of trees per diameter classes should be taken into consideration. The calculation may also include the wood debris that could be used as energy wood.

By applying different interest rates a figure of 0.5495% was calculated, due to the fact that it fulfils the conditions defined by discounting and capitalizing. Based on the formula (3) the discounted value of costs of establishing the stand (reduced to the beginning of the rotation period) is presented.

$$(3)\, C_0 = \frac{C_n}{\left(1+\frac{r}{100}\right)^n}, 6223,64 Eur = \frac{6944,53 Eur}{\left(1+\frac{0,5495}{100}\right)^{20}}$$

Based on a formula (2) the capitalized value on the end of rotation period (120 years) is calculated

$$(2)\ Cn = C_0 \cdot \left(1 + \frac{r}{100}\right)^n, 12012,53 Eur = 6223,64 Eur \cdot \left(1 + \frac{0,5495}{100}\right)^{120}$$

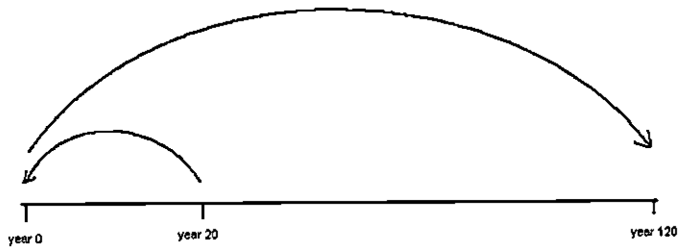

Figure 1. Determining the interest rate by discounting and capitalizing
Slika 1. Utvrđivanje kamatne stope diskontiranjem i kapitaliziranjem

For the management class of pedunculate oak the Ordinance on forest management proscribes a rotation period of 120 years. According to this statement the time of compounding equals to 71 year. When assessing the future value it should be taken into consideration that the stand was up to its 49th year managed by the principles of regular management, and for the purpose of this article it is presumed that all future management activities are prohibited. Literature review did not find a model by which the costs that occur when the stand surpasses 120 years, although the model of infinite rent can be applied (Leppanen, 2005). By using the calculated interest rate we can get future values of invested funds (Table 4)

Table 4. Determining the interest rates
Tablica 4. Utvrđivanje stope složenog ukamaćenja

Discount factor [%] *Šumarski kamatnjak [%]*	Present value *Sadašnja vrijednost*	Future value *Buduća vrijednost*
0,5165	6.264,64	11.624,62
0,5220	6.257,79	11.688,40
0,5275	6.250,94	11.752,53
0,5330	6.244,11	11.817,00
0,5385	6.237,28	11.881,83
0,5440	6.230,46	11.947,00
0,5495	**6.223,64**	**12.012,53**
0,5550	6.216,84	12.078,42
0,5605	6.210,04	12.144,66
0,5660	6.203;25	12.211,27
0,5715	6.196,47	12.278,23

Although the researched stand is in the development phase of a young stand, according the data available from the Forest management plan there were no thinning operations in it, and thus there were no revenues. For that reason it was not necessary to capitalize revenues of thinning in the end of rotation period, and it was not necessary to discount its costs in the beginning of the rotation period. Stands in which thinning was done have a more complex calculation of interest rates due to the multiple discounting and capitalizing of costs and revenues at different time intervals.

$$(1)\ NPV = \frac{\frac{Cn}{U_{N-n}}}{\frac{r}{100}}, 30789{,}32Eur = \frac{\frac{12012{,}53Eur}{71god}}{\frac{0{,}5495}{100}}$$

By usage of the formula (1) the value of a single payment for 1 ha in the "EEFS" Dotršćina, compartment 2a, is 30789.32 €. In the final value the "ecological" functions of forests were not taken into consideration due to the fact that the forest and the forest land does not change its ownership, and that the economical function was replaced by the protection function.

CONCLUSIONS
ZAKLJUČCI

Because of different characteristics of forest stands, the presented method of calculation must be applied individually for each stand, and then subsequently for the entire forest. In case that the forest taken into consideration is managed by an uneven-aged regime, it is necessary to make alterations to the model. The amount of single payment to compensate for the inability to perform felling activities is almost three times larger than the value of the forest determined by the method of current felling value. The reasons for this discrepancy are the "ecological" functions of the forest. The analysis presented in this paper did not take into consideration these "ecological" functions, because they are not affected by the payment system that compensated forest owners their loss of forest management rights.

The presented model has its limitations. First, the model assumes the halting of active management of the forest compartment, which in practice is not a common case. Most of the measures prescribed for forest areas that fall within Natura 2000 network have management recommendations that affect "normal" management regime in a manner that they limit the allowed time span of forest activities to the intervals in which the sensitive stages (like breeding) of species and habitats of EU importance are not disturbed. Other type of management recommendations favours activities by which the conservation status of habitats is improved (like continuous grazing of mountain pastures), or certain ecological requirements are added to forestry activities (like silvicultural activities which take care of the diversity of forest edges). All these cases require its own specific approach to calculation, and all of them would have their calculated values smaller that the one presented in this paper.

Also, the presented model assumes single payment. This would be hard to implement in practice owing to difficulties in securing long term status of prescribed management. For this reason most of the EU countries use a system of long-term contracts (e.g. 30 years). On the level of EU 25 the average annual cost of implementation of the Natura 2000 network for all types of land cover is 63€/ha (Gantioler et al, 2010). Introducing a single payment is applicable to higher, regional level for a certain measure or a habitat type. Due to the changes in ownership or inheritance, it is probable that most of the forest owners would accept a single payment system. The transaction costs of drawing up a contract and determining payment for a single private forest owner are too high. Such contracts are applicable only to forest owners with relatively large forest lots, where it should be strived towards an active management system which has for a goal the improvement of the conservation status of habitats and species of EU interest. On the basis of presented findings, it is difficult to apply the method for different habitat types. For these reasons it is important to conduct additional research and calculations on different management classes, so that the level of compensations for the loss of management right over forest under Natura 2000 for forest owners could be calculated.

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Izvorni znanstveni članak

PHYTOCOENOSES OF COMMON SPRUCE (*Picea abies* (L.) Karsten) IN THE ALTIMONTANE AND SUBALPINE BELT OF CROATIA

FITOCENOZE OBIČNE SMREKE (Picea abies (L.) Karsten) U ALTIMONTANSKOM I SUBALPSKOM POJASU HRVATSKE

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Abstract

Three associations of common spruce in the altimontane and subalpine belt of the Croatian Dinaric Mountain range have been described using the Central European phytocoenological method (Braun-Blanquet 1964). These associations differ in terms of ecological conditions, floral composition, and partially of their distribution range. Spruce forests of western Croatia (Gorski Kotar) belong to the association *Lonicero caeruleae-Piceetum* Zupančič (1976) 1999, which were identified in Croatia for the first time with nine new phytocoenological relevés. The association *Laserpitio krapfii-Piceetum abietis* Vukelić, Alegro et Šegota 2010 is developed as a permanent stage on steep, north-facing, cold and rocky mountains between 1100 and 1500 m a. s. l., mostly on Mount Velebit. The association *Hyperico grisebachii-Piceetum* (Bertović 1975) Vukelić, Alegro, Šegota et Šapić 2010 extends predominantly above 1400 m a. s. l., often on inaccessible, distinctly rocky, open tops and upper steep stony exposed slopes of northern Velebit and Bjelolasica.

Key words: *Picea abies* (L.) Karsten, forest communities, altimontane and subalpine belt, Dinaric range, Croatia

Sažetak

Prema standardnoj srednjoeuropskoj fitocenološkoj metodi (Braun-Blanquet 1964) opisane su tri asocijacije obične smreke u altimontansko-subalpskom pojasu hrvatskih Dinarida. Međusobno se razlikuju prema ekološkim uvjetima, flornom sastavu, a dijelom i prema arealu (slika 1, tablice 2 i 3). Smrekove šume zapadne Hrvatske (Gorski kotar) pripadaju asocijaciji Lonicero caeruleae-Piceetum Zupančič (1976) 1999 koja je sa devet novih fitocenoloških snimaka (tablica 1) prvi puta utvrđena u Hrvatskoj. Asocijacija Laserpitio krapfii-Piceetum abietis Vukelić, Alegro et Šegota 2010 razvijena je kao trajni stadij na strmim, sjevernim, hladnim i sjenovitim padinama između 1100 i 1500 m, uglavnom na Velebitu. Asocijacija Hyperico grisebachii-Piceetum (Bertović 1975) Vukelić, Alegro, Šegota et Šapić 2010 rasprostire

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se pretežno iznad 1400 m nadmorske visine na često neprohodnim, izrazito stjenovitim, otvorenim vrhovima i gornjim strmim kamenitim izloženim padinama sjevernoga Velebita i Bjelolasice.

Ključne riječi: *Picea abies (L.) Karsten, šumske zajednice, altimontansko-subalpski pojas, dinarsko gorje, Hrvatska*

INTRODUCTION
UVOD

The Dinaric area in the Republic of Croatia above an altitude of 1200 m covers 76,000 ha, or only 1.4% of the area. Of this, over half are under forests, while the rest consists of scrub communities, mountain clearings, grasslands and rocks. The forest cover is completely dominated by the subalpine beech forest, while spruce in Croatia, unlike the Alps and the Carpathians, does not constitute a special height belt, nor does it form large complexes as it does in Slovenia and Bosnia and Herzegovina. It is developed as a permanent stage and inhabits localities that are not conducive to the growth of beech and fir stands; therefore, spruce is favoured by local climatic and orographic factors across its entire natural range, which gives it precedence over beech and fir (Beck-Mannagetta 1901, Horvat 1925, 1938, 1950, 1962, 1963, Anić 1959, Horvat, Glavač i Ellenberg 1974 et al.).

Phytocoenoses containing spruce as the edifying species are found in three large massifs in Croatia: Risnjak in Western Croatia, Bjelolasica in the Central Dinaric range and Velebit. The floral composition of spruce communities growing on these massifs differ from one another as a consequence of their biogeographic position and floral-genetic development, general ecological factors, macro and micro-climatic features of particular associations, and anthropogenic impacts. Spruce forests of Western Croatia are still under the alpine influence; even their macro-climate differs significantly from other Dinaric areas in Croatia. For example, the average annual temperature in the subalpine belt of Northern Velebit is 3.5 °C, and the average annual rainfall is 1898 mm (meteorological station Zavižan, 1594 m above sea level, period 1961-1990, data from the State Hydro-Meteorological Service). At Veliki Risnjak, situated about 100 m lower in Gorski Kotar, the average annual temperature is about 2 °C and the precipitation quantity is higher by almost 2000 mm than on Zavižan.

Spruce forests in the altimontane and subalpine belt of Croatia were described by Ivo Horvat (1950, 1962) as a macro-association *Piceetum croaticum subalpinum*. He presented this association in a synthetic form with 19 relevés (in Cestar 1967), comprising mainly the Gorski Kotar area. Subsequent research into spruce forests of Croatia (Bertović 1975, Vukelić et al. 2010a, Vukelić et al. 2010b) highlighted their heterogeneity, so two new associations were described. The association *Hyperico grisebachii-Piceetum* (=*Calamagrostio variae-Piceetum* Bertović 1975 nom. Illeg.) was identified in the rocky part of Velebit above an altitude of 1400 m. The second association, *Laserpitio krapfii-Piceetum abietis* Vukelić, Alegro et Šegota 2010, is developed as a permanent stage on steep, north-facing, cold and shady slopes between 1100 and 1500 m above the sea. However, both these associations are distributed mainly on Velebit, while stands from Western Croatia growing towards the border area with Slovenia, which were also included in Horvat's complex of *Piceetum subalpinum*, are not part of them. For this reason, we surveyed the Risnjak massif and Bjelolasica areas, compared the stands with the results of earlier research into spruce forests of Croatian and adjacent areas, and defined them into three independent associations in terms of ecology and floral composition.

MATERIALS AND RESEARCH METHODS
MATERIJALI I METODE ISTRAŽIVANJA

Research was conducted using the method of the Zurich-Montpellier Phytocoenological School with a six-point scale. The relevés were entered into the Turboveg database (Hennekens & Schaminée

2001) and were statistically processed in the Primer 6 software (Clarke & Gorley 2001). We used MDS (Non-metric Multi-Dimensional Scaling) and the UPGMA (Unweighted Pair-Group Method Using Arithmetic Averages) agglomerative hierarchical method with the Bray-Curtis similarity index. The average Ellenberg's ecoindicator values (Ellenberg 1979) of the communities were calculated by means of the JUICE 7.0 software (Tichý 2002) and were compared in STATISTICA 8.0 (StatSoft Inc. 1984-2008) using the Kruskal-Wallis test ($p<0.05$).

The floristic composition was classified according to the social affiliation of the species, plant nomenclature was coordinated according to the Flora Croatica Database (Nikolić 2008), and mosses were adjusted according to Koperski et al. (2000).

The floristic composition and structure of spruce stands in Croatia are presented on the basis of 54 phytocoenological relevés, of which 19 are by I. Horvat (Cestar 1967), 6 are by S. Bertović (1975), and 29 relevés have been investigated by the authors in the past two years. Horvat's relevés were not taken into consideration for statistic analysis because they are not in the analytical form. Nine new relevés of the association *Lonicero caeruleae-Piceetum* are presented in the analytical Table 1. Three associations from Croatia and two from Slovenia (Acceto 2006, Zupančič 1999) are given in the synoptic form in Table 2. One of them (column 1) represents the association *Lonicero caeruleae-Piceetum* from research by Zupančič exactly as he described it.

RESEARCH RESULTS AND DISCUSSION
REZULTATI ISTRAŽIVANJA I RASPRAVA

The statistical analysis of 35 analytical relevés, as well as the comparison in Table 2 shows three clearly distinct associations (Figure 1). The sociological affiliation of the species in particular associations (Table 3) points to their mutual differences. These differences are the consequence of the biogeographic position and floral-genetic development, general ecological factors, macro- and micro-climatic features of a particular association and anthropogenic impacts.

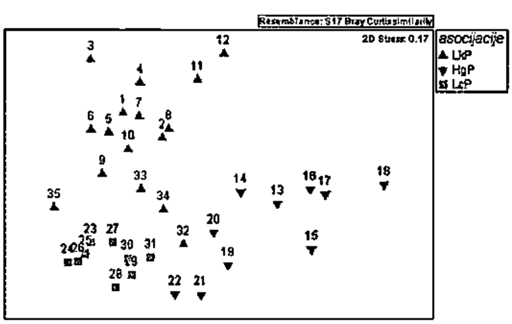

Figure 1 Multi-Dimensional Scaling
Slika 1 Multidimenzionalno skaliranje

Subalpine Forest of Spruce with Blue-Berried Honeysuckle
(Lonicero caeruleae-Piceetum abietis Zupančič (1976) 1999 corr.*)*

The association named *Piceetum subalpinum dinaricum* was established by Zupančič in 1976 on Slovenia's Snežnik, which forms a coherent ecological-vegetational unit with the Risnjak area, i.e. with Western Croatia. In his later works (1994,1999), Zupančič renamed the association into *Lonicero caeruleae-Piceetum* and defined *Lonicera caerulea* subsp. *borbasiana* and the moss *Sanionia uncinata* as the characteristic species of the association, while *Lycopodium annotinum* and *Vaccinium vitis-idaea* were identified as locally differential species. With the exception of the moss *Sanionia uncinata,* other species participate significantly in the subalpine spruce forests of Gorski Kotar. In addition to the geomorphological, ecological and other similarities, this is the most important reason that the stands from Gorski Kotar have, for the time being, been added to the association *Lonicero caeruleae-Piceetum.* It must be stressed, however, that more detailed research is necessary in order to make the final determination. The floristic composition of the association is given in Table 1. Compared to the other two associations, the composition is considerably dominated by the species of spruce forests of the class *Vaccinio-Piceetea* (51:36:39) (Table 3).

Table 1 Floristic composition of association *Lonicero caeruleae-Piceetum* in Croatia
Tablica 1 Floristički sastav asocijacije Lonicero caeruleae-Piceetum u Hrvatskoj

Ass. Lonicero coeruleae-Piceetum												
Number of releve / *Broj snimke*			1	2	3	4	5	6	7	8	9	Presence degree / *Stupanj udjela*
Locality / *Lokalitet:*			Gl	G2	Li1	Li2	MB	BS1	BS2	BS3	SS3	
Exposition / *Ekspozicija*			i	sz	si	ji	si	si	si	si	i	
Inclination / *Nagib* (°)			40	45	10	20	30	40	45	35	30	
Altitude / *Nadmorska visina* (m)			980	1010	960	1050	995	1020	1210	1205	1290	
Relevé area / *Površina snimke* (m²)			400	400	600	400	900	600	400	400	400	
Cover / *Pokrovnost (%)* A			80	60	90	80	75	95	85	70	65	
B			60	50	70	50	60	40	70	60	70	
C			80	80	80	90	65	70	70	85	70	
D			80	80	70	60	55	25	50	60	65	
Floristic composition / *Florni sastav*												
Char. and diff. species of association / *Svojstvene i razlikovne vrste asocijacije*												
a	Lonicera nigra	B	1	1	1	2	+	+	+	+	.	5
a	Lonicera caerulea borbasiana		.	.	.	.	.	+	+	+	+	3
a	Lycopodium annotinum	C	+	+	1	3	2	.	2	2	2	5
a	Vaccinium vitis-idaea		.	.	.	.	1	.	+	1	.	2
a	**Vaccinio-Piceenion**											
	Polystichum lonchitis		+	+	.	.	+	.	+	+	.	3
	Luzula sylvatica		+	.	.	.	+	.	.	.	.	1
	Luzula luzulina		.	.	.	.	+	.	.	.	+	1
	Plagiothecium undulatum	D	.	+	+	+	+	.	.	.	.	3
	Rhytidiadelphus loreus		.	.	.	.	.	+	1	1	1	3
	Mylia taylori		.	.	.	.	+	.	.	.	.	1
	Rhizomnium punctatum		.	.	.	.	.	.	.	+	.	1
b	**Abieti-Piceenion**											
	Abies alba	A	2	1	1	2	+	2	1	+	2	5
	Abies alba	B	3	3	2	2	1	+	+	.	2	5
	Clematis alpina		3	1	1	1	1	2	2	1	2	5
	Valeriana tripteris	C	3	2	1	2	+	1	2	1	+	5
	Dryopteris expansa		1	1	+	+	+	.	+	+	+	5
	Veronica urticifolia		1	+	+	1	+	.	1	1	+	5
	Abies alba		+	+	+	+	.	+	+	.	.	3
	Dryopteris dilatata		+	1	+	+	.	.	+	+	.	3
	Adenostyles alpina		.	.	.	.	.	+	+	.	2	2
	Streptopus amplexifolius		+	+	.	.	.	.	.	.	.	1

c	**Vaccinio-Piceion**										
	Picea abies	A	4	4	4	4	5	4	3	4	4	**5**
	Picea abies	B	1	+	+	+	+	.	1	.	1	**4**
	Picea abies	C	.	+	+	+	+	+	.	+	+	**4**
	Hieracium murorum		.	.	+	.	+	.	+	+	+	**3**
	Bazzania trilobata	D	.	.	.	.	+	.	.	.	.	**1**
d	**Vaccinio-Piceetea, Piceetalia**											
	Sorbus aucuparia	A	.	.	.	.	.	.	1	+	+	**2**
	Rosa pendulina	B	4	3	1	1	1	2	2	2	1	**5**
	Vaccinium myrtillus		1	.	1	3	2	2	3	3	2	**5**
	Sorbus aucuparia		.	.	+	+	+	+	+	+	+	**4**
	Rubus saxatilis		.	.	.	.	1	.	.	.	.	**1**
	Homogyne sylvestris	C	3	2	2	2	.	1	+	1	+	**5**
	Gentiana asclepiadea		1	1	1	1	1	+	+	+	+	**5**
	Maianthemum bifolium		1	1	1	1	2	+	1	+	+	**5**
	Oxalis acetosella		1	1	+	.	+	+	+	+	1	**5**
	Huperzia selago		+	+	+	.	1	1	1	1	+	**5**
	Phegopteris conectilis		1	1	1	1	.	.	+	+	.	**3**
	Calamagrostis arundinacea		+	1	.	+	1	3	.	1	.	**3**
	Gymnocarpium dryopteris		.	.	.	.	+	.	.	+	.	**1**
	Melampyrum velebiticum		.	.	.	.	+	.	.	.	.	**1**
	Sorbus aucuparia		.	.	.	.	.	.	.	.	+	**1**
	Polytrichum formosum	D	2	2	2	1	1	1	1	1	1	**5**
	Dicranum scoparium		1	1	1	1	1	2	2	2	1	**5**
	Rhytidiadelphus triquetrus		+	+	+	+	.	.	.	1	.	**3**
e	**Erico-Pinion, Erico-Pinetalia**											
	Cirsium erisithales	C	+	.	.	+	1	+	.	.	+	**3**
	Calamagrostis varia		.	.	.	.	.	+	+	+	3	**2**
f	**Aremonio-Fagion**											
	Rhamnus alpinus fallax	B	+	.	.	.	.	.	.	.	.	**1**
	Cardamine trifolia	C	2	1	1	+	+	+	+	+	1	**5**
	Euphorbia carniolica		+	+	+	+	.	.	.	.	.	**3**
	Cardamine enneaphyllos		.	.	1	.	+	1	+	+	.	**3**
	Scopolia carniolica		.	.	.	.	.	+	+	+	+	**3**
	Calamintha grandiflora		.	.	.	.	+	.	.	+	.	**1**
	Aremonia agrimonoides		+	.	.	.	.	.	.	.	.	**1**
	Omphalodes verna		.	.	+	.	.	.	.	.	.	**1**
	Cyclamen purpurascens		.	.	.	.	+	.	.	.	.	**1**
g	**Adenostylon, Adenostyletalia**											
	Rubus idaeus	B	+	.	+	1	+	.	+	.	+	**3**
	Salix grandifolia		.	+	.	.	1	.	+	+	+	**3**
	Dryopteris filix-mas	C	+	+	+	+	+	+	+	1	+	**5**
	Polygonatum verticillatum		1	1	+	+	+	.	.	+	+	**4**
	Athyrium filix-femina		+	+	+	+	.	.	+	+	+	**4**
	Ranunculus platanifolius		2	1	1	.	.	.	+	1	1	**3**
	Doronicum austriacum		+	+	+	+	.	.	.	+	.	**3**

	Veratrum album		+	+	+	.	.	.	+	+	+	**3**
	Saxifraga rotundifolia		.	.	.	.	.	+	+	+	+	**3**
	Aruncus dioicus		3	3	1	.	.	.	.	.	.	**2**
	Cicerbita alpina		.	.	.	+	.	.	.	.	+	**1**
	Senecio ovatus		.	.	.	.	.	+	.	+	.	**1**
h	**Fagetalia**											
	Fagus sylvatica	A	+	.	.	.	.	1	1	+	.	**3**
	Fagus sylvatica	B	.	+	+	+	.	+	.	.	.	**3**
	Daphne mezereum		+	+	.	.	+	+	+	+	.	**3**
	Acer pseudoplatanus		.	.	+	+	+	+	.	.	+	**3**
	Lonicera alpigena		.	.	.	+	.	+	+	+	.	**3**
	Sambucus racemosa		.	.	.	.	+	.	+	+	+	**3**
	Prenanthes purpurea	C	1	1	+	1	+	+	+	+	+	**5**
	Solidago virgaurea		+	+	+	1	+	+	+	+	1	**5**
	Paris quadrifolia		+	+	+	+	.	.	1	+	.	**3**
	Mercurialis perennis		1	1	+	.	+	1	.	+	.	**3**
	Mycelis muralis		+	.	+	+	.	+	+	.	1	**3**
	Polystichum lobatum		1	1	+	.	.	.	+	+	.	**3**
	Actaea spicata		+	+	.	.	.	+	+	+	+	**3**
	Galeobdolon luteum		+	+	.	.	.	+	.	.	+	**3**
	Phyteuma spicatum		.	+	.	.	+	+	+	+	+	**3**
	Asplenium scolopendrium		.	.	.	.	.	+	.	+	+	**2**
	Polygonatum multiflorum		.	+	.	.	+	.	.	.	.	**1**
	Symphytum tuberosum		.	+	.	.	.	.	.	+	.	**1**
	Geranium robertianum		.	.	.	+	.	.	.	+	.	**1**
	Melica uniflora		.	+	.	.	.	.	.	.	.	**1**
	Carex sylvatica		.	.	.	+	.	.	.	.	.	**1**
	Viola reichenbachiana		.	.	.	.	+	.	.	.	+	**1**
	Fagus sylvatica		.	.	.	.	+	.	.	.	.	**1**
	Acer pseudoplatanus		.	.	.	.	.	+	.	.	.	**1**
	Epilobium montanum		.	.	.	.	.	.	.	+	1	**1**
	Asarum europaeum		.	.	.	.	.	.	.	+	.	**1**
	Melica nutans		.	.	.	.	.	.	.	.	+	**1**
	Neckera crispa	D	+	1	+	+	.	1	.	.	2	**3**
i	**Querco-Fagetea**											
	Sorbus aria	A	.	.	.	.	.	+	.	.	.	**1**
	Taxus baccata		.	.	.	.	.	+	.	.	.	**1**
	Sorbus aria	B	+	.	.	+	.	.	.	.	.	**1**
	Anemone nemorosa	C	2	1	1	1	+	+	+	1	1	**5**
	Carex digitata		+	+	+	.	+	.	.	.	.	**3**
	Carex ornithopoda		.	.	.	.	.	1	+	+	.	**2**
	Anemone hepatica		.	.	.	.	+	+	.	.	.	**1**
	Convallaria majalis		.	.	.	.	1	.	.	+	.	**1**
	Ctenidium molluscum	D	3	3	3	2	1	3	2	3	1	**5**
j	**Asplenietea trichomanes**											
	Asplenium viride	C	+	+	1	+	+	.	1	+	.	**4**
	Asplenium trichomanes		.	+	+	.	.	+	.	+	+	**3**

	Moehringia muscosa		+	.	.	.	+	+	.	+	.	**3**
	Polypodium vulgare		+	.	.	.	.	+	.	+	.	**2**
	Asplenium ruta muraria		.	.	.	.	.	+	.	.	.	**1**
	Corydalis ochroleuca		.	.	.	.	.	.	+	.	.	**1**
	Cystopteris alpina		.	.	.	.	.	.	.	+	.	**1**
	Cystopteris fragilis		.	.	.	.	.	.	.	.	+	**1**
I	**Other species** / *Ostale vrste:*		.	.	.	.	.	.	.	.	.	.
	Fragaria vesca	C	.	.	.	+	.	.	.	.	.	**1**
	Silene pusilla		.	.	.	.	.	.	+	.	.	**1**
	Mahovine / *Mosses*	D										
	Tortella tortuosa		+	+	+	1	2	+	+	1	+	**5**
	Fissidens dubius		+	+	2	+	.	+	+	+	1	**5**
	Eurhynchium striatum		+	.	+	+	+	.	.	.	.	**3**
	Isothecium aloperuroides		.	+	.	+	.	+	+	.	.	**3**
	Mnium marginatum		+	.	+	.	.	.	.	+	1	**3**
	Plagiochila porelloides		.	.	.	.	.	+	+	1	1	**3**
	Mnium thomsonii		.	.	.	.	.	+	+	+	.	**2**
	Schistidium apocarpum		.	.	.	.	+	.	.	.	+	**1**
	Brachythecium velutinum		.	.	+	+	.	.	.	.	.	**1**
	Leucobryum glaucum		.	.	+	+	.	.	.	.	.	**1**
	Scapania aspera		.	.	.	.	.	+	.	+	.	**1**
	Hypnum andoi		.	.	+	.	.	.	.	.	.	**1**
	Metzgeria furcata		.	.	.	.	+	.	.	.	.	**1**
	Neckera pumila		.	.	.	.	+	.	.	.	.	**1**
	Syntrichia ruralis		.	.	.	.	+	.	.	.	.	**1**
	Jungermannia leiantha		.	.	.	.	.	+	.	.	.	**1**
	Neckera complanata		.	.	.	.	.	+	.	.	.	**1**
	Blepharstoma trichnophyllum		.	.	.	.	.	.	+	.	.	**1**
	Bryum capillare		.	.	.	.	.	.	+	.	.	**1**
	Cephalozia catenulata		.	.	.	.	.	.	+	.	.	**1**
	Cirriphyllum piliferum		.	.	.	.	.	.	+	.	.	**1**
	Lophozia ascendens		.	.	.	.	.	.	+	.	.	**1**
	Lophozia incisa		.	.	.	.	.	.	+	.	.	**1**
	Riccardia palmata		.	.	.	.	.	.	+	.	.	**1**
	Tritomaria exsecta		.	.	.	.	.	.	+	.	.	**1**
	Scapania umbrosa		.	.	.	.	.	.	+	.	.	**1**
	Eurhynchium angustirete		.	.	.	.	.	.	.	+	.	**1**
	Bryum flaccidum		.	.	.	.	.	.	.	+	.	**1**
	Calipogeia fissa		.	.	.	.	.	.	.	+	.	**1**
	Pedinophyllum interruptum		.	.	.	.	.	.	.	+	.	**1**
	Pseudolaskea catenulata		.	.	.	.	.	.	.	+	.	**1**
	Rhynchostegium murale		.	.	.	.	.	.	.	.	1	**1**
	Atrichum undulatum		.	.	.	.	.	.	.	.	+	**1**
	Plagiothecium laetum		.	.	.	.	.	.	.	.	+	**1**

Locality / *Lokalitet:* Gašparac (G), Lividraga (L), Bijele stijene (BS), Samarske stijene (SS), Markov brlog (MB)

Along with the already mentioned differentiating species and compared to the other two subalpine spruce communities in Croatia, the phytocoenosis *Lonicero caeruleae-Piceetum* is characterized by higher participation of the species *Calamagrostis arundinacea, Abies alba, Gentiana asclepiadea, Solidago virgaurea, Phegopteris connectilis,* while of other syntaxa, *Cardamine trifolia* is particularly distinct. On the other hand, compared to the ecologically and physiognomically similar community *Laserpitio krapfii-Piceetum,* the species *Melampyrum velebiticum, Calamagrostis varia, Carex ornythopoda, Campanula rotundifolia* agg., and a larger number of the species of the order *Fagetalia* are either absent or are less well represented.

Figure 2 Association *Lonicero caeruleae-Piceetum* in locality Gašparac in Gorski Kotar
Slika 2 Asocijacija Lonicero caeruleae-Piceetum na lokalitetu Gašparac u Gorskome kotaru

The most representative stands of this association are located in the rocky massif of Risnjak (Figure 2), especially in the Smrekovac area, as well as in several localities of Velika Kapela, where Bijele and Samarske Stijene are particularly prominent.

Subalpine Forest of Spruce with *Laserpitium krapfii*
(Laserpitio krapfii-Piceetum abietis Vukelić, Alegro et Šegota 2010*)*

The association *Laserpitio krapfii-Piceetum abietis,* researched and determined by Vukelić, Alegro and Šegota (2010), only partially encompasses Horvat's macro-association *Picetum croaticum* *subalpinum* from 1950. The community belongs to the altimontane and subalpine belt of the Dinaric area in Croatia. It is predominantly developed on steep, north-facing, cold and closed sinkholes and depressions, where snow is high and of long duration and altitudes range from 1100 to 1500 m. As a rule, the phytocoenosis *Hyperico grisebachii-Piceetum* occurs above it.

The phytocoenosis *Laserpitio krapfii-Piceetum* has macro-climatic features of a pre-alpine beech forest in whose belt it is situated. However, the decisive factor for its occurrence is the microclimate modified primarily by the relief, altitude and other geomorphological factors (Cindrić 1973).

The characteristic species of the association is *Laserpitium krapfii*, the differentiating species are *Knautia drymeia*, *Petasites albus*, *Euphorbia amygdaloides*, *Symphytum tuberosum*, *Adenostyles alliaria*, *Melampyrum velebiticum* and *Campanula rotundifolia* agg., while *Valeriana montana*, *Geranium sylvaticum* and *Trollius europaeus* have diagnostic importance.

The phytocoenosis of spruce with *Laserpitium krapfii* is developed as a permanent stage on more humid, colder and shadier sites. Locally, it descends into sinkholes and lower slopes to the beech-fir forest, and is therefore richer in the *Adenostyletalia* species in relation to the other two associations (Table 3). Due to dolomitized limestone and breccia, which supply the soil (calcomelanosol and cambisol) with large quantities of calcium, as well as to strong impacts of zonal beech forests on the narrower and smaller complexes of these spruce stands, the best represented elements are those of the order *Fagetalia* and lower units, which makes them the differentiating species of beech forests. The average soil pH determined in water for the layer of 0 to 5 cm in depth is 5.50.

Subalpine Forest of Spruce with *Hypericum richeri* ssp. *grisebachii*
(As. *Hyperico grisebachii-Piceetum* (Bertović 1975) Vukelić, Alegro, Šegota et Šapić 2010)

The association *Hyperico grisebachii-Piceetum* is distributed above 1400 a.s.l. (slightly lower on Samarske Stijene). It often covers inaccessible, distinctly rocky tops, ridges, hips, karren, and very steep sunny slopes high up. The stoniness of the terrain, always above 50%, is the essential feature of the site of spruce forest with *Hypericum richeri* ssp. *grisebachii* and significantly contributes to the broken tree canopy and the structure of shrubs and ground vegetation. The soils are generally different sub-types of calcomelanosol, ranging from organogenic, organomineral to browned soils, and less frequently shallow cambisol (Bakšić et al. 2010). The ecological amplitude of the occurrence of the community is very narrow, whereas the specific conditions of the relief, pedology and climate (represented by Zavižan Meteorological Station) are not favourable for the successful development of forest vegetation.

In relation to the other two, the community is poorer in spruce species, as well as in the species of the order *Fagetalia* and *Adenostyletalia* (Table 3). Due to the rocky mountain tops and ridges where it occurs, it is much richer in the species of primary and secondary mountain screes and pastures of the class *Asplenietea trichomanis* and *Seslerietea albicans*. The differentiating species of the association, *Salix appendiculata*, *Sambucus racemosa*, *Juniperus communis* subsp. *nana*, *Achillea clavenae*, *Gentiana lutea* subsp. *symphyandra*, and locally *Festuca bosniaca* and *Convallaria majalis* reflect exactly these conditions. The high participation of the species of the class *Erico-Pinetea* and lower units - *Calamagrostis varia*, *Cirsium erysithales*, and even *Carex ornithopoda*, deserves special mention. The number and the cover of the species of the orders *Fagetalia* and *Adenostyletalia* is considerably lower than in the phytocoenosis *Laserpitio krapfii-Piceetum* (31:45), which occurs in lower positions.

Although the phytocoenosis does not have any commercial significance, its protective and natural-scientific importance is very high. The most important stands are found in the National Park of North Velebit and on Samarske Stijene, and less so on other rocky tops of Velika Kapela and the Risnjak massif. Its composition is not uniform in this entire distribution range: the high ridges which it inhabits are relatively remote enclaves with their geobotanical and horologic specific features. Some particular localities contain rare and protected species, e.g. Samarske Stijene with *Berberis croatica*, *Leontopodium alpinum*, *Saxifraga paniculata* and others.

Other Differences in the Constitution of Site and Vegetation

In addition to the already highlighted differences between particular associations, their phytocoenological analysis also indicates the general floristic-vegetational characterisation in terms of their position in the entire Dinaric massif. It is partly explained in the works of Vukelić et al. 2010a and 2010b and will not be repeated here.

Table 2 Phytocoenoses of Common Spruce in the Altimontane and Subalpine Belt
Tablica 2 Fitocenoze obične smreke u altimontanskom i subalpskom pojasu

	Number of column / *Broj stupca*:		1	2	3	4	5	6
	Number of releves / *Broj snimaka*:		39	19?	9	17	10	16
Char. and diff. species of ass. / *Svojstvene i razlikovne vrste asocijacija*								
a	Lonicera nigra	B	5	5	5	3	1	1
	Lonicera caerulea borbasiana		4	4	3	.	5	2
	Lycopodium annotinum	C	5	5	5	3	2	1
	Vaccinium vitis-idaea		4	4	2	3	3	3
b	Sanionia uncinata	D	3	.	.	.	.	1
j	Campanukla justiniana	C	.	.	.	5	.	.
	Silene hayekiana		.	.	.	2	.	.
g	Salix appendiculata	B	3	5	3	3	5	3
d	Juniperus communis nana		.	4	.	1	5	1
h	Sambucus racemosa		.	.	3	1	4	3
l	Gentiana lutea	C	.	.	.	.	4	1
k	Achillea clavenae		.	.	.	.	3	1
l	Festuca bosniaca		.	.	.	.	3	.
i	Convallaria majalis		.	.	1	.	3	1
c	Laserpitium krapfii		.	1	.	.	4	4
h	Petasites albus		.	.	.	1	1	4
f	Knautia drymeia		2	.	.	.	.	4
h	Euphorbia amigdaloides		1	.	.	.	.	3
g	Adenostyles alliariae		1	.	.	.	.	4
d	Melampyrum velebiticum		.	.	1	.	3	3
l	Campanula rotundifolia agg.		.	.	.	.	2	4
e	Aquilegia nigricans		.	.	.	.	1	2
d	Huperzia selago		5	5	5	4	2	2
	Calamagrostis arundinacea		5	5	3	.	.	2
b	Clematis alpina	B	3	4	5	5	5	2
a	Polystichum lonchitis	C	2	3	3	1	5	4
d	Maianthemum bifolium		4	5	5	1	2	3
	Homogyne sylvestris		4	5	5	5	3	4
g	Doronicum austriacum		4	2	3	.	2	4
h	Melica nutans		2	3	1	2	3	3
	Solidago virgaurea		2	2	5	3	2	1
b	Adenostyles alpina		3	2	2	4	5	3

i	Carex digitata		3	.	3	4	2	3
e	Calamagrostis varia		1	.	2	5	5	4
h	Mercurialis perennis	C	2	.	3	2	3	3
l	Hypericum richeri grisebachii		.	3	.	.	4	5
	Valeriana montana		.	.	.	.	2	4
a	**Vaccinio-Piceenion**							
	Luzula sylvatica	C	5	3	1	4	1	3
	Luzula luzulina		1	3	1	.	1	2
	Listera cordata		1	5	.	.	.	.
	Moneses uniflora		1	2	.	.	.	.
	Melampyrum sylvaticum		4	.	.	.	.	.
	Rhytidiadelphus loreus	D	5	5	3	.	2	2
	Plagiothecium undulatum		2	2	3	.	.	.
	Mylia taylori		2	5	1	1	.	1
	Mnium spinosum		1	2	.	.	.	.
	Rhizomnium punctatum		1	.	1	1	.	.
	Peltigera leucophlebia		2	.	.	.	.	.
	Mnium orthorrhynchium		.	.	.	3	.	.
b	**Abieti-Piceenion**							
	Abies alba	A	1	5	5	5	2	1
	Abies alba	B	4	5	5	3	2	3
	Veronica urticifolia	C	4	5	5	2	3	5
	Valeriana tripteris		4	5	5	5	3	4
	Abies alba		1	4	3	3	.	1
	Dryopteris expansa		5	.	5	1	.	3
	Streptopus amplexifolius		.	3	1	.	.	2
	Dryopteris dilatata		.	5	3	.	.	1
	Saxifraga cuneifolia		1	.	.	1	.	.
c	**Vaccinio-Piceion**							
	Picea abies	A	5	5	5	5	5	5
	Picea abies	B	5	5	4	5	4	3
	Sorbus chamaemespilus		1	.	.	.	.	1
	Hieracium murorum	C	4	4	3	3	3	5
	Picea abies		2	4	4	4	2	.
	Bazzania trilobata	D	1	2	1	2	.	1
d	**Vaccinio-Piceetea, Piceetalia**							
	Sorbus aucuparia	A	1	1	2	2	2	3
	Vaccinium myrtillus	B	5	5	5	5	5	5
	Rosa pendulina		5	4	5	5	4	5
	Sorbus aucuparia		5	4	4	3	2	4
	Rubus saxatilis		3	5	1	.	2	4
	Pinus mugo		.	1	.	1	2	.
	Oxalis acetosella	C	5	5	5	3	3	5
	Gentiana asclepiadea		5	5	5	4	2	3
	Orthilia secunda		.	2	.	3	1	.
	Gymnocarpium dryopteris		5	.	1	2	2	3

	Phegopteris connectilis		3	5	3	.	.	.
	Sorbus aucuparia		1	2	1	2	.	1
	Aposeris foetida		3	1	.	.	.	1
	Avenella flexuosa		1	1	.	.	.	.
	Luzula pilosa		2	1	.	.	.	.
	Dicranum scoparium	D	2	5	5	5	5	5
	Rhytidiadelphus triquetrus		4	5	3	1	3	2
	Polytrichum formosum		4	5	5	4	3	3
	Hylocomium splendens		3	5	.	1	2	.
	Hypnum cupressiforme		2	2	.	5	2	.
	Pleurozium schreberi		1	2	.	.	.	.
	Polytrichum commune		2	.	.	2	.	.
	Dicranum polysetum		4	.	.	.	.	.
	Grimmia pulvinata		.	.	.	5	.	.
	Leucobryum glaucum		.	.	.	2	.	.
e	**Erico-Pinion, Erico-Pinetalia**							
	Amelanchier ovalis	B	.	.	.	1	.	.
	Cirsium erisithales	C	4	4	3	3	5	5
	Buphthalmum salicifolium		.	.	.	2	1	.
	Erica carnea		.	.	.	3	.	.
	Epipactis atrorubens		.	.	.	2	.	.
f	**Aremonio-Fagion**							
	Rhamnus alpinus fallax	B	.	1	1	1	1	1
	Cardamine enneaphyllos	C	4	3	3	2	1	5
	Aremonia agrimonoides		1	1	1	2	.	3
	Euphorbia carniolica		1	.	3	.	.	2
	Cardamine trifolia		3	3	5	1	.	1
	Calamintha grandiflora		1	1	1	.	.	.
	Cyclamen purpurascens		.	.	1	2	.	1
	Omphalodes verna		.	.	1	1	.	.
	Scopolia carniolica		.	.	3	.	1	.
g	**Adenostylon, Adenostyletalia**							
	Rubus idaeus	B	3	4	3	4	4	5
	Ribes alpinum		1	.	.	.	2	1
	Ribes petraeum		.	1	.	.	.	1
	Salix glabra		2	.	.	.	.	.
	Polygonatum verticillatum	C	4	4	4	1	4	5
	Dryopteris filix-mas		2	1	5	2	2	3
	Veratrum album		4	4	3	.	2	3
	Senecio ovatus		1	.	1	2	3	2
	Saxifraga rotundifolia		1	.	2	1	.	2
	Ranunculus platanifolius		1	3	3	.	1	2
	Athyrium filix-femina		4	2	4	.	.	2
	Viola biflora		2	.	.	.	3	3
	Aconitum lycoctonum vulparia		1	.	.	.	2	1
	Cicerbita alpina		1	.	1	.	.	3

	Aruncus dioicus		1	.	2	.	.	1
	Geranium sylvaticum		.	.	.	.	1	4
	Chaerophyllum cicutaria		2	.	.	.	.	.
	Senecio ovirensis		2	.	.	.	.	.
h	**Fagetalia**							
	Fagus sylvatica	A	1	2	3	3	2	4
	Acer pseudoplatanus		1	1	.	.	.	1
	Fagus sylvatica	B	4	2	3	3	1	4
	Daphne mezereum		3	2	3	5	2	4
	Lonicera alpigena		1	3	3	2	3	2
	Acer pseudoplatanus		1	1	3	2	.	3
	Rubus hirtus		1	.	.	.	.	.
	Prenanthes purpurea	C	2	4	5	4	3	5
	Phyteuma spicatum coeruleum		3	4	3	1	2	4
	Mycelis muralis		.	1	3	4	2	4
	Paris quadrifolia		2	2	3	.	2	4
	Symphytum tuberosum		2	.	1	.	1	5
	Viola reichenbachiana		1	.	1	.	2	3
	Polystichum aculeatum		1	.	3	1	.	2
	Geranium robertianum		.	.	1	.	.	1
	Galeobdolon luteum		2	.	3	.	1	3
	Epilobium montanum		.	.	1	1	1	2
	Actaea spicata		1	.	3	.	3	1
	Thalictrum aquilegifolium		2	.	.	.	.	3
	Fagus sylvatica		.	.	1	2	.	1
	Gymnocarpium robertianum		.	.	.	3	.	1
	Festuca altissima		1	.	.	2	.	2
	Acer pseudoplatanus		1	.	1	.	.	.
	Ranunculus lanuginosus		2	.	.	.	.	.
	Carex pilosa		2	.	.	.	.	1
	Carex sylvatica		.	1	1	.	.	.
	Heracleum sphondylium		.	.	.	.	2	2
	Poa nemoralis		.	.	.	.	2	1
	Euphorbia dulcis		.	2	.	.	.	.
	Asplenium scolopendrium		.	.	2	.	.	.
	Asarum europaeum		.	.	1	.	1	.
	Neckera crispa	D	.	.	3	4	1	1
	Eurhynchium zeterstedti		2	.	.	1	.	.
i	**Querco-Fagetea**							
	Sorbus aria	A	.	.	1	1	.	1
	Taxus baccata		.	.	1	.	.	.
	Sorbus aria	B	.	1	1	2	2	1
	Cotoneaster tomentosa		.	.	.	.	1	.
	Anemone nemorosa	C	5	5	5	.	2	4
	Anemone hepatica		.	.	1	2	.	1
	Carex ornithopoda		.	.	2	.	2	1

	Pteridium aquilinum		.	.	.	2	.	.
	Ctenidium molluscum	D	4	.	5	5	4	5
	Isothecium myurum		2	.	.	3	.	.
j	**Asplenietea trichomanes**							
	Moehringia muscosa	C	1	3	3	1	1	5
	Asplenium viride		5	2	4	.	4	3
	Cystopteris fragilis		1	.	1	1	2	1
	Asplenium trichomanes		.	4	3	3	1	1
	Asplenium rura-muraria		.	.	1	3	1	1
	Polypodium vulagre		.	.	2	2	.	.
	Cystopteris alpina		.	.	1	.	2	.
	Asplenium fissum		.	.	.	.	2	.
	Kernera saxatilis		.	.	.	2	.	.
k	**Seslerietea albicans**							
	Aster bellidiastrum	C	1	3	.	.	1	.
	Campanula scheuchzeri		1	.	.	.	2	.
	Erigeron polymorphus		.	.	.	1	1	.
	Galium anisophyllum		.	.	.	.	2	1
	Carlina acaulis simplex		.	.	.	.	2	1
	Ranunculus carinthiacus		.	.	.	.	2	2
	Phyteuma orbiculare		.	.	.	.	2	.
l	**Ostale vrste** / *Other species:*							
	Rosa pimpinellifolia	B	.	.	.	.	.	1
	Salix capraea		.	.	.	.	.	1
	Fragaria vesca	C	3	3	1	3	.	2
	Silene pusilla		.	.	1	.	2	1
	Ajuga reptans		.	.	.	.	1	1
	Luzula luzuloides		1	1	.	.	.	1
	Dryopteris carthusiana		1	.	.	.	2	.
	Polygonum viviparium		1	.	.	.	1	.
	Trolius europaeus		1	.	.	.	.	2
	Festuca nigrescens		1	.	.	.	.	1
	Carex brachystachys		.	.	.	2	1	.
	Poa alpina		.	.	.	.	2	2
	Epilobium angustifolium		.	.	.	.	2	1
	Thymus praecox		.	.	.	.	2	1
	Solanum dulcamara		.	.	.	.	2	1
	Dryopteris villarii		.	.	.	.	2	1
	Deschampsia caespitosa		2	.	.	.	.	.
	Carex brizoides		2	.	.	.	.	.
	Parnassia palustris		2	.	.	.	.	.
	Heliosperma alpestre		2	.	.	.	.	.
	Melampyrum pratense		.	2	.	.	.	.
	Orchis maculata		.	2	.	.	.	.
	Carex atrata		.	2	.	.	.	.
	Carduus acanthoides		.	.	.	.	2	.

	Geranium macrorrhizum		.	.	.	.	2	.
	Silene vulgaris		.	.	.	.	.	2
m	**Mahovine** / *Mosses*							
	Tortella tortuosa	D	5	5	5	5	4	5
	Plagiochila asplenoides		3	3	.	3	.	.
	Mnium undulatum		1	2	.	.	.	.
	Fissidens cristatus		3	.	.	3	.	.
	Schistidium apocarpum agg.		.	.	1	.	2	2
	Mnium marginatum		.	.	3	.	1	1
	Fissidens dubius		.	.	5	.	1	2
	Eurhynchium striatum		.	4	3	.	.	.
	Scaponia aspera		.	2	1	.	.	.
	Isothecium alopecuroides		.	.	3	.	.	3
	Mnium thomsonii		.	.	2	.	.	1
	Rhynchostegium murale		.	.	1	.	.	2
	Eurhynchium angustiarte		.	.	1	.	.	1
	Brachythecium velutinum		.	.	1	.	.	1
	Metzgeria furcata		.	.	1	.	.	1
	Plagiomnium undulatum		.	.	.	1	1	.
	Fissidens adianthoides		.	.	.	1	1	1
	Thuidum tamariscinum		.	.	.	.	1	1
	Dicranella sp.		.	.	.	.	1	1
	Plagiochila porelloides		.	.	3	.	1	.
	Fissidens sp.		.	4	.	.	.	.
	Sphagnum sp.		.	2	.	.	.	.
	Dicranum montanum		.	.	.	4	.	.
	Brium cappilare		.	.	.	3	.	.
	Encalypta streptocarpa		.	.	.	3	.	.
	Homalothecium sericeum		.	.	.	2	.	.
	Porella platyphylla		.	.	.	2	.	.
	Scapania nemorea		.	.	.	2	.	.
	Cirriphyllum tenuierve		.	.	.	2	.	.
	Pteryginandrum filiforme		.	.	.	2	.	.
	Ditrichum flexicaule		.	.	.	2	.	.
	Mnium sp.		.	.	.	.	.	2
	Ctenidium sp.		.	.	.	.	.	2

1 - *Lonicero coeruleae-Piceetum* (Slovenija; Zupančič 1999)
2 - "*Piceetum croaticum subalpinum*" (Gorski kotar, Velebit; Horvat in Cestar 1964)
3 - *Lonicero coeruleae-Piceetum* (Gorski kotar; Vukelić i dr. 2010)
4 - *Campanulo justinianae-Piceetum abietis* (Slovenija; Accetto 2006)
5 - *Hyperico grisebachii-Piceetum abietis* (Sjeverni Velebit, Samarske stijene; Vukelić et al. 2010)
6 - *Laserpitio krapfii-Piceetum* (Sjeverni Velebit ; Vukelić et al. 2010)

A -Trees / *drveće* B - Shrubs / *grmlje* C - Undergrowth / *prizemno rašće* D - Mosses / *mahovine*
a-f - sinsystematic affiliation / *sistematska pripadnost*

*The table excludes species that are represented in only one column with presence degree 1 / *Izostavljene su vrste koje se pojavljuju samo u jednom stupcu sa stupnjem udjela 1*

Subalpine spruce forests in Western Croatia are similar to spruce forests of the Dinaric and subalpine region of Slovenia. They contain boreal spruce species, such as *Lonicera nigra, Lycopodium annotinum, Huperzia selago, Listera cordata, Calamagrostis arundinacea* and *Rhytidiadelphus loreus*. On the other hand, spruce forests of Velebit show greater similarity with Bosnian and Herzegovinian subalpine communities *Sorbo-Piceetum* Fukarek 1964 and *Pyrolo-Piceetum* (Fukarek 1969) Zupančič 1990, although there are also a number of species that differentiate them. For example, about thirty species that constantly occur in spruce forests of Northern Velebit are either absent or occur very rarely in the related forests of Bosnia and Herzegovina: *Campanula rotundifolia* agg, *Knautia drymeia, Calamagrostis varia, Polystichum lonchitis, Clematis alpina, Adenostyles alpina, Maianthemum bifolium, Heracleum sphondyllium, Doronicum austriacum, Melica nutans, Actaea spicata, Mercurialis perennis, Petasites albus, Carex digitata, Moehringia muscosa, Silene vulgaris* and others. On the other hand, these associations contain species which are either not represented or are less frequent in sub-alpine spruce forests of Velebit, such as *Homogyne alpina, Melampyrum sylvaticum, Moneses uniflora, Orthillia secunda, Listera cordata, Rhytydiadelphus loreus, Plagiotecium undulatum, Avenella flexuosa, Pleurozium schreberi, Corallorrhiza trifida, Pyrola rotundifolia, Pulmonaria obscura, Knautia dinarica, Scabiosa leucophylla* and others. In conclusion, going from the north-west towards south-east of the Dinaric range, the alpine-boreal and Central European species are completely absent or their participation is decreasing, while the Illyrian and Balkan species are gradually occurring or their presence is increasing (Horvat 1953, Zupančič 1980, 1988, 1990, Vukelić i dr. 2010a).

Table 3 Number of species by syntaxonomic categories
Tablica 3 Broj vrsta prema sintaksonomskim kategorijama

	Lc-P	***Hg-P***	***Lk-P***	***Lb-P***	***Hg-P***	***Lk-P***
	number of species			%		
Vaccinio-Piceenion	14	8	8	8.7	6.2	5.2
Abieti-Piceenion	8	5	9	4.9	3.9	8.8
Vaccinio-Piceion	5	4	5	3.1	3.1	3.2
Vaccinio-Piceetea, Piceetalia	25	19	17	15.4	14.7	11
Spruce species ∑	**52**	**36**	**39**	**32.1**	**27.9**	**25.2**
Erico-Pinion, Erico-Pinetalia	**2**	**4**	**3**	**1.3**	**3.1**	**1.9**
Aremonio-Fagion	9	3	7	5.6	2.3	4.5
Adenostyletalia	**13**	**12**	**19**	**8**	**9.3**	**12.3**
Fagetalia	**24**	**20**	**28**	**14.8**	**15.5**	**18.1**
Querco-Fagetea	8	7	7	4.9	5.4	4.5
Asplenietea	8	7	5	4.9	5.4	3.2
Seslerietea albicans	**1**	**8**	**6**	**0.6**	**6.2**	**3.9**
Other	**6**	**21**	**15**	**3.7**	**16.3**	**9.7**
Moss	39	11	26	24.1	8.6	16.7
∑	**162**	**129**	**155**	**100**	**100**	**100**

The three associations differ in terms of ecological factors (Table 4). The association *Hyperico grisebachii-Piceetum* proved to be the coldest, containing the least humidity and nutrients, the lowest acidity degree and the highest amount of light, thus reflecting the subalpine rocky terrains and open sites in which it grows. The association *Lonicero caeruleae-Piceetum* has the highest acidity degree and site humidity. This is also understandable, since the area in which it occurs is colder than the rest of Croatia and receives a much higher amount of rainfall. In such conditions, the decomposition of the organic floor is the poorest, causing the highest acidity by the formation of raw humus. In terms of light conditions, humidity, acidity and nutrient wealth, the association *Laserpitio krapfii-Piceetum* is between the two previous ones.

Table 4 Comparison of ecological indicator values (Kruskal-Wallis test; p<0,05)
Tablica 4 Usporedba ekoindikatorskih vrijednosti (Kruskal-Wallis test; p<0,05)

Ecological factor	LkP		HgP		LcP	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Light	4.87	0.300	5.26	0.251	**4.26**	0.240
Temperature	4.00	0.334	**3.66**	0.248	3.99	0.148
Continentality	3.64	0.171	**4.09**	0.133	3.79	0.096
Moisture	5.37	0.140	**5.21**	0.193	5.40	0.113
Soil reaction	6.04	0.353	6.10	0.203	**5.58**	0.248
Nutrients	4.96	0.277	**4.40**	0.422	4.93	0.230

CONCLUSIONS
ZAKLJUČCI

The results of the analysis and comparison of the floristic composition, ecological conditions, distribution range and physiognomy of the recorded stands show three clearly distinct associations with the following synsystematic affiliation:

Class: *Vaccinio-Piceetea*
Order: *Vaccinio-Piceetalia*
Alliance: *Vaccinio-Piceion*
As: *Lonicero caeruleae-Piceetum abietis* Zupančič (1976) 1999 corr.
Laserpitio krapfii-Piceetum abietis Vukelić, Alegro et Šegota 2010
Hyperico grisebachii-Piceetum (Bertović 1975) Vukelić, Alegro, Šegota et Šapić 2010

The association *Lonicero caeruleae-Piceetum* with the characteristic species *Lonicera caerulea* subsp. *borbasiana*, *Lonicera nigra* and *Sanionia uncinata* was identified in the Gorski Kotar area. In relation to the other two associations, the prevailing species of this association are those of spruce forests of the class *Vaccinio-Piceetea.* In terms of Ellenberg's ecoindicator values, it proved to be the most acidophilic and contains the least amount of light.

The association *Laserpitio krapfii-Piceetum* belongs to the altimontane and subalpine belt of the Dinaric area in Croatia. It is predominantly developed on steep, north-facing, cold and closed sinkholes and depressions. It has macro-climatic features of a pre-alpine beech forest in whose belt is occurs. The characteristic species of the association is *Laserpitium krapfii*, while species of the order *Fagetalia* and lower units constitute the differentiating species.

The association *Hyperico grisebachii-Piceetum* extends above an altitude of 1400 m. and inhabits the tops of Samarske Stijene, and less so other rocky tops of Velika Kapela and the Risnjak massif. The differentiating species of the association include *Salix appendiculata, Sambucus racemosa, Juniperus communis* subsp. *nana, Achillea clavenae,* and *Gentiana lutea* subsp. *symphyandra.* The species of the class *Erico-Pinetea* should be pointed out for reasons of their high participation. The amount and cover of the species of the orders *Fagetalia* and *Adenostyletalia* is much lower than in the phytocoenosis *Laserpitio krapfii-Piceetum,* which occurs in lower positions.

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Original scientific paper
Izvorni znanstveni članak

THE EFFECT OF REGULATING STREAMFLOWS ON THE BEAVER HABITAT IN CROATIA

UTJECAJ UREĐIVANJA VODOTOKOVA NA STANIŠTA DABRA U HRVATSKOJ

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Abstract

Beaver adjusts well to all the changes in its habitat on condition that food and water is provided throughout the year. In some cases beaver inhabits areas with very few food resources.

The fact that beavers unexpectedly choose some quite unusual habitats to settle on was in fact the reason for doing the research on these seemingly marginal habitats in the first place.

Although in Croatia there is a fair amount of well preserved habitats, some smaller stream flows are permanently being regulated, and that's which has to a higher or a lesser degree diminished their natural quality. In order to establish the real effect of stream flow regulation on the beaver habitat, research was made on 9 rivers in Central Croatia and it consisted of fieldwork and mapping the stream flows. As a control method we used topographic maps 1:25.000 and satellite photos provided by Google Earth.

938 km of stream flows were inspected on 9 km of rivers. It was recorded that natural vegetation covers 70% of those stream flows. 18% of stream flows were previously regulated (leveling beds, building dams etc.), but, due to ecological succession, herbaceous and ligneous vegetation - which we named "successive vegetation" - recovered and made it possible for the beaver to inhabit those terrains once again. On those parts of stream flows, beavers are commonly present, but there is also a danger of them getting hurt or forced out beacause of the stream flow regulation that periodically takes place.

Some time after the stream flow regulation, beavers cannot settle on those terrains because they have no vegetation. The stream flows that are regulated every year, cannot be inhabited by beaver at all.

Instructions that can be given to the company that conducts the stream flow regulations are not to remove the vegetation directly on the banks or inside the 5m perimeter. That would provide the conditions for the beavers, birds and other semi aquatic animal species. It would also prevent water temperature from rising and enrich the water with oxygen. Those instructions are being partly accepted, but in the future they should be applied on the majority of regulated stream flows.

Key words: Beaver, streamflow regulation, vegetation, protection of habitat, population density

Sažetak

Dabar se dobro prilagođava svim promjenama u staništu, pod uvjetom je da čitave godine osigurana voda i hrana. U nekim slučajevima obitava na ekstremno siromašnom području kada je u pitanju izbor hrane. Upravo odabir staništa i nastanjivanje dabrova na nekim neočekivanim područjima ponukale su na istraživanje dabra u naizgled marginalnim staništima. Iako Hrvatska ima očuvana staništa, neki manji vodotoci su pod stalnim meliorativnim zahvatima čime je bitno smanjena ili u potpunosti devastirana prirodnost tih vodotokova.

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Da bi utvrdili stvarni utjecaj na staništa dabra, pa i na same familije koje su već nastanjene na pojedinim lokacijama, izvršeno je istraživanje prirodnosti staništa na 9 rijeka središnje Hrvatske. Istraživanja su vršena obilaskom i terenskim kartiranjem vodotokova a za kontrolu i kao pomoćna metoda kod planiranja i provođenja terenskih istraživanja služile su topografske karte 1:25.000 te satelitski snimci Google Erth programa.

Na 9 rijeka ukupno je istraženo 938 km vodotokova. Na istraženim vodotocima utvrđeno je 70 % prirodne vegetacije, odnosno u cijelosti očuvanih prirodnih staništa. Na 18 % tokova izvršena je ranije melioracija (uređenje vodotoka, izravnavanje korita, izgradnja nasipa i sl.) ali se prirodnim putem (sukcesijom) vratila zeljasta i drvenasta vegetacija, koju smo nazvali sukcesivna, jer se prirodnim procesom sukcesije vratila vegetacija i na taj način stvoreni su uvjeti za obitavanje dabrova. Na takovim dijelovima vodotokova česta je prisutnost dabrova, ali je i stalna opasnost od protjerivanja ili stradavanja, jer se ti dijelovi vodotoka periodički ponovno čiste od vegetacije i uređuju.

Nakon uređivanja vodotokova određeno vrijeme nema uvjeta za dabrove jer nema ni vegetacije (dok se ponovno ne razvije) a na dijelovima gdje se svake godine čisti vegetacija, trajno je „sterilno" područje za dabrove.

Sugestija poduzeću koje gospodari vodama, da se ostavlja vegetacija neposredno na obali i do 5 metara uz obalu, kako bi ostali uvjeti za dabra, druge semiakvatične vrste, ptice močvarice, kako bi se spriječilo zagrijavanje vode i vršilo obogaćivanje vode kisikom, djelomično je prihvaćeno i na nekim dijelovima se primjenjuje, ali bi to trebalo primijeniti na vučinu vodotokova koji su već uređeni i koji se održavaju čišćenjem vegetacije u inundacijskom pojasu.

Ključne riječi: *Dabar, uređenje vodotoka, vegetacija, zaštita staništa, gustoća populacije*

INTRODUCTION
UVOD

Beaver habitats are well known and defined by the fact that beaver belongs to the semi-aquatic animal species. Hence, water surfaces rich with green succulent vegetation are the most suitable habitats for beaver, because they before all provide food but also peace and shelter.

Regarding the wide array of plant species beaver uses for food in the vegetation period or in winter, when the major part of its menu consists of soft broadleaves' bark, beaver inhabits a wide area of suitable biotopes. Beaver is well adjusted to environmental changes, provided that food and water are available throughout the year. In some cases, it also inhabits extremely poor habitats regarding food. Due to its relatively modest habitat demands, which the animal itself arranges in order to enhance living conditions, as well as high reproduction capacity (Heidecke 1983, Heidecke et al, 2003) provide this species with an advantage when inhabiting new areas. Beaver's ability to adjust to different habitat conditions enabled successful reintroduction in the greater part of Europe (Weinzierl 1973, Reicholf 1976, Zahner et al., 2005, Grubešić 2008). Watershed of the river Sava is one of the areas where three spatially divided projects of beaver introduction were successfully carried out (Grubešić et al. 2001, Grubešić et al. 2006).

Immediately after the beaver's return to Croatia, a dynamic spreading of beavers through the rich network of confluents commenced, even at a remarkably large distances in very short periods (Grubešić 2008).

The search for new habitats is the reason why beavers inhabited some unexpected areas (Grubešić 2008). Certain locations of beavers' families triggered the research of causes for migrations to larger distances and inhabitation of apparently marginal biotopes. These "marginal" biotopes in the middle part of Croatia are primarily the results of human activities regarding streamflow regulation and maintenance.

Similar problems for beaver, but also with beaver, in the inadequate habitat conditions are known in the areas where beaver is present long since and in greater numbers (Schwabet et al. 1994, Maier 1994, Zahneret et al. 2005). The influence of men on beaver habitat and the environment which they inhabit is the conflict that lead towards the disappearance of beaver from the major part of Europe (Zahner et al. 2005), and with its reappearance it is actual again.

Together with the monitoring of beaver population in Croatia, there is also a need for the monitoring of natural state of certain habitats, especially confluents inhabited by beavers.

MATERIALS AND METHODS
MATERIJALI I METODE

For the purpose of this research and analysis, streamflows from the central part of Croatia which comprise the watershed of the river Sava were used.

The following confluents were taken into analysis: Kupa, Glina, Odra, Mrežnica, Korana, Lonja, Česma, Pakra, Ilova, Dobra and Krapina. During the field research, and in regard to beaver habitats recording and mapping of their distribution, these streamflows were analyzed and recorded on their specific parts according to the state they were in regarding the natural environment. Streamflows were divided into three categories regarding they natural look, i.e. the extent of the anthropogenic influence. Certain segments of streamflows were defined based on the following criteria:

- Segments of steramflows which remained intact and withstood natural appearance, where there were no regulations of river bed, shores and the littoral, i.e. which maintained their original course, natural shores and original - pristine vegetation inside the streamflow as well as on the shores and the surrounding area (min. 15 metres far from the shore).
- Streamflow segments under anthropogenic influence where some regulation has been carried out, shores and dikes were constructed, but in time succession took over the shores and the littoral area covering them with vegetation, shrubbery and trees which are very similar to the original ones (succulent plants of swamp and humid habitats, soft broadleaves' trees and shrubs), so that there is an impression of an almost original habitat.
- Segments of streamflows under anthropogenic influence where regulations were carried out, shores and the littoral part are arranged and (at least annually) grass mowing, succulent vegetation and trees and shrubbery removal is being conducted alongside the streamflow.

For certain parts of streamflows, their length and state of the flow, shores and the littoral area were observed and recorded.

For the purpose of habitat mapping, standard maps in proportion 1:25.000 and GPS equipment were used to state the positions of transition points and distances of certain parts of springflows. All the streamflows and specific situations were photographed and documented.

As a control method for determining the conditions of specific segments of springflows, satellite images from Google Earth application were used.

Collected data base on locations of specific beaver families was used to perform the estimation of the optimal habitat capacities of specific streamflows, i.e. the dangers beaver families may encounter regarding springflow regulations.

RESULTS
REZULTATI

The research was conducted on eleven rivers in total length of 1 186 km, which comprises 95% of the total length of all catchments. Collected data on the vegetation structure are presented in table 1. Cleaning and removing of vegetation is the most intense on river Lonja where more than 40% of streamflow is without vegetation. Almost 100% natural vegetation was recorded on 6 of the researched streamflows (62% of the researched area). These streamflows are the greatest potential for spreading of the beaver population. Apart from the vegetation mapping, a model of beaver population development was also made (presented in Figure3).

Table 1 Confluents researched regarding the type of vegetation
Tablica 1 Istraživani vodotoci obzirom na tip vegetacije

River *Rijeka*	Length *Duljina*	Investigated length *Istražena duljna*	Natural vegetation *Prirodna vegetacija*	Without vegetation *Bez vegetacije*	Succession vegetation *Sukcesivna vegetacija*
		%	km	km	km
Kupa	296	100	291	5	0
Glina	113	95	106	1	0
Odra	50	91	42	0	4
Mrežnica	64	100	64	0	0
Korana	134	100	134	0	0
Lonja	133	92	36	54	32
Česma	123	70	0	17	69
Pakra	72	88	35	9	19
Ilova	85	91	48	11	33
Dobra	104	100	104	0	0
Krapina	75	100	15	11	49
Total *Ukupno*	1249	95	874	108	206

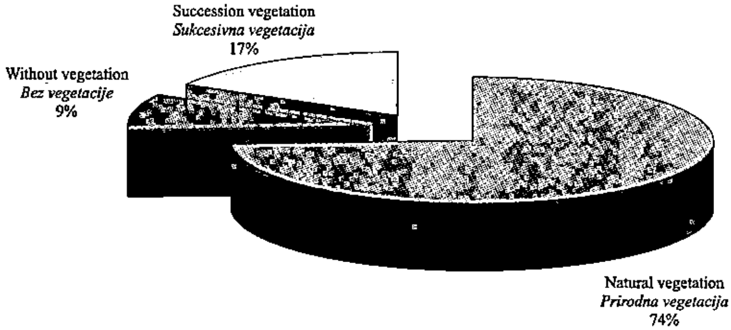

Figure 1 Structure of vegetation on the research area
Slika 1 Struktura vegetacije istraživanog područja

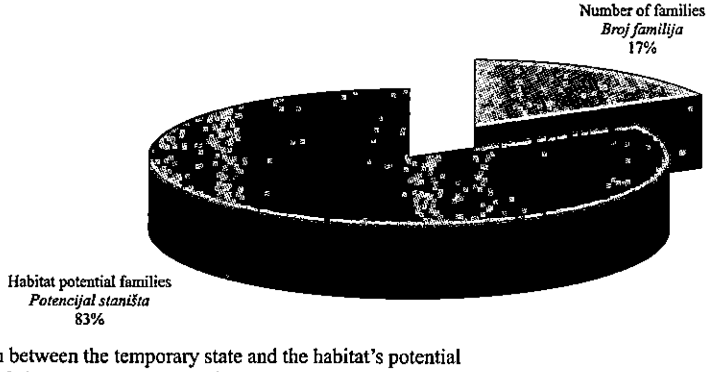

Figure 2 Relation between the temporary state and the habitat's potential
Slika 2 Odnos sadašnjeg stanja i potencijala staništa

DISCUSION AND CONCLUSIONS
RASPRAVA I ZAKLJUČCI

The analysis of 11 streamflows in a length of 1 186 kilometres shows that preserved natural spots with original vegetation are still dominant on shores and littoral areas. This is what enables the further spreading of beavers' families, i.e. filling of the available living space suitable for dwelling of beavers' families.

After the more detailed analysis of the wider area around the researched streamflows, the conclusion arises that the intensity of actions on streamflows coincides with the intensity of utilization of the surrounding surfaces, namely agricultural. Actions for streamflow regulations, construction of dikes and canals and their regular maintenance (grass mowing, shrubbery and trees removal), are the efforts made in order to protect the area from floods and water logging. Unfortunately, these actions also negatively affect habitats of mammals, birds and fish. It is beyond any doubt that preservation or return of the natural vegetation on meliorated parts of streamflows would result in favourable habitat conditions for numerous species, among which is also a beaver. Having in mind the experiences of researchers in other parts of Europe (literature citing) regarding beavers' presence within the agricultural ecosystems, the question emerges whether such localities are at all desirable as habitats for beavers, concerning all the potential damage they can cause on crops and shores, which will also affect the level of tolerance towards this species, shifting the attitude from desirable to undesirable.

Hence, it is beyond any doubt that streamflow regulation affects negatively the natural composition of the same, as well as other water and swamp habitats, but the amount of natural streamflows and their segments where succession brought back the initial vegetation after the regulation took place still provides stability and sufficient space for beaver population, with the possibility of spreading and the increase of population density.

According to the above stated, it is estimated that there is still room for the increased number of beavers, enhancement of the population density within the suitable parts of streamflows as well as colonization of confluents, oxbow lakes and other water surfaces with permanent water and a quality food basis.

According to foreign findings (Meyer et al, 2006), the estimation is that the optimal number of beavers for the researched streamflows is approximately 310 families, which is almost five times bigger number than at present.

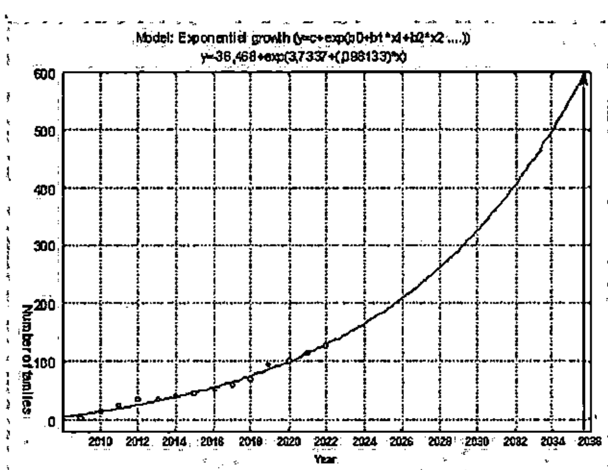

Figure 3 Model of beaver population development on the research area
Slika 3 Model razvoja populacije na istraživanom području

Based on the present research, the conclusion is that a population doubles in the period between 3 to 4 years, which means that 14 years remain until the habitat reaches its full capacity (Figure 3).

Measures required for protection of beavers and their habitats
Potrebne mjere za zaštitu dabrova i staništa

Having in mind that it is impossible to stop the regulation of streamflows, which is highly justified in some cases (flood prevention); it is essential to conduct regular activities regarding the informing and education of staff in water management companies. In the first place, contacts must be maintained with the competent staff and managers who decide when, where and what will be regulated and agree on protection measures for beaver families which inhabit the areas planned for regulation. It is also important to spread the information to the executive chiefs and machine operating staff who implements the streamflow regulation operations, especially mechanics who operate the machines, because the greatest danger a beaver may encounter is to be squashed by a machine while seeking logical refuge inside its den. It is recommended to exclude areas with dens, dams and increased beaver activities from such regulation operations, unless they are necessary for other water management objects.

Despite of wide regulation operations on streamflows, which were conducted on several places without the increased danger from floods or other negative consequences of the increased water-level, there is a great chance that such sites could in perspective be "returned" into the state of suitable habitats not only for beaver but also for the rest of the semi-aquatic species as well as swamp birds and the fish fauna.

Hence, in some regions (e.g. Žutica), where beaver colonisation was conducted in Croatia and the surrounding area, the agreement with the water management sector was reached, and even partially realized, to leave vegetation alongside shores of water management objects (canals, streams, oxbow lakes) and in the zone of 5 metres from shores. This resulted in several positive effects, for instance:

- preservation of the original shore vegetation as well as the natural features of the streamflow
- on parts of streamflows which are already regulated, alongside shores and in the littoral, succulent and wooden vegetation grows which is in its composition very similar to the vegetation which grows on natural habitats (succession of vegetation)
- food, shelter and reproduction space for semi-aquatic species and swamp birds is ensured
- The vegetation prevents overheating of water in summer, thus providing more favourable conditions for organisms which live in the water.
- Alongside the streamflow, there are various obstacles (fallen trees, branch piles and soil) that generate waterfalls which enrich the water with oxygen and also purify it (halt solid substances that the water carries).

In cooperation with the respective ministry for nature protection, the strategy for the regulation of streamflows, priorities and the extent of operations must be agreed, since it is not always necessary to completely remove the vegetation from a streamflow and the surrounding area under the excuse of proper functioning of a streamflow or a canal.

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VARIATION OF CLIMATE IN THE REGION OF GORSKI KOTAR

KOLEBANJE KLIME NA PODRUČJU GORSKOG KOTARA

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Abstract

Climate is a complex ecological factor described by different climate elements and events that affect vegetation development and its natural distribution. For forest vegetation, the most important factors are air temperatures, amount of precipitations, air humidity, snow and wind. The aim of this research was to determine changes of climate elements in Gorski kotar region. The increasing or decreasing trends of individual climate elements were analysed using the linear trend method. Values of climate elements from the referent line were compared to the period from 1991 to 2007. For the research of climate element trends in the region of Gorski kotar the meteorological stations with the longest period of observations were chosen. Trends of air temperatures at all meteorological stations were positive. Negative trend of annual precipitation was recorded at all meteorological stations. Trend of days with snow and maximal snow height showed the smallest changes. Forest vegetation in the region of Gorski kotar is adapted to certain climate conditions that are predominant in this region. These conditions change through time, and this reflects on growth and development of all organisms. Assumed climate variations can lead to changes in spatial distribution of forest vegetation, change in composition, structure and productivity of forest ecosystems, change in ecological stability, health status of forest as well as non-wood forest functions.

Key words: climate variation, climate elements, Gorski kotar

Sažetak

Klima je kompleksan ekološki čimbenik koji opisujemo pomoću različitih klimatskih elemenata i pojava koji utječu na razvoj vegetacije i njeno prirodno rasprostiranje. Za šumsku vegetaciju najvažnije su temperature zraka, količine oborina, vlaga zraka, snijeg i vjetar. Cilj istraživanja je bio utvrditi promjene klimatskih elemenata na području Gorskog kotara. Trendovi smanjenja ili povećanja pojedinih klimatskih elemenata analizirani su pomoću linearnog trenda. Uspoređene su vrijednosti klimatskih elemenata referentnog niza sa razdobljem 1991-2007. Za istraživanje trendova klimatskih elemenata na području Gorskog kotara odabrane su meteorološke postaje sa najduljim razdobljem motrenja. Trendovi temperatura zraka na svim meteorološkim postajama su pozitivni Na svim meteorološkim postajama je utvrđen negativan trend vrijednosti godišnjih količina oborina. Trendovi broja dana sa snijegom i maksimalnih visina snijega su pokazali najmanje promjene. Šumska vegetacija na području Gorskog kotara je prilagođena na određene klimatske uvjete koji prevladavaju u tom području. Ti se uvjeti mijenjaju kroz vrijeme, a to se odražava na rast i razvoj svih organizama. Pretpostavljena klimatska kolebanja mogu dovesti do promjena u prostornoj razdiobi šumske vegetacije, promjeni u sastavu, strukturi i proizvodnosti šumskih ekosustava, promjeni ekološke stabilnosti, zdravstvenog stanja šuma te općekorisnih funkcija šuma.

Ključne riječi: *kolebanje klime, klimatski elementi, Gorski kotar*

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INTRODUCTION
UVOD

The term climate change refers to the change that takes place in one direction while the climate variation refers to the rhythmic oscillation with larger or smaller deviations around a single mean value. In determining climate change, time becomes a key factor. Namely, a change in one direction during a certain period can be observed as part of climate variation if observed for a longer period of time. Climate change can be determined by using change of one climate element. Change of one element is associated with changes of other elements and appearances. Changes of air temperatures are associated with change of precipitation (Kirigin, 1975). According to Penzar et al. (1975) changes can occur at the same time for most of climate elements (air temperature, air humidity, air pressure, precipitation) or just some of them.

Significant climate changes that appear or will appear in the future as a result of increased CO_2 levels, will have serious biological and ecological consequences on forest ecosystems. The threat of negative climate events must not be underestimated, especially for species very sensitive to climate stressors like silver fir (Becker et al., 1989). Among stress factors effecting damage of forest ecosystems, destruction of tree assimilation system and subsequent dieback of entire ecosystem Oszlányi (1997), drought, climate change and sudden and unexpected temperature changes were reported.

Since the problem of tree dieback is mainly associated with air temperatures and amount of precipitations (Vajda, 1965, Prpić, 2001, Ugarković, 2011), the effect of these two climate elements can be the crucial factor causing tree dieback.

Climate changes are an important element in the process of tree dieback as they determine water balance, especially in situations of disturbed water supply and water transport in forest trees (Tesche, 1989; Saxe, 1993). According to Usčupulić et al. (2007) climate is the main factor causing tree dieback. Long perennial droughts have weakened the condition of plants and their system of defence against biotic harmful agents (mistletoe, *Armillaria* fungi and insects). At the same time, these conditions have caused Bark beetle reproduction over the critical threshold for species number.

Trends are the greatest in the northern boreal geographical latitudes, 1-2°C from 1970. The greatest warming happens during spring and winter, when the minimal daily air temperatures raise more rapidly than the maximal ones (Easterling et al., 1997; Boisvenue & Running, 2006; Bonsal et al., 2001).

Global precipitations trends are less consistent, but have been generally showing an increase of 3 to 5% in the last decade (Groisman et al., 2004; Boisvenue & Running, 2006). This increase of precipitation amount does not necessarily mean that greater water amount is available to the forest. High air temperatures cause greater water losses by evapotranspiration, and an increase of annual precipitations amount in the form of rain increases surface flow (water loss), greater than accumulation of water in form of snow cover (Knowles et al., 2006).

Height of snow cover decreased significantly during the last 30 to 50 years in the west part of the USA, as well as and in Canada, and spring flow appears one to four weeks earlier (Stewart et al., 2005). Also, there is evidence that moist climate becomes even moister, and dry climate even drier, resulting in greater extremes in hydrological cycle.

Hasselman (1997) found that during the last century mean air temperature increased by 0.5°C. Weber et al. (1997) reported changes of temperature regime during the 20^{th} century for the mountain region of Middle Europe. Research included differences between maximal and minimal air temperatures during a hundred year long linear trends. Mountain meteorological stations at higher altitudes showed small changes in differences between maximal and minimal air temperatures.

Seletković, Tikvić and Ivkov (1993) analysed meteorological data over the last hundred years from the meteorological station Zagreb-Grič and found changes in temperature and precipitation regime in Croatia. Matić et al. (1998) defined climate changes that caused dieback of certain tree species, especially of silver fir. At the same time, stands with different ratio of tree species in the mixture ratio were formed, somewhere with other tree species.

In order to understand importance and role of climate changes on growth and increment of forest trees, Hasenauer et al. (1999) used ecosystem model "Forest-BGC" to predict net primer production of forest trees. Authors researched growth and increment of forest trees in regard to climate change in Austria for period from 1961 to 1990 and found no changes in precipitation amount i.e. precipitation regime. Authors reported significant increase of the mean annual air temperature of 0.7°C, the mean annual minimal temperature of 0.8°C, winter temperature of 2.3°C as well as an increase of vegetation temperatures and prolongation of vegetation period by 11 days. All these climate changes resulted in an increase of radial increment of silver fir trees in Austria. Owing to air temperature increase during the last twenty years, heights of annual snow cover in Northern Hemisphere decreased by 10% (Groisman et al., 1994). For this reason in Alpine countries like Austria, with maximal amount of precipitation during vegetation period (Auer, 1993), prolongation of vegetation period as a result of higher air temperatures in combination with changes of habitat conditions can result in increased forest production.

Forest ecosystems are affected by numerous local meteorological and climatic conditions. Various ecological processes (photosynthesis, evapotranspiration, respiration, decomposition of substances, etc.) are closely connected with meteorological conditions. Recent damages of forests in Europe are more and more emphasised (Mueller-Edzards et al., 1997). Meteorological stress factors (like drought, high and low temperatures, cold, etc) are considered to be the possible causes of these forest damages. To study these processes and determinate possible causes, correct climate data are necessary (Xia et al., 2001).

Emphasised sensitivity of fir and beech-fir forests, as well as tree dieback and dieback of entire stands have contributed to the choice of Gorski kotar region as location for climate researches. The aims of this research were to determine variation and calculate trends of climate elements (air temperature, precipitation amount, number of warm and cold days, number of snow days, and height of snow).

RESEARCH AREA
PODRUČJE ISTRAŽIVANJA

The research was done in the mountain region of Croatia, in the area of beech-fir and fir forests in Gorski kotar. According to Köppens classification, Gorski kotar can be classified into Cfsbx type of climate. This type is characterised by moderate warm rain climate, without the drought period. The mean annual air temperature in the researched region was 7.2°C, and the mean amount of precipitation was about 2000 mm (Seletković, 2001). The basic substrate is composed of limestone, dolomites and sandstones of varying age. The dominant soil types are humus, brown and illimerized soils, rendzinas, dystric brown soils and brunipodzol. The relief of researched region is very irregular and loose. It is broken with heads, ditches, rocks, coves and cliffs i.e. karsts geomorphologic forms.

MATERIALS AND METHODS
MATERIJALI I METODE

For meteorological stations (table 1) in the researched region, linear trends of annual air temperatures and amount of precipitations, absolute maximal and minimal air temperatures, number of warm and hot days, number of days with precipitation ≥ 0.1 mm, number of days with snow ≥1 cm, maximal snow height were calculated. The data analysed using the linear-regression method.

By using the Student's *t* test of independent samples, the mean values of climate elements of the referent line (1961-1990) were compared with the period 1991-2007.

According to conclusions of the 13th Meeting Commission for Climatology of the World Metrological Organization, the referent period 1961-1990 is used for general comparisons, up to the end of

Table 1 List of meteorological stations, type of station and monitoring period
Tablica 1 Popis meteoroloških postaja, tip postaje i obrađeno razdoblje motrenja

Meteorological station *Meteorološka postaja*	Type of station *Tip postaje*	Monitoring period *Razdoblje motrenja*
Vrelo Ličanke	Climatological *Klimatološka*	1960 - 2007
Lokve Brana		1960 - 2007
Parg		1950 - 2007
Mrzla Vodica	Rain gauge *Kišomjerna*	1946 - 2007
Ravna Gora		1946 - 2007

the next referent (normal period) 1991-2020, meaning untill 2021 (Prikaz br.18, 2008; Šegota & Filipčić, 1996). All data were analysed using KlimaSoft 2.1 and Statistic 7.1. software.

RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

According to the results presented in Table 2 linear trends of annual air temperatures in the researched region are positive. The mean annual air temperatures and the absolute maximal temperatures are increasing significantly. The trends of the absolute minimal air temperatures are negative and are not significantly different (Table 3).

Table 2 Linear trends of annual and vegetation air temperatures
Tablica 2 Linearni trendovi i signifikantnost trendova godišnjih i vegetacijskih temperatura zraka

Meteorological station *Meteorološka postaja*	Mean annual temperature (°C) *Srednje godišnje temperature (°C)*				
	Linear trend *Linearni trend*	Beta	B	t	p-level (95%)
Vrelo Ličanke	Y=0,0508x + 6,4551	0,6468	0,0508	4,7984	0,0000*
Lokve Brana	Y= 0,0161x + 6,8087	0,3506	0,0161	2,5396	0,0145*
Parg	Y= 0,017x + 6,7459	0,3782	0,0170	3,0578	0,0034*

*p<0,05

Table 3 Linear trends of mean annual and absolute annual maximal and minimal air temperatures
Tablica 3 Linearni trendovi i signifikantnost trendova srednjih godišnjih i apsolutnih godišnjih maksimalnih i minimalnih temperatura zraka

Meteorological station *Meteorološka postaja*	Absolute maximal temperatures (°C) *Apsolutne maksimalne temperature (°C)*				
	Linear trend *Linearni trend*	Beta	B	t	p-level
Vrelo Ličanke	Y= 0,1008x + 28,378	0,5019	0,101	3,2832	0,0024*
Lokve Brana	Y= 0,0489 + 28,101	0,4137	0,0489	3,0827	0,0034*
	Absolute minimal temperatures (°C) *Apsolutne minimalne temperature (°C)*				
Vrelo Ličanke	Y= -0,0182x -17,235	-0,0499	-0,0181	-0,2829	0,7790
Lokve Brana	Y= -0,0157x – 17,268	-0,0639	-0,0156	-0,4347	0,6657

*p<0,05

Significant increase in the number of warm and hot days was found in the researched area (Table 4).

Decreasing trends of annual precipitations were found at all meteorological stations. Decreasing trend of annual precipitations was significant at meteorological stations Vrelo Ličanke and Lokve (Table 5).

Table 4 Linear trends of number of warm and hot days
Tablica 4 Linearni trendovi i signifikantnost trenda broja toplih i vrućih dana

Meteorological station *Meteorološka postaja*	Number of warm days ($T \geq 25°C$) *Broj toplih dana ($T \geq 25°C$)*				
	Linear trend Linearni trend	Beta	B	t	p-level
Vrelo Ličanke	Y= 0,8093x + 13,749	0,5824	0,81	4,0531	0,0003*
Lokve Brana	Y= 0,384x + 8,4043	0,4896	0,384	3,8090	0,0004*
Parg	Y= 0,2539x + 12,63	0,4351	0,254	3,6163	0,0006*
	Number of hot days ($T \geq 30° C$) *Broj vrućih dana ($T \geq 30° C$)*				
Vrelo Ličanke	Y= 0,1751x – 0,8877	0,5200	0,175	3,4444	0,0016*
Lokve Brana	Y= 0,0569x – 0,4991	0,4712	0,057	3,6236	0,0007*
Parg	Y= 0,0407x – 0,1307	0,3744	0,0407	3,0218	0,0037*

*p<0,05

Table 5 Linear trends of annual and vegetation precipitations
Tablica 5 Linearni trendovi i signifikantnost trendova godišnjih i vegetacijskih količina oborina

Meteorological station *Meteorološka postaja*	Annual precipitations (mm) *Godišnje količine oborina (mm)*				
	Linear trends *Linearni trend*	Beta	B	t	p-level
Vrelo Ličanke	Y= -13,543x + 2801,4	-0,3712	-13,54	-2,2620	0,0306*
Lokve Brana	Y= -15,265x + 2724,4	-0,4943	-15,26	-3,8574	0,0003*
Parg	Y= -2,6431x + 1920,7	-0,2125	-2,643	-1,6281	0,1091
Mrzla Vodica	Y= -2,7766x + 2794,3	-0,1061	-2,800	-0,8199	0,4155
Ravna Gora	Y= -1,0819x + 1965	-0,0654	-1,052	-0,5035	0,6164

*p<0,05

The trend of the number of days with precipitation was also negative i.e. decreasing. The trend of the number of days with snow was negative in the area of Lokve, while in the area of Vrelo Ličanke and Parg an increase in the number of days with snow was found. In the area of Vrelo Ličanke and Parg the decreasing trend in maximal snow height was also characteristic. This decreasing trend of maximal snow heights was found at all stations, except in the area of Lokve (Table 6).

Significant increase in the mean annual air temperatures for period 1991-2007 in regard to the referent line was from 0.5° C to 1.0° C (Table 7).

Similar to the significant increase in the mean annual air temperatures, the significant increase in the number of warm days (($T \geq 25°$ C) in the period 1991-2007 was from 10 to 14 days (Table 8).

According to the results presented in Table 9, significant increase in the number of hot days ($T \geq 30°$ C) in the period 1991-2007 was from 1 to 3 days.

In the researched area, annual precipitations during 1991-2007 in regard to the referent line have decreased from 48.3 mm in the area of meteorological station Parg to the significant 289.4 mm in

Table 6 Linear trends of number of days with precipitation, number of days with snow and maximal snow height
Tablica 6 Linearni trendovi i signifikantnost trendova broja dana sa oborinom, broja dana sa snijegom i maksimalnih visina snijega

Meteorological station *Meteorološka postaja*	Number of days with precipitation ≥ 0,1 mm *Broj dana sa oborinom ≥ 0,1 mm*				
	Linear trend *Linearni trend*	Beta	B	t	p-level
Vrelo Ličanke	Y= -0,3439x + 160,05	-0,2221	-0,3439	-1,2887	0,2067
Lokve Brana	Y= -1,025x + 192,28	-0,6261	-1,025	-5,4469	0,0000*
Parg	Y= -0,1758x + 178,13	-0,1676	-0,1758	-1,2722	0,2085
	Number of days with snow ≥ 1 cm *Broj dana sa snijegom ≥ 1 cm*				
Vrelo Ličanke	Y= 0,0814x + 81,193	0,0268	0,0814	0,1519	0,8801
Lokve Brana	Y= -0,3445x + 101,13	-0,1797	-0,3445	-1,2396	0,2213
Parg	Y= 0,0213x + 97,218	0,0144	0,0212	0,1085	0,9139
	Maximal snow height (cm) *Maksimalne visine snijega (cm)*				
Vrelo Ličanke	Y= -0,2941x + 73,235	-0,0870	-0,2941	-0,4945	0,6243
Lokve Brana	Y= 0,1617x + 33,393	0,1687	0,162	1,1613	0,2514
Parg	Y= -0,1672x + 75,192	-0,0897	-0,1672	-0,6742	0,5029

*p<0,05

Table 7 Result of *t* test for mean annual air temperature values (°C) from referent line with period 1991-2007
Tablica 7 Rezultat Studentovog t-testa nezavisnih uzoraka usporedbe srednjih vrijednosti godišnjih temperatura zraka (°C) referentnog niza sa razdobljem 1991-2007

Meteorological station *Meteorološka postaja*	Referent line *Referentni niz* 1961-1990 (°C)	Period 1991-2007(°C) *Razdoblje 1991-2007 (°C)*	Level of significance *Razina značajnosti*
Vrelo Ličanke	6,8 ±0,55	7,8 ± 0,67	*
Lokve	7,0 ± 0,54	7,5 ± 0,71	*
Parg	6,9 ± 0,57	7,8 ± 0,84	*

*p<0,05; (LSMEAN±SD)

Table 8 Result of *t* test comparison of mean number of warm days (T ≥ 25° C) of referent line with period 1991-2007
Tablica 8 Rezultat Studentovog t-testa nezavisnih uzoraka usporedbe srednjih vrijednosti broja toplih dana (T ≥ 25° C) reterentnog niza sa razdobljem 1991-2007

Meteorological station *Meteorološka postaja*	Referent line 1961-1990 *Referentni niz 1961-1990*	Period 1991-2007 *Razdoblje 1991-2007*	Level of significance *Razina značajnosti*
Vrelo Ličanke	20,9 ± 10,49	34,8 ± 13,47	*
Lokve	14,3 ± 7,40	24,8 ± 12,94	*
Parg	18,0 ± 6,98	27,7 ± 11,12	*

*p<0,05; (LSMEAN±SD)

the area of meteorological station Lokve. In the area of meteorological station Ravna Gora an increase of 9.3 mm was found (Table 10).

The number of days with precipitation in the area of meteorological stations Vrelo Ličanke and Lokve has deceased by 6 days and by the significant 18 days. In the area of meteorological station Parg, an increase in number of days with precipitation of 5 days was recorded (table 11).

Table 9 Result of *t* test comparison of mean number of hot days (T ≥ 30° C) of referent line with 1991-2007
Tablica 9 Rezultat Studentovog t-testa nezavisnih uzoraka usporedbe srednjih vrijednosti broja vrućih dana (T ≥ 30° C) referentnog niza sa razdobljem 1991-2007

Meteorological station *Meteorološka postaja*	Referent line 1961-1990 *Referentni niz 1961-1990*	Period 1991-2007 *Razdoblje 1991-2007*	Level of significance *Razina značajnosti*
Vrelo Ličanke	0,6 ± 1,05	3,7 ± 4,13	*
Lokve	0,3 ± 0,71	1,9 ± 2,38	*
Parg	0,7 ± 1,29	2,17 ± 2,48	*

*p<0,05; (LSMEAN±SD)

Table 10 Result of *t* test comparison of mean precipitation amount (mm) of referent line with period 1991-2007
Tablica 10 Rezultat Studentovog t-testa nezavisnih uzoraka usporedbe srednjih vrijednosti količine oborina (mm) referentnog niza sa razdobljem 1991-2007

Meteorological station *Meteorološka postaja*	Referent line *Referentni niz* 1961-1990 (mm)	Period *Razdoblje* 1991-2007 (mm)	Level of significance *Razina značajnosti*
Vrelo Ličanke	2630,9 ± 428,36	2497,7 ± 281,40	ns
Lokve	2433,6 ± 440,89	2144,2 ± 273,50	*
Parg	1849,3 ± 176,51	1801,0 ± 194,45	ns
Mrzla Vodica	2759,0 ± 444,7	2634,2 ± 366,4	ns
Ravna Gora	1919,6 ± 269,51	1928,9 ± 259,06	ns

ns=nesignifikantno; ns=not significant; *p<0,05; (LSMEAN±SD)

Table 11 Result of *t* test comparison of mean values of days with precipitations (≥ 0.1 mm) of referent line with period 1991-2007
Tablica 11 Rezultat Studentovog t-testa nezavisnih uzoraka usporedbe srednjih vrijednosti broja dana sa oborinom (≥ 0,1 mm) referentnog niza sa razdobljem 1991-2007

Meteorological station *Meteorološka postaja*	Referent line *Referentni niz* 1961-1990	Period *Razdoblje* 1991-2007	Level of significance *Razina značajnosti*
Vrelo Ličanke	156,7 ± 16,47	151,3 ± 14,26	ns
Lokve	172,4 ± 21,59	154,1 ± 14,73	*
Parg	167,9 ± 15,20	173,0 ± 17,34	ns

ns=nesignifikantno; ns=not significant; *p<0,05; (LSMEAN±SD)

Table 12 Result of *t* test comparison of mean values of days with snow (≥ 1 cm) of referent line with period 1991-2007
Tablica 12 Rezultat Studentovog t-testa nezavisnih uzoraka usporedbe srednjih vrijednosti broja dana sa snijegom (≥ 1 cm) referentnog niza sa razdobljem 1991-2007

Meteorological station *Meteorološka postaja*	Referent line *Referentni niz* 1961-1990	Period *Razdoblje* 1991-2007	Level of significance *Razina značajnosti*
Vrelo Ličanke	81,7 ± 36,97	83,4 ± 22,64	ns
Lokve	97,5 ± 27,60	86,2 ± 23,57	ns
Parg	103,6 ± 25,59	95,8 ± 21,06	ns

ns=nesignifikantno; ns=not significant; (LSMEAN±SD)

A decrease in the number of days with snow in period 1991-2007 was recorded in the areas of all meteorological stations. This decrease was from 1 to 12 days and was not significant (Table 12).

DISCUSSION
RASPRAVA

Along with air temperature that depends on cloudiness and air insolation, precipitations as a main source of soil moisture have the greatest effect on development of vegetation. Dry periods as stress factors are one of the main reasons of dieback, damage and poor health status of silver fir forest ecosystems (UN-ECE & EC, 2003). Dry years, especially on calcium lacking soils, have a negative impact on Ca status in silver fir trees (Potočić et al., 2005).

Precipitations deficiency, along with high air temperatures weakens the resistance of certain forest tree species as a result of increased evapotranspiration. According to Vajda (1965) because of lack of precipitations, soil becomes drier and drier on a daily basis so that a tree cannot compensate for water lost by transpiration from soil. The increase of air temperatures in the region of Gorski kotar that has been determined will affect the general increase of potential evapotranspiration and the decrease of soil moisture. Therefore, longer dry periods affect the soil dryness and deterioration of physiological processes in trees. The increase of the mean annual air temperatures and the occurrence of climate excesses important for the today's climate change can cause stress states for tree species of narrow ecological valence. This especially refers to the direct ecological factors (heat and water).

With the rapid decrease of precipitation amount causing the physiological weakening of a tree, concurrent increase of the air temperature happens, having a very unfavourable effect on the development and spreading of harmful insects (Androić, 1969).

Changes in physiological status caused by precipitation deficiency are considered to be the cause of Spanish fir dieback and deterioration in the region of Pyrenees (Fromard et al., 1991). These changes are reflected in decreased increment. Greater dieback of trees along with decreased increment, increased numbers of dry years, and other stress factors result in a decrease of wood stock of certain species in comparison to the normal which brings into question the functioning of forest ecosystem of certain species.

Air temperature has key effect on climate character. In that respect, the differences found between temperatures of analysed periods have given us important insight on whether and how these differences affected the change of climate character of the researched area. In the area of meteorological stations in Gorski kotar the mean annual air temperatures during 1991-2007 in regard to the referent line have increased significantly by 0.5°C to 1.0°C. At the same meteorological stations a decrease in the mean annual amount of precipitation of 48.3 mm up to 289.4 mm was found.

A greater increase of the mean annual air temperatures was observed in the area of meteorological stations at the edge of Gorski kotar in comparison to meteorological stations in the inland areas. Also, a greater decrease of the annual amount of precipitations was observed at the edge of Gorski kotar region.

In 1988 in Greece in the areal of Greek fir (*Abies cephalonica* L.) forests, only 60% of annual precipitations and 26% during vegetation period was recorded in comparison to the referent line 1961-1987. The 1988 drought in Greece caused physiological weakening of Greek fir trees, as well as gradation of secondary pests resulting in catastrophic dieback of trees in 1989. In Gorski kotar region, such a drastic decrease of precipitations as in the case of 1988 drought in Greece was not found.

In the area of meteorological stations of Gorski kotar region linear trends of the number of days with snow, and of maximal snow heights showed no significant changes. In the area of all meteorological stations, a negative relation between number of days with snow and maximal snow heights was observed. A positive trend in number of days with snow was followed by a negative trend of maximal snow heights.

The researches of Usčupulić et al. (2007) showed that perennial drought, particularly a very dry year of 2003 was critical for bark beetles infestation. This indicates the need of taking into account climate conditions in managing the forests, especially in planning and performing protective measures. In dry years more attention should be paid to the forest hygiene maintenance. In case of fractured and windthrown trees the bark needs to be removed or trees taken out of the forest immediately. Cutting and export of wood from forest needs to be expedited. Stanovsky (2002) researched the effect of climate factors on health status of forest ecosystems in Czech Republic. During the ten-year long research period (1991-

2000) the trend of dieback trees coincided with the duration of drought period. Using cross-correlation function, a highly significant correlation was found between the duration of drought period (days) and the volume of dieback trees. The cause of this catastrophic dieback of forest ecosystems in Silesian Lowland region was precipitation shortage during the vegetation period and gradation of secondary pests. According to Ugarković et al., (2010, 2011) air temperatures, amount of precipitations, number of dry days and potential evapotranspiration in Gorski kotar are climate factors that significantly affect tree dieback and crow defoliation of silver fir. Global climate changes will cause changes in the environment, and consequently the changes of ecological niches.

Researches done by Anić et al. (2009) showed that climate change will significantly affect tree species with narrow ecological valence. Authors found that double increase of greenhouse gasses concentration caused an increase of the mean annual air temperature of 2.5°C and a decrease of the mean annual precipitations of 152 mm in comparison to the referent line 1950-2000. The research showed that these changes could cause decrease of silver fir ecological niche in Croatia ($p<0.9$) by almost 85% compared to the present state.

The observed significant increase of the mean annual air temperatures in the period of 1991-2007 from 0.5°C to 1°C and the decrease of precipitations from 48.3 mm to 289.4 mm shows significant variation of climate elements important for forest ecosystems of silver fir.

CONCLUSIONS
ZAKLJUČAK

Based on the research conducted, certain variations of climate elements in the region of Gorski kotar were found. The trends of the mean annual and the absolute maximal air temperatures, as well as the number of warm and hot days were positive and significant. The trends of the absolute minimal air temperatures showed no significant changes.

In the area of all meteorological stations, negative trends of annual precipitations were found. The trends were significant in the area of the meteorological satiations Vrelo Ličanke and Lokve. A negative trend of days with precipitations was significant only in the area of metrological station Lokve. The trends of snow precipitations showed no significant changes.

Changes of air temperatures were much more pronounced than in the case with precipitations and snow. In the area of meteorological stations in Gorski kotar, the mean annual air temperatures in the period of 1991-2007 in regard to the referent line have significantly increased by 0.5°C to 1.0°C. In accordance with the increase of the mean annual air temperatures and with the significant positive trend of the absolute maximal air temperatures, the number of warm days during the period of 1991-2007 has increased by 10 to 14 days, and the number of hot days by 1 to 3 days.

For the same meteorological stations a significant decrease of annual precipitations of 48.3 mm to 289.4 mm was found.

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INTRODUCTION
Uvod je kratak i jasno prikazuje područje koje se obrađuje. Glavna zadaća autora je da argumentima obrazloži zbog čega se odlučio na takvo istraživanje te što je novost koju rad donosi. Uvod treba dati kratki pregled najznačajnijih ranijih istraživanja. Na kraju uvoda autor mora jasno navesti hipotezu i zadane ciljeve svog istraživanja. Uvod ne sadržava rezultate i zaključke.

MATERIJALI I METODE
MATERIALS AND METHODS
Sadrži podatke o vremenu i mjestu provođenja istraživanja (lokalitet), kriterije izbora pokusnih ploha, korištene materijale i metode, korištene metode statističke analize

Statistička analiza
Statistic analysis
Autori trebaju navesti sve primijenjene statističke testove. Također je potrebno navesti unaprijed izabranu razinu značajnosti (p), odnosno koju su vrijednost p autori smatrali statistički značajnom (0,05 ili 0,01). Na kraju odlomka potrebno je navesti korišteni računalni statistički program, proizvođača i verziju.

REZULTATI ISTRAŽIVANJA
RESEARCH RESUL TS
Rezultati rada prikazuju se jasno i precizno, u obliku teksta, tablica ili grafičkih prikaza, dajući prvo najvažnije rezultate. Rezultate treba popratiti razumnim brojem tablica i slika. Rezultate prikazane ili tablicom ili grafom ne treba ponavljati u tekstu, već samo naglasiti najznačajnija zapažanja. Za sve testirane razlike nužno je navesti točno dobivenu p vrijednost cijelim brojem (primjerice pisati p=0,048 umjesto p<0,05).

Tablice
Tables
Tablice trebaju sadržavati samo rezultate istraživanja, tj. brojčane vrijednosti. Treba izbjegavati tablice koje imaju samo tekstualne podatke. Takve je podatke bolje prikazati u obliku natuknica. Svaka tablica mora imati naslov i redni broj koji se povezuje s tekstom (u radu se navode kao Table 1 itd.). Svaki stupac mora imati kratki naziv, a detaljnije objašnjenje može se napisati u legendi ispod tablice. Sve neuobičajene kratice također je potrebno objasniti u legendi.

Table 1 Measures of central tendency and variability of the investigated pedological variables for the surface mineral soil horizons per studied localities

Tablica 1 Mjere centralne tendencije i varijabiliteta istraživanih pedoloških varijabli za površinske mineralne horizonte tala po istraživanim lokalitetima.

Variable *Varijabla*		Units *Mjerne jedinice*	Papuk - PAP			Macelj - MAC			Medvednica - MED			Vrbovsko - VRB		
			N	Mean	St. dev.	N	Mean	St. dev.	N	Mean	St. dev.	N	Mean	St. dev.
Inclination		°	10	24	8,80	4	35	5,25	6	20	3,63	10	17	8,13
Thickness		cm	10	7	3,01	4	8	1,63	6	10	1,51	10	6	5,15
Particle size distribution *Tekstura*	2,0 - 0,2 mm	mas. %	10	29,0	10,22	4	16,3	12,42	6	19,4	9,07	10	7,6	7,42
	0,2 - 0,02 mm	mas. %	10	42,8	8,18	4	57,1	13,08	6	37,7	8,13	10	49,6	5,44
	0,02 - 0,002	mas. %	10	19,4	6,11	4	16,1	1,27	6	28,3	4,66	10	26,8	5,53
	<0,002	mas. %	10	8,8	1,87	4	10,4	1,83	6	14,6	2,29	10	16,1	4,44
pHH$_2$0		-	10	4,44	0,27	4	4,02	0,45	6	4,31	0,15	10	4,10	0,28
pH CaCt		-	10	3,86	0,24	4	3,41	0,36	6	3,74	0,14	10	3,58	0,29
OrgC		g kg^{-1}	10	56,4	19,16	4	106,0	55,20	6	106,3	24,98	10	54,1	43,12
N tot.		g kg^{-1}	10	3,7	0,92	4	8,0	2,65	6	6,6	3,14	10	4,4	2,41
CM		-	10	15	2,18	4	13	3,75	6	19	9,10	10	12	2,65
Soil adsorption complex *Adsorpcijski kompleks tla*	Ca	cmol(+) kg^{-1}	10	0,87	0,79	4	2,71	0,27	6	1,08	0,86	10	0,53	0,81
	Mg	cmol(+) kg^{-1}	10	0,30	0,08	4	0,05	0,00	6	0,05	0,01	10	0,18	0,11
	Na	cmol(+) kg^{-1}	10	0,32	0,02	4	0,53	0,06	6	0,37	0,07	10	0,34	0,02
	K	cmol(+) kg^{-1}	10	0,79	0,15	4	1,20	0,40	6	0,89	0,08	10	0,68	0,09
	Al	cmol(+) kg^{-1}	10	4,19	1,91	4	4,39	2,19	6	4,29	1,23	10	11,68	4,85
	H	cmol(+) kg^{-1}	10	1,05	0,60	4	2,48	1,41	6	1,77	0,29	10	2,80	1,09
	Fe	cmol(+) kg^{-1}	10	0,10	0,09	4	0,29	0,24	6	0,13	0,06	10	0,23	0,19
	Mn	cmol(+) kg^{-1}	10	0,11	0,07	4	0,07	0,04	6	0,31	0,11	10	0,08	0,04
	BCE	cmol(+) kg^{-1}	10	2,29	0,79	4	4,49	0,62	6	2,39	0,86	10	1,73	0,90
	ACE	cmol(+) kg^{-1}	10	5,44	2,50	4	7,23	3,55	6	6,50	1,42	10	14,78	5,59
	CEC	cmol(+) kg^{-1}	10	7,72	2,32	4	11,72	4,09	6	8,89	2,13	10	16,51	5,18
	Base saturation	%	10	31,8	13,30	4	41,3	12,51	6	26,6	3,99	10	12,3	9,28

Slike

Figures

Slike su crteži, karte, grafikoni, dijagrami i fotografije. Kolor slike objavljuju se o trošku autora. Svaka slika treba biti označena naslovom i rednim brojem, prema redosljedu kojim se pojavljuje u tekstu članka. Fotografije treba priložiti kao zaseban dokument u jednom od formata *.tiff ili *.jpg u rezoluciji 300 dpi, dok crteže, grafove i dijagrame treba slati u rezoluciji 600 dpi. Redni broj slike i naslov stavljaju se ispod slike. Ključne informacije potrebne za razumijevanje slike nalaze se ispod naslova ako nisu već navedene unutar same slike.

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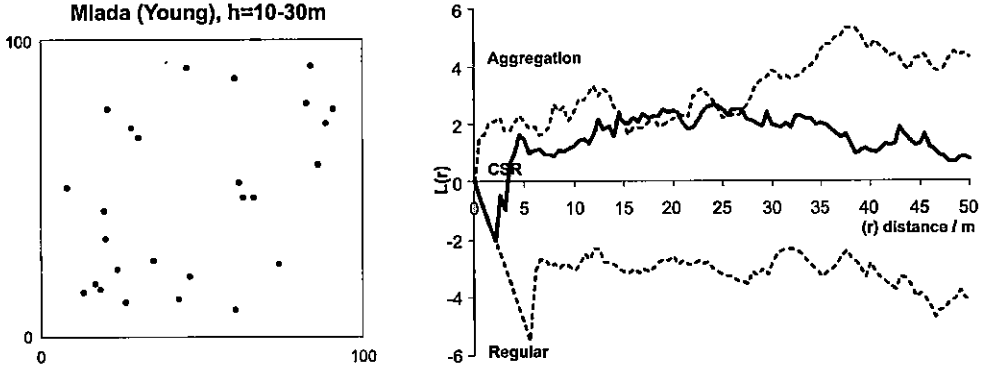

Slika 1. Horizontalna projekcija stabala na pokusnoj plohi lijevo, rezultati PP analize desno

RASPRAVA
DISCUSSION

U raspravi autor bi trebao naglasiti najvažnija saznanja provedenog istraživanja i nastojati ne ponavljati do u detalje sve svoje rezultate. Potom treba razmotriti sve moguće razloge zbog kojih su dobiveni upravo takvi rezultati te načiniti usporedbu s drugim relevantnim navodima iz literature. Osobito je važno istaknuti ograničenja vlastitog istraživanja te naposlijetku navesti kako se dobiveni rezultati odražavaju na buduća istraživanja.

ZAKLJUČCI
CONCLUSIONS

Zaključke treba povezati s navedenim ciljevima istraživanja. Treba istaknuti samo najznačajnije zaključke.

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Radovi se u tekstu navode prema harvardskom sustavu. U zagradi se nalazi prezime prvoga i možebitno drugoga autora rada, nakon čega slijedi godina izdanja, npr. (Vukelić 2006) odnosno (Vukelić & Baričević 2006). Ako rad potpisuje više od dva autora, nakon prezimena prvog autora treba rabiti kraticu *et al,* npr. (Vukelić et al. 2006). Ako se uzastopno navodi više radova, podaci za pojedine radove odvajaju se zarezom, a u slučaju više radova istog autora u jednoj godini treba ih razlučiti dodavanjem latiničnih slova, npr. (Vukelić 2006a, Vukelić 2006b).

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Primjeri navođenja literature:

Časopis

Pernar, N., D. Bakšić, O. Antonić, M. Grubešić, I. Tikvić, M. Trupčević, 2006: Oil residuals in lowland forest soil after pollution with crude oil. Water, Air and Soil pollution, Vol 177, No 1-4, p 267-284.

Knjiga

Vukelić, J. & Đ. Rauš, 1998: Šumarska fitocenologija i šumske zajednice u Hrvatskoj. Sveučilište u Zagrebu, Šumarski fakultet, p. 310, Zagreb.

Poglavlje iz knjige, monografije, enciklopedije

Matić, S., I. Anić, M. Oršanić, 2003: Uzgojni postupci u bukovim šumama), In: S. Matić (ed.), Obična bukva *(Fagus sylvatica* L.) u Hrvatskoj). Akademija šumarskih znanosti, Zagreb, p. 340-380.

Članak iz zbornika

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Table 1 Measures of central tendency and variability of the investigated pedological variables for the surface mineral soil horizons per studied localities

Tablica 1 Mjere centralne tendencije i varijabiliteta istraživanih pedoloških varijabli za površinske mineralne horizonte tala po istraživanim lokalitetima.

Variable *Varijabla*		Units *Mjerne jedinice*	Papuk - PAP			Macelj - MAC			Medvednica - MED			Vrbovsko - VRB		
			N	Mean	St. dev.	N	Mean	St. dev.	N	Mean	St. dev.	N	Mean	St. dev.
Inclination		°	10	24	8,80	4	35	5,25	6	20	3,63	10	17	8,13
Thickness		cm	10	7	3,01	4	8	1,63	6	10	1,51	10	6	5,15
Particle size distribution *Tekstura*	2,0 - 0,2 mm	mas. %	10	29,0	10,22	4	16,3	12,42	6	19,4	9,07	10	7,6	7,42
	0,2 - 0,02 mm	mas. %	10	42,8	8,18	4	57,1	13,08	6	37,7	8,13	10	49,6	5,44
	0,02 - 0,002	mas. %	10	19,4	6,11	4	16,1	1,27	6	28,3	4,66	10	26,8	5,53
	<0,002	mas. %	10	8,8	1,87	4	10,4	1,83	6	14,6	2,29	10	16,1	4,44
pHH$_2$0		-	10	4,44	0,27	4	4,02	0,45	6	4,31	0,15	10	4,10	0,28
pH CaCt		-	10	3,86	0,24	4	3,41	0,36	6	3,74	0,14	10	3,58	0,29
OrgC		g kg^{-1}	10	56,4	19,16	4	106,0	55,20	6	106,3	24,98	10	54,1	43,12
N tot.		g kg^{-1}	10	3,7	0,92	4	8,0	2,65	6	6,6	3,14	10	4,4	2,41
CM		-	10	15	2,18	4	13	3,75	6	19	9,10	10	12	2,65
Soil adsorption complex *Adsorpcijski kompleks tla*	Ca	cmol(+) kg^{-1}	10	0,87	0,79	4	2,71	0,27	6	1,08	0,86	10	0,53	0,81
	Mg	cmol(+) kg^{-1}	10	0,30	0,08	4	0,05	0,00	6	0,05	0,01	10	0,18	0,11
	Na	cmol(+) kg^{-1}	10	0,32	0,02	4	0,53	0,06	6	0,37	0,07	10	0,34	0,02
	K	cmol(+) kg^{-1}	10	0,79	0,15	4	1,20	0,40	6	0,89	0,08	10	0,68	0,09
	Al	cmol(+) kg^{-1}	10	4,19	1,91	4	4,39	2,19	6	4,29	1,23	10	11,68	4,85
	H	cmol(+) kg^{-1}	10	1,05	0,60	4	2,48	1,41	6	1,77	0,29	10	2,80	1,09
	Fe	cmol(+) kg^{-1}	10	0,10	0,09	4	0,29	0,24	6	0,13	0,06	10	0,23	0,19
	Mn	cmol(+) kg^{-1}	10	0,11	0,07	4	0,07	0,04	6	0,31	0,11	10	0,08	0,04
	BCE	cmol(+) kg^{-1}	10	2,29	0,79	4	4,49	0,62	6	2,39	0,86	10	1,73	0,90
	ACE	cmol(+) kg^{-1}	10	5,44	2,50	4	7,23	3,55	6	6,50	1,42	10	14,78	5,59
	CEC	cmol(+) kg^{-1}	10	7,72	2,32	4	11,72	4,09	6	8,89	2,13	10	16,51	5,18
	Base saturation	%	10	31,8	13,30	4	41,3	12,51	6	26,6	3,99	10	12,3	9,28

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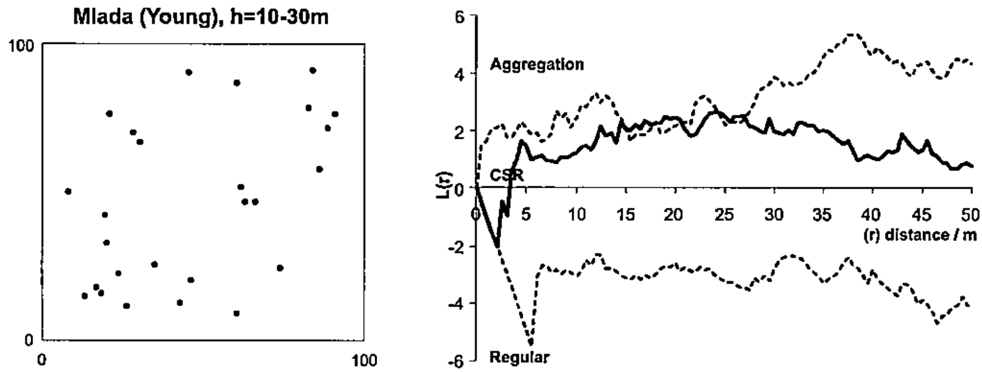

Fig.1 Horizontal projection of trees on test site on the left, results of PP analysis on the right.
Slika 1. Horizontalna projekcija stabala na pokusnoj plohi lijevo, rezultati PP analize desno

DISCUSSION
RASPRAVA

This chapter should contain the major findings of the research, without detailed repetitions of all results. All possible reasons for the achievement of such results should be discussed. Comparison with other relevant quotations from the literature should be made. It is particularly important to point at the limitations of the authors' own research. It should be concluded how the achieved results reflect upon future research.

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Acknowledgements
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At the end of the article the authors may express their gratitude to all who have contributed to the research and are not considered the authors themselves (persons, institutions, firms, projects, etc.).

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Book

Vukelić, J. & Đ. Rauš, 1998: Šumarska fitocenologija i šumske zajednice u Hrvatskoj. Sveučilište u Zagrebu, Šumarski fakultet, p. 310, Zagreb.

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