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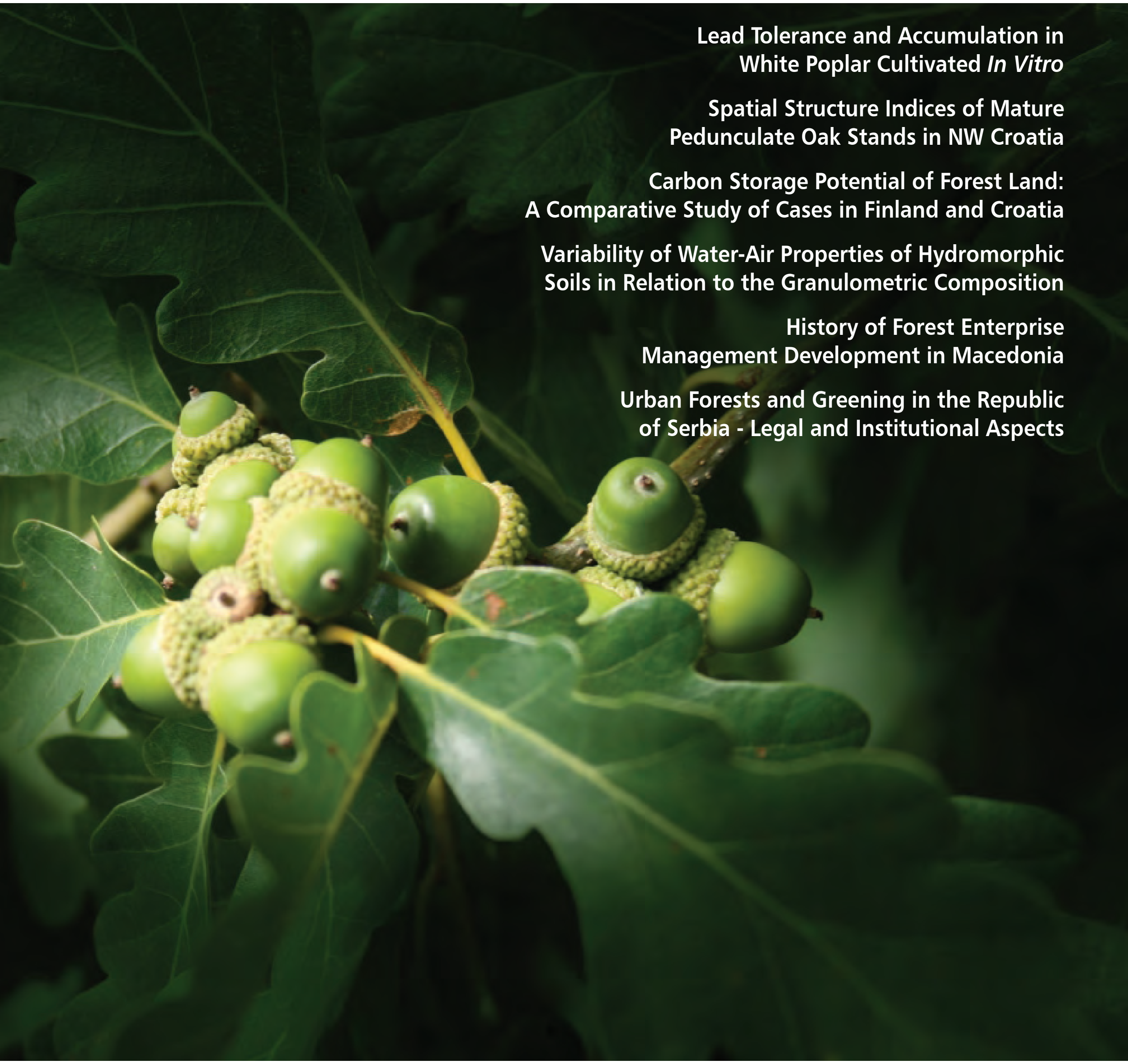

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Dear readers,

At the beginning of the fourth year of publishing we would like to brief you on what has been done, introduce some changes and present our future plans.

But, first, a few words about us. SEEFOR was established in 2009 by eight scientific and educational Institutions from the South-East European region with the primary aim to contribute to the development of scientific, research and other activities in the scientific field of forestry, as well as to encourage international cooperation and the creativity of employees of the journal and other contributors. The scope of the Journal's interests ranges over all ecological, economical, technical, technological, social and other aspects of forestry, urban forestry and wood processing technology.

From the first issue in 2010 until now, 6 issues in 3 volumes have been published. Scientists and researchers from the Region, but also from other parts of Europe and the world have offered their significantly contribution, whether by submitting papers or by reviewing them. In total, 36 papers were published within the last three years, which means 12 papers per year. Among the published papers, 23 were in the category Original Scientific Papers, 5 in the category Preliminary Communication, 2 were review papers and 6 professional papers. The published works covered a great variety of topics from the field of forestry, from forest management, forest inventory and remote sensing, forest ecology, forest pedology and forest genetics to forest economics and forest policy. The last published issue (Vol. 3, No. 2) dealt with urban forestry and consisted of the peer-reviewed papers per invitation from the IUFRO Conference "Forests for Cities, Forests for People: Perspectives on Urban Forest Governance". Overall, the majority of the published works were from SEE (Croatia 8, Serbia 6, Bosnia and Herzegovina 4, Macedonia 4, Hungary 3, Slovenia 1), but there were also papers from other parts of the world (2 from United Kingdom and one from Albania, Colombia, Lithuania and Turkey, respectively). It is important to highlight that the SEEFOR Journal is not only for scientists and researchers from the SEE Region, but also for all who want to present their research.

We are very glad to inform you that SEEFOR is included in one more important citation database. Apart from the CAB Abstract Database, where the Journal has been indexed from its first issue, AGRICOLA Database (National Agricultural Library) will also index it. After the successful evaluation process, we were informed that the Journal, with all the published papers, will be indexed by the end of this year. In order to increase the visibility of the Journal, during this year we plan to apply for the evaluation process in other citation databases, such as SCOPUS and Web of Science.

Also, in this fourth year of publishing we have a new Editorial Board. The novelty is that apart from the representatives of the Journal's founders, the Editorial Board has been expanded with eminent scientists from different relevant European forestry Institutions. We use this opportunity to thank all new members of the Editorial Board for their consent to invest time and effort in the Journal's progress.

At the end, we wish you pleasant summer holidays hoping that you find some interesting papers in this new issue!

Dijana Vuletić
Editor-in-Chief

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Original scientific paper

Lead Tolerance and Accumulation in White Poplar Cultivated *In Vitro*

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Abstract

Background and purpose: *This paper analyses the lead tolerance and accumulation in white poplar genotypes in vitro, in order to optimize genotype evaluation and other procedures in their implementation in phytoremediation projects and landscaping in areas endangered by lead accumulation.*

Material and Methods: *The lead tolerance and accumulation of five white poplar genotypes after 35 days in vitro cultivation on media supplemented with lead was examined. The following $Pb(NO_3)_2$ concentrations were used: 0, 10^{-6}, 10^{-5}, 10^{-4} and 10^{-3} M. Tolerance analysis (described by tolerance indices) was based on morphological parameters, biomass accumulation and the content of photosynthetic pigments, while lead accumulation was described by shoot lead accumulation and shoot lead content.*

Results and Conclusions: *The chosen lead concentrations appeared not to be lethal. Moreover, the obtained results showed that the tested lead concentrations had a positive effect on: number of formed roots, shoot moisture content and shoot height. The best differentiation among the examined genotypes was gained by the tolerance index based on the shoot height on 10^{-4} M $Pb(NO_3)_2$. The shoot lead accumulation and shoot lead content significantly increased on 10^{-4} and 10^{-3} M $Pb(NO_3)_2$ media. Thus, the concentration of 10^{-4} M $Pb(NO_3)_2$ is recommended for further research. Two examined genotypes of horticultural value (LCM and LBM) achieved a significantly higher lead shoot content compared to the wide spread genotype "Villafranca" (almost 200% and 125% higher, respectively).*

Keywords: Populus alba, *tissue culture, phytoextraction*

Abbreviations

ACM - Aspen culture medium
BAP 6 - Benzylaminopurine
NAA α - Naphthalene acetic acid
$Pb(NO_3)_2$ - Lead nitrate
Chl - chlorophyll
AAS - Atomic Absorption Spectrophotometer

INTRODUCTION

In recent years, the ecosystem and human habitable zones have been significantly polluted by various heavy metals. Heavy metals are potentially harmful to human health, as well as to plants and other living beings in general [1].

The toxic effect of most heavy metals is caused by their bonding to SH protein groups leading to the inhibition of enzyme activity and compromising their structure. They also substitute essential elements in biomolecules causing their deficiency [2]. High concentrations of metal ions in the soil limit the assimilation of important micro- and macronutrients by plants [3, 4].

Lead is one of the most toxic heavy metals [5] and a major pollutant in both terrestrial and aquatic ecosystems [6]. It affects enzyme activity and inhibits electron transport during oxidative phosphorylation, stimulating the formation of free radicals and reactive oxygen species resulting in oxidative stress [7, 8]. Lead naturally occurs in the soil but its content may be greatly increased by human activities [7]. River sediments also receive significant anthropogenic loads of metals from both point and nonpoint sources [9].

The research on the influence of different plant species on the contaminated soils and underground water started in the early 1980s [10-12]. The technology of using plants to remove heavy metals from the substrate is known as phytoremediation. Trees were suggested as a low-cost, sustainable and ecologically sound solution for the remediation of heavy metal-contaminated land [13], especially by phytoextraction [14].

Poplars are often used in phytoremediation due to their fast growth, adaptability, a well-developed root system that reaches underground waters, and the ability to transpire considerable amounts of water [15]. Poplars are not able to match hiperaccumulators in the heavy metal accumulation, but their main advantage is in the large biomass production [13] and a relativly high quantity of extracted metal per plant [14]. White poplars (section *Leuce* Duby.) in particular, are interesting for their high tolerance to arid conditions and their implementation in horticulture and landscaping, especially the genotypes with a pyramidal tree shape [16, 17]. The *in vitro* culture of tree species offers a rapid instrument to produce the clonal planting stock, but it may also facilitate studies on the effects of elevated levels of heavy metals on plant performance and the selection of metal-tolerant genotypes. Developmental and molecular data obtained by Castiglione et al. [18] in the research of white poplars suggested that the *in vitro* model was a sensitive and reliable system to study heavy metal stress responses. This is an important fact considering the difficulties in experimenting on large, long-lived organisms. The tolerance of white poplars to heavy metals, including lead, was tested in controlled conditions, and the differences among the genotypes were found [14, 19-23].

In this research, we studied different white poplar (*Populus alba* L.) genotypes *in vitro* for their lead tolerance based on morphological parameters, biomass accumulation and photosynthetic pigments content, as well as the lead accumulation in the above-ground plant parts.

The aim was to evaluate and select lead tolerant and accumulating genotypes, potentially interesting for lead phytoextraction on lead contaminated soils.

MATERIAL AND METHODS

Plant Material and Shoot Multiplication

Five white poplar genotypes, considered to be interesting for the biomass production, landscaping and horticulture were used in the research (Table 1). The genotype "Villafranca" was used as a standard, regarding the fact that it is widely used in biotechnology and *in vitro* studies of the heavy metal effect on white poplars [14, 18]. ACM (Aspen Culture Medium), described by Ahuja [24], supplemented with 20 mg/l adenine-sulphate, 100 mg/l myo-inositole, 0.5 mg/l benzylaminopurine (BAP), 0.02 mg/l α-naphthaleneacetic acid (NAA), 9 g/l of agar and 20 g/l of sucrose, pH 5.5, was used for the shoot multiplication. Shoots of all five tested genotypes were multiplied through the shoot tip culture. The cultures were kept at 26±2°C in the white fluorescent light (3500 lux) with a 16 hour photoperiod and sub-cultured at 4-week intervals.

Lead Treatments

For the experiment, 1.5-2.0 cm long shoot tips of the previously multiplied shoots were placed on the rooting medium based on ACM with added 9 g/l of agar and 20 g/l of sucrose, pH 5.5, and supplemented with the following concentrations of lead in the form of $Pb(NO_3)_2$: 0 (as a Control), 10^{-6}, 10^{-5}, 10^{-4} and 10^{-3} M.

The cultures were kept in the same conditions as previously described. Three jars with five plants per jar were set for each combination of the genotype × lead concentration in three repetitions. For pigment content determination, additional three jars with five shoots per jar were established per each combination of the genotype × lead concentration.

Lead Tolerance Assessment

After 35 days of cultivation, the following morphological traits were determined: the number of

TABLE 1
Examined white poplar genotypes

Name	Origin [a)]	Description
Villafranca	Italy	Model genotype, straight narrow tree
L-12	Serbia	Experimental clone, vigorous straight tree
L-80	Serbia	Experimental clone, vigorous straight tree
LBM	Serbia	Horticultural genotype, straight pyramidal tree shape
LCM	Serbia	Horticultural genotype, straight "bolleana" variety

[a)] - All examined genotypes were selected in Institute of Lowland Forestry and Environment, Novi Sad, Serbia, except the clone "Villafranca", that was selected in Poplar Research Institute in Casale Monferrato, Italy roots per shoot and the height of the shoot. The data for the number of roots was transformed by square transformation ($\sqrt{X+1}$) in order to meet the normal distribution of frequencies.

The following traits describing biomass were determined: fresh shoot mass per plant, dry shoot mass per plant and the shoot water content. For the dry biomass calculation fifteen rootless shoots tips were dried at 100°C for 24 h and weighted. The fresh and dry biomass production was calculated as a difference between the fresh and dry biomass at the beginning and at the end of the experiment. The concentration of chloroplast pigments: chlorophyll a (Chl a), chlorophyll b (Chl b) and total carotenoids, was determined spectrophotometrically [25]. The Chl a+b and chlorophyll a/b ratios were calculated.

The toxicity of the applied lead concentration and differences in lead tolerance among the examined genotypes were evaluated by tolerance indices. The tolerance index (TI) was calculated according to [26], as a ratio between the value of a parameter on the medium with a particular lead concentration ($X_{c(Pb)}$) and the value obtained on the Control ($X_{Control}$):

$$TI = \frac{X_{c(Pb)}}{X_{Control}} \quad .$$

Tolerance indices were calculated for morphological traits, dry shoot biomass production traits and photosynthetic pigments content parameters.

Lead Accumulation Assessment

In order to determine lead accumulation i.e. the lead concentration in the dry biomass (mg/kg), samples were mineralized by wet ashing in the microwave digester and 65% HNO_3 and 30% H_2O_2 (5:1 *v/v*). The lead content in a sample was detemined by the atomic absorption sectrometry (AA 240FS Fast Sequental Atomic Absorption Spectrometer, Varian, Australia). For the evaluation of the lead shoot accumulation of examined genotypes, shoot lead accumulation (Pb^{2+} content per shoot dry mass) and shoot lead content (calculated as the product of mean dry biomass of shoot per plantlet and mean Pb^{2+} content per shoot dry mass) were determined.

Statistical Analysis

The whole experiment was designed as completely randomized. The obtained data was analyzed by ANOVA and ANCOVA, as well as the LSD test with STATISTICA 10 statistical program [27].

RESULTS

Morphological Characters

No considerable chlorosis, necrosis or decay of shoot tissue was observed, and the rooting was nearly 100% on all examined media. Only on the medium with 10^{-3}M c($Pb(NO_3)_2$) a partial darkening of roots was noticed. According to the results of ANOVA, differences among the genotypes had significant effect on the variation of the examined morphological traits (Table

TABLE 2
Results of F-test for examined characters in white poplar genotypes on examined media

Examined characters	Source of variation		
	Genotype (A)	c($Pb(NO_3)_2$) (B)	Interaction A×B
Morphological characters			
Number of roots	34.58** [a)]	3.55**	0.77
The length of the longest root (mm)	28.42*	1.75	0.88
Shoot height (mm)	27.23**	5.33**	1.17
Biomass characters			
Shoot water content (%)	3.816**	4.883**	1.203
Fresh shoot mass production (g/plant)	12.761**	3.089*	0.413
Dry shoot mass production (g/plant)	4.776**	3.058**	0.361
Content of photosinthetic pigments			
Chlorophyll a content (mg/kg)	12.938**	0.453	0.722
Chlorophyll b content (mg/kg)	6.924**	0.974	0.919
Chlorophyll a+b content (mg/kg)	9.580**	0.597	0.726
Carotenoides content (mg/kg)	11.581**	0.633	0.781
Chlorophyll a/b ratio	82.763**	1.335	3.100**
Shoot lead accumulation characters			
Shoot lead accumulation (mg/kg)	1.86	43.08**	0.58
Shoot lead content (mM Pb^{2+}/plant)	2.94*	33.13**	0.96

[a)] Labels for F-test: * - significant at the level α=0.05; ** - significant at the level α=0.01

2). The effect of lead concentration was significant for a number of roots and shoot height, while interaction genotype × lead concentration had no significant influence on any of the examined morphological traits. The controlled sources of variation had the lowest influence on the variation of the length of the longest root.

All examined lead concentrations significantly stimulated root formation. The most stimulative effect on the number of roots was observed in L-12 in the medium with 10^{-6} M $c(Pb(NO_3)_2)$ and in L-80 in media with 10^{-4} M and 10^{-6} M $c(Pb(NO_3)_2)$ (Table 3). The differences in tolerance indices for this trait and for the length of the longest root were mostly not significant, therefore indices based on these two traits were excluded from further tolerance evaluation (data not shown).

Shoot height showed a similar positive reaction to lead treatment as the number of roots (data not shown). The tolerance indices for this trait were mostly higher than 1, indicating a high tolerance of the examined clones to the presence of lead (Table 4). Tolerance indices for this trait differed significantly among the examined genotypes in all tested lead concentrations, with best results for genotypes L-12 and L-80.

Biomass Characters

All biomass traits were significantly affected by both genotype and Pb concentration in the nutrient medium (Table 2).

Generally, tolerance indices revealed the highest dry shoot mass production was achieved on the medium with 10^{-6} M $Pb(NO_3)_2$, followed by decrease on media with 10^{-5} M $Pb(NO_3)_2$ and 10^{-4} M $Pb(NO_3)_2$, and not significant increase in medium with 10^{-3} M $Pb(NO_3)_2$ (Table 5). Similar relations among treatments were found for fresh shoot mass production, but plants on all media supplemented with lead had a significantly higher shoot water content than in the Control (data not shown).

According to the tolerance index based on dry shoot mass production, the differences among the genotypes were only significant on the medium with 10^{-6} M $Pb(NO_3)_2$. The differences in tolerance index were rather low among the examined genotypes. The highest tolerance index for dry shoot mass production was observed in genotype L-12 (Table 5). The data for fresh shoot mass revealed similar relations among the genotypes (data not shown).

Influence of Rooting and Shoot Height on Biomass Traits

The analysis of the covariance showed that the number of roots had a significant influence on the shoots' height and water content (Table 6). The influence of the number of roots on dry shoot mass production was not significant, but a significant influence of the tolerance index for shoot height on the variation of the tolerance indices of dry shoot mass production was observed.

TABLE 3
Number of roots in white poplar on examined lead concentration in medium (LSD test)

$c(Pb(NO_3)_2)$ (M)	Villafranca	L12	L80	LBM	LCM	Mean value by medium
0	4.31 $^{abcdef\ *)}$	3.61 ^{cdef}	3.16 ^{fg}	3.37 ^{ef}	1.67 ^{h}	3.18 ^{b}
10^{-6}	4.54 ^{abcde}	5.26 ^{a}	4.51 ^{abcde}	4.32 ^{abcdef}	2.05 ^{h}	4.07 ^{a}
10^{-5}	4.76 ^{abc}	4.97 ^{ab}	3.60 ^{cdef}	4.33 ^{abcdef}	2.28 ^{gh}	3.94 ^{a}
10^{-4}	4.59 ^{abcd}	4.26 ^{abcdef}	4.62 ^{abcd}	3.45 ^{def}	2.17 ^{gh}	3.77 ^{a}
10^{-3}	5.20 ^{a}	4.56 ^{abcde}	3.86 ^{bcdef}	3.52 ^{def}	2.26 ^{gh}	3.83 ^{a}
Mean value by genotype	4.73 ^{a}	4.62 ^{a}	4.00 ^{b}	3.90 ^{b}	2.13 ^{c}	

*) The differences among values marked with the same letter are not significant at the level α=0.05

TABLE 4
Tolerance index for shoot height of white poplar on examined lead concentration in medium (LSD test)

$c(Pb(NO_3)_2)$ (M)	Villafranca	L-12	L-80	LBM	LCM	Mean value by medium
10^{-6}	1.028 ^{fgh}	1.350 ^{a}	1.281 ^{abc}	1.259 ^{abcd}	1.131 ^{bcdefgh}	1.210 ^{a}
10^{-5}	0.963 ^{h}	1.320 ^{ab}	1.227 ^{abcdef}	1.228 ^{abcdef}	1.064 ^{defgh}	1.160 ^{a}
10^{-4}	0.984 ^{gh}	1.240 ^{abcde}	1.328 ^{ab}	1.071 ^{defgh}	1.042 ^{efgh}	1.133 ^{a}
10^{-3}	1.063 ^{defgh}	1.319 ^{ab}	1.167 ^{abcdefg}	1.025 ^{gh}	1.099 ^{cdefgh}	1.135 ^{a}
Mean value by genotype	1.010 ^{c}	1.307 ^{a}	1.251 ^{a}	1.146 ^{b}	1.084 ^{bc}	

*) The differences among values marked with the same letter are not significant at the level α=0.05

TABLE 5
Tolerance index for dry shoot mass production of white poplar on media with examined lead concentrations (LSD – test)

$c(Pb(NO_3)_2)$ (M)	Villafranca	L-12	L-80	LBM	LCM	Mean value by medium
10^{-6}	0.801 ^{bc}	1.328 ^{a}	0.887 ^{abc}	1.068 ^{abc}	1.175 ^{ab}	1.052 ^{a}
10^{-5}	0.666 ^{c}	0.739 ^{bc}	0.646 ^{c}	0.741 ^{bc}	0.943 ^{abc}	0.747 ^{b}
10^{-4}	0.681 ^{c}	0.757 ^{bc}	0.747 ^{bc}	0.878 ^{abc}	0.916 ^{abc}	0.796 ^{b}
10^{-3}	0.927 ^{abc}	0.946 ^{abc}	0.818 ^{bc}	0.960 ^{abc}	0.910 ^{abc}	0.912 ^{ab}
Mean value by genotype	0.769 ^{a}	0.942 ^{a}	0.775 ^{a}	0.912 ^{a}	0.986 ^{a}	

*) The differences among values marked with the same letter are not significant at the level α=0.05

The effect of the differences among the genotypes on this trait was not significant.

Photosynthetic Pigments Content

According to the ANOVA results, genotype had a significant effect on the variation of the content of the examined photosynthetic pigments, as well as Chl a/b ratio, while the interaction genotype × lead concentration had a significant effect only on Chl a/b ratio (Table 2).

The content of all of the studied pigments, the base tolerance index, was not significantly affected by the controlled sources of variation. However, the tolerance index based on Chl a/b was also under a significant influence of the genotype and genotype × lead concentration (data not shown). The highest tolerance indices were observed in "Villafranca" and the lowest in LCM and L-12. The tolerance index gradually decreased with the increase of lead concentration, suggesting the increase of the chlorophyll b share (Table 7).

TABLE 6
F-test from the analysis of covariance for some characters of interest for lead tolerance in white poplar genotypes

Source of variation	Covariate variable				
	Number of roots				Tolerance index for shoot height
	Dependent variable				
	Shoot height	Water content	Dry shoot mass production	Fresh shoot mass production	Tolerance index for dry shoot mass production
Covariate	4.910*	4.133*	0.102	2.038	4.856*
Genotype (A)	6.666**	4.525**	3.987**	10.163**	2.026
$c(Pb(NO_3)_2)$ (B)	2.573*	2.853*	2.923*	2.859*	2.794
Interaction A×B	0.816	1.138	0.361	0.269	0.504

[1)] Labels for F-test: * - significant at the level α=0.05; ** - significant at the level α=0.01

TABLE 7
The effect of lead concentration in medium on the tolerance index for Chl a/b ratio in white poplar genotypes (LSD – test)

$c(Pb(NO_3)_2)$ (M)	Villafranca	L12	L80	LBM	LCM	Mean value by medium
10^{-6}	1.373 ^{ab}	0.977 ^{cde}	1.159 ^{bc}	1.065 ^{cd}	0.708 ^{f}	1.068 ^{a}
10^{-5}	1.039 ^{cde}	0.940 ^{cdef}	1.107 ^{c}	0.952 ^{cdef}	1.073 ^{cd}	1.032 ^{ab}
10^{-4}	1.448 ^{a}	0.941 ^{cdef}	1.013 ^{cde}	0.950 ^{cdef}	0.836 ^{def}	1.038 ^{ab}
10^{-3}	1.053 ^{cd}	0.958 ^{cde}	1.020 ^{cde}	0.940 ^{cdef}	0.801 ^{ef}	0.954 ^{b}
Mean value by genotype	1.228 ^{a}	0.954 ^{c}	1.089 ^{b}	0.976 ^{bc}	0.855 ^{c}	

*) The differences among values marked with the same letter are not significant at the level α=0.05

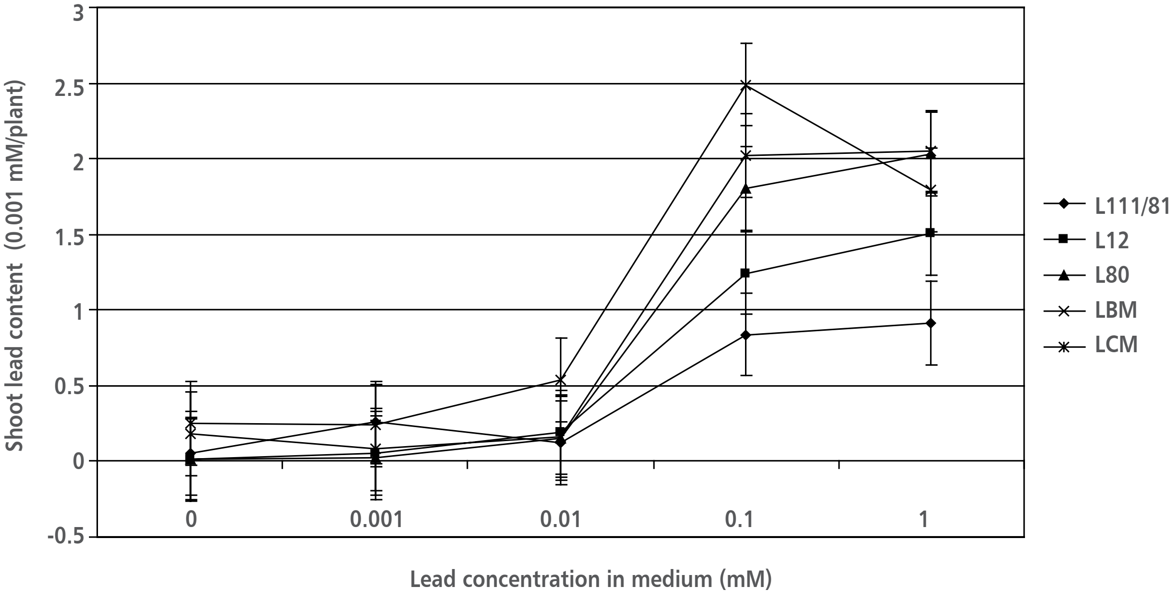

FIGURE 1
Shoot lead content (μM Pb^{2+}/plant) in white poplar plantlets grown on examined growing media (SE derived from the results of ANOVA is marked)

Shoot Lead Accumulation and Content

In contrast to other traits, the variation of shoot lead content per plant and variation of lead content in dry shoot mass (shoot lead accumulation) were influenced principally by the lead concentration in the media. ANOVA showed that influence to be highly significant (Table 2).

The shoot lead accumulation on the media with 10^{-4} and 10^{-3} M $Pb(NO_3)_2$ was significantly higher than on the media with other examined lead concentrations. The best differentiation in shoot lead accumulation among the examined genotypes was achieved with the concentration of 10^{-4} M $Pb(NO_3)_2$. The highest shoot lead accumulation on that medium was observed in genotype LCM, and the lowest in genotype "Villafranca" (Table 8).

The shoot lead content per plant data was associated with the results of shoot lead accumulation. A considerable increase in shoot lead content was observed on the media with 10^{-4} and 10^{-3} M $Pb(NO_3)_2$. The shoot lead content in "Villafranca" plants on 10^{-4} M $Pb(NO_3)_2$ was more than 2.5 times lower than in LBM and LCM on the same medium (Figure 1).

DISCUSSION

The success of phytoextraction is mainly related to the ability of plants to tolerate the presence of a pollutant in the substrate and to accumulate it in their above-ground parts [14, 28]. Thus, high lead tolerance and accumulation were principal criteria in the evaluation of the genotypes in our research. Also, beside the selection of genotypes, the concentration

TABLE 8
The lead content in dry shoot biomass (mg/kg) (shoot lead accumulation) in white poplar rooted shoots grown on examined growing media (LSD – test)

$c(Pb(NO_3)_2)$	Villafranca	L12	L80	LBM	LCM	Mean value by medium
0	5.123 $^{e *)}$	0.734 ^{e}	1.025 ^{e}	13.616 ^{e}	16.778 ^{e}	7.015 ^{b}
10^{-6}	28.178 ^{de}	2.728 ^{e}	1.325 ^{e}	5.598 ^{e}	14.316 ^{e}	10.429 ^{b}
10^{-5}	15.797 ^{e}	17.767 ^{e}	11.670 ^{e}	16.651 ^{e}	37.856 ^{de}	19.948 ^{b}
10^{-4}	108.372 ^{c}	117.031 ^{bc}	121.150 ^{bc}	174.934 ^{ab}	186.062 ^{a}	141.510 ^{a}
10^{-3}	87.390 ^{cd}	111.331 ^{c}	125.571 ^{abc}	135.521 ^{abc}	140.425 ^{abc}	120.047 ^{a}

*) The differences among values marked with the same letter are not significant at the level α=0.05

of lead in the medium was evaluated in order to select the media that achieved the best differentiation among the genotypes, in order to determine the appropriate lead concentration for further *in vitro* tests.

Considering the tolerance of the examined genotypes, it may be said that there was no necrosis or decay of shoots on any media with lead, which indicates no significant lead pollution in the examined concentrations. This is consistent with the results obtained by Katanić et al. [21], who found no difference in leaf colour of white poplar shoots on the multiplication media with 0, 10^{-5} and 10^{-4} Pb·EDTA. However, in our experiment, root necrosis was present on the medium with 10^{-3} M $Pb(NO_3)_2$. This is in accordance with the results of Di Lonardo et al. [14], who found roots of white poplar genotypes *in vitro* to be more sensitive to heavy metals than shoots. The absence of a significant decrease of the content of photosynthetic pigments also confirmed that the examined lead concentrations had not severe inhibitory effects on the plants' vitality.

The tolerance indices based on morphological, biomass and photosynthetic pigment content traits also suggested a high tolerance of the examined genotypes on the applied lead concentrations.

Lead treatment had a stimulative effect on the number of roots. According to Seregin and Ivanov [7], low lead concentrations promoted root growth. However, on relatively high concentrations of 2.0 mM $Pb(NO_3)_2$, Bojarczuk [20] found an inhibitory effect of on shoot and root development on the calluses of hybrid aspen on the regeneration medium. However, there were no significant differences among the genotypes in the tolerance indices based on the number of roots, as well as the length of the longest root (data not shown).

The tolerance index for shoot height (mostly above 1), indicated the absence of inhibition, if not a stimulative effect of the examined lead concentrations on shoot growth, especially in the medium with the 10^{-6} M $Pb(NO_3)_2$. The strong influence of differences among the genotypes recommeded this index to be used in tolerance evaluation tests in the future. According to the analysis of the covariance, shoot height was significantly influenced by the number of roots that also significantly influenced the shoot water content. The number of roots had no significant effect on dry shoot mass production, while the tolerance index based on shoot height significantly influenced the tolerance index of dry shoot mass production. These results suggested that the tolerance index based on shoot height is a good indicator of the lead tolerance of the tested genotypes. The positive effect of the implementation of this index would also be the option to establish more efficient and larger lead tolerance tests for white poplar genotypes *in vitro*. As the tolerance index for shoot height provided the best differentiation among the genotypes on the media with 10^{-4} M $Pb(NO_3)_2$, this lead concentration may be recommended in further testing.

The decrease in dry shoot mass production was observed on lead concentrations higher than 10^{-6} M $Pb(NO_3)_2$. Kališova-Šprirochova et al. [19] reported a stimulative effect of 10^{-4} M Pb^{2+} on the total plant biomass accumulation in aspen rooted shoots in the liquid medium *in vitro*. However, Katanić et al. [21] found inhibitory effects on the fresh biomass of white poplar shoot tips grown on the multiplication medium supplemented with 10^{-4} M Pb·EDTA. The differentiation among the genotypes in the tolerance index based on dry shoot biomass production was low. Significant differences were recorded only on 10^{-6} M $Pb(NO_3)_2$ where the genotype L-12 had a significantly higher index than in the standard genotype "Villafranca".

There was a low effect of lead concentration on the variation of photosynthetic pigment traits, except for the Chl a/b ratio, where the influence of the interaction genotype × medium on its variation was significant. Ewais [29] found a statistically significant decrease of the content of photosynthetic pigments in leaves of three weed species grown in pots with 200 mg/kg (0.6 mM/kg) of Pb acetate. Also, Zengin and Munzuroglu [8] found a significant decrease on the chlorophyll content in leaves (about 10%) together with the increase of several oxidative stress indicators in the lead-treated seedlings of common bean. However, Sarvari et al. [30] found a mild increase of the chlorophyll content in hydroponically grown white poplars in the nutrient solution with 10^{-5} M $Pb(NO_3)_2$ and 10^{-4} M $Pb(NO_3)_2$, while 10^{-4} M $Pb(NO_3)_2$ had an inhibitory effect on the chlorophyll content in cucumber plants. Kalsila et al. [31] also found a slightly stimulative effect of lead acetate added to the substrate in the concentration 200 mg/kg of lead on the chlorophyll content in oat and barley leaves. In general, the tolerance index for Chl a/b ratio was higher than 1 at the low lead concentration (10^{-6} M $Pb(NO_3)_2$), but decreased at higher concentrations. According to Sarvari et al. [30] the increase of Chl a/b ratio in poplar leaves in hydroponics with 10 μM Pb^{2+} may be explained by the increase in the amount of core complexes. However, at a higher lead concentration (100 μM), the lowering of the Chl a/b ratio occured due to a stronger decrease in the amount of PSI and the relative stability of PSII. Kamel [32] found a higher Chl a/b ratio on 4.8 mM Pb^{2+} and lower in the 48 mM Pb^{2+} solution compared to the control in *Vicia faba* hydroponics after 96 hours of growth. The best differentiation among the examined genotypes, according to the tolerance index based on the Chl a/b ratio, was observed on media with 10^{-4} and 10^{-3} M $Pb(NO_3)_2$. Regarding the results of Sarvari et al. [30], high values for "Villafranca" indicated a lower disturbance in chlorophyll synthesis and thus a higher lead tolerance by this parameter. However, the changes in tolerance indices based on the Chl a or Chl b content in shoot fresh mass may not be detected (data not shown), which additionally supported the conclusion of low differences among the examined genotypes in their lead tolerance.

The highest shoot lead accumulation and shoot lead content of the examined white poplar genotypes appeared on the media with 10^{-4} and 10^{-3} M $Pb(NO_3)_2$. The best differentiation among the genotypes was achieved on the 10^{-4} M $Pb(NO_3)_2$ medium. This is consistent with Sakan et al. [9] who found that shoot lead accumulation in the leaves of white poplar plants was not significant in hydroponics with 10^{-5} M $Pb(NO_3)_2$, but it was in hydroponics with 10^{-4} M $Pb(NO_3)_2$. These results suggested that the medium with 10^{-4} M $Pb(NO_3)_2$ may be recommended to be applied in further tests on shoot lead accumulation in white poplar tissue cultures.

The widely-used genotype "Villafranca" was used as the standard [14, 18] in evaluation of the genotype tolerance to different lead concentrations, as well as the shoot lead accumulation. Lead tolerance was satisfying in the examined genotypes but the differences among them were rather low, in general. The mostly used tolerance indices in lead tolerance studies are based on the length of the longest root [33] or dry mass production [14], but in our research they gave a poor differentiation among the genotypes. The best differentiation was obtained by the tolerance index based on shoot height. According to this parameter, the most tolerant were genotypes L-80 and L-12. On the other hand, lead accumulation in the above-ground parts appeared to be highly influenced by the differences among the genotypes, emphasizing the importance of shoot lead accumulation in the evaluation of the genotypes for the lead phytoextraction potential. The highest shoot lead accumulation on the medium with 10^{-4} M $Pb(NO_3)_2$ was achieved by the genotype LCM (cca. 70% higher compared to "Villafranca"). The relation among the genotypes was similar for shoot lead content, but the difference between LCM and "Villafranca" was observed to be even higher (almost 200%). Beside LCM, similar results were observed also in the genotype LBM. Thus, as the tolerance of genotypes LCM and LBM was at the same level as most of the other genotypes and they achieved a high shoot lead accumulation, they may be recommended for further examination in lead phytoextraction plantations.

Considering the observed differences among the examined genotypes regarding lead tolerance and accumulation, *in vitro* tests may be utilized for selecting a group of candidate genotypes for lead phytoextraction projects. Watson et al. [34] and Pulford et al. [35] demonstrated in *Salix sp.* that the results obtained in hydroponics and in field are comparable. The general opinion is that the differences in the bioavailability of contaminants, the processes of pollutant uptake and metabolite distribution are likely to be substantial in tissue culture and field conditions. Thus, based on the results from tissue cultures, the response of plants to environmental contaminants may be predicted with a cost reduction of the subsequent conventional whole plant experiments [36, 37]. However, for the final evaluation of a particular genotype, further research should be done considering the lower availability of lead in soil, the higher juvenility of the *in vitro* material and the complexity of interactions between plants and their habitat.

CONCLUSIONS

According to the presented results, the following conclusions were drawn for the examined group of white poplar genotypes:

The tested lead concentrations had a positive effect on a number of formed roots, and by this trait on further on shoot moisture content and shoot height.

The tolerance index based on shoot height (significantly related to the tolerance index based on dry shoot mass production) and lead shoot content on a medium with 10^{-4} M $Pb(NO_3)_2$ were proposed to be used in further lead tolerance and accumulation research and testing.

Two examined genotypes of horticultural value (LCM and LBM) achieved a significantly higher lead shoot content compared to the wide-spread genotype "Villafranca" (almost 200% and 125% higher, respectively).

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Spatial Structure Indices of Mature Pedunculate Oak Stands in NW Croatia

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Abstract

Background and Purpose: In order to potentiate a valid comparison of forest stands, numerous indices were developed to express forest structure numerically. Each of those indices described a specific measured or calculated value. In the present study, three of the stand structure indicators, dependent on tree distance, were used: the aggregation index of Clark and Evans, the species mingling index and the diameter differentiation index. The objectives of this study were: to obtain further information about forest structure using the selected indices and to discover any limitations that the implemented indices might display.

Materials and Methods: Mature pedunculate oak stands were selected as objects of the study, all located within the "Repaš – Gabajeva Greda" forest management unit, the Forest Administration of Koprivnica. The stands were aged 75 to 132 years. A systematic 500 m grid of 45 circle sample plots was established. The sample plot radius was 15, 25 or 30 meters, depending on the stand's age. In 2001, the DBH (diameter at breast height) and tree positions in regard to the centre of a plot were measured on each sample plot. The mutual distances between trees were calculated, as well as the values of the three selected stand structure indices. The two procedures of the aggregation index of Clark and Evans were calculated for all 45 sample plots. In the first case only the pedunculate oak trees were observed, and in the other all trees on the plot. The species mingling index and the diameter differentiation index were calculated for each tree in two procedures: in relatio to three and four nearest neighbouring trees. The plot/stand totals were managed as the average index of individual trees.

Results: Values of the aggregation index of Clark and Evans after all trees have been observed were from 0.89 to 1.28, which indicated a random distribution of trees. In case of considering only pedunculate oak trees, the index of the plots was 1.02 to 1.51. This indicated a tendency to a regular distribution of trees. The species mingling index that considered three nearest neighbouring trees was 0.395 to 0.620. When observing four nearest neighbouring trees, the index values showed slight decreases in all age classes. The diameter differentiation index (0.407-0.424) when three or four nearest neighbour trees were taken into account, showed almost the same differentiation in the 5th, 6th and 7th age class.

Conclusion: Though they contained the component of distance between the trees and were based on individual trees parameters, the three analysed stand structure indicators were a useful tool in further categorizing of forest stands.

Keywords: forest structure, spatial tree arrangement, stand structure indices, pedunculate oak

INTRODUCTION

The word *structure* has multiple meanings: the interior component parts arrangement within a whole, a set of interdependent parts, organisation, a manner of composing components or particular immutable details into a whole [1]. All of these meanings may be used entirely even for defining the forest structure. Many Croatian authors suggested their definitions of forest structure and discussed them in the scientific literature of forestry.

The authors Pranjić and Lukić [2] concluded: "The term stand structure implies species distribution, tree number and tree dimension distribution per unit area. The stand structure is the result of the simultaneous growth intensity of each tree species exposed to human and natural influences".

The stand structure was directly or indirectly studied in research done by Matić [3], Pranjić and Lukić [4], Lukić [5], Božić [6], Novotny [7], Novotny et al. [8, 9], Dubravac [10], Marjanović [11], Marjanović et al. [12].

Many authors in the world were also studying and defining the stand structure. Some of them will be mentioned here.

Oliver and Larson [13] defined forest structure as a physical and chronological distribution of trees in the stand. The simple definition by Kimmins [14] is that stand structure is its vertical and horizontal tree arrangement. Pommerening [15] gave an overview of three main stand structure aspects and units that may describe them (Figure 1).

In the present study, three of the distance-dependent stand structure indicators were used: the aggregation index of Clark and Evans, the species mingling index and the diameter differentiation index. The aggregation index of Clark and Evans (CEI) represents the relationship of the observed and the expected mean distance between the nearest neighbouring trees. CEI equal to 1 indicates a random distribution of trees. If CEI is greater than 1, it points to a tendency of a regular tree distribution. CEI values lower than 1 indicate an aggregated distribution of trees.

The species mingling index and the diameter differentiation index observe the reference trees and at least three (or four) of their nearest neighbours. Such a group of trees is called a *structural group of four* (Figure 2).

The species mingling index (MI) gives the proportion of three or four nearest neighbouring trees that do not belong to the same species as the reference tree (Figure 2). The stand's condition may be described by using the distribution of the mingling variable

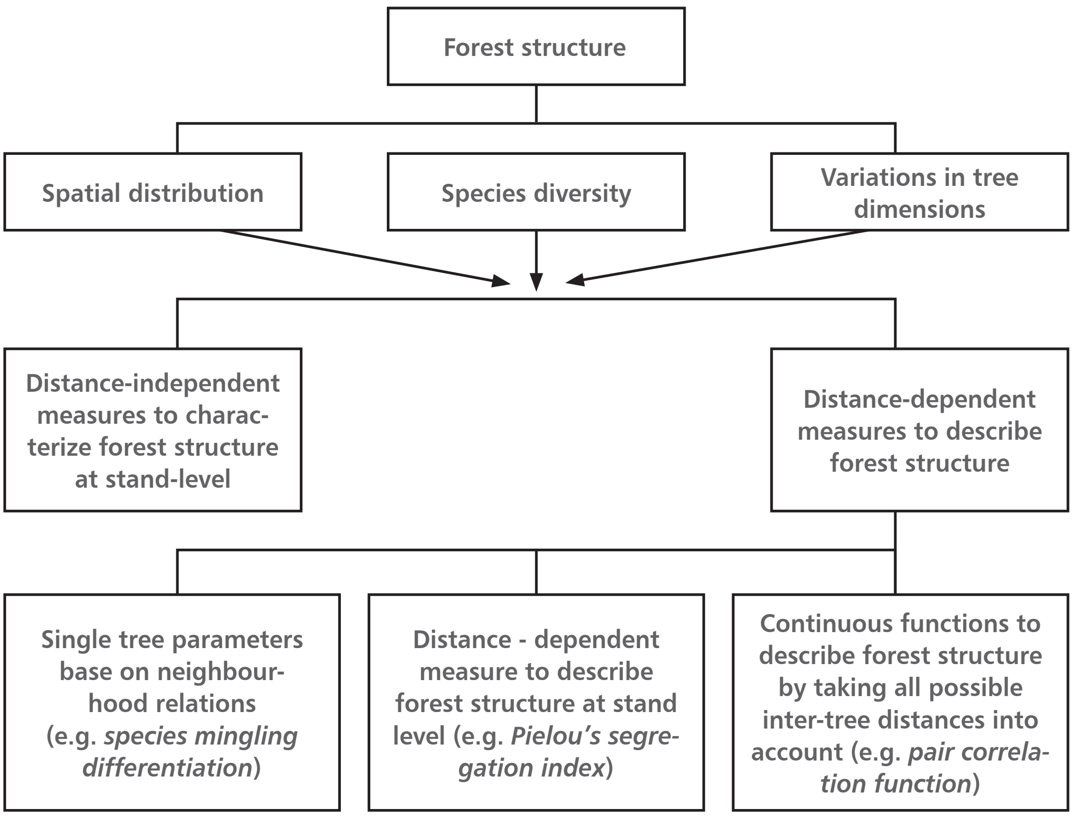


FIGURE 1
The overview of the three major characteristics of forest structure and the groups of variables by which forest structure was assessed (Pommerening [15] modified from Albert [16])

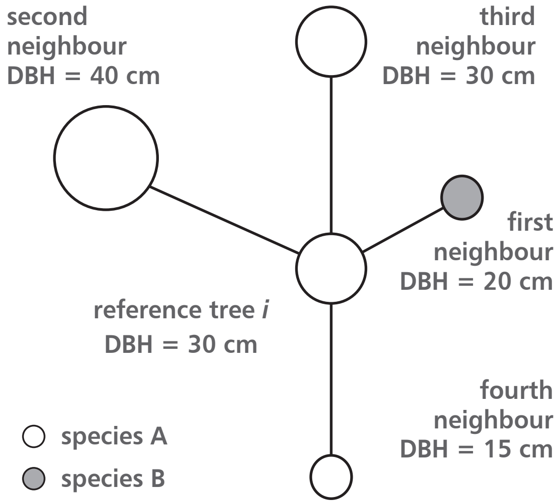


FIGURE 2
A structural group of four for calculating the species mingling and the DBH differentiation index (Pommerening [15] modified after Albert and Gadow [17])

[15]. When at least three nearest neighbouring trees are selected, four possible results may be assumed (0.00; 0.33; 0.67; 1.00). With four neighbours, there are five possible results (0.00; 0.25; 0.50; 0.75; 1.00). The overall mingling index for the stand (sample plot) is defined by the average value of all reference trees. The bigger the mean mingling, the more different tree species are intermingled. Lower values are pointing to segregation [18].

The diameter differentiation index (TI) indicates the range of the difference in size of the neighbouring trees and describes the spatial distribution of tree sizes. The possible values of the index are between 0 and 1. If the index assumes the value 0, it means that the neighbouring trees have the same diameter as the reference tree. The overall diameter differentiation index for the stand (sample plot) is defined by the average value of all reference trees. According to Pommerening [15], values may be classified and interpreted as below:

- a small differentiation level ($0.0<\mathrm{TI}<0.3$) – the tree with the smallest DBH is 70% or more of the reference tree's size;
- an average differentiation level ($0.3<\mathrm{TI}<0.5$) – the tree with the smallest DBH is 50 to 70% of the reference tree's size;
- a large differentiation level ($0.5<\mathrm{TI}<0.7$) – the tree with the smallest DBH is 30 to 50% of the reference tree's size;
- a very large differentiation level ($0.7<\mathrm{TI}<1.0$) – the tree with the smallest DBH is thinner than 30% of the reference tree's size.

The objects of the present study were some mature pedunculate oak stands, all belonging to the phytocenosis of *Carpino betuli – Quercetum roboris* /Anić 1959/ emend. Rauš 1969. The specified phytocenosis is present in the lowlands forest cover in the Republic of Croatia. The habitat is out of the reach of floods, the fact proved by the appearance of the common hornbeam.

The sample plots were set up in the stands that were 75 to 132 years old in 2001. In the overall area of the managed high forests classified into a pedunculate oak management class in the Republic of Croatia, the most common are the 5th and 6th age classes (age 81 to 120), contributing 41% [19].

The goals of this study were: to give a methodology overview for the selected indices, to use them to obtain further information about the forest structure and to perceive any limitation that implemented indices might display.

MATERIALS AND METHODS

Field Measurements

The data used in this study were collected from 45 sample plots located in the Repaš – Gabajeva Greda forest management unit. The sample plots were set and measured from April 7, 2000 to February 13, 2001. The location of the samples was determined by the North-South (East-West) oriented, 500 m square grid, laid over the entire surface of the observed area (Figure 3).

Each tree on the sample plot was measured, starting from the north, and moving clockwise within the specified radius of the plot. The measured attributes were:

- the distance between the centre of the plot and each tree (in meters, with the precision of 1 decimetre),
- the azimuth of each tree (in degrees),
- each tree's DBH (two cross values measured in the north-south and east-west direction (in millimetres).

The distance from the centre of the plot to each tree was measured by a 50 m long measuring tape and rounded to 1 dm. The length was taken from the left side of the vertical axis of each particular tree, observed from the centre.

The azimuth of the vertical axis for each tree was set by a precise geodetic compass with a bubble level and rounded to 1 degree. All trees were numbered. The tree nearest to the north direction was numbered as 1. Further numeration proceeded clockwise.

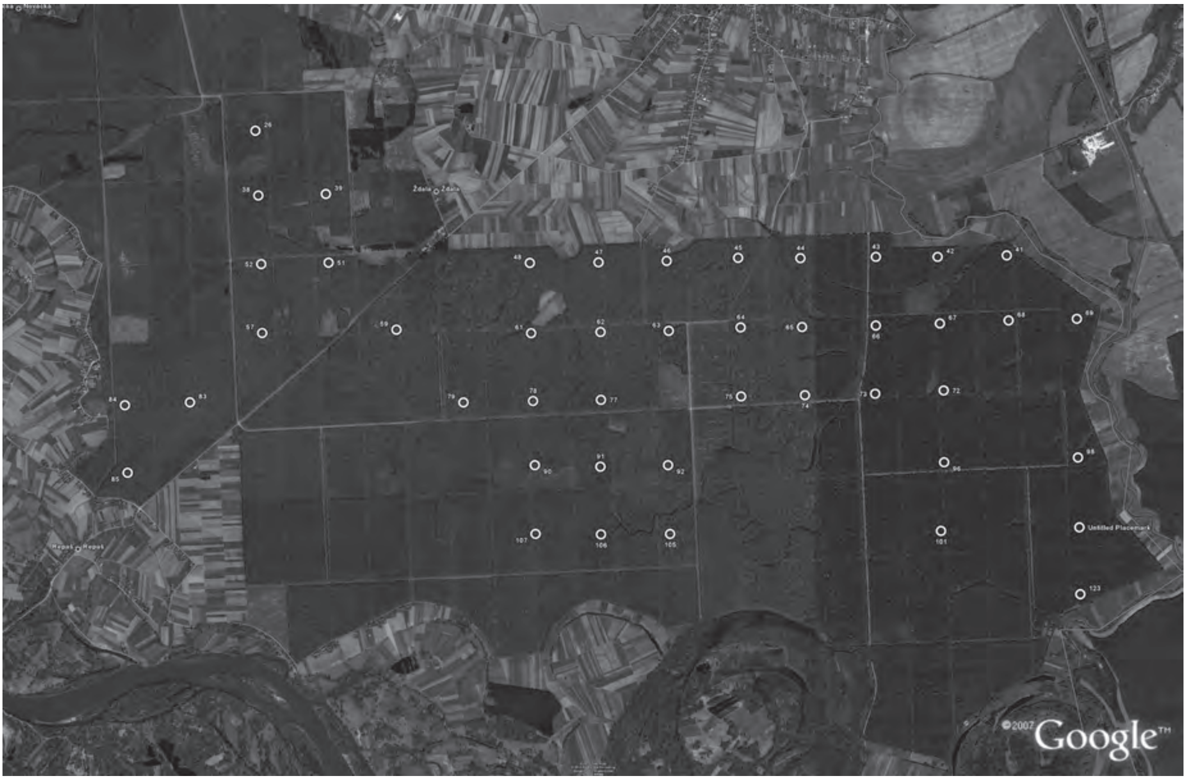


FIGURE 3
The position of the plots in the research area (the Repaš – Gabajeva Greda management unit)

For each tree, two DBH values at the right angle were measured, using the Haglof caliper in millimetres, with the precision of 1 mm. The first DBH was measured by caliper arms tangent to the west and east surface of the trunk, i.e. the caliper arms were directed north-west. The second DBH was taken perpendicular to the first one, with caliper arms tangent to the north and south side of the trunk.

Data analysis

The average DBH of each tree was derived as an arithmetic mean of two perpendicular measured values, with the precision of 1 mm. The position of each tree was defined by the measured azimuth and distance values. Since for the selected indices the calculation of the distance between individual trees was required, this stand element was derived as well. In the plane with the origin in the centre of the sample plot, the coordinates x_i and y_i of the *i*-th tree were calculated using the following formulas (Equation 1, 2):

$$x_i = r_i * \cos\left(\frac{90-\alpha_i}{180} * \pi\right) \qquad (1)$$

$$y_i = r_i * \sin\left(\frac{90-\alpha_i}{180} * \pi\right) \qquad (2)$$

r_i – the distance from the *i*-tree to the centre of the plot (m),
α_i – the azimuth of the *i*-tree (°).

The *Euclidean distance* between two trees ($Dist_{i\text{-}j}$) was derived with a formula for the distance between two points on a plane (Equation 3):

$$Dist_{i\text{-}j} = \sqrt{\left(x_j - x_i\right)^2 + \left(y_j - y_i\right)^2} \qquad (3).$$

For each individual sample plot, the aggregation index of Clark and Evans (CEI) was calculated, with no correction for edge effects, in two instances. In the first case there were only pedunculate oak trees taken into consideration. All trees were considered in the second approach. This was the way of finding out the aggregation degree of oak trees in the upper part of the stand regarding the overall aggregation index when all trees were considered.

$$CEI = \frac{\bar{r}_{observed}}{E(r)} \qquad (4)$$

$$E(r) = \frac{1}{2\sqrt{\frac{N}{A}}} \qquad (5)$$

CEI – the aggregation index of Clark and Evans,
$r_{observed}$ – the mean distance from the tree to the nearest neighbouring tree on the plot,
E(r) – the expected mean distance to the nearest neighbouring tree,
N – tree number,
A – the area of the plot.

The species mingling index was calculated for each individual tree (Equation 6). The index value of the plot/stand was an average of the particular indices.

$$MI = \frac{1}{n}\sum_{j=1}^{n} v_{ij} \qquad MI\ \varepsilon\ (0,1) \qquad (6)$$

MI – the species mingling index,
n – the number of nearest neighbouring trees (3 or 4)
v_{ij} = 1, if the reference tree *i* and the neighbour *j* are different tree species
v_{ij} = 0, otherwise

To each particular tree and for the sample plot in total, there were two species mingling indices calculated, taking into account 3 or 4 nearest neighbouring trees.

The diameter differentiation index (TI_{ij}) describes the spatial distribution of tree diameters. For the reference tree '*i*' and its n=3 or the 4 nearest neighbouring trees, '*j*' the diameter differentiation index (TI_{ij}) was defined as shown below (Equation 7):

$$TI_{ij} = 1 - \frac{\min(DBH_i, DBH_j)}{\max(DBH_i, DBH_j)} \qquad TI_{ij}\ \varepsilon\ (0,1) \qquad (7).$$

The numerator was always the lower of the two observed diameters (the reference tree's DBH and *n*-th the neighbour's DBH) and the denominator was always the greater. The index value was increasing with the increase of the neighbouring trees' mean DBH difference. The index was 0 when the observed trees had the same diameter.

The overall plot diameter differentiation index was calculated by adding all individual tree indices together and then dividing this total by the number of values, so that the result was the average TI_{ij}. For each individual tree, two diameter differentiation indices were calculated: considering 3 or 4 nearest neighbouring trees.

RESULTS

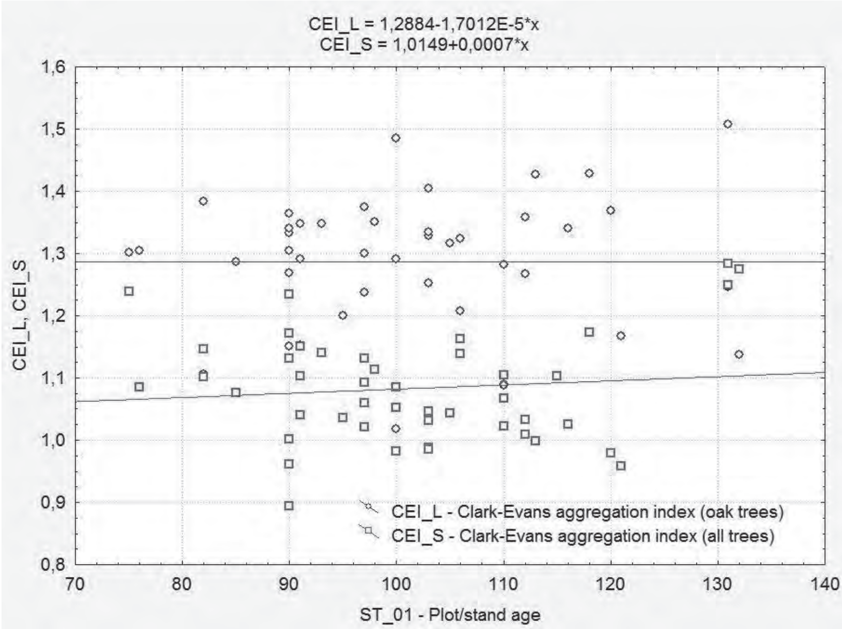
In 2000, 4668 trees were measured on sample plots, 1514 of which were pedunculate oak, and 2339 were common hornbeam. The rest of the measured trees on the plots were less frequent species: field maple, elm, narrow-leafed ash, black alder and other hardwood.

The aggregation index of Clark and Evans was calculated for all 45 plots in two procedures. Only pedunculate oak trees (CEI_L) were taken into account by the first calculation, and all trees present on the plot (CEI_S) were considered by the other (Table 1).

TABLE 1
The aggregation index of Clark and Evans by 20-year age classes

Clark and Evans aggregation index	Age class (years)	No. of plots	Mean $\overline{x}$	Range		STDEV	CV (%)
				min	max		
CEI_L – oak trees	4 (61 – 80)	2	1.303	1.302	1.305	0.002	0.2
	5 (81–100)	22	1.287	1.018	1.485	0.107	8.3
	6 (101–120)	17	1.290	1.088	1.428	0.110	8.6
	7 (121–140)	4	1.265	1.138	1.508	0.168	13.3
	Σ	45	1.287	1.018	1.508	0.109	8.5
CEI_S – all trees	4 (61 – 80)	2	1.162	1.085	1.239	0.109	9.4
	5 (81–100)	22	1.079	0.895	1.234	0.077	7.2
	6 (101–120)	17	1.054	0.980	1.174	0.062	5.9
	7 (121–140)	4	1.191	0.958	1.283	0.156	13.1
	Σ	45	1.083	0.895	1.283	0.089	8.2

FIGURE 4
The Clark and Evans aggregation index values according to the plot/stand age



When all trees were observed, the aggregation index of Clark and Evans values was 0.89 to 1.28, what pointed to the nearly random spatial tree arrangement.

When only pedunculate oak trees were considered, the index on plots was 1.02 to 1.51, as there was a tendency to a spatial distribution regularity (Table 1). As the age of the stand increased, no tendency of a significant increase of the index value was present. According to the linear regression model, the index value was 1.29 (Figure 4). It lead to the conclusion that pedunculate oak trees in the observed stands, even in the age of 70, reached the spatial distribution regularity which they tend to keep until the rotation ends.

The species mingling index in its formulation for 3 or 4 nearest neighbouring trees examined the probability of the nearest tree being the same tree species as the reference tree. The index was 0 and 1. When none of the nearest trees belonged to the tree species of the central tree, the index was 1 at the most. When all the neighbouring trees were different species, the index value was 0. The index was calculated for each tree separately. The overall index value for the plot/stand was derived through average indices of individual trees.

When three nearest neighbouring trees were considered, the results shown by the 20-year age classes were index values from 0.395 to 0.620 (Table 2).

Variation coefficients were high, particularly for age classes that had less sample plots. When 4 nearest neighbours were considered, the index values and the coefficient of variation decreased slightly in all age classes (Table 2). The sample plots from the 4th and 7th age class had significantly lower index values, what points to a lower species diversity. According to the fact that in the 4th age class there was a plot with a small share of common hornbeam trees, this result confirmed it.

The mean value of the species mingling index for all 45 plots (all age classes) was 0.570 when 3, and 0.594 when 4 neighbours were taken into account. The majority of the sample plots indices were between 0.6 and 0.8.

The diameter differentiation index was calculated for all trees. For the overall plot its value was derived as an average index of individual trees on the plot. As it was the case with the species mingling index, there were two approaches: calculations with 3 and 4 nearest neighbouring trees.

When three nearest neighbours were observed, the results by the 20-year age classes showed that the diameter differentiation in the 5th, 6th and 7th age class was almost the same as the average index (0.407 to 0.424). That presented an average differentiation ($0.3<TI<0.5$) because the tree with the lowest DBH was 50 to 70% of the reference tree DBH. The index value was lower only in the 4th age class (0.299). Almost the same situation was when the 4 nearest

TABLE 2
The species mingling index by the 20-year age classes

Mingling index	Age class (years)	No. of trees	Mean $\overline{x}$	Range		STDEV	CV (%)
				min	max		
MI3 - 3 nearest neighbours	4 (61 – 80)	54	0.395	0.000	1.000	0.343	86.8
	5 (81–100)	2211	0.620	0.000	1.000	0.294	47.5
	6 (101–120)	2095	0.566	0.000	1.000	0.311	55.0
	7 (121–140)	308	0.393	0.000	1.000	0.353	90.0
	Σ	4668	0.578	0.000	1.000	0.312	54.0
MI4 - 4 nearest neighbours	4 (61 – 80)	54	0.370	0.000	1.000	0.321	86.7
	5 (81–100)	2211	0.611	0.000	1.000	0.267	43.6
	6 (101–120)	2095	0.560	0.000	1.000	0.285	50.9
	7 (121–140)	308	0.379	0.000	1.000	0.341	89.9
	Σ	4668	0.570	0.000	1.000	0.287	50.4

TABLE 3
The DBH differentiation index values by the 20-year age classes

Diameter differentiation index	Age class (years)	No. of trees	Mean $\overline{x}$	Range		STDEV	CV (%)
				min	max		
TI3 - 3 nearest neighbours	4 (61 – 80)	54	0.299	0.102	0.678	0.160	53.5
	5 (81–100)	2211	0.414	0.044	0.834	0.163	39.3
	6 (101–120)	2095	0.424	0.019	0.835	0.167	39.3
	7 (121–140)	308	0.407	0.055	0.851	0.188	46.3
	Σ	4668	0.417	0.019	0.851	0.167	40.0
TI4 - 4 nearest neighbours	4 (61 – 80)	54	0.289	0.105	0.677	0.147	50.9
	5 (81–100)	2211	0.409	0.043	0.834	0.149	36.4
	6 (101–120)	2095	0.420	0.052	0.822	0.152	36.1
	7 (121–140)	308	0.401	0.062	0.858	0.175	43.7
	Σ	4668	0.412	0.043	0.858	0.153	37.1

neighbouring trees were taken into consideration. Consequently, there was no significant DBH difference among the stands in the age of 81 to 140 (Table 3).

The mean diameter differentiation index value for all 45 sample plots (all age classes) was 0.415 with the 3 nearest neighbours considered, and 0.425 when the 4 nearest neighbours were considered.

DISSCUSION

Each of the three used stand structure indices quantifies spatial relations in a specific way. The aggregation index of Clark and Evans observes the regularity of the spatial arrangement of trees. The species mingling index strives to describe the biodiversity, because of the amount of diffe-rent species sharing the habitat. The diameter differentiation index observes the dimensions (DBH) of the nearest neighbouring trees and shows the level of their differentiation.

The results of the aggregation index of Clark and Evans, calculated for all 45 plots, showed that the index had values from 0.89 to 1.28 and displayed a slight tendency for further growth (Figure 4).

However, when the spatial arrangement of only pedunculate oak was observed, then the values of the aggregation index showed a higher spatial regularity.

With the increase of the stand age to 130 years, the values were practically the same (the equalization line had an insignificant gradient). The conclusion is that mature pedunculate oak trees in the observed stands, achieved the amount of spatial regularity to be maintained until the end of the rotation, to their age of 70 years. The results obtained by the present study were relatively comparable with the study of Marjanović et al. [12], that observed the trend of that index in mature pedunculate oak and common hornbeam stands of the central Croatia. The results of this study indicated that the index had the range of values from 0.8 to 1.2. That pointed to a random spatial arrangement of trees when all trees in the stand were observed. According to Marjanović, the trend of a slightly increased regularity in older stands was irrelevant.

Stoyan and Pentinnen [20] observed stands in different development phases, and concluded that old stands had a tendency to a random spatial arrangement of trees.

The reliability of the results was significantly higher with a correction for edge effects [21].

The species mingling index according to the results shown in Table 2 failed to provide any firm conclusion about any trend. Contrary to expectations that this index would increase by age, the trend of index values was unnoticeable, and the high variability affected the results when common hornbeam and other tree species were present. By aging, the number of pedunculate oak trees decreased and thereby the probability of hornbeam trees as the nearest neighbouring trees increased. The same goes for other associated tree species that had a large number of thin trees. The diameter differentiation index for the majority of the studied stands assumed approximate values within the range from 0.40 to 0.42 for the 5th, 6th and 7th age class (20-year age classes). According to Pommerening [15] those values represent the mean differentiation of diameters. The index remained within the same range of values with very slight differences, regardless of whether three or four nearest trees were considered, or the 10-year or 20-year age classes. Slightly lower values (0.29) in the 4th age class, where diameter differences among trees were less prominent, may be explained by a smaller range of the DBH values in younger stands. The conclusion was that the stands stabilized their structure in the border age range between the 4th and 5th age classes, so further diameter differentiation index values did not significantly change.

The species mingling and the diameter differen-tiation indices were both using the method of three or four nearest neighbours for the calculations.The imperfection of this approach became evident in the case of large distances between the trees, when their interaction was doubtful, as small distances between the trees implied their strong interaction. Pommerening [15] pointed to the convenience of the method that uses three or four nearest neighbours, in case of measuring only specific nearest tree distances, without recording positions for all trees. That is why the method of taking samples through a *structural group of four* was developed (Figure 2). This particular method gave an insight into the forest structure at minimal cost.

The indices of species mingling and diameter differentiation may be derived even from the sample plots commonly used in the present forest inventory. In that case, rather than tree diameters, the distance between the nearest trees in relation to the referent tree should be measured.

The three indices of the forest structure studied in this paper may be used as an additional indicator of the stand structure, because in this way apparently imperceptible differences in spatial relations among the forest tree species may be expressed. The studied indices may be applied as tools for the stand comparison as well.

The 10-year age classification was not proven as a step forward in reviewing the trends of the calculated indices. That was partly the result of inaccurate stand/ plot age data and because of the relatively small structure differences in mature stands that were studied as well. The use of common 20-year age class width was satisfying in the specified context.

The necessity of knowing the spatial distribution of trees on the plot (in the stand) makes the three indices observed here less applicable in the forest practice. Measurement and calculation of tree distances makes the whole procedure more expensive, and may be applicable only to small scale studies.

The absence of any corrections for edge effects was a disadvantage of all tree indices. The calculated nearest neighbour for a tree standing near the edge of the sample plot was not necessarily the effective nearest neighbour. A distortion of the correct index value may arise as a result. It should, however, be emphasized that the error caused by edge effects was bigger when small sample plots were researched, and that the edge effect correction for the aggregation index of Clark and Evans was not valid in case of circular plots [22].

More intensive processes of growth and deve-lopment in younger pedunculate oak and common hornbeam stands would certainly show more significant changes in the observed indices, than some mature stands. This may partially be concluded even from the research of Marjanović [11], and should be a subject for further studies.

CONCLUSIONS

The calculated values of the aggregation index of Clark and Evans showed mostly random spatial distribution of trees in the observed pedunculate oak stands. When only pedunculate oak trees were taken into consideration, that index was greater than 1.51 for all plots which pointed to a tendency of a regular tree distribution. The pedunculate oak trees in the observed stands, even in the age of 70, had the amount of tree distribution regularity that was going to be held until the end of the stand's rotation. The species mingling index on the plots showed values that allowed no firm conclusions about the trend in mature stands. The diameter differentiation index by age classes indicated very small differences among the values, regardless of whether three or four nearest trees were considered. It meant that at the age of about 80 years, the stands stabilized to the level after which there should be no significant changes in the relation among the pedunculate oak and associated tree species DBHs.

The three of the applied stand structure indices should be a useful tool in further categorizing forest stands, because of the tree distance component integration and their individual tree parameters basis.

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Preliminary communication

Carbon Storage Potential of Forest Land: A Comparative Study of Cases in Finland and Croatia

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Abstract

Background and Purpose: *The concentrations of greenhouse gases in the atmosphere have been increasing over the last hundred years in relation to the Fourth IPCC assessment report that highlighted human activities as a direct influence on climate changes. Since Croatia and Finland signed the Kyoto Protocol, they are both committed to fulfil international obligations of lowering GHG's emissions, enhancing the storage, as well as protecting and enhancing the current pools where the forestry sector has a prominent role. These obligations created a need for a review on carbon storage potentials for both countries with the aim of setting further scientific and management guidelines as the basic purpose of this research.*

Materials and Methods: *Data collection was conducted within the scope of the Sort Term Scientific Mission (STSM) in the period from May 2 – July 22, 2009 in the Finnish Forest Research Institute in Joensuu. The research encompassed an overview of literature, personal contacts with scientists and experts from both countries (research institutes, ministries, the EFI branch office in Joensuu) and a field inspection which altogether provided an insight into the applied silvicultural and utilization activities. A significant data source were official documents and published project results on the carbon storage potential.*

Results and Discussion: *Mitigation activities within the framework of the LULUCF project reduced the total emissions for 33.4 millions tons of* CO_2 *equivalents in Finland in 2006 (this data has varied from 18 to 33.4 millions tons* CO_2 *equivalents in the last fifteen years) while for Croatia the availability of such data is limited. Finland has some former agricultural land which may be afforested but not in the substantial share, while in Croatia such areas amount to around 1 million ha. According to the climate change scenario for Finland (FINADAPT), predicting the largest climate changes, the total forest growth nationwide is estimated to increase by 44% which will have positive impact on the forest carbon storage in the future. In Croatia there is no such kind of research. There is about 12.6 % of all forest land in Finland under protected forests (strictly protected areas about 3.6 %) in which enhancement of carbon storage potential may be enhanced. About 21% of the forests in Croatia (513 155 ha) are forests in some degradation stage in addition to about 500 ha of forests where management is prevented because of the land mines. These areas present a potential for carbon storage enhancement. Forest fires pose a great threat to carbon pools especially in the Croatian karst areas where the total of 251 901 ha of the Croatian land area burned in the period 1992-2007, which in average amounts to 15 744 ha annually. Nevertheless, Finland and Croatia do not undertake any significant current deforestation activities.*

Conclusions: *Even though Croatia and Finland have the same goals, they also show significant differences in relation to the already finished, current and planned scientific activities, legislation, implementation, natural conditions and constrains of* CO_2 *sequestration and storage. It is estimated that a significant potential in Finland lies in the reduction of* CO_2 *emissions through substitution effects, protection of stored carbon pools in forest ecosystems, avoiding the changes in land use, etc. Croatia, on the other hand, has a significant potential through afforestation activities on uncovered forest and abandoned agricultural lands. Further research on the categorisation of land, appropriate species and provenances selection is necessary. The effects of individual measures on emission reduction and carbon balance by forests are small on the national, as well as on the European scale, but if combined together the overall effects present a great potential to fulfill international obligations in both countries.*

Keywords: *Kyoto Protocol commitments, natural conditions, legislation, silvicultural activities, land use change.*

INTRODUCTION

The concentrations of greenhouse gases (GHGs) in the atmosphere have increased over the last hundred years. According to the Fourth IPCC assessment report [1] the concentrations of the GHGs, e.g. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone and halogenated hydrocarbons (F gases) in the atmosphere have increased over the last hundred years. The GHGs are gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of the infrared radiation emitted by the Earth's surface, atmosphere and clouds. In this way greenhouse gases prevent heat from radiating back into space, as a consequence of which they cause the greenhouse effect (global warming). According to the IPCC 2007 report [1], human activities were highlighted as a direct influence on climate change and the current scientific knowledge confirms that forests may reduce the concentration of CO_2 in the atmosphere and therefore mitigate climate changes [1-6]. According to Goodale et al. [7], forests in the northern hemisphere (Canada, United States, Europe, Russia, China) provided a total sink for 0,6-0,7 Pg of C per year (1Pg = 10^{15} g) during the early 1990s. The internationally accepted definition of mitigation states is that they are anthropogenic interventions to reduce the anthropogenic forcing of the climate system [1]. They include strategies to reduce GHGs sources and emissions, as well as enhancing GHGs sinks. According to the Protocol agreed upon at the Third UNFCCC (United Nations Framework Convention on Climate Change) in Kyoto [8], industrial economies and economies in transition are committed to reduce their collective emissions in 2008–2012 to 5% below the levels of 1990.

Finland and Croatia signed the Kyoto Protocol, but their ratification and implementation in legislative and forest management is quite different. The human influence on forests in both countries has been extensive and it has a long history. In Finland the livelihood and cultural development of humans has been more dependent on forests than anywhere else in Europe. The forest cover in Finland is more extensive than in any other European country. The three fourths of the land area in Finland is covered by forests (some 23 million hectares) [9]. The forest cover in Croatia is about 2.5 million ha [10] and Croatia has about 10 times less forest area per capita then Finland, 79.23 m^3 in Croatia and about 412.48 m^3 in Finland. About 60% of Finland's forests are privately-owned, while the situation in Croatia is completely different with about 81% of state-owned forests [11]. "Metsähallitus" in Finland and "Croatian Forests Ltd" in Croatia manage, use, and protect natural forest resources and other property on the state-owned lands under their administration. In Finland, the function of the 151 Forest Management Associations is to promote the profitability of forestry practiced by forest owners and to support the attainment of objectives they set for their operations. The associations are funded and operated by the forest owners. The Forest Management Associations are organized geographically into Unions of Forest Management Associations (ten unions as of January 1st 2007). In Croatia, the Forest Advisory Service was established in 2007 and empowered by the Government to advise forest owners, but also to fulfill legal obligations in the management, exploitation and protection of private forests. In 2010, the Croatian Government canceled all activities of the Forest Advisory Service and once again empowered the "Croatian Forests Ltd." to manage private forests, due to the cutting of expenses of government services.

Natural conditions for forest growth in these two countries are quite different which has a direct impact on the possibilities of carbon storage. Croatia lies in the temperate and the Mediterranean zone, while Finland is situated in the boreal zone. Therefore, the conditions for forest growth are completely different, nevertheless, both countries have specific areas with large limitations for forest growth. Owing to the conditions in the north, forest management in Finland takes place in climatically exceptional conditions because of the low temperature and high precipitation [12]. Geographically, Finland lies in the intermediate zone between the maritime and continental climates, belonging mostly to the boreal vegetation zone. Because Finland is over 1.100 km long on the north-south axis, the conditions for growth vary considerably between the southern and northern parts of the country. Croatia has also very different conditions for forest growth, from the lowland regions with the temperate climate, mountains and hilly regions, to the Mediterranean part with specific climate limitations, such as low precipitation in the vegetation period, high temperatures and high risks of natural disturbances. The impacts of climate changes on the forest cover in Europe and its ability to store carbon dioxide are at the moment well-discussed at international conferences and addressed by numerous international projects. Climate changes have a different impact on both countries with estimations that the impact is to be more severe in Croatia due to the already harsh conditions of high temperatures and drought periods in the Mediterranean part (e.g. Joensuu Forestry Networking Week, 2009).

Even though there are specific differences between these two countries, both countries have the same goals to meet their international obligations, in the first place the Kyoto Protocol, but also other EU and UN obligations related to specific mitigation and adaptation issues. Within the scope of those obligations, both countries should try to enhance carbon sequestration if possible and preserve and enhance current carbon pools through their activities. There are several different ways to achieve the goals of mitigation through forestry and the forest-based sector. The first is the mitigation through carbon dioxide storage in forest lands, and through the active management of forests by increasing the sequestration capacity of wooden biomass. The second encompasses the reduction of carbon dioxide emissions through, for example, forest wood products. Emissions trading, according to Article 17 of the Kyoto Protocol, allows countries that have extra emission units to sell this excess capacity to countries that exceed their targets. Each carbon credit, known as a Certified Emission Reduction (CER), represents a ton of carbon dioxide, or an equivalent, not emitted other greenhouse gas [8].

The potential of forests to mitigate climate changes is defined within the framework of the LULUCF project (land-use, land-use change and forestry) [13]. It encompasses afforestation, reforestation and different silvicultural practices which enhance carbon sequestration by forests (e.g. an increase in the growing stock and its influence on carbon storage in the soil). "Afforestation" according to the definition of UNFCC [14] is the direct, human-induced conversion of lands not forested for a period of at least 50 years to forested lands by planting, seeding and/or the human-induced promotion of natural seed sources. "Reforestation" [14] is the direct, human-induced conversion of non-forested lands to forested lands by planting, seeding and/or the human-induced promotion of natural seed sources, on lands previously forested but converted to non-forested lands. Those mitigation activities in Finland reduced the total emissions for 33.4 millions tons of CO_2 equivalents in 2006. This number has varied in the last fifteen years from 18 to 33.4 millions tons CO_2 equivalents. For Croatia, the availability of this kind of data is rather limited.

Within the scope of the LULUCF project, the avoiding of the change of land use on the global scale refers mainly to deforestation activities. Forest fires also pose a great threat to climate change mitigation since they release the stored carbon into the atmosphere and reduce carbon stocks in the living biomass. In relation to different intensities of wild forest fires, there are more and less dangerous fires which have to be taken into account. Some forest fires may influence the forest's ability to regenerate which causes the total devastation of the burned area. These already mentioned national and international obligations created a need for a review of the carbon storage potentials for both countries with the aim of setting further scientific and management guidelines as the basic purpose of this research.

MATERIALS AND METHODS

Since the options and potentials for climate change mitigation depend on local circumstances and specific issues, the need arose within the scope of the COST Action ECHOES (Expected Climate Change and Options for European Silviculture, Working Group III: Mitigation) to investigate differences and possible similarities of the potentials for climate change mitigation in Finland and Croatia. The research was conducted within the scope of the Sort Term Scientific Mission (STSM) in the period from May 2 – July 22, 2009 in the Finnish Forest Research Institute in Joensuu. This international cooperation was based on the mitigation potential comparison together with political, legislation and management implementation issues and, therefore, presents the basis for creating a COST database on the potentials of forests and forest products in Europe to mitigate climate change. The research encompassed an overview of literature, personal contacts with scientists and experts from both countries (research institutes, ministries, the EFI branch office in Joensuu) joined with a field inspection, which altogether provided an insight into the applied silvicultural and utilization activities. A significant data source were official documents and results of the published project on the carbon storage potential.

RESULTS AND DISCUSSION

Historical Circumstances, Current Legislation and Associated Projects

The Kyoto Protocol, besides committing industrial economies and economies in transition to reduce their collective emissions to five percent below the levels of 1990 in 2008–2012 [1], also obliges them to implement the containing measures to mitigate climate change into their policies national programmes by addressing the sources and removals by sinks. Furthermore, they have to promote the processes that control, reduce or prevent emissions of GHGs in relevant sectors and promote sustainable management, conservation and enhancement of sinks and reservoirs, including biomass, forests and oceans, as well as other terrestrial, coastal and marine ecosystems.

Finland

In Finland, the Ministry of Environment is in charge of the matters related to the UN's Framework

Convention on Climate Change (UNFCCC) and international negotiations under the Convention [9]. Several national expert teams were nominated to facilitate the negotiation and the reporting process. The Finnish statements to the climate negotiations were prepared under the "Climate Work Group" and the "Gas Work Group", nominated by the Ministry of Environment which is responsible for the Finland's Annual Inventory Report on GHGs submitted to the UNFCCC [15-17]. Finland´s *National Strategy for Adaptation to Climate Change* was completed in 2005. The Strategy described, among other things, the impacts of climate changes on forestry and outlined measures to be implemented in the forest management. On the basis of the *Strategy,* the research program on the adaptation to climate change, called ISTO (Climate Change Adaptation Research Programme) was launched in 2006 [18, 19].

In Finland, according to Karjalainen and Mäkipää [15], the national reporting of GHG inventories for changes of land-use and forestry category utilizes forest inventory results with appropriate studies on the allocation of biomass and wood properties, as well as the national wood consumption statistics allowing the use of country-specific values instead of overall default values provided in the IPCC guidelines. Several studies assessing carbon stocks and fluxes, as well as the impacts of forest management on carbon stocks and fluxes, were carried out in several research organizations. Besides the already mentioned annual national reports under the UNFCCC, there is an immense amount of literature related to climate change mitigation in Finland [20-30].

Croatia

The situation in Croatia is quite different from the situation in Finland. In Croatia, the Ministry of Environmental Protection, Physical Planning and Construction is in charge of the international negotiations under the UNFCCC [31]. Even though Croatia signed the Kyoto Protocol in 1990, the document was not ratified until May 2007, after long and hard negotiations to assure an equal position as all other European countries. As a result of specific circumstances related to the war in Croatia, the initiation of the Kyoto related activities in legislative and political terms, together with its implementation in Croatia, was delayed in relation to other countries. In February 2002, Croatia issued its first National Report on greenhouse gas emissions for the UNFCCC, followed by others [32, 33]. The Ministry has recently published the National Strategy for the Implementation of the Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol in the Republic of Croatia with an action plan [31]. This Strategy was published on the basis of the Project LIFE04 TCY/CRO/029: "Capacity Buildingfor the Implementation of the United Nations Framework Convention on Climate Change and the Kyoto Protocol in the Republic of Croatia". There are several projects related to climate change issues conducted within the scope of the Ministry of Environmental Protection, Physical Planning and Construction and several other scientific institutions in Croatia.

For example, "Expedited Financing of Climate Change Enabling Activity - Phase II (CRO/03/G31/A/1G/99)" [31]; "UNDP/GEF Capacity Building for Improving the Quality of Greenhouse Gas Inventories (Europe/CIS region)" [31]. With the above mentioned documents the Ministry provided the base for addressing climate change mitigation in Croatia.

Studies related to carbon storage in Croatia were conducted within the scope of the activities by the Croatian Forest Research Institute (projects lead by H. Marjanović: The Sustainability of Carbon Storage in the Managed Pedunculate Oak Forests; Enhancement of the Information System "HŠ Fond" with a Module for Monitoring and Recording Carbon Forest Storage" HŠ-Fond-Carbon"). The studies assessing carbon stocks and fluxes, as well as the impacts of forest management on carbon stocks and fluxes were carried out within the scope of activities of the Croatian Forest Research Institute [34, 35].

In Croatia, the literature related to this kind of research is rather limited due to the fact that most research is still in progress and only some results were published [33, 34, 35, 37]. Papers published up to now are more related to the production of the biomass of different alohtonous and autochtonous species in various bioclimates in Croatia [38, 39].

Afforestation Activities

In Article 3.3 of the Kyoto Protocol [8], the UN stated that carbon sequestration after afforestation may be accounted as a sink in the national GHG budgets. Therefore, these activities present a possible solution in the GHG emission reduction for many countries [40].

Finland

Small amounts of potential areas for afforestation in Finland, together with complex issues of the transformation of peat into the forest soil, limit these activities and significantly influence its carbon balance (H. Peltola, unpublished data). Finland has got a certain amount of former agricultural land to be afforested within the scope of the LULUCF activities, but not in the substantial share which would make it significant as a carbon sequestration potential on the national level. Most of the abandoned agricultural land suitable for afforestation in Finland are former peat land areas, and those have mostly been afforested by now so they present no actual sequestration potential (Heli Peltola, unpublished data). Nevertheless, there is a certain controversy about the afforested peat land areas since they may increase carbon emissions in relation to the original peat lands, but lower methane emissions. In that way, they may have a positive impact on the reduction of GHG emissions [40] but its share in the total GHG balance for Finland would probably not be significant.

The significance for afforestation and reforestation of other uncovered lands in Finland is low in terms of climate change mitigation. Finland has the largest share of the forest cover in the whole Europe (three thirds). There are some areas (the Lapland area) where, by means of natural succession induced by changed climatic conditions, the tree limit is shifting further towards the north. Those areas have a large biodiversity and a low share in the total country area, therefore, specific activities should be applied to prevent the tree limit shifting [19]. There are also 3.2 million ha of wasteland in Finland, but the capability to produce volume increment on those areas is low (less than 0.1 m^3 ha^{-1} $year^{-1}$) so those areas have no significant potential for climate change mitigation through afforestation. There are current research activities, for example, in the Mekrijärvi research station of the University of Eastern Finland, about the potential of biomass production with reed canary grass on drained peat lands and the influence on carbon emissions from peat, but such activities do not belong to the forestry sector.

Croatia

Available areas for afforestation in Croatia are subjects of rough estimation. They amount to around 1 million ha, which, in comparison with the total of 2 688 687 ha of forests and forest land, clearly shows the importance of the afforestation potential and possibilities for Croatia [42]. Croatia has a bigger potential for mitigation through afforestation of abandoned agricultural lands in relation to its land area than Finland. Some of the Management units in private forests have already been substantially enlarged by areas left to natural succession (abandoned agricultural lands). The exact size of these areas will be known after the completion of the new management plans for private forests, but evidently those areas are growing constantly. The problem is that the afforestaton of those areas is expensive and there are no current subsidies in Croatia for afforestation activities. Therefore, many of those areas are in some stage of degradation waiting for the management to take effect. The current management plans incorporate some traditional management activities for the spontaneously afforested areas through natural succession, but climate change mitigation or adaptation measures were not implemented. Also, those areas are in different bioclimates in Croatia with different volume production capacities (e.g. high in lowland areas and rather low in the Mediterranean region), so if the true potential of these areas is to be known, there should be more scientific research on this matter, especially in the Mediterranean region.

On the other hand, there are 208 467 ha of available uncovered forest land for afforestation activities in Croatia [11] which is a significant area. This land has a different share in separate regions of Croatia with different production capacities and, therefore, different potentials for climate change mitigation. In this case, as well as in the case of the afforestation of former agricultural land, there is no current data on sequestration expected in those areas since there is no current data on the soil sequestration and the potential productivity on separate sites (carbon storage may be estimated through the potential of wood production on separate sites). The project “Preservation of Stability and Productive Ability of Forest Cultures” (Perić and Tijardović, within the Ministry of Science, Education and Sport) deals with the issue of establishing and producing forest cultures throughout Croatia. Also, two ongoing projects (2011-2013) conducted under the auspice of the “Croatian Forests Ltd” (Perić and Tijardović) deal with afforestation activities and the potential production in the continental part of Croatia (“Afforestation of Karst Wasteland in the Lika Region” and “Management of Forest Cultures in Croatia with a Special Attention on the Conversion Activities”). There are some estimations of carbon sequestration within the scope of the UNFCCC national reports, but there should be more research to gain more reliable and more accurate estimations (especially for specific regions). Nevertheless, carbon sequestration in the soil currently presents a gap in the scientific knowledge in Croatia and therefore it requires more scientific research on this matter. The presented information is related only to the uncovered state-owned forest areas, while the precise size of privately-owned wasteland areas is still unknown. There may be some potential in forest lands in private ownership in Croatia as well, because there are many unsuccessfully naturally regenerated areas which were left to natural succession in the past (their current state in most cases is some degradation stage, which may potentially provide more benefits for the carbon balance on the national level), but more detailed data will be available after the completion of management plans. In addition, there are special issues which have not yet been investigated, regarding some areas in the Croatian mountain region where pastures have been overtaken by forests of autochthonous tree species (*Picea abies)* through the process of natural succession. In those areas the carbon pool in the soil would be decreased [43], but also the carbon sequestration through biomass production may benefit climate mitigation. But, this process raises the issue of acceptability from the point of gaining carbon credits, because pastures are usually not managed (private lands with questionable ownership). In addition, succession processes may induce a decrease in the biodiversity and therefore be contradictory to the UN´s Convention on Biological diversity [44] and guidelines of the IUCN for afforestation and reforestation for climate change mitigation. If those areas may officially be converted to forests in order to gain carbon credits and wood certificates, how much that would participate in the total potential for mitigation in Croatia remains an open question for further research. There is no current data about the size of those areas, but it may be substantial (e.g. Lika and Gorski Kotar). Therefore, further research is needed if those areas are to be considered as potentials for mitigation.

Forest Extension Services

One of the main problems in both countries is that basically it is the responsibility of the forest owner to implement those activities into their management. For Finland, it represents an important issue due to a high share of private forests. In Croatia, a large gap in the knowledge about climate changes and adaptation or mitigation activities is currently present among forest managers or private forest owners. The subsidies and education on climate change and mitigation was planned to be implemented into the actions of the Croatian Forest Advisory Service. Currently, workshops organized within the framework of the Low-Emission Development Strategy (LEDS) are the only available education on climate change issues for forest managers or policy-makers. The administrative period of transferring the activities from the "Forest Advisory Service" to the "Croatian Forests Ltd" was a period with no involvement of private forest owners in mitigation and adaptation activities. In Finland, there are no current national subsidies for afforestation activities (excluding the EU financing in some special cases). The education of private forest owners is done within the scope of the activities by the Forest Management Associations. Education of private forest owners and subsidies are probably the only way to persuade private forest owners to afforestate their land.

In addition, there should be more scientific research on these issues in both countries, especially Croatia, and the results should be incorporated by educating forest officers, regardless of whether they work in privately- or state-owned forests. There may be a big potential in Croatia for mitigation by establishing energy plantations and cultures for biomass production, but this issue is heavily influenced by the entire chain of biomass production, not yet successfully established in Croatia. Nevertheless, these activities may have a significant negative impact on biodiversity which has to be taken into account [45].

Changes in Carbon Storage in Soil after Afforestation

Finland

Extensive research has been done up to now and a lot of publications are available in Finland in relation to the influence of carbon storage in the soil after afforestation, especially on drained peat land areas [46-51]. Also, extensive research was done on carbon storage in the soil with various stand ages, species composition and predictions of climate changes [52-56]. After afforestation and preceding the drainage of the peat land, it becomes a source of carbon. Nevertheless, in relation to the produced woody biomass and related to carbon storage together with a reduction of methane and nitrous dioxide emissions, there may be a positive effect in some locations. In accordance with the papers published by the International Peat Society [45, 57] the maintenance of large stores of carbon on undisturbed peat lands should be a priority, but it was also stated that due to changes in the climate, those areas might become drier and therefore emit more carbon dioxide into the atmosphere. The remaining question in this matter is the uncertainty of climate predictions together with the size of those areas in the future and their suitability for afforestation in relation to natural succession and biodiversity.

In case of mineral soils, the temporary reduction of soil carbon storage after afforestation is not so significant since there is a great carbon storage in forest products which are suitable to substitute fossil fuels and many other materials. Since the period of afforestation of the former agricultural land is presumably over in Finland, this presents an issue of a lesser significance for Finland.

Croatia

For Croatia there is no currently available literature to cover the issues of afforestation influencing carbon storage in the soil. There is an ongoing project regarding the carbon balance of pedunculate oak in the lowland region of the river Kupa within the scope of determining carbon storage in the soil (Marjanović 2011-2013). The research on the change of carbon storage in Croatian acid soils, covered by *Pteridium* and *Calluna* species, after afforestation with different species, would provide more accurate data than the current estimations for other soils. Such results would present a valuable contribution on the carbon sequestration potential of those areas since these represent a significant part of the area available for afforestation in central Croatia with a good production capacity. Also, the research on the influence of afforestation in different soil types throughout Croatia and the conversion and substitution of tree species on carbon storage in the soil, may be interesting in relation to the changes in the soil C pool.

Enhancement of Forest Sequestration through Silvicultural Measures

Finland

The potential of forests to store carbon varies in relation to climate changes [56, 57]. According to the climate change scenario for Finland (FINADAPT), given the largest climate changes [60], the total forest growth nationwide is estimated to increase by 44% which will have a positive impact on the forest carbon storage in the future. Nevertheless, a high uncertainty in climate change prediction has to be emphasized and adaptation measures more investigated. The second issue related to silvicultural measures is concerning protected forests. There is a share of about 12.6% of all forests and forest lands in Finland under protection. Strictly protected areas have a share of about 3.6% [19]. In accordance with the Opinion of the European Economic and Social Committee on the role of forests and the forest-based sector at the meeting of the EU's climate commitments [61], there is an important difference between commercial forests and natural forests in terms of carbon sequestration. From the perspective of climate protection, natural forests in their equilibrium state represent a carbon sink, where carbon sequestration through the growth of biomass and carbon release through decay of biomass are in balance. On the other hand, commercial forests are constantly developing new and additional carbon sequestration capacities due to the harvesting of timber. So, this strong evidence opens the question of the high share of protected forests in Finland in relation to mitigation. The question of natural regeneration of protected forests due to changed climatic conditions is also relevant because the implementation of adaptation measures in those areas is prevented.

Forests in Finland are mainly already continuously extensively managed so there are no possibilities to enhance carbon sequestration other than applying fertilization with the aim to enhance production or establishing new stands only with the selected genetic material which may enhance wood production by 20-30% in relation to the unselected planting material (Heli Peltola, unpublished data). The increased use of small-sized trees for bioenergy purposes, obtained by tending measures in young forests, have improved the profitability of management and developed an interest to take care of this less profitable management phase of stands. In the last several years there has been a significant decrease in pulp and paper production in Finland [62]. The issue was raised of temporarily stopped thinnings which may lower the sequestration rate (exp. in private forests) and possibly have a negative effect on the position of pulp and paper industry in the future. But, currently there are activities on the interconnection between pulp and bio-fuel industry in Finland, so there may be a small influence of this crisis on C sequestration in the future.

There are many issues on the implementation of mitigation activities in private forests, especially in Finland, since the biggest share are private forests. One of the difficulties is the joined ownership of descendants after the death of previous owners. A larger number of private owners and the decreased average area of private forest add difficulties to the implementation of appropriate measures. In addition there are large areas of private forests in Croatia which have not been properly managed (e. g. during the war) those areas may become significant carbon sinks through the implementation of proper silvicultural activities and the education of forest advisors and forest owners.

Croatia

The share of strictly protected forests in Croatia is lower than in Finland (5.605 km^2 or 9.9% of the land area according to the Law on Nature Protection) [18]. Nevertheless, according to the Forest Management Plan for Croatia [63], 84% of all forest areas are managed forests with a commercial function, but the remaining 16% are forests with protective and special functions where only salvage cutting is allowed. This kind of management makes those forests high risk forests so the same issues may be relevant for Croatia in relation to mitigation potentials.

This question is even more opened for discussion and further research because some of these areas are in the Mediterranean region and therefore subjected to high risks of fires (carbon storage in forests subjected to natural disturbances is questionable) and strong projected influence from drought due to the changing climate (also questionably protected function in the future).

The share of high forests in Croatia is about 54% of all covered areas (1 283 561 ha) where silvicultural treatments are conducted for the production of high quality technical wood on the basis of natural principles (the *Quercus robur* forests in the Slavonia region), so there is no possibilities to enhance carbon sequestration (the potential) through silvicultural measures unless the stability of forests or quality of products is reduced. But about 21% of all forests in Croatia (513 155 ha) are forests in some degradation stage (garrigue 1%, maquise 2%, shrub 18%), where commercial exploitation is not financially interesting, so those areas may have a substantial potential for mitigation. Their carbon storage is low, but if those areas should be converted to high forests for timber production (on sites where the site conditions allow it) or they be used for biomass production, their carbon storage potential may be much higher. Since some of these areas are in the Mediterranean region under a high risk of fires, exploitation for biomass may present a possibility for reducing fire risks. Within the scope of climate adaptation, the only way of reducing fuel in the Mediterranean forests, and thus reducing the risks of fire ignition and fire intensities, would be to render those forest financially interesting [64]. Without any further research on the distribution of this kind of forests (different bioclimates provide different volume production potentials), it is almost impossible to make any kind of estimation. There should be further scientific research on the policy and legal reimbursement of those measures which currently do not exist in Croatia. Further research about the sequestration in forest soils, as well as in the wood biomass, in those areas is also needed.

In addition, there are about 3% of forest cultures in Croatia about 40 to 60 years old and where none or very little management has been done due to different social reasons. They are currently included in the ongoing project about the best ways for silvicultural practices and management of those cultures from the economical point of view and with a special overview on climate change adaptation measures (Perić and Tijardović Management of Conifer Cultures in Croatia 2011-2013). Those areas may have some potential for mitigation, but more research on this matter is required.

In addition, there are about 500 ha of Croatian forests where management is prevented because of the land mines from the war in Croatia [65]. This area is not significant, but the question was raised due to carbon storage and its sensitivity to natural disturbances (e. g. forest productivity and carbon storage may be lost due to windthrow or decreased because of the lack of silvicultural measures).

Influence of Wildfire Behavior on Carbon Storage

Finland

Due to efficient monitoring and favorable natural conditions, such as high precipitation and lower summer temperatures in Finland, forest fires have remained extremely rare although there are several hundred fires each year. So, for Finland this is not an important issue for mitigation even though changes in climate may increase plausible conditions for the occurrence of fire.

Croatia

On the other hand, forest fires pose a great threat in Croatia, especially in the karst area where 3 678 forest fires occurred in the period 1992-2007, 4 851 fires in total in the whole country [66]. In the same period, 251 901 ha of Croatian land area was burned, which in average amounts to 15 744 ha annually. The only possible way that the risks of fires may significantly be reduced, besides monitoring, is if those forests would become economically efficient, for example through the substitution of biomass which is important for mitigation. Therefore, this may be a great mitigation possibility for Croatia and further research is needed since this depends on the entire chain of biomass production.

Avoided Changes in Land Use

Finland

Changes in land use may have a significant impact on the decrease of carbon storage if deforestation activities are taken into account. In both countries, Finland and Croatia, there are no significant current deforestation activities. Finland and the Finnish people have always had a strong connection with peat lands, since there is about 10.4 million ha of peat lands in Finland (one third of the whole land area). About 5.7 million ha of peat land is currently used in forestry [57]. But, there are many issues related to peat lands, as mentioned already, since drained peat lands may emit carbon dioxide. Natural, undrained peat lands produce methane emissions, and agricultural lands with the highest nitrous oxide emissions produce the most GHG emissions. The afforested drained peat lands and the afforested former agricultural peat lands may have a positive balance of GHG emissions, but that depends on specific site conditions (i.e. soil water, temperature). Also, the changing climate may have an effect on peat lands in diverse ways. For instance, warming may move the area of the raised bogs northwards, which in turn may result in an increase of the total accumulation of carbon in northern peat lands, but perhaps decrease the rate in southern mires due to accelerated decomposition [57]. In terms of GHG management, the maintenance of large stores of C in undisturbed peat lands should be a priority [45]. Therefore, this presents an important issue for Finland forestry and mitigation, especially in the future. However, there are available publications which address the issues of peat land in the conditions of the changing climate [e.g. 45, 66, 67] and those for Finland in particular [21, 57, 68].

Croatia

Peat lands in Croatia do not have much influence on the total carbon balance for the whole country since there are only 26 km^2 of peat lands in Croatia [32, 33]. There may be some more not registered peat land areas, since they were converted into the agricultural lands.

There is the question of changing the use of land,from agricultural to forest biomass production sites. If the sustainability criteria for biofuels is to be included into the Directive of Green Public Procurement, these issues certainly have to be addressed there [9]. Also, Croatia has swamps as natural GHG sources. Even though those areas are not substantial for GHG emissions for Croatia in general, their emission may change due to climate changes (i.e. higher temperatures and less precipitation). Most of those areas are protected due to the conservation of natural diversity.

Exploitation areas (e.g. queries in Croatia, peat utilization in Finland) and the questions of their revitalization are important from the aspect of the changing climate condition, the occurrence of extreme events and consequently more problematic revitalizations in those areas (i.e. preserving carbon balance on deforested area and assuring its stability after revitalization). But, it has a low influence on the total carbon balance on the national level, since at the moment there are no other significant changes of land use.

CONCLUSIONS

On the basis of the international experience and knowledge exchange, several conclusions may be drawn. The available areas for afforestation in Croatia are important for the total carbon balance in Croatia, but there is no substantial quantity of such areas in Finland. Croatia has a significant potential for the emission reduction on the national level through the afforestation of the abandoned agricultural lands and, therefore, more attention should be given to these issues. In Finland there have been no changes in the forest area during the last 50 years.

In relation to the risk from natural disturbances, it is important to highlight that this issue is present in Finland's forestry, but has an even more importance for Croatia (especially in the Mediterranean area), so more attention should be given to research and the application of carbon storage preservation activities.

Protected forest areas are currently in carbon balance, but commercial forests are always acting as carbon sinks (due to the wood substitution effect), so it is important to raise the question of the size of protected areas, especially for Finland, where this question is not addressed at the moment.

There is a great importance of the implementation of mitigation measures into management forest plans on the local scale for both countries, as well as the education of forest managers and forest owners on the possibilities of carbon reduction through the forestry sector.

The final and the most important conclusion is that the effects of some individual measures to enhance the storage of carbon dioxide in forests is small on the national, as well as on the European scale. Nevertheless, by fullfilling of all the above mentioned individual potentials, together with the implementation of carbon emission reduction measures, their combined effect is of a great importance not only for carbon balance in both countries, but also on the European scale. Therefore, more effort should be made on the political, legislative, scientific and implementation basis in both countries, especially in Croatia. The education of forest managers and private forest owners on climate change dynamics, further possible impact of climate changes on human lives and the importance of forests and the forestry-based sector in climate change mitigation is important to meet international obligations and fight the current climate changes, as well as those in the near future.

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Review paper

Variability of Water-Air Properties of Hydromorphic Soils in Relation to the Granulometric Composition

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Abstract

Background and Purpose: *The study of the particle-size distribution of hydromorphic soil and its relations to water and air qualities contributes to the better understanding and use of the land. The granulometric distribution has a significant impact on physical properties of the soil, such as: water-holding capacity, available water for plants, air capacity and residual porosity. The aim of this study was to show the relationship of texture composition and water retention under the pressure of -0.33, -6.25 and -15.00 bar, the capacity for air and available water for plants in different texture classes, and the relationship between the particle-size distribution and the content of a rough, medium, fine and ultra-fine pores in the excavated soil.*

Material and Methods: *In order to analyze the relations of particle size distribution and air-water features of hydromorphic soil, the Middle Danube Region was researched. The following soil types were determined: fluvisol, humofluvisol, humogley and eugley. Soil samples were taken in degraded and natural state of soil profiles. Samples were analyzed in the laboratory of the Institute of Lowland Forestry and Environment, University of Novi Sad, with standard pedological methods. After the performed analysis, the mean air-water soil properties for different textural classes were calculated and presented.*

Results and Conclusion: *According to the presented results of moisture retention at pressures of -0.33, -6.25 and -15.00 bar, it may be concluded that pressure treatments lead to an increase of moisture retention values of the texture classes - sand to clay loam texture class, which is in close connection with the textural composition of the hydromorphic soil samples. The texture class of sand and loamy sand had the largest capacity for air, while the increased content of silt and clay decreased the air capacity and only slightly increased it in sandy clay loam and clay loam. Water available to plants was mostly present in the textural classes of sandy loam and loam.In the sand and loamy sand and sandy clay loams with clay loam the values of this parameter were lower due to the unfavorable ratio of fractions in the textural composition. According to the content of the pores in various soil textural classes, the highest content of rough pores was found in the sand and loamy sand. The content of medium-sized pores increased with the proportion of silt and clay, it was largest in the sandy loam, loam and sandy clay loam. The content of tiny and fine pores was common for textural classes of a heavier texture or clay loam.*

Keywords: *Central Danube Region, granulometric composition, hydromorphic soils, water-air properties*

INTRODUCTION

The erosion power of a river has a major role in the formation of the land in river basins [1]. Different landform terrains are formed according to that process and different types of soil, depending on the textural composition of the formed soil particles. In the area of bottomland soils, the following hydromorphic types of soils may be found: undeveloped land, meadow land and gley soils. These soils differ primarily in the shares of certain granulometric fractions, on the basis of air-water features specific for each type of soil [2]. The granulometric distribution has a significant impact on the physical and chemical properties of the soil. As

Živanov [1] stated, it has great impact on water capacity, nutrient elements and their accessibility for plants, as well as the ability to process within the soil. The same author stated that as lands were non-structured, the influence of the particle size distribution of these features was higher. Pekeč et al. [3] also noted a close connection of the textural class and the tested parameters of physical properties of the soil in the gley soil of Middle Danube. According to Živanov [1], the average value of certain fractions of alluvial soil were presented, so that the share of the grit was 6.8%, fine sand from 19.2 to 91.0%, powder (dust) 20.6% and the clay fraction from 0.4 to 35.2%. Ivanišević [4] stated that the most important characteristic of the soil, formed in the alluvial plain of the Danube, was its textural composition or participation of certain granulometric fractions. The main indicator of this relation, was the average content of the total clay in the rhizosphere zone, and on the cross-section of the Danube River bottomland in the Middle Danube Basin. The sedimentation of the above mentioned fraction has the form of a logarithmic function. There exists a very large vertical stratification of the alluvial soil, [4], as a result of the river's fluvial sedimentation, with not many rapid changes in the properties and the high variability of the textural content.

Also, studying the Middle Danube area Živanov [5] and Živanov and Ivanišević [6] stated that fluvisol soils formed in this area were characterized by rapid changes in the particle-size distribution, while the humofluvisols feature layers were not clearly defined.

According to Galić et al. [7], the analysis of the content and layout of the silt + clay was found in the similarity of the genesis of loam forms - fluvisol and humofluvisols. Having explored different forms of fluvisol soils, Pekeč et al. [8] suggested different water-air features for each explored form, depending on the prevailing granulometric fractions. Pekeč et al. [9] analyzed the gley-marshy land in the Middle Danube region and showed a decline in the share of finer textural classes and an increase of the coarser texture class of soil with depth.

Thus, Ivanišević [10] indicated that fluvisol land had significant differences in the clay fraction between the varieties of soils. The average content of clay fraction and dust, relevant for the fertility elements [4], was 32.5%, and ranged from 4.6 up to 71.7%. The same author stated the following quantitative representation of certain fractions of the granulometric fractions: coarse sand (2.4 to 26.2%), small sand (26.9 to 71.8%), silt (0.9 to 47.6%) and colloidal clay (1.1 to 23.1%).

The granulometric features of soils may in some circumstances be essential for the productivity of the land. The occurrence of sand layers with loamy is also beneficial, since both texture components represent a favorable habitat for the growth and development of the types of trees frequent throughout the alluvial plain.

Until now, most of the soil research has indicated the importance of the particle-size distribution of the land in the inundation of our rivers. All indicators of fertility in the soil area of flooding rivers have been closely correlated with the content of the silt + clay in the soil. It should also be considered that the water-air properties, as well as the hydrological regime, depend on the granulometric composition of the soil.

MATERIALS AND METHODS

Soil samples were collected from the Middle Danube Region. Open soil profiles were present at 19 sites, also describing the internal and external morphology of the profile. The soils from the hydromorphic types were determined, namely: fluvisol, humofluvisol, humogley and eugley. Soil samples were taken in their disrupted and natural states. In their disrupted state 120 soil samples were taken, 360 undisturbed soil samples were taken by Kopecky cylinders of 100 cm^3.

The collected soil samples were analyzed in the laboratory of the Institute of Lowland Forestry and Environment, University of Novi Sad, Serbia. The following analyzes were performed:

- Determining of the soils' mechanical composition by the international B-pipette method, along with the preparation of sodium-pyrophosphate. Thus, certain mechanical earth fraction were determined [11], as well as the soil's textural class according to the ISSS (International Society of Soil Science), Baize [12];
- Determining of the soil's specific gravity by the Albert-Boggs method, with the use of xylol as an inert liquid, according to Bošnjak et al. [13];
- Determininig of the soil's bulk density in Kopecky cylinders, volume 100cm^3, according to Bošnjak et al. [13];
- The total porosity (%), calculated from the value of the specific and bulk density, according to Bošnjak et al. [13];
- Moisture retention at the pressure of -0.33 bar with the Richards-plate equipment [14];
- Moisture retention at pressures of -6.25 and -15.00 bar, with the Pressure-Membrane equipment [14];
- Available water capacity (vol.%) of soils (available water for plants), calculated from the difference between values at pressures of -0.33 bar and -15.00 [13];
- Air capacity (%) [13];
- Pore categories were determined from the difference between the total porosity and the moisture retention under different pressures;
- After laboratory analyses, all the data were processed in the computational program STATISTICA [15] so average values and the analysis of the variance for

the given parameters were determined and presented graphically.

RESULTS AND DISCUSSION

All studied samples showed large variations in the water retention effect on soil, at the pressure of -0.33 bar (Figure 1), that was primarily caused by a high textural variation in the depth profile. In order to show the importance of the soil texture and the textural class on water retention, the mean values for all samples at this pressure were presented.

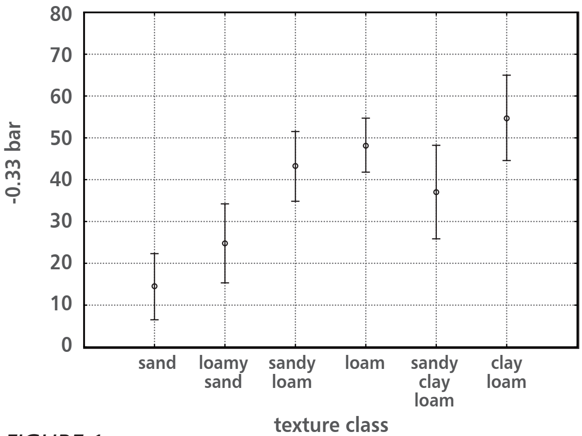

FIGURE 1
Water-retention effects at the pressure of -0.33 b (vol.%) compared to the texture class

The retention of water at the pressure of 0.33 bar was the least in the sand (13.9 vol.%) and soils of a light-mechanical composition, and gradually increased to clay loam textural classes (55.4 vol.%), except in the texture class of sandy clay loam, where the retention of water was slightly lower. The most significant differences are between the sand and loamy sand compared to clay loam ($p = 0.00000$). It may be noticed that the increase in the proportion of the clay fraction, also meant the increase in the value of water retention at -0.33 bar. Thus, Živanov [1,16] stated the following values of water retention at -0.33 bar for alluvial soil textural classes taken from the alluvial plains of the Danube, Drava and Tamiš: sand 7.1 vol.%, loamy sand 20.3 vol.%, sandy loam 32.2 vol.% loam 48.5 vol.%, powdered clay 51.7 vol.%. Studying the Middle Danube lands, the water retention values at -0.33 bar were in scope of the following interval: from 3.4 to 44.8 vol% [4].

In the treatment of the samples at -6.25 bar, the samples with a light-mechanical composition retained a small amount of water, in relation to patterns of heavier textures. That conclusion is presented in the following graph (Figure 2). It is evident that with the increase of silt and clay, the value of retention capacity was also increasing. There are significant differences between the texture classes sand, loamy sand and sandy loam compared to the clay, sandy clay loam and clay loam ($p = 0.00000$). Studying the Middle Danube lands, the water retention value, at -6.25 bar pressure, ranged from 2.0 to 21.7 vol%, according to Ivanišević [4].

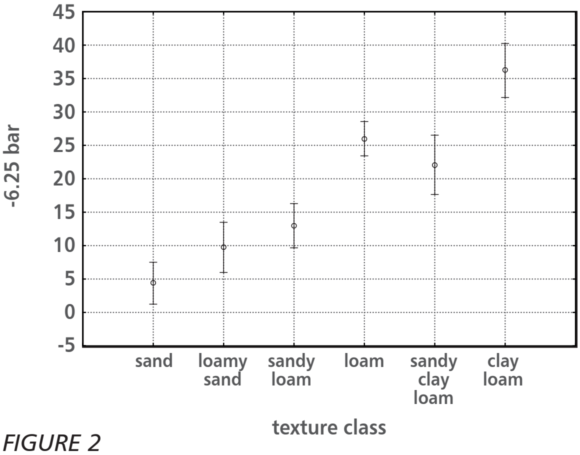

FIGURE 2
The retention of water at -6.25 bar (vol.%), in comparison with the textural class

According to Živanov [1], this water content in the soil is characterized by the lento-capillary moisture, respectively, the lower limit of available water for the plant, and according to his data, soil samples had moisture at -6.25 bar, ranging from 0.91 to 29.3 vol.%, and the average value was 11.6 vol.% for all tested samples. This value of water retention at the pressure of -6.25 bar indicated that the lower threshold humidity in plants may still be restored when it comes to wilting, and this is the lowest percentage of moisture in the soil in which it is irrigated.

As with earlier data presented here, it may also be seen (Figure 3) on the analyzed textural class, that the least value of water retention was in the soil samples

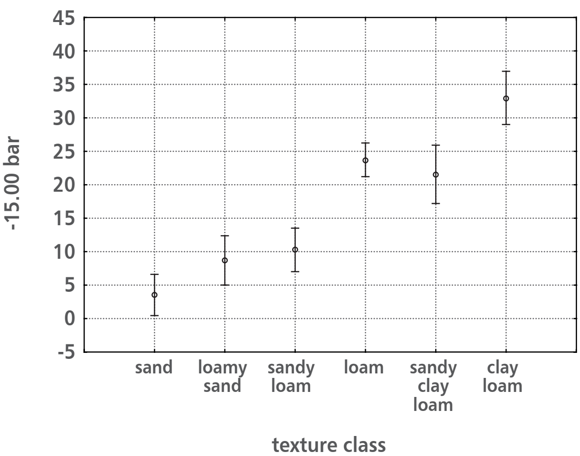

FIGURE 3
The retention of water at -15.00 b (vol.%) in comparison with the textural class

made of a light-mechanical composition, and at the increase of silt and clay, the value of water retention under the pressure of -15.00 bar also increased. Significant differences were found between textural classes identical to the previous treatment of -6.25 bar (p = 0.00000). The value of -15.00 bar was used as the lowest limit when calculating available water for plants. The humidity fading of plants raised, according to Živanov [2], the pF value of 4.2, which was conventionally taken as the value for the calculation of available water. The values of the retained water at -15.00 bar ranged from 0.8 to 22.2 vol.% according to Živanov [2]. For the soils of the Middle Danube Basin, water retention values at -15.00 bar ranged from 1.6 to 16.5 vol%, as Ivanišević stated [4]. According to the presented results of the moisture retention at different pressures, we may conclude that all treatments lead to an increase of the moisture retention values in the sand texture class to clay loam texture class, which was in close connection with the textural composition of the hydromorphic soils samples.

Air capacity is an important feature that determines the productivity of the soil. It actually represents non-capillary pores in the soil; [1], air capacity is the difference between the total porosity and the field water capacity.

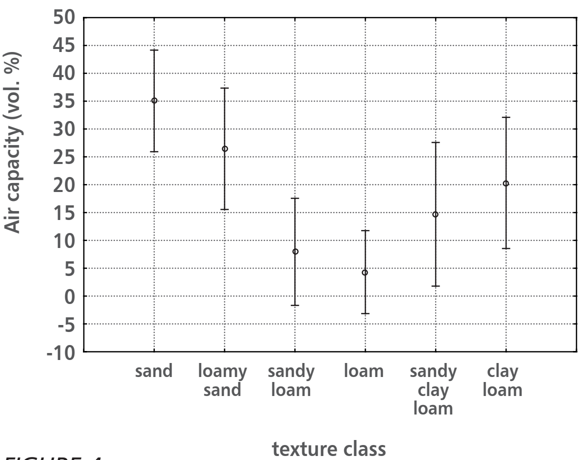

FIGURE 4
The air capacity (vol.%) of soils with different textural classes

Looking at the average values in Figure 4, we may conclude that the texture class of sand and loamy sand has the greatest capacity for air, while it decreases with the increased content of silt and clay, except in the case of sandy clay loam and clay loam where the capacity was slightly higher than the value of other samples of a heavier texture. Significant differences are between sand and sandy loam and clay (p = 0.00007). The texture class of sandy clay loam has a high variation coefficient of air capacity due to the heterogeneous texture, as Živanov interpreted it [1], and the specific the value of air capacity for the alluvial soils of Danube was up to 52.2 vol.%. According to Živanov [1], the air capacity of sandy soil was 30 to 40 vol.% and in loamy soils 10 to 25 vol.%, in soils with clay it ranges from 5 to 15 vol.%. Due to the layout and size of the soil pores at the respondents' textural classes, this actually affects the composition and distribution of various pores in the soil, the result showing that a higher proportion of textural soils with coarser particles increases the value of air capacity.

For the values of available water capacity (vol.%) of soils, it is evident that they vary according to the displayed values (Figure 5), and they depend on the texture of soil. As Živanov [1] stateed, for plants it is easiest to use water through the field-soil moisture capacity. The more soil moisture capacity is distant from the field-soil capacity, it is more difficult for plants to absorb water. This value and the amount of water accessible to plants, is the water between the threshold humidity of -0.33 bar and -15.0 bar and the fact that it is the amount of water in the soil that is more or less available for plants to absorb.

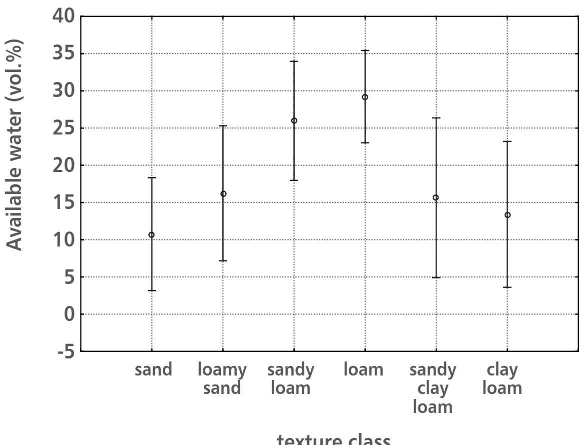

FIGURE 5
Available water capacity (vol.%) of soils compared to the textural class

Figure 5 shows that the maximum available water was in the textural classes of sandy loam and clay, which confirms that because of the share of mechanical fraction the pores of these textural classes may contain a higher proportion of physiologically active water, and these are mostly middle-sized pores to fine soil pores. In sand and loamy sand and also sand clay loam and clay values of this parameter are lower because of the negative relation of some factions within textural classes. The results were twofold: one was in the occurrence of rough pores and the swelling of large quantities of water available only for a short period (sand and loamy sand) and the second was the appearance of fine pores in heavier soils (sandy clay loam and clay loam) where water is bound with more forces, difficult to access or totally unavailable to plants. Significant differences, according to this parameter, are only between sand and clay (p = 0.00374).

The total porosity represents all the pores in the soil, while the residual porosity shows the distribution of pores according to their size. As Živanov [1] stated, it is impossible to determine the actual size of the pores, except indirectly, by assuming that water in certain pores may be displaced by a certain pressure, Vučić as explained [17].

In this paper, the pores were classified into three groups according to Miljković [18]. Rough or coarse and fine coarse pores were grouped into one category-coarse pores, the size of more than 50 and up to 10 microns (pF values in the range of 0-2.54), medium pores, which keep water accessible to plants, were of a diameter from 10-0.2 microns (pF from 2.54 to 4.2), and micro-fine pores that contain water inaccessible to plants, with a diameter below 0.2 microns (pF values over 4.2).

Since the ratio of pores in the soil is associated exclusively with the participation of the granulometric fractions in the soil, the charts show the relationship of certain categories of pores with respect to the soil texture classes.

Figure 6 presents the relation between coarse pores and textural classes. Coarse pore content was the highest in light mechanical soil compositions, such as: sand and loamy sand, and dust was reduced with the increased clay content in this category of pores.

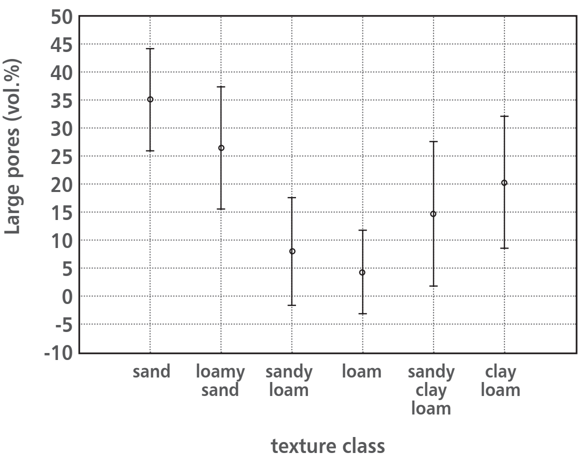

FIGURE 6
The relationship of coarse pores (vol.%) and textural classes in all samples

The textural classes of sandy clay loam and clay loam showed a somewhat higher value of coarse pores compared to other classes of clay, which may be explained by a greater variation of granulometric fractions in these texture classes. Significant differences in this the treatment are between grain size fractions of sand, loamy sand and clay (p = 0.00007).

The values of coarse pores in alluvial soils, which were in range of 10.8 to 44.3%, and the texture classes had, according to Ivanišević [4], the following air capacity: sand 42.2%, 33.8% loamy sand, sandy loam 25.5%, 14.8% loam and silt loam 10.8%.

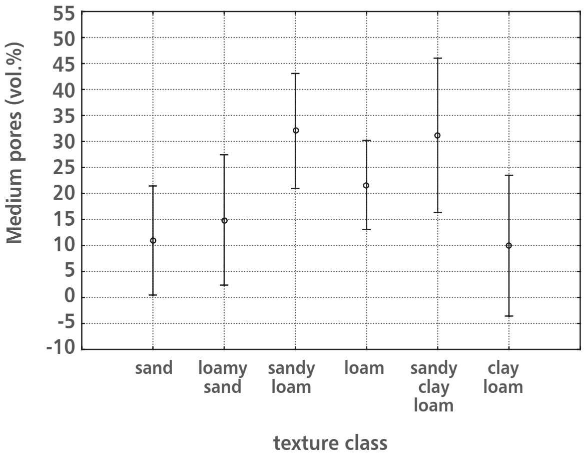

FIGURE 7
The ratio of middle-sized pores (vol.%) and textural classes of samples

Figure 7 is shown the content of middle-sized pores in relation to textural classes. Since the medium pore diameter ranged between 10-0.2 microns and water within them was retained by higher forces, the data showed that there were at least those types of pores in textural classes sand and loamy sand, consisting mostly of coarse pores, as well as clay loam, where micro-fine pores prevailed. The highest values were in the classes of sandy loam, loam and sandy clay loam. This parameter didn't show significant differences between textural classes (p = 0.3579). Middle-sized pores were directly related to the proportion of fine sand and dust in the soil and if they predominated, then the granulometric fractions were compared to medium pores present in higher percentages. The limit of this group of pores was in the range of 1.8 to 28.3%, according to Ivanišević [4].

Figure 8 presents the contents of fine pores and it may be concluded that the increased use of granulometric fractions in a heavier composition, as well as the increased content of silt and clay, lead to

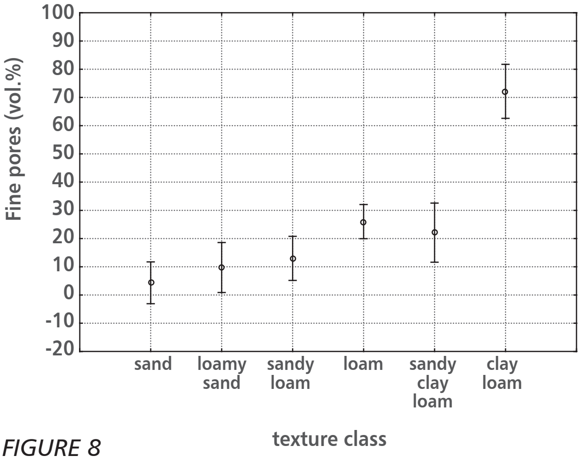

FIGURE 8
The ratio of fine pores (vol.%) and textural classes of samples

the increase of tiny pores in the soil, explained by the gap between all the fractions, so, the content of fine pores was higher in heavier-textured soils. Significant differences are showed between the texture class of sand and clay, while the clay-loam texture class is significantly different from all textural classes (p = 0.00000). According to Ivanišević [4], this group of pores in alluvial soils, determined in laboratory conditions, ranged from 1.6 to 16.5%.

CONCLUSIONS

According to the shown ratios for size distribution and moisture retention at different pressures, we may conclude that in all three treatments the moisture retention value of texture classes was increased - sand to clay loam texture class, which is in close connection with the textural composition of the hydromorphic soil samples.

The investigated capacity values for all samples showed that air capacity was higher in soil samples of a lighter mechanical composition and texture classes of sand, loamy sand, while a reduction was noticed in samples of heavier texture, or sandy loam and clay. A small increase in the sandy clay loam and clay loam was also noticed. The highest available water capacity of soils was in located in the textural classes of sandy loam and clay, due to the content of favorable medium- and small-sized pores in fine texture classes.

The contents of coarse pores was increased in the soils of a light mechanical composition, such as sand and loamy sand. The share of medium-sized pore texture classes was such that the data showed they were more present in the following textural classes: sandy loam, loam and sandy clay loam, which was directly caused by the textural composition and the granulometric size of particles. The content of tiny pores in analyzed soils increased with the domination of mechanical fractions of a heavier composition and the increased silt and clay contents.

Acknowledgments

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Review paper

History of Forest Enterprise Management Development in Macedonia

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Abstract

Background and Purpose: *The central theme of the paper is the development of forest enterprise management in Macedonia and the adaptation to changes throughout the history. The change has become a permanent phenomenon that has to be addressed and managed appropriately in order to ensure organizational survival. Because of the changes in technology, the market place, social values and work force created a dynamic and unpredictable environment especially for those organizations who are unable to respond to the changes and adapt.*

Methods and Methodology: *For the purpose of the research, a content analysis was applied to forest enterprises that appeared in all documents starting from 1900 to 2012. In order to increase the validity of the research and avoid any gaps, the data was divided into categories according to the meaning of the words. Hence, words with similar meanings were placed into the same categories, in order to obtain a better review of the researched phenomena.*

Results and Conclusions: *The results showed that throughout the history there were different types of forests enterprise managements in Macedonia. According to the analysed documents, during the period of the administration after the World War II (May 1945) the first federal forest company "FESUMA" was established with the help of ASNOM (Anti-Fascist Assembly for the People's Liberation of Macedonia) and the Department of Forestry and Mining. All modifications of forests funds and legislation thereafter have influenced and provoked a lot of changes in the forest enterprise management. At the same time it is interesting to emphasize that the results obtained from the research show that in order to survive and stay competitive on the market, forest enterprises have been developing and adapting to the changes in the environment.*

Keywords: *forest enterprise management, modifications, development, adaptation, history, changes*

INTRODUCTION

The following sentence is often attributed to Charles Darwin: "It is not the strongest of the species that survive, or the most intelligent, but those most responsive to change". As Darwin noticed, change has been an impelling force in the society since the beginning of mankind. Thus, the same should apply for the institutions and organizations created by man. Only the companies who are flexible enough to respond to the shifts in the market environment survive. The ones who stagnate slowly fade and vanish as the history has so expressively shown us. Although the speed of those transformations and evolutions has increased rapidly during the last decades, the phenomenon itself is not new [1].

The change has become a permanent phenomenon that has to be addressed and managed appropriately in order to ensure organizational survival, as Church and McMahan stated in 1996. They asserted that changes in technology, the market place, social values, work force demographics, and the political environment all had a significant effect on the processes, as well as on the products and services produced. The culmination of these forces reflected an external environment that was dynamic, unpredictable and often devastating to those organizations that were unprepared or unable to respond, they added [2].

While talking about organizational changes, we should start with defining what the meaning of the word organization is as the main subject of modification. In our everyday life we mainly use the word organization for an organized business activity of a group. As defined in the Thesaurus Online Dictionary, an organization is ''a structure through which individuals cooperate systematically to conduct business''. In the academic world various theoretical approaches set different priorities while defining the essence of organizations [1].

According to Hall [3], ''Organizations are a dominant component of contemporary society''. They surround us. We are born in them and die in them. The space between us is filled with them. They are just about impossible to escape. They are as inevitable as death and taxes. The great social transformations in history were essentially organizationally based. The Roman Empire, the spread of Christianity, the growth and development of capitalism and socialism, and the changes that took place in both capitalism and socialism were and still are accomplished through organizations. These simple examples were intended to suggest that the careful analysis of organizations is a serious and important matter [3].

Organizations need to take into consideration a multitude of different expectations. Expectations and values need to be coherent with the prospected output. Also, organizations have to take into consideration the wants and needs of the society and the ideas of this society regarding their function and the ultimate necessity. The ability of organizations to adapt and change has become a central research issue focusing on the complexities of regulatory, political, technological and social changes. Nowadays, it is commonplace to note that the volatility of changes confronting organizations has dramatically increased [4].

PROBLEM STATEMENT

The first written documents regarding forest enterprise management in Macedonia appeared at the beginning of the 1900's. In 1992, Macedonia declared independence from the former Yugoslavia and shifted from the monopolistic into a pluralistic and democratic society which caused many changes. All the changes that happened over time, did not only evoke a shift in forest areas and legislation, but at the same time provoked changes in the forest enterprise management. Taking into account that around 35% of the surface in Macedonia is covered by forests, out of which 90% belong to and are managed by state enterprises, the forest enterprise management is of a particular importance not only to the enterprises themselves, but also to the entire forest sector of the country. Hence, the obtained data regarding the development of forest enterprise management is to provide important information for the main instigators of modifications and, on the other hand, such data will provide recommendations for the more appropriate types of forest enterprise management.

Until today, many studies have been done regarding forestry issues in Macedonia, but there is a lack of particular studies exploring the development of forest enterprise management and the adaptation to changes throughout the history. Bearing in mind the importance of the adaptation to changes for enterprises and their survival, as well as the fact that this is a completely new and unexplored component, this research emphasizes the significance and importance for the entire forest sector.

OBJECTIVES OF THE RESEARCH

In order to better understand the speed and limits of adaptations to changes in forest enterprise management, it was very important to have a clear overview of the changes over time. Hence, the problem statement of this research is to better understand the development and adaptation of the forest enterprise management in Macedonia in last 100 years. Thus, goal of the study was to achieve and broadly elaborate the following objectives:

- Identify the types of forest enterprise management over time.
- Analyze and describe the adaptation to changes of the forest enterprise management in Macedonia over time.

The purpose of this study is to explore and highlight the main characteristics of the historical development of forestry enterprises and to give a clear review on changes throughout the history regarding forests areas, legislation and forest management. In order to meet the objective of this study, the following research questions were examined:

- Which forests enterprises have been developing in forestry in Macedonia over time?
- How have forests enterprises developed and adapted to changes in Macedonia over time?

The response to those questions gave a clear overview of the development of enterprises in forestry in Macedonia and their adaptation throughout the history.

THEORETICAL FRAMEWORK

Throughout the history, many scientists attempted to analyze and explore organizations, starting from their own point of view, thereby concentrating on various aspects of organizations and applying different theories for the purpose of their own studies. Before we continue with theories that analyze organizations, it may be useful to define some common terms first. Webster's Dictionary defines an organization as ''an association or a society of people working together to some end''. Organization theory refers to the broad body of literature that explores the structure and design of organizations. Organization theory may be separated into sub-specialties, looking at different aspects of an organization.

Some organization theorists observe an organization's structure, and suggest ways an organization may redesign itself for a better performance. Other organization theorists observe an organization's processes or personnel, while others explore the importance of the rewards systems to motivate employees. Organization theorists both describe how organizations operate, and suggest how they may improve to operate more effectively and efficiently [5].

For the purpose of this research and at the same time in order to better analyze and explore the development of organizations in forestry and to understand their adaptation to changes throughout the history, organizational learning theory was applied.

Organizational learning theory is consists of models about the way organizations learn and adapt to the changing environment. In order to be competitive in a changing environment, an organization has to learn and change its goals and actions in response to changes of circumstances, as well as to link their actions to the outcome.

The notion of organizational learning as a key process within an organization modulating and shaping its performance might be traced back to the beginning of the 1960-s [6]. Organizational learning was conceived as a part of the managers' portfolio, and managers have been increasingly adopting the notion, to the extent that many managers consider organizational learning to be a powerful tool to improve the performance of an organization [6]. Organizational learning is an adaptive process where goals, attention rules and search rules adapt to the experiences within the organization.

The later developments included a distinction between adaptive learning – a response to the changed environmental conditions – and proactive learning – the planned organizational changes reaching beyond the mere reaction to environmental changes. Adaptive learning is considered more automatic and less cognitively induced than proactive learning. Hence, many theorists consider adaptive learning inferior to proactive learning [7]. Some authors emphasized that organizational decisions depended on certain rules and, hence, that organizational learning was executed on the basis of rules. The rules were determined and (re)shaped by experiences gained within this organization [5].

According to Senge [8], learning organizations are: ''*Organizations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning to see the whole together*''.

In the situation of a changing environment only those who are flexible, adaptive and productive seem to be able to stand out. Thus, organizations have to consider how to challenge people to commit and learn at all levels. Senge [8] identified five disciplines of organizational learning: system thinking, personal mastery, mental models, building shared vision and team learning. System thinking means the interaction with other components in the system, that is, instead of isolating things as a single unit, they are observed as a range of interactions within the whole system. If I believe that my current state was created by somebody else, or by forces outside my control, why should I hold a vision? The central premise behind holding a vision is that somehow I am able to shape my future; System thinking helps us understand how our own actions shape our current reality, thereby giving us confidence that we may create a different reality in the future [9].

Personal mastery is: ''*The discipline of personal growth and learning*'' [8]. ''*Organizations learn only through individuals who learn. Individual learning does not guarantee organizational learning. But without it no organizational learning occurs*''. ''*People with a high level of personal mastery live in a continual learning mode. They never 'arrive'. Sometimes, language, such as the term 'personal mastery' creates a misleading sense of definiteness, of black and white. But personal mastery is not something you possess. It is a process. It is a lifelong discipline. People with a high level of personal mastery are acutely aware of their ignorance, their incompetence and their growth areas. And they are deeply self-confident. Paradoxical? Only for those who do not see the 'journey is the reward*'' [8]. People with a high level of personal mastery have the ability to create personal visions and accurately assess their reality according to their vision. In order for an organization to become successful in learning, it should include people at all levels capable of personal mastery, but who understand that personal mastery is a choice and not an order. Thus, organizations should create an environment that may assist employees to developed personal mastery [5].

In the words of Hall [8]: ''*Mental models are deeply held internal images of how the world works, images that limit us to familiar ways of thinking and acting. Very often, we are not consciously aware of our mental models or the effects they have on our behavior*''.

In the learning process every organization has to develop its own capacity for people to change their mental models and learn new skills, because metal models have to be changed first in order to be able to change the future. A shared vision is a driving force for an improvement and a base for engagement and trust in the company [8]. The main idea of a shared vision is the common dream or goal of the individuals in an organization, this idea inspires work to achieve the vision [8] and considers the team a key-learning unit in the organization. Hall [8] defined team learning as ''*the process of aligning and developing the capacity of a team to create the results its members truly desire. It builds on the personal mastery, for talented teams are made up of talented individuals*''.

There are three dimensions of team learning: the first dimension is to think insightfully about complex issues, the second is the ability to take innovative and coordinate actions and the last one is the ability to create a network that will allow other teams to take action as well.

METHODOLOGY

The research design of this study has a descriptive character; therefore it uses the content analysis of relevant documents as a research method for the purpose of the study.

Content analysis is a method of analysing written, verbal or visual communication messages. Content analysis as a research method is a systematic and objective means of describing and quantifying phenomena. It is also known as a method of analysing documents. Content analysis allows the researcher to test theoretical issues to enhance the understanding of the data. Through a content analysis, it is possible to distil words into fewer content-related categories. It is assumed that, when classified into the same categories, words, phrases and the like share the same meaning [10].

The research was conducted in Skopje during 2012 and the areas of research were forest enterprises appearing in all documents, starting from the early 1900 until 2012. A content analysis was done on the following written documents: previous research of others that are in some way more or less related to the subject of this research, dissertations, reports from the public enterprise, forest laws, strategies, trade laws, laws on public supply, scientific articles, internet sources, as well as all other relevant literature that enabled a clear overview of the development and adaptation to the changes in forest enterprise management. To get a better overview, as well as to increase the validity of data and skip potential mistakes during research, data was divided into three categories forest area, legislation and management. Hence, the words of similar meaning were placed into the same categories, in order to enable a better and clear review of the research phenomena. At the same time it was very important to highlight that the approach of the content analysis of this research was deductive, taking into account that a theory was tested during the research, which means a move from the general to the specific.

RESULTS

In order to understand the history of the development of forests enterprise management in Macedonia more clearly, the obtained results were divided into three parts. The first part was related to forest funds, the second to forest legislation and the third part to forest enterprise management. The aim of exploring forest funds and legislation was to gain a better insight and understanding of the relations to the changes in forests enterprise management. At the same time that helped point out the main instigators which provoked changes in forests enterprises over the years. The analysis performed on relevant strategies, documents, dissertation, articles, laws and other relevant documents, for the purpose of this study, obtained the following results.

Forest areas

According to the statistical data on Macedonian forests in 1938, there were about 615 216 ha of forests or about 24% of the total geographical area. Of all the forests at that time, 162 054 ha or 26.3% were state-owned, 360 797 ha or 58.6% were rural or communal, 84 914 or 13.8% were private and 7 496 ha or 1.2% were church forests. The statistical data from 1938 was used for the period of the Second World War. In the period from 1947-1949 the so-called ''first inventory'' was done at the level of the former SFR Yugoslavia [11].

The first forest inventory was carried out in 1961 and according to it, the total forest area was about 887 517 ha from the total geographical area of the Republic of Macedonia where the surface of land without the forest cover was 411 398 ha. This means that the total forest surface and areas without the forest cover were 1 298 915 ha or about 50.5% of the geographical area. Of the total forest area, 792 025 ha or 89.3% were commercial forests, 52 486 ha or 5.9% were protected and 42 006 ha or 4.7% special purpose forests. The second inventory of forests was carried out in 1979. According to the obtained data from the second forest inventory

TABLE 1
Forest areas in Macedonia

Year	Total forest area (ha)	Type of forest	Forest area (ha)
1938	615 216	state	162 054
		rural	360 797
		private	84 914
		church	7 496
1961	887 517	commercial	792 025
		protected	52 486
		special	42 006
1979	905 653	state	816 633
		private	89 020

in 1979, the total forest area in Macedonia was 905 653 ha or about 35.2% of the total surface of the Republic of Macedonia. In 1961 forest area was increased by about 18 136 ha or 2.0%. From the data we may conclude that forest funds from 1961 to 1979, from first to the second inventory, changed significantly in their manufacturing capability and less in the amount of forest area. Such changes were the result of many cultivation measures, as well as the continuous and comprehensive preventive care of forests [11].

The total forest area was 950594 ha in 1999 which, compared to the forest area in 1979, meant an increase of 60288 ha or about 5.0%. The state-owned forest areas increased from 816633 ha in 1979 by 838 599 ha or for about 2.7%, while privately-owned increased from 89 020 ha to 11 995 ha or more than 25.8% [12].

Forest Legislation

Forest management is regulated and determined by forest laws. Historically speaking, forest legislation in Macedonia is recent. The first forest law was adopted before the Second World War, in 1929, by the Kingdom of the Serbs, Croatians and Slovenians or Yugoslavia, a part of which the Republic of Macedonia was at that time. This law with some amendments was in force until the Second World War. After the Second World War, in 1947, a General Forest Law was passed, while Forests Statutes were passed in 1961 and 1965. In 1997 the new Forest Law in Macedonia was adopted (The Official Gazette of R.M, No.47/97).

Forests and forest lands are legally treated in societies as the natural wealth and therefore special protective measures are provided by the law. Their cultivation, utilization and protection has to be performed in a manner to preserve their value, increase the growth and yield under natural conditions ,as well as to preserve and improve their production and useful functions [11].

Forest Enterprise Management

1965, when the Secretariat of Forestry at the Executive Council of NRM was formed. In the middle of 1968, the Secretariat of Forestry transformed into the Secretariat of Agriculture and Forestry of NRM. At that time, the Directorate for Wood Industry established several self-managed wood industry companies, while forest entities operated as self-financing institutions [11].

Forest entities and national parks were established by the National Board for the Environment. In 1957, twenty four forests entities were established in Macedonia , two national parks, two administrations for urban and non-urban greenery and seven sections for rain torrent regulations. In the period from 1960 until 1970, certain integration processes occurred not only between forests entities that turned into economic organization, but also occurred between forestry and wood industry. At that time two industry organizations in Macedonia: ''Treska Skopje'' and ''Macedonia wood'' were founded. After the constitutional changes in 1974 and the adoption of the Law on Associated Labour, or popularly called the Workers' Constitution, in 1976, the economic entities formerly working as companies, organizations and institutions, etc., were organized as Organizations of Associated Labour (OUR), or the Basic Organizations of Associated Labour (OOUR), respectively. The notion of those basic organizations generally, and in the forestry in particular, meant basic organizations, working organizations, complex organizations and other higher forms of association. Namely, the Basic Organizations of Associated Labour (OOUR) merged into Working Organizations (RO), and those into Complex Organizations of Associated Labour (SOUR). At the end of 1980, some changes occurred in the organization of economic entities, changes based on the constitutional amendments passed in 1988, when the Trade Law was adopted (The Official Gazette of the Socialist Federal Republic of Yugoslavia, No. 77/88) when the current law on associated labour was practically suspended. In the next 2-3 years, disintegration processes occurred in forestry, so most of the forests entities that operated as OOURs in the framework of Working Organizations (RO) or independently until then, were organized as Communal Organizations for the Management of Forests. Hence, until the adoption of the new law on forests in 1997 (The Official Gazette of R. of Macedonia, No.47/97), out of the thirty 30 (thirty) former forests entities, 28 (twenty eight) were organized as communal organization, while Kruševo and Delčevo were organized as public enterprises. Based on Article 17 of the Forest Law (The Official Gazette of R. of Macedonia, No. 47/97) and Article 46, paragraph 3 of the Administrative Law of the Republic of Macedonia (The Official Gazette of the Socialist R. of Macedonia, No. 38/90 and The Official Gazette of R. of Macedonia, No. 63/94), the Government of Macedonia decided to establish a public enterprise for forest management (The Official Gazette of R. of Macedonia, No.65/97) on their meeting held on December 15,1997 [11].

The public enterprise for managing forests "Macedonian Forests" has been managing public forests in the Republic of Macedonia. The enterprise was founded on July 1, 1998 as the legal successor of several forests economic entities that had been managing forests until then. For the successful and efficient performance of its activities, the public enterprise "Macedonian Forests" was organized into one head office and thirty branch offices, with the centralized budget and decision-making system.

For the efficient and rational management, forests were divided into commercial forest units. The management of private and state-owned forest, regardless their purpose, is now in accordance with the general management plans adopted by the Government of the Republic of Macedonia for the period of twenty years. The general management plan determines the management of forests in accordance with natural conditions and opportunities for existence, regeneration and development of forests, also dividing forests by type, preservation, timber, road infrastructure, vulnerability to negative influences, general directions and goals for future management measures for the care, protection, development, improvement and expansion of forests in the Republic of Macedonia. In accordance with the general management plans, the public enterprise has adopted special plans for forest management for the duration of ten years. Action or special plans were later approved by the Ministry of Agriculture, Forest and Water Management, while the control of the performed activities from action plans is done by the Forest Inspectorate. Considering the fact that one of the most important actions in forestry is forest management. Particularly because of the forests' multifuncti-onalities, the management of forests is organized through the public enterprise. Beside the public enterprise, that was mainly established to perform activities of public interest, it is possible to establish other forms of organizations in forestry regulated by special laws on trade companies. By adopting the Trade Law, old terminology also changed, and this Law also meant the expiration of the old legislation on companies (The Official Gazette of R.M., No. 15/93) where the term "enterprise" was used as a synonym for a profitable economic entity. Thus all legal subject that performed activities of public interest and that were founded as Public Enterprises, are now organized as trade companies respectively, according to the Trade Law on Companies [11].

DISCUSSION AND CONCLUSIONS

The relationship between the development and adaptation of forest enterprise management to changes throughout the history is a very complex and dynamic issue to follow and understand. Nevertheless, at the same time such information may significantly assist the better understanding and following of forest enterprise management. Hence, this data may help other forest enterprises in showing them a way to further develop, handle and adapt to changes in the environment.

The analysis and review of the existing literature reveals that a lot of changes occurred throughout the history of the forest enterprise management in Macedonia. Regardless of their origin and nature, they all influenced and initiated many changes within the enterprises themselves. In order to survive, these forest enterprises needed to develop and adapt to the ongoing changes in the environment. Based on the obtained results from the research it may be said that all forest enterprises established in Macedonia have followed the changes in the ecological and economic environment. This is confirmed by the fact that changes in forests areas, forest legislation and management initiated and were followed by the modifications in the forest enterprise management.

Concerning the testing of the organizational learning theory for the purpose of this study, some conclusions may be drawn. It is known that the organizational learning theory explores the way and models on which organizations learn and adapt to changes in the environment in order to survive and be competitive on the market. Therefore, organizations need to be flexible and adapt to the changing environment. From the results obtained by this research it is evident that all forest enterprises in Macedonia have more or less been developing and adapting to changes of the environment. Starting with the first federal forest organization ''FESUMA'', established in 1945, which was replaced by the newly-formed administration on forest industrial companies after a few years. Later, with the decentralisation of federal administration and the introduction of the new economic system, the main forestry administration was transformed into the Federal Administration of Forestry and remained so until 1965 when the Secretariat of Forestry at the Executive Council of NRM was formed. In the middle of 1968, the Secretariat of Forestry transformed into the Secretariat of Agriculture and Forestry of NRM.

After the constitutional changes in 1974 and the adoption of the Law on Associated Labour, or popularly called the Workers' Constitution, in 1976, the economic entities formerly working as companies, organizations and institutions, etc., were organized as Organizations of Associated Labour (OUR), or the Basic Organizations of Associated Labour (OOUR), respectively. This organization merged into Working Organizations (RO), and those into Complex Organizations of Associated Labour (SOUR). At the end of 1980, some changes occured in the organization of economic entities, changes based on the constitutional amendments passed in 1988, when the Trade Law was adopted (The Official Gazette of the Socialist Federal Republic of Yugoslavia, No. 77/88) when the current law on associated labour was practically suspended. All this changes continued until 1997 when thirty independent forest organizations, responsible for the management of state-owned forest in Macedonia, conjoined into one large public enterprise, called "Macedonian forests". This enterprise is still operational, although with the change of the political, social and economical system of the country, as well as with changes of forest areas, legislation and management, some modifications occurred in the structure of the enterprise. That is an ongoing process in order for this organization to adapt and survive on the market.

As Segne emphasize in his discipline, in order to survive on the market of a big importance for the organization is to have: ability to interact to other components of the system, people who have ability to create personal visions, ability to change the image on mental models, shared vision and team learning. Because when people learn and become more familiar with the reality, they become much more secure and comfortable to predict, change and adapt to the future. Hence, all the above mentioned issues are presented in the results which are a clear confirmation of the validity of the organizational learning theory and the five discipline of Segne, as well as the importance of the adaptation and development of forest enterprise management over time.

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Professional paper

Urban Forests and Greening in the Republic of Serbia – Legal and Institutional Aspects

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Abstract

Background and Purpose: *This research attempted to answer some general questions about the legal and institutional support for urban forests and greening in Serbia by focusing on the important aspect of urban forests and greening from the perspective of social sciences. It was interesting to reveal which institutions are in charge of these areas and who claims to have responsibility for their management and protection. This research was expected to contribute to the better understanding of the status of urban forests and greening in Serbia today.*

Materials and Methods: *Document analysis and face-to-face interviews were applied as methods of collecting relevant empirical data in order to discover if any, and which legal documents were addressing urban forests and greening in Serbia.*

Results and Conclusions: *The term "urban forests" is not generally accepted by domestic practice and among professionals who work in this or related fields. Instead, terms like peri-urban forests and park-forests are used in Serbia. The Serbian law does not recognize this term and states that forest may not be areas smaller than 5 ha. Because of the difficult period Serbia has endured in the last 20 years (wars, UN sanctions, the economic crisis) the overall care for urban greenery has fallen into background and is no longer an important topic among the politicians and the general public. In the last few years we have noticed some positive improvements like the adoption of new, more adequate laws, reviving of institutions that affect this field etc.*

Keywords: *urban forests, urban greening, legislation and institutions, Republic of Serbia*

INTRODUCTION

Green areas in cities are considered integrated parts of every larger settlement and absolutely required for the life quality of its citizens. Cities without this element are considered extremely inadequate for living. We may say that residents have literally been fleeing the parts of cities where green elements are missing, as if these spaces had turned "sick". The greenery in urban areas offers multiple benefits. Plants, especially trees and shrubs, with their forms, structures and life features, are irreplaceable natural elements in cities that contribute to the melioration of the environment in the broadest sense of the word [1]. The importance of urban greening may best be described with the idea of "garden cities" presented to the public by the English architect Ebenezer Howard in late 19th century. This idea, although sometimes considered as utopia, represented the attitude that the greenery and the presence of plants in urban areas, create the only environment framework enabling humans a dignified life [2].

When we speak about urban forests, there are several definitions. The term may be described as the space dominated by high woody vegetation accessible to city residents by foot, bicycle or public transportation, having a primary social and ecological purpose [3]. Urban forestry is the management of planted and naturally occurring trees in urban and urban-interfaced areas [3] and, also, the art, science and technology of managing trees and forest resources in and around urban community ecosystems for the physiological, sociological, economic and aesthetic benefits to the society provided by trees [4].

While forestry is expected to be, in most cases, an income generating activity and to provide existence for some people, we do not expect landscape architecture and city green spaces to produce economic income [1], at least not directly. Nevertheless, should we

FIGURE 1
Various types of urban greenery in the City of Novi Sad, Serbia (source: www.geosrbija.rs)

realize that a well-organized and developed green infrastructure raised the income of tourism, decreased health problems and increased work enthusiasm and productivity among citizens, we might say that green spaces were, in general, highly profitable.

Several different elements significantly affect urban forests and city greenery. Some of them are financial support, the awareness of the importance of urban forests and greenery, the development level of professionals who work in this field and, lastly, but not less important – legal and institutional aspects, that is, the legal support this subject should receive from the society. Adequate laws and other types of legislature are important, but also, this legislature should be respected and implemented in the field, as well as in everyday life. The latter is a task for public institutions on different authority levels. Serbia has three authority levels (national, provincial and local) so it is important we understood the functioning of the political mechanisms in this field and to establish a better collaboration among institutions.

The main aim of this research was to find out the state of urban forests and greening in the Republic of Serbia from legal and institutional aspects, as well as to reveal whether the term "urban forests" existed in Serbian legislature and whether it is used by the professionals working in this field. It was interesting to reveal which institutions are in charge in these areas and who claims to have responsibility for their management and protection. The research was expected to contribute to the better understanding of the status of urban forests and greening in Serbia today.

MATERIALS AND METHODS

This research was done by two different methods: (I) document analysis and (II) face-to-face interviews.

Document analysis

The main source of information for the document analysis was based on a large database of valid Serbian laws [5, 6, 7], spatial and urban plans [6], national and local strategies [8, 9], decisions [10], statutes, local greenery regulations [11], action plans, studies [12], publications [13], national programs and inventories [14, 15], as well as drafted laws [16] that are to be enacted in the near future and similar documents that influence or will affext urban forests and city greening in the Republic of Serbia. During this period (February 2012 – August 2012) the author studied more than 50 different official documents, but the majority carry no reference to urban forests and greening which implies that this subject is not represented well in domestic documents and legislative. All three levels of authority with the right to pass legislature were taken into account – national, provincial and local, in order to achieve a broader picture of the current state of this field.

Face-to-face interviews

The second research method were visits to all relevant institutions working and influencing urban forests and greening. Face-to-face interviews were applied as a method to obtain adequate information on this topic. During the research period (May 2012 – July 2012), 10 institutions, located in the City of Novi Sad, Serbia, were visited and of their employees' answers recorded. The visited institutions were: one institute (for lowland forestry and environment), four public companies (for city greening, urbanism, forests and city development), two city administration offices (for environment and communal activities), two province secretariats (for urbanism and protection of nature) and one non-governmental organization (NGO). One employee was interviewed in each institution. The criteria for the selection were that the employee was in charge of business related to urban forests and greening within the institution and had a high education background (university level) in the related field. All were asked the same, open type questions about the responsibilities in this area: the compliance to the laws; the applicability of current laws, etc.

RESULTS AND DISCUSSION

Document analysis

In general, urban and peri-urban forestry and greenery has been receiving little attention on political agendas despite its importance to the society in terms of the social, economic, aesthetic and environmental benefits. This is even more problematic in developing countries and countries with economies in transition, where urban development is too often accompanied by the severe degradation of the environment (including trees and forests), increased poverty and food scarceness. Good tree and forest management in and around cities, combined with good governance, appropriate policies, participatory approaches and the capacity building of stakeholders should lead to convincing and promising results [17].

In Serbia, city greening has developed in five different historical periods. The first was during the medieval Serbian state when organized greening was done in and around monasteries and castles, parts of that greening being gardens with medicinal herbs, fruit and vegetable gardens and monastery forests. The second period was during the Ottoman Empire occupation when private gardens surrounded with high walls were presented as intimate family spaces. Public greening was reduced to cemeteries, mosque yards and around an occasional public buildings. During the third period and the renewal of the Serbian state, settlements were planned in orthogonal order, many public buildings surrounded with greenery, while some markets become parks or squares as alleyways appeared along important city streets. In the period between the two World Wars (the fourth period), the building of parks intensified, especially in the capital city of Belgrade, and most of them still exist today. The fifth period was marked with efforts to deal with the city greenery according to modern conceptions. The principal problems for further development in this area were limited space possibilities in highly populated areas. The remaining free land in the cities become too expensive and priority was not given to greenery. The current greenery city system was not built in an organized way so its sanitary and hygienic effect is not satisfactory [18].

Urban forests may be seen as a link between classic forests and urban greenery, but this research reveals that the term "urban forest" is not generally accepted in the domestic professional community, as well as in Serbian literature and legislation. Mentioning urban forests in the institutions that deal with this and the related fields, showed the understanding of the concept and its acceptance as relevant only in rare cases. This implies that it would take some time for this concept to be accepted and adopted in the domiciliary practice. The best proof thereof are the few laws, such as the Forest Law [5]: "A forest, under this Act, means the area of land larger than 5 acres covered with forest trees. The term forests does not include separate groups of trees in an area of less than 5 acres, trees in urban parks, and trees beneath the power supply lines". This legislation also emphasizes that the purpose of forests is not just the production but it is also a place where citizens have free access the purpose of enjoyment, relaxation and recreation, with a personal responsibility for their own safety and the obligation not to devastate the forest. This law implies that managing forests as a natural resource is under the jurisdiction of the Republic of Serbia and under the governance of the Ministries, the governing body of the autonomous province on its territory, and all legal entities for forest management for the state-owned entities and state forests owners [5].

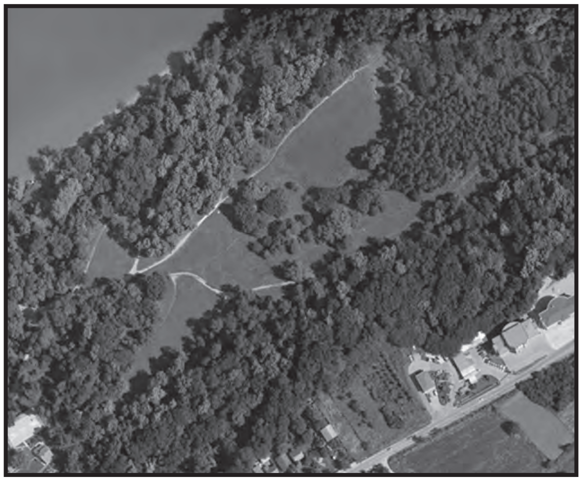

FIGURE 2
An urban forest, Novi Sad, Serbia (source: www.geosrbija.rs)

When we deal with the protection of urban forests, it is important to know that "The conservation of biological diversity of forest ecosystems is implemented to strengthen the overall useful function of forests" [19] which includes social functions. The first reference to the protection of forest areas originates from the 14th century and the King's Dušan Code – the first official law in Serbia, stating that the significance of forest protection had been realized very early [13]. Some other documents implied that primary education and the mass media do not provide enough information about the importance of forests, forestry and their benefits to people and the general development of Serbia. Also that this deficiency shows in the undeveloped environmental awareness of our citizens that often manifests itself in a variety of negative aspects, especially in relation to forestry activities [8]. Under various legal provisions, whole or parts of urban forests and urban green spaces may be protected as the natural and cultural heritage important for the city or state [12], the fact that may significantly improve the condition and the longevity of some important green areas.

In 2005, the Government adopted the National Strategy of the Republic of Serbia to join the European Union. Since 2004, intensive projects have been done on the harmonization of domestic legislation with the legislation of EU [6]. One of the major problems is the financing of environmental protection, which also includes urban forests and greening. The strategy of biodiversity implies that the sources of financing the environmental protection in the Republic of Serbia, including the funds from the national budget, shall be allocated across ministries, institutions and special purpose funds, as well as the budgets of local governments, so that financial means should be provided by a number of bilateral and multilateral agreements. Major international funds are certainly pre-accession EU funds [9]. A source for funding may be also found in the income from the penalties for inappropriate treatment of trees and city green spaces. In a few other laws we may find strict fines, such as: "a fine of 500 € to 5000 € for a legal entity in case of the violation of green spaces and a fine of 200 € to 500 € for individual persons in case of the same violation" [7]. One draft law, soon to be passed, regulates that "every person or a legal entity shall be charged a fee of 2000 € if a tree is cut without the permission of local authorities" [16]. Currently, in Serbian cities citizens are paying for communal services co-financed by the state and city budgets which is an aggravating circumstance. Public utilities should be financially supported by applying the principles of the full cost recovery for environmental services [14] in order to improve the maintenance and the current condition of urban forests and city greenery.

Forests cover 30.7% of the Republic of Serbia [15]. In comparison, this percentage is closer to the global coverage of 30%, and much lower than in the EU, which is 46% [15]. Also, rare cities have an adequate percentage of green spaces (15 - 25 m^2/1 city resident) [12] and even less have urban forests of good quality, providing a pleasant stay and being accessible to common people on foot, by a bicycle or public transport. The last two decades have witnessed the loss of green and open spaces in urban areas and the vulnerability of public spaces. Many cities are changing the purpose of such spaces, where parks, public and green spaces are recognized as new "spatial options" for construction. This reduces the ecological quality of the existing environment and creates an imbalance which threatens the sustainability of cities. The rules of construction and changing the purpose of urban spaces are currently defined primarily by the interests of investors and only then by the interests of citizens and the public. In this way, the cities in the Republic of Serbia lose the quality of the urban structure [6]. On the local level - through local plans, projects and initiatives cities and other urban areas undertake the obligation to limit the spreading of urban/suburban areas and provide an absolute protection of green and open urban spaces [6]. Protecting and improving green spaces should be done by municipal authorities, legal entities, individuals and enterprises, institutions and other professional organizations involved in the planning, implementation, design, construction, supervision and maintenance of green areas on territories of local self-governments [16].

Users and citizens are also responsible for the state of urban forests and greenery, therefore also required: (*a*) to use public green spaces according to their main purpose; (*b*) to send a written notice to the public company responsible for city greening, that a tree or other vegetation poses a danger to life, health or property; (*c*) to maintain special-purpose communal gardens and greenery; (*d*) to obtain a consent from the appropriate public company prior to planting vegetation and later to maintain the planted vegetation [10]. It is important to emphasize that public spaces and personal engagement is a contemporary trend of greening big cities where the motivation is to envolve the users in the process of planning, construction, maintenance and the conscientious use of green spaces [12].

Lately, the professionals working in this domain have become aware of the usefulness of GIS systems, because the GIS of green spaces for a large number of European and world cities is a key part of an information base, a modern tool for a more efficient and cost-effective maintenance of the existing and the planning of new green spaces [11]. Spatial and urban plans and projects on local levels are very effective and powerful tools in the field of urban forests and greening. We may say that there are significant improvements in this area because of a considerable increase of referring to forests and greening in such plans. A good example is the Spatial Plan for the City of Novi Sad, where the concept of forests and forest land development within the plan means increasing forest areas, improving the existing forests and their use in accordance with the principles of environmental protection, as well as realizing their cultural, social and production functions.

Face-to-face interviews

The main results of the research interviews are that the interviewed professionals currently do not accept the term "urban forests" and the reference to it causes doubts. A public company responsible for urban greening does not take care of urban forests surrounding Novi Sad and these forests are under the jurisdiction of the public company responsible for the forests in the province of Vojvodina. This implies that these forests are not seen as parts of the city greenery, they are not linked enough with the city greenery system and the residents do not visit them often.

The interviewed professionals quote the main problem of urban greenery to be the lack of funds, the lack of moisture in the soil and the lack of city irrigation systems, political interference in profession matters, the lack of a targeted production of planting material that must be compensated by the import of seedlings from far away countries with different climates, the absence of legislation (law, strategies) that would clearly define urban forests and greening, the excessive paving of the city, etc.

CONCLUSION

Urban forests and greening have fallen into background, because of the economic crisis that has lasted for over 20 years, several wars and UN sanctions in the 90s, as well as the overall lack of care for the environment. This was also not an important topic among the politicians and in public, since people were preoccupied with existential problems. The situation is not different even today, but now we are noticing some positive improvements in this field reflected in the adoption of new, more adequate laws, in greater financial investments and the gradual spreading of environmental awareness of people who are beginning to realize that a healthy environment is extremely important for our quality of life and that urban forests and greening are one of the most important factors of that environment. It is surprising how this issue affects so many different institutions and sometimes even professionals who are in charge in this field, nevertheless not completely certain exactly which institution is responsible for what. This should be changed and maybe this research will contribute to the better understanding of the status of urban forests and greening in Serbia, as well as in the other countries that have similar situation.

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