CONTENTS
PAPERS FROM CONFERENCE "FORESTRY: BRIDGE TO THE FUTURE", MAY 13–15, 2010

Research papers

Research notes

The Conference "Forestry: Bridge to the Future" (13–15 May 2010) was dedicated to the 85th anniversary of higher forestry education in Bulgaria. It was organized by the University of Forestry Sofia, Faculty of Forestry and National Project Center for Coppice Forest Management in Southeastern Europe (CoppForSEE)

Acknowledgement to reviewers of the manuscripts submitted to "Forestry Ideas"

Matthias **Albert** – Northwest German Forest Research Station, Göttingen, Germany

Boris **Assyov** – Institute of Biodiversity and Ecosystem Research, BAS

Sezgin **Ayan** – Kastamonu Universitesi, Turkey

Linas **Balčiauskas** – Institute of Ecology of Nature Research Centre, Vilnius, Lithuania

Ariane **Bernard-Laurent** – National Office for Hunting and Wildlife, Nice, France

Pete **Bettinger** – University of Georgia, Athens, USA

Dilyanka **Bezlova** – University of Forestry, Sofia, Bulgaria

Ivan **Blinkov** – Ss. Cyril and Methodius University, Skopje, Macedonia

Lorenzo **Bonosi** – Agricultural Institute San Michele all'Adige, Trento, Italy

Patrick **Büker** – University of York, Heslington, United Kingdom

Serdar **Carus** – University of Suleyman Demirel, Isparta, Turkey

Piermaria **Corona** – University of Tuscia, Viterbo, Italy

Ulises **Diéguez-Aranda** – University of Santiago de Compostela, Lugo, Spain

Igor **Drobyshev** – Lund University, Sweden

Vasileios **Drosos** – Democritus University of Thrace, Thessaloniki, Greece

Panos Stavros **Economidis** – Aristotle University of Thessaloniki, Greece

Nikolai **Friesen** – University of Osnabrück, Germany

Velichko **Gagov** – University of Forestry, Sofia, Bulgaria

Dimitar **Georgiev** – University of Forestry, Sofia, Bulgaria

Björn **Hånell** – Swedish University of Agricultural Sciences, Umeå, Sweden

Klaus **Høiland** – University of Oslo, Norway

Nasko **Iliev** – University of Forestry, Sofia, Bulgaria

Vasilije **Isajev** – Faculty of Forestry, Belgrade, Serbia

Hans-Peter **Kahle** – University of Freiburg, Germany

Petar **Kitin** – Royal Museum for Central Africa, Belgium

Boštjan **Košir** – University of Ljubljana, Slovenia

Georgi **Kostov** – University of Forestry, Sofia, Bulgaria

Konstantin **Krutovskii** – N. I. Vavilov Institute of General Genetics, Russian Academy of Sciences, Moscow, Russia and Texas A&M University, Tamu, USA

Noël **Le Goff** – INRA Équipe de Croissance et Production, Champenoux, France
Bojcho **Marinov** – Institute of Mechanics, BAS, Sofia, Bulgaria
Ulrik **Mårtensson** – Lund University, Sweden
Katinka **Mihova** – University of Forestry, Sofia, Bulgaria
Milko **Milev** – University of Forestry, Sofia, Bulgaria
Stefan **Mirchev** – University of Forestry, Sofia, Bulgaria
Andrea **Monaco** – Regional Park Agency – Latium, Roma, Italy
Valentin **Nikolov** – Todor Kableshkov University of Transport, Bulgaria
Karin **Öhman** – SLU, Department of Forest Resource Management, Sweden
Kyle **O'Keefe** – University of Calgary, Canada
Ivan **Paligorov** – University of Forestry Sofia, Bulgaria
Elsa **Pastor** – Universitat Politècnica de Catalunya, Barcelona, Spain
Antoaneta **Petrova** – Botanical Garden, BAS, Sofia, Bulgaria
Rosica **Petrova** – University of Forestry, Sofia, Bulgaria
Timo **Pukkala** – School of Forest Sciences, University of Eastern Finland, Joensuu, Finland
Mari **Rusanen** – Finnish Forest Research Institute, Vantaa, Finland
Peter **Rademacher** – University of Goettingen, Germany
Károly **Rédei** – Forest Research Institute, Budapest, Hungary
Francis **Roesch** – USDA-Forest Service, Station Headquarters, Asheville, NC, USA
Slavcho **Savev** – University of Forestry, Sofia, Bulgaria
Dmitry **Schepaschenko** – Moscow State Forest University, Russia
Bartolomeo **Schirone** – University of Tuscia, Viterbo, Italy
Yulin **Tepeliev** – University of Forestry, Sofia, Bulgaria
Rumen **Tomov** – University of Forestry, Sofia, Bulgaria
Neno **Trichkov** – University of Forestry, Sofia, Bulgaria
Genoveva **Tzolova** – University of Forestry, Sofia, Bulgaria
Harald **Vacik** – University of Natural Resources and Applied Life Sciences, Vienna, Austria
Paul **Van Deusen** – National Council for Air and Stream Improvement, USA
Jozef **Viglasky** – Technical University in Zvolen, Slovakia
Rafael **Zas** – Lourizán Forestry Research Center, Apdo, Pontevedra, Spain
Petar **Zhelev** – University of Forestry Sofia, Bulgaria
Tomasz **Zielonka** – Institute of Botany, Polish Academy of Sciences, Kraków, Poland

FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

STRUCTURE AND LIVE BIOMASS OF GREEN FOREST FLOOR IN MIXED DECIDUOUS-CONIFEROUS FORESTS DURING REFORESTATION IN TAIGA ZONE

Tatiana Pristova

Institute of Biology, Komi Scientific Centre, Ural Branch, Russian Academy of Sciences. 28 Kommunisticheskaya st., Syktyvkar, Russia.
E-mail: pristova@ib.komisc.ru

UDC 630

Received: 05 May 2010
Accepted: 08 November 2011

Abstract

Forest cutting and natural reforestation essentially affect the species diversity, structure and live biomass of trees and green forest floor (GFF). Spruce forests, different-aged mixed deciduous-coniferous stands, and birch young forest in the taiga zone of northeastern Russia (Komi Republic) have been studied. Tree species are represented by *Betula pendula, B. pubescens, Populus tremula, Pinus sylvestris, Picea obovata, Abies sibirica.* Soil types at study objects are weakly peaty-weakly podzolic gley soil and illuvial-humus-iron podzol. Before cutting instead of today's deciduous forests there grew a 150–190-year-old spruce forest. GFF live biomass vary from 0.4 upto 3.9 t.ha^{-1} and reaches its highest values in spruce forest and the lowest values in 37-year-old birch-aspen forest. High resistant of phytomass in spruce forest and 90 years old birch-aspen forest, low resistant phytomass characterizes middle-aged deciduous-coniferous forests. Weight proportion grasses/mosses makes 1:1 in middle-aged deciduous-coniferous forests, 3:5 in birch young forest and 90-years-old birch-aspen forest, and 1:8 in spruce forest.

Key words: deciduous-coniferous stands, phytomass, species diversity, taiga.

Introduction

Formation of secondary mixed deciduous-coniferous stands at large areas after clear cutting during the 20th century became a characteristic feature of northern forests. These stands are represented by aspen and birch in over story and by coniferous tree species, mainly spruce, in understory. A specificity of reforestation in northwestern Russia is a combination of natural regeneration and artificial reforestation (Leinonen et al. 2009). The cut areas of 1950–1990 on the territory of Komi Republic are now secondary spruce-birch and pine-birch forests. Most of them are result of natural regeneration.

The studies of succession processes in mixed deciduous-coniferous forests are important for understanding the dynamics of taiga forests. Phytomass structure is one of the most important characteristics of vegetation cover. For the Republic of Komi, species composition and structure of deciduous and deciduous-coniferous stands were studied by Degteva (2002), reforestation processes by Ilchukov (2003) and Pautov and Ilchukov (2001).

Anthropogenic impact and following natural reforestation substantially change composition, structure, and phytomass of trees and vegetation cover. Species composition of GFF after cutting initial forest is formed under influence of a series of factors. Grasses at cut areas actively respond to changes of ecological conditions. Estimating of plant phytomass is of a high practical and theoretical significance. The type of secondary forest depends on the mode of cutting, initial forest characteristics, on climatic, soil, and biotic factors (Melekhov 1954). The aim of the study was to reveal the principle characteristics of GFF in forests at different succession stages.

Materials and Methods

Mixed deciduous-coniferous and spruce forests have been studied for 10 years at the Lyali Forest-Ecological Station on the North-West of Russia (Komi Republic).

The studied objects are ranked by age from youngest to oldest (Table 1).

Birch-spruce young forest and middle-aged birch-aspen forest replaced once felled haircap-moss bilberry spruce forest and bilberry spruce forest, relatively, with tree stand composition 80% spruce and 20% birch, undergrowth composition 10% spruce, age 150–190 years. Studying of GFF in sphagnum bilberry spruce forest and bilberry spruce forest provides us the information on live biomass, species composition and structure before cutting.

Estimation of GFF live biomass was made by hay-harvest method at the area of 400 cm^2 in a 40-fold replication and at area 878.9 cm^2 in a 20-fold replication. Species composition and live biomass were measured at each test plot for 3 years.

Results and Discussion

GFF of the studied forests is mosaic, especially in deciduous young forest and middle-aged birch-aspen forest. The studied forests differed by species composition and species number in GFF. Total number of plants in the studied phytocenoses was 65 species, among them 52 vegetation cover species. North and south taiga subzones of Komi Republic may count up to 361 plant species in birch forests. Mixed deciduous-coniferous forests had as many as 1.4 times more plant species than spruce forests. Species number in deciduous stands of Komi Republic was sometimes higher than one in spruce forests by 1.5–2 times, and it increased due to perennial grasses (Degteva 2002).

The most amounts of species were found in deciduous-coniferous forest (No 3) and the least amounts in pine-deciduous forest (No 4) (Fig.1). Species composition of GFF during reforestation depends on type of cutting. GFF at clear cuttings is most dynamic (Melekhov 1954). Species composition formation in secondary deciduous forests is a very special process and is influenced by number of factors. Several reforestation principles, well-known in forestry that are appropriate for the species composition of study forests could be mentioned:

1. Grass plants at cuttings with different types of technogenic disturbance actively respond to changing of ecological conditions. Ten years after cutting the number of grass species increased by 1.6 times on logger-roads and by 2.3 times on timber-loading areas. Thirty-five years after tree cutting, species number increased by 6 and 20%, respectively, compared to the 10-year-old cutting (Ilchukov 2003). According to our results, species number in GFF of birch young forest and spruce forests was about the same, while in deciduous-coniferous stand it was about 1.5 times more than that in the spruce forest.

2. During the reforestation the green mosses decreased in amount because of changing of illumination (Melekhov 1954, Ilchukov 2003). Six green moss species were found in the studied spruce forests and 2–4 species in the deciduous forests.

3. The typical indicator-species of cut areas was *Chamerion angustifolium*. There is some this species in deciduous

Table 1. Characteristic of plots.

No	Tree stand composition	Forest age, years	Forest type	Type of soil
1	Birch 80% Spruce 20%	12	Grassy	peaty-weakly-podzolic gley soil
2	Aspen 50% Birch 40% Spruce 10% Fir (*Abies*) – singly	37	Grassy	peaty-podzolic-weakly gley soil
3	Aspen53% Birch 40% Pine 4% Spruce 3%	45	grassy-bilberry	illuvial-humus-iron podzol
4	Pine 51% Birch 24% Aspen 23% Spruce 2%	45	bilberry	illuvial-humus-iron podzol
5	Aspen 70% Birch 20% Spruce 10% Fir (*Abies*) – singly	90	Grassy-green moss	typical podzolic soil
6	Spruce 90% Birch 10% Pine <1% Fir (*Abies*) – singly	106-200	bilberry-sphagnous	peaty-podzolic-weakly-gley soil
7*	Spruce 80% Fir (*Abies*) 10% Birch 10% Pine <1%*	80-150	bilberry moisture	illuvial-humus-iron podzol

* Bobkova (2006)

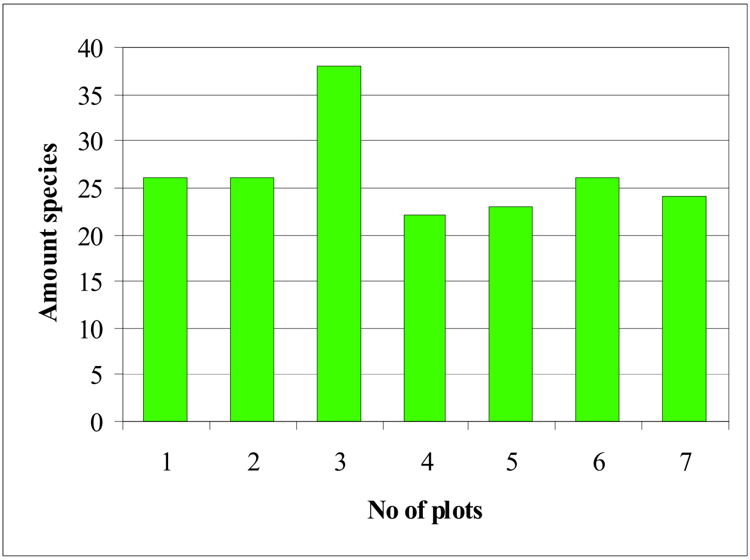


Fig. 1. Amount of plant species on the sample plots.

stand but does not bloom (Melekhov 1954). We did not found *Chamerion angustifolium* only in the spruce and mixed pine-deciduous forests.

We have applied the Stugren-Radulesku coefficient for comparing the species composition. The highest values of this coefficient were obtained when comparing between birch-aspen and pine-deciduous forests (0.27). There was almost no similarity between spruce forest and young forest and middle-aged deciduous forests.

Specific similarity between plots was estimated by the Jaccard's coefficient (K_J). The maximum similarity value (K_J>70%) was observed for birch-spruce young forest and aspen-birch stands (37- and 90-year-old stands). The high degree of similarity is attributed to the fact that they grow on the same soil type.

High similarity values (K_J>50%) were found among all middle-aged stands and young forest. In this case, it is related to similar composition, age and origin of tree stands. A high similarity degree between spruce forests and young forest (K_J=58%) is due to the fact that cut area (now young forest) remained with some spruce undergrowth, spruce trees and typical spruce forest plants. This is one of important reforestation and vegetation cover formation factors (Melekhov 1954).

The differences between sample plots in terms of species composition were estimated also by the differentiation coefficient (K_D). The highest differentiation degree (K_D>60%) was found between middle-aged deciduous and spruce forests due to essentially different species composition, and forest site quality. High degrees of differentiation (K_D>50%) were found between 90 years old birch-aspen and spruce forests, 90 years old birch-aspen and middle-aged forests. This indicates that 90-year-old stand has a special species composition different from both spruce forest and middle-aged deciduous forests.

The maximum phytomass was accumulated in bilberry-sphagnum spruce forest (No 6) – 3858±369 kg.ha^{-1}, and the minimum in birch-aspen forest (No 2) – 406±62 kg.ha^{-1} (Table 2). Among deciduous forests, phytomass accumulation reached its maximum in birch-spruce young forest – 1950 ± 220 kg.ha^{-1} and its minimum in birch-aspen forest – 406 ± 62 kg.ha^{-1} (Table 2). GFF live biomass was dominated by *Vaccinium myrtillus* L., *V. vitis-idaea* L., *Agrostis tenuis* Sibth., *Geranium sylvaticum* L., *Chamerion angustifolium* (L.) Scop., *Melampyrum sylvaticum* L., *Solidago virgaurea* L., *Cirsium heterofillum* (L.) Hill., *Polytrichum commune* (Hedw.) Br., Sch. Et Gmb., *Plerozium schreberi* (Brid.). Mitt., *Hylocomium splendens* (Hedw.) Br., Sch. et Gmb., *Sphagnum magellanicum* Brid.

Phytomass of ferns, horsetails, and club-mosses was never above 5% of total GFF live biomass in study forests and never above 10% for gramineous plants. Dominating groups of plants are undershrubs, grasses, and mosses. In middle-aged deciduous-coniferous and birch-aspen forests we found about 40% of grasses, undershrubs – 20% and mosses – 40% of the total (Table 2). In birch-spruce young forest and birch-aspen (90 years old) forest, grasses had about 30% and mosses more than a half of the total mass. High live biomass of undershrubs (70%) was observed in pine-deciduous stand. The proportion between mosses and grasses depends on tree stand composition, age and soil type. For example, in middle-aged deciduous forests on illuvial-humus-iron podzols the ratio was 1:1, in birch young forest and birch-aspen (37 years old) forests on peaty weakly-podzolic weakly-gley soil – 1:2. In spruce

Table 2. GFF live biomass, kg dry matter ha^{-1}/%.

No	Forest type	Total phytomass	Moss	Subshrubs	Grass
1	Birch-spruce young forest	1951 ± 221 / 100	1119 ± 130 / 57	292 ± 33 / 15	540 ± 28 / 28
2	Birch-aspen (37 years)	407 ± 63 / 100	151 ± 16 / 37	79 ± 22 / 19	177 ± 14 / 44
3	Deciduous-coniferous	1033 ± 241 / 100	429 ± 165 / 42	221 ± 13 / 21	383 ± 88 / 37
4	Pine-deciduous	702 ± 131 / 100	120 ± 58 / 17	471 ± 207 / 67	110 ± 12 / 16
5	Birch-aspen (90 years)	681 ± 39 / 100	351 ± 35 / 52	64 ± 17 / 9	266 ± 26 / 39
6	Spruce forest	3858 ± 360 / 100	3190 ± 272 / 83	86 ± 8 / 2	583 ± 59 / 15
7	Spruce forest*	1837 ± 56 / 100	1498 ± 43 / 82	270 ± 12 / 15	69 ± 7 / 3

* Bobkova (2006)

forest mosses were dominant and so the proportion became 1:7.

We applied the coefficient of variation (V) for statistical analysis of phytomass. The data presented indicate relative stability of the studied phytocenoses in GFF live biomass (Table 3).

Table 3. The variation coefficient of GFF live biomass, %.

Forest type	Total phytomass	Moss	Subshrubs	Grass
Birch-spruce young forest	11.3	11.6	11.3	9.6
Birch-aspen (37 years)	15.5	10.5	27.7	10.6
Deciduous-coniferous	23.4	38.5	6.0	31.0
Pine-deciduous	18.7	48.2	43.9	18.7
Birch-aspen (90 years)	5.6	10.1	27.1	24.2
Spruce forest	9.3	8.5	9.8	16.8
Spruce forest *	3.1	2.9	4.6	10.3

* Bobkova (2006)

Spruce forests and birch-aspen forest (90 years old) were the most stable according to the total phytomass index of vegetation cover plants. Less stable were the middle-aged deciduous forests. On the whole the variation coefficient for GFF live biomass varied within a small range, except for some groups of plants. Mosses live biomass was stable in spruce forest, birch-aspen forests, and birch young forest. This stability is related to peaty weakly-podzolic weakly-gley soil and wide participation of sphagnum in the phytomass. *Polytrichum commune* and *Sphagnum* spp. mosses can develop instead of green mosses at cut areas (former spruce forests) under certain conditions. This is because green mosses are less tolerant to changing illumination (Melekhov 1954). The birch young forest was found on small wet plots (former logger-roads) dominated by sphagnum mosses.

Live biomass of moss cover in the middle-aged deciduous forests varied widely. Subshrub layer in deciduous-conifer and spruce forests was the most stable one. A high variation coefficient for subshrub phytomass in the pine-deciduous forest (43.9%) indicates a possible decrease of their share in the total phytomass. This stand was dominated by bilberry and cowberries, but they may decrease in phytomass because of the second spruce canopy formation and the consequent illumination change. The highest species diversity and mosaicity of grasses in GFF are typical for the deciduous and mixed deciduous-coniferous forests. Phytomass of grasses in the deciduous and mixed deciduous-conifer forests was 1.6–7.8 times higher as compared to the bilberry spruce forests. Mosses phytomass in the spruce forests was 2.9–12.5 times higher as compared to deciduous and deciduous-coniferous forests (Table 2).

Conclusion

The obtained results show that species composition and phytomass of GFF in the secondary deciduous forests depends on tree composition and age, soil type, and succession stage.

References

Bobkova K.S. 2006. Virgin spruce forest of North: biodiversity, structure, functions. Saint-Petersburg “NAUKA”, 320 p. (in Russian).

Degteva S.V. 2002. Deciduous forests of south and middle taiga subzones of Komi Republic. Dissertation abstract for Doctor of Biology degree, 37 p. (in Russian).

Ilchukov S.V. 2003. Forest cover structure dynamics at clear cut areas. Ekaterinburg. UrD RAS, 120 p. (in Russian).

Leinonen T., Turtiainen M., Siekkinen A. 2009. Forest restoration in northwestern Russia in comparison with Finland. Ioensuu. Scientific-Research Forest Institute of Finland, 36 p.

Melekhov I.S. 1954. To the types of concentrated clearings with relation to changes in soil cover: Concentrated clearings in northern forests (Articles Book). AS USSR Publishing House. Moscow: 110–125. (in Russian).

Pautov Yu.A., Ilchukov S.V. 2001. Spatial structure of secondary tree stands at concentrated clear-cuts in Komi Republic. Lesovedenie [Forestry Journal] 2: 27–32. (in Russian).

FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

BIOLOGICAL AND WOOD PROPERTIES OF *AILANTHUS ALTISSIMA* (MILL.) SWINGLE

Panayot Panayotov[1]*, Kuncho Kalmukov[2], and Momchil Panayotov[3]

[1]Faculty of Forest Industry, University of Forestry, 10 Kliment Ohridski Bulv., 1756 Sofia, Bulgaria. *E-mail: ppanayotov45@abv.bg
[2]Experimental Station for Fast-Growing Forest Species, 18 Nove str., Svishtov, Bulgaria. E-mail: kkalmukov@abv.bg
[3]Faculty of Forestry, University of Forestry, 10 Kliment Ohridski Bulv., 1756 Sofia, Bulgaria.
E-mail: mp2@abv.bg

UDC 630.12

Received: 31 May 2010
Accepted: 19 November 2011

Abstract

We studied the growth in height, diameter, volume and the most important wood properties of 11-year old *Ailanthus altissima* (Mill.) Swingle trees grown at the Research station for fast-growing species near Svishtov, Bulgaria. We found that the height growth was most intensive during the first years with maximum rate in the 5th year. The diameter and volume growth were continuous and by the 11th year still had not reached a decrease in the rate. The wood density at air-dry condition (w = 7.5%) was 620 kg.m^{-3}, at absolutely dry condition (w = 0%) was 580 kg.m^{-3}, while at maximally saturated with water (density in row condition) it was 1045 kg.m^{-3}. The volume shrinkage was 14.85%. Head hardness, studied following Brinel method (in direction parallel to the grains), was 83.41 N.mm^{-2}, the hardness in radial direction was 61.48 N.mm^{-2} and in tangential direction – 52.03 N.mm^{-2}. The bending strength (MOR) of air-dry wood was 71.11 N.mm^{-2}. The modulus of elasticity (MOE) was 11.906 GPa. The compression strength parallel to the fibres was 55.83 N.mm^{-2}. The shear strength parallel to the fibers in tangential plain was 14.41 N.mm^{-2}, while in radial plain was 13.65 N.mm^{-2}. Our results show that *Ailanthus altissima* is underestimated fast-growing species, whose wood can be successfully used for production of paper and furniture. Therefore we consider appropriate a recommendation to start trials with establishment of experimental plantation.

Key words: timber properties, density, hardness, bending strength, gluing strength.

Introduction

The native land of *Ailanthus altissima* is China. The word "ailanthus" derives from the Moluccan name "aylanto" and means "tree-of-heaven". The word "altissima" means very tall (Kowarik and Saumel 2007). Besides the characteristics of the tree, this also reflects the very long leaves, which can reach more than 1 m in length. It was introduced in Europe in 1751 (in England) and in America in 1874 (Alden 1995). In these years this tree was planted in parks and gardens. *Ailanthus altissima* is fast-growing tree species. In its first year it can reach 3 m in height. For the duration of their life individuals can reach 20–30 m in height and 0.6–0.8 m in diameter (Hu 1979). The trees produce wide crown with thick and sparsely situated branches. At early age the bark is smooth, yellowish-gray or brown-gray in color. At higher age the bark is shallow and with longitudinal cracks. The leaves are decompound, i.e. the prolonged oval leaf blades are bilaterally and horizontally situated over thin sticks with 1 m length. The leaves are rich in tannins and when ground with fingers the *Ailanthus* leaves foul odor. The flowers have similar odor. The *Ailanthus* tree blossoms in June. The flowers are small greenish-yellow, unisexual or synoecious, gathered in heavy, straight broom racemes. The fruit is a nut with one winglet. The seeds become ripe in October and spend the winter on the tree (Hu 1979, Swearingen 2009). They are easily transported by wind. The species reproduces easily vegetatively from root and stem sprouts and generatively with abundant seeds. Characteristic biological feature of *Ailanthus altissima* is that the trees form huge quantities of root suckers. Its root system is developed in both horizontal and vertical direction (Kowarik and Saumel 2007). It settles down in fertile soils, but can be found also on poor soils. The trees are also tolerant to calcium content in the soil. *Ailanthus* prefers sunny locations. It tolerates sudden temperature changes. Due to the ability of the species to colonize rapidly open territories and its wide tolerance to soil conditions, many trials for evaluation of its potential as erosion control species were established in Bulgaria. Often the species displays pioneer character and in some regions of the world (including parts of Bulgaria) is considered as “invasive” (Swearingen 2009). Especially in abandoned city environment it can quickly colonize wide territories. An important feature that gives *Ailanthus* advantage in this respect is that the tree is allelopathic and can limit the growth of other species by releasing plant toxins (Lawrence et al. 1991). Yet, the species is still widely used as a garden tree and as economically important one. Among the features that make it valuable are medical uses of the plant, use of the wood for furniture production and energy source, and for breeding of the moth *Samia cynthia* from which valuable “eri silk” is produced (Hu 1979). The species is spread in countries all over the world in both warm and temperate zones. In Bulgaria *Ailanthus* was introduced probably at the end of 19th or at the beginning of 20th century for the purpose to lay out city lawns, parks and gardens. A great amount of *Ailanthus* trees at the age of 80 years are preserved. They are in good condition with diameters from 40 to 94 cm. The oldest tree can be seen in Sofia behind the King`s palace. Probably this venerable tree is from the period of the initial garden plantings. Its diameter is 116.9 cm and the height is 18 m. This changes the former perception that the maximum age that the species may reach in Bulgaria is 40–50 years (Enchev 1975). During the second half of the 20th century experimental *Ailanthus* plantations were established in the Research station for fast-growing species near the village of Vardim close to Danube river. The purpose was to test the growth of this fast-growing species under controlled conditions. Yet, despite initial data showing fast growth and high potential for production of wood and biomass, up to this moment *Ailanthus* was neglected especially from the point of view of wood production. The main reason is the common perception in Bulgaria that the wood is of low quality and not usable for practical purposes. Yet, wood properties were studied in other countries. A study in the Madison laboratory (Alden 1995) reported that *Ailanthus* stems have wide core, narrow light grey-reddish heartwood and wide yellowish-white sapwood (Moslemi and Bhagwat 1970). The wood has ring porous structure. Tracheas have big diameter and are arranged in narrow stripe spring zone, which can be seen at the beginning of the annual ring with a naked eye. The annual rings are wide, the latewood takes 90% of the ring. In the longitudinal tangential section of the stem core rays can be seen with a naked eye. Their appearance resembles glittering brief stripes. Anatomic sections revealed that core rays are monostichous and polystichous with brief spindle shape (Enchev 1975). A study of wood properties made by Alden (1995) demonstrated that the specific gravity at 12% humidity was 0.531 $g.cm^{-3}$ and density in air-dry condition was 537-617 $kg.m^{-3}$. The modulus of elasticity (MOE) during bending unseasoned wood was 6.343 GPa and of dry wood it was 10.48 GPa. Modulus of rupture (MOR) or border bending strength of unseasoned wood was 41.37 MPa and of dry wood it was 81.361 MPa. Pressure strength parallel to the fibers of unseasoned wood was 16.548 MPa and of dry wood it was 36.268 MPa. Pressure strength cross to the fibers of unseasoned wood was 2.62 MPa and of dry wood it was 7.791 MPa. Shear strength parallel to the fibers of unseasoned wood was 7.239 MPa and of dry wood it was 15.444 MPa (Hoshovsky 1988). Here we aim at studying the wood properties of *Ailanthus* trees grown under controlled conditions in Bulgaria. Our purpose was to obtain data for the most important technical characteristics and thus to provide initial data about the potential of the species for fast wood production.

Material and Methods

We used the timber of 11-years old *Ailanthus* tree from the seed-garden in the village of Vardim. We did annual measurements of the height and diameter of the tree. At the time it was felled the sample tree had diameter 16 cm and height 12.6 m. The stem was cut to planks with 60 mm thickness at each meter and they were left outdoors covered by shelter. Thus they were subjected to natural drying under the influence of the weathering factors for a period of three years. Then we did standard stem analysis measuring the tree ring increment for each plank. From the central planks we made samples which were used to determine the most important physical and mechanical properties. In the study we followed standard procedures according to the Bulgarian standards and correspondent with DIN 1052. Gluing properties of *Ailanthus* wood were studied following regulations of BDS EN 204, BDS EN 205, BDS EN 301 and BDS EN 302. Gluing was done in laboratory conditions in cold press with glue Jowacol 107 and in hot press (125°C) with glue Prefere 4114. The used specific pressure was 0.5 MPa. The adhesion strength of protective decorative films to wood surface was examined according to a method that is regulated in BDS 13088:86 and BDS EN 4624.

Results

Tree growth

The height growth was most intensive during the first 4 years. It reached its maximum rate in the 5th (Fig. 1). The rate of diameter increment was steady until the 8th year and then decreased slightly (Fig. 2).

The diameter growth at 1.3 m height was as follows: at the 1-st year – 0.8 cm; at the 2-nd year – 2.5 cm; at the 3rd – 4.1 cm; at the 4th – 5.8 cm; at the 5th – 7.65 cm; at the 6th – 9.55 cm; at the 7th – 11.6 cm; at the 8th – 13.3 cm; at the 9th – 14.6 cm; at the 10th – 16.3 cm and at the 11th – 17.7 cm without bark (fig. 2). The curve of volume increment until the age of 11 years showed ascending tendency and culmination has not yet been reached (fig. 3). Our results demonstrate that *Ailanthus* is indeed a fast growing species with high accumulation of wood in the first one to two decades of growth. The only faster growing valuable trees in Bulgaria are poplar cultivars, which can reach up to 20 m height at age of 11 years (data for cultivar "I-214" grown in the same location).

Wood properties

During the initial visual analysis of wood samples we determined that the annual rings were very wide in the first five years. In that period they were 15–17 mm. In the next few years they were slightly narrower (11–13 mm). In longi-

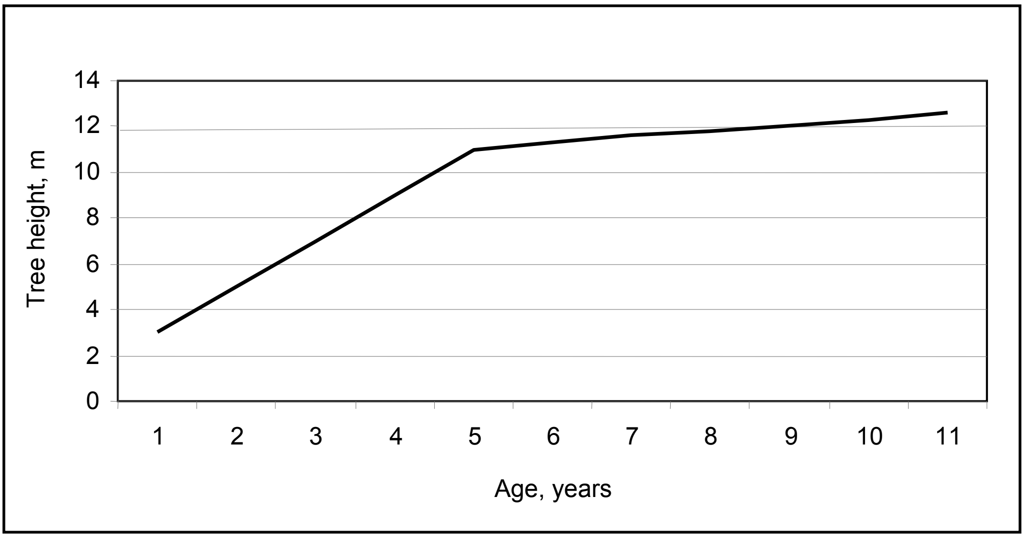


Fig. 1. Height growth of 11-years old *Ailanthus* tree.

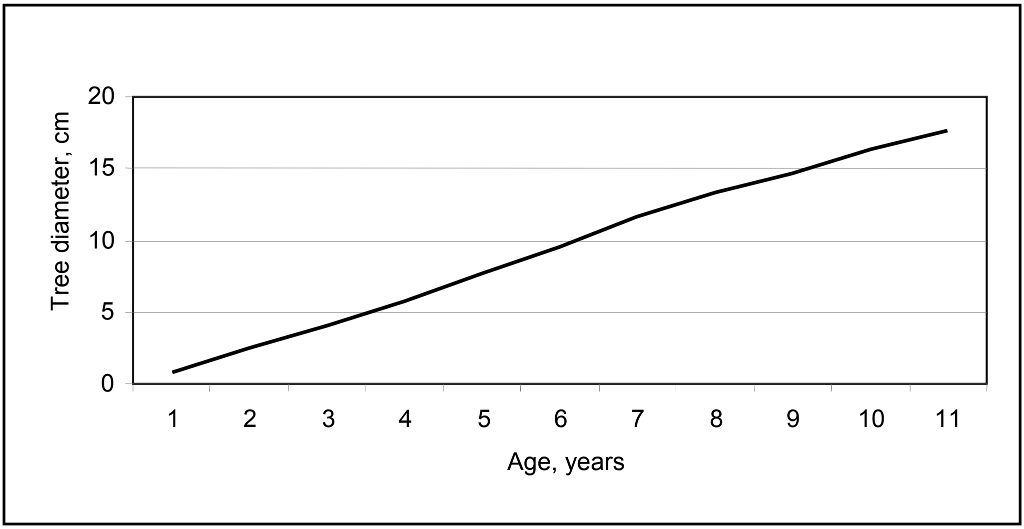


Fig. 2. Diameter growth of 11-years old *Ailanthus* tree.

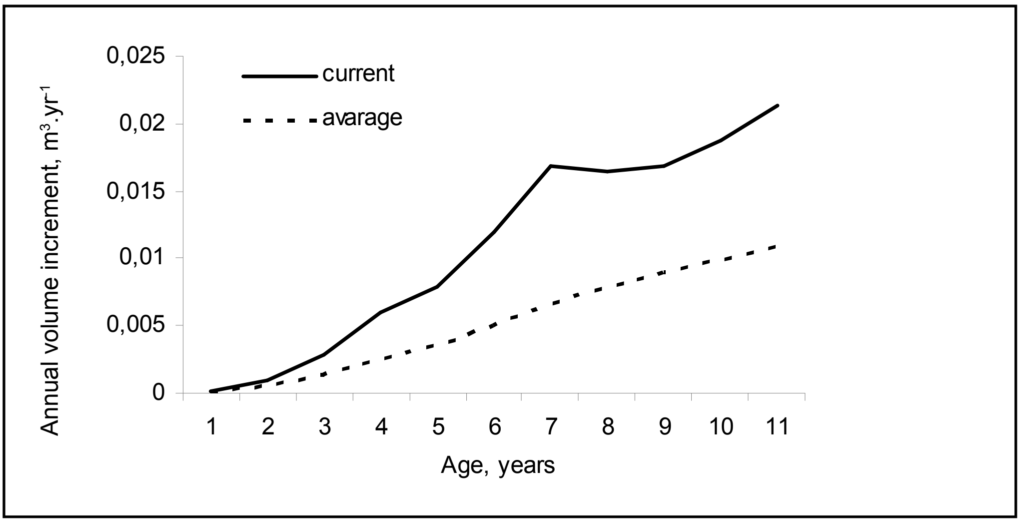


Figure 3. Annual volume increment of 11-years old *Ailanthus* tree.

tudinal sections the extract substances in tracheas could be seen with a naked eye. They resembled glittering yellowish-orange crystals. The average values of the studied physical and mechanical properties of *Ailanthus* timber are shown in Table 1. In respect to density and static hardness it was estimated that *Ailanthus* timber refers to the group with average density and hardness. The wood density at air-dry condition (w = 7.5%) was 620 kg.m^{-3}. When the wood was in condition with the highest degree of water content, the density

Table 1. Physical and mechanical properties of the timber of 11-years old *Ailanthus* tree.

No	Property	n	Variation indexes				
			Aver.	St.D.	Error	V, %	P, %
1	Density in row condition, kg.m^{-3}	81	1,045	23.9	2.66	2.3	0.25
2	Density in dry condition, kg.m^{-3}	81	620	23.5	2.61	3.8	0.42
3	Density in abs.dry condition, kg.m^{-3}	81	580	21.0	2.33	3.6	0.41
4	Conventional density, kg.m^{-3}	81	485	24.8	2.75	5.1	0.57
5	Water absorption, %	81	115	3.85	0.43	3.3	0.37
6	Tangential swelling, %	81	12.34	1.89	0.21	15.3	1.70
7	Radial swelling, %	81	6.41	1.45	0.16	22.6	2.51
8	Swelling in size, %	81	19.51	2.83	0.31	14.5	1.61
9	Tangential shrinkage, %	81	10.82	1.43	0.16	13.2	1.46
10	Radial shrinkage, %	81	6.12	1.06	0.12	17.3	1.92
11	Shrinkage in size, %	81	17.09	1.45	0.16	8.48	0.94
12	Head hardness-Yanka, N.mm^{-2}	64	59.68	4.25	0.53	7.12	0.89
13	Radial hardness-Yanka, N.mm^{-2}	64	44.07	4.52	0.56	10.2	1.28
14	Tangential hardness-Yanka, N.mm^{-2}	64	54.07	4.73	0.59	8.75	1.09
15	Head hardness-Brinel, N.mm^{-2}	64	83.41	16.9	2.11	20.3	2.53
16	Radial hardness-Brinel, N.mm^{-2}	64	61.48	21.7	2.71	35.3	4.41
17	Tangential hardness-Brinel, N.mm^{-2}	64	69.23	14.2	1.78	20.5	2.56
18	Compression strength parallel the direction of fibers, N.mm^{-2}	64	55.83	3.63	0.45	6.5	0.81
19	Tangential shear strength parallel the direction of fibers, N.mm^{-2}	64	14.41	1.68	0.21	11.6	1.45
20	Radial shear strength parallel the direction of fibers, N.mm^{-2}	64	13.65	2.64	0.33	19.3	2.42
21	Radial split strength parallel the direction of fibers, kN.m^{-1}	64	85.18	17.7	2.21	20.7	2.59
22	Tangential split strength parallel the direction of fibers, kN.m^{-1}	64	106.4	20.4	2.55	19.2	2.39
23	Static bending strength, N.mm^{-2}	64	71.11	8.56	1.07	12.1	1.51
24	Modulus of elasticity during static bending, N.mm^{-2}	64	11,906	1,873	234	15.7	1.97

Symbol: n – quantity of samples.

was 1045 kg.m^{-3}. The density at absolutely dry condition (w=0%) was 580 kg.m^{-3}. The conventional density was 485 kg.m^{-3}. Head hardness, defined by the Yanka method, was 59.68 N.mm^{-2}. Head hardness, defined by the Brinel method, was 83.41 N.mm^{-2}. The cross radial hardness, defined by the Yanka method, was 44.07 N.mm^{-2}. The cross radial hardness, defined by the Brinel method, was 61.48 N.mm^{-2}. The cross tangential hardness, defined by the Yanka method, was 54.07 N.mm^{-2}. The cross tangential hardness, defined by the Brinel method, was 69.23 N.mm^{-2}. The hardness in tangential direction, i.e.

in radial section (radial cross hardness) had lower values in comparison with that in radial direction. According to this index the *Ailanthus* wood is of equal worth to walnut wood, which has head hardness 72 $N.mm^{-2}$ and cross hardness 54 $N.mm^{-2}$ (Enchev 1975). The compressive strength parallel to the direction of the *Ailanthus* fibers (55.83 $N.mm^{-2}$) was lower than that of oak (*Quercus*), 76.2 $N.mm^{-2}$ (Enchev 1975). The shear strength parallel to the *Ailanthus* fibers (13.65 $N.mm^{-2}$ in radial plane and 14.41 $N.mm^{-2}$ in tangential plane) was almost equal of this of oak-tree: 13.8 $N.mm^{-2}$. The *Ailanthus* wood can split parallel to the direction of the fibers more difficult in tangential direction: 106.42 $kN.m^{-1}$, than in radial direction: 85.18 $kN.m^{-1}$. The modulus of linear deformation during static bending of *Ailanthus* timber (11,906 $N.mm^{-2}$) was almost equal to that of walnut (12,500 $N.mm^{-2}$), but it was considerably lower than that of the oak-tree (16,000 $N.mm^{-2}$) (Enchev 1975). We would like to stress the fact that both walnut and oak trees need much more years to reach the same diameter as the one studied in *Ailanthus* tree.

Table 2. Gluing strength of the timber of 11-years old *Ailanthus* tree.

No	Variant	Glue	n	Variation indexes in $N.mm^{-2}$					Destruction, %	
				Aver.	St.Dev.	Error	V, %	p, %	W	AF
1	P+P	Prefere 4114	36	5.01	1.01	0.17	20	3.3	100	-
2	P+P	Jowacol 107	36	4.85	1.15	0.19	24	3.9	90	10
3	A+ A	Prefere 4114	36	15.24	2.43	0.41	16	2.6	25	75
4	A+ A	Jowacol 107	36	13.13	2.83	0.47	22	3.6	10	90
5	A+ A	Jowacol 107	36	13.13	2.83	0.47	22	3.6	10	90
7	R+ R	Prefere 4114	36	16.93	3.08	0.51	18	3.0	20	80
8	R+ R	Jowacol 107	36	13.27	3.12	0.52	23	3.9	15	85

Symbols: P – *Paulovnia* timber; A – *Ailanthus* timber; Q – *Quercus* timber; A – *Robinia preudoacacia* timber; n – quantity of samples; W – destruction in wood; AF – adhesion destruction between wood and protective film.

The results displayed in Table 2 demonstrate that *Ailanthus* wood sticks very well with dispersion polyvinilacetate glues and with reactive urea-formaldehyde glues. The gluing strength of *Ailanthus* wood with the reactive glue Prefere 4114 was 15.24 N.mm^{-2} and with the dispersion glue Jowacol 107 was 13.13 N.mm^{-2}.

The *Ailanthus* wood can be varnished very well. Table 3 shows the average values of adhesion coatings formed with two-component polyurethane system (Pu-683/50+B-640) and the average values of coatings, formed with water-diluted acrylic varnishes (Aquis). The average values of adhesion of polyurethane (Pu) coatings ranged from 3.84 N.mm^{-2} to 6.37 N.mm^{-2}. The average values of adhesion of acrylic (AqA) coatings varied from 4.37 N.mm^{-2} to 9.75 N.mm^{-2}.

The comparative analyses proved that adhesion values depend on the roughness of wood surfaces over which the coatings are formed. When roughness of surface decreased, the cohesion of coatings also decreased, respectively. For example, series with index Pu 40 with roughness values 5.63 μm had adhesion 6.37±0.21

Table 3. Adhesion of coats on the timber of 11-years old *Ailanthus* tree.

Index	R_a μm	M_{dc} g.m^{-2}	Δ μm	n	Variation indexes in N.mm^{-2}					Destruction,%	
					Aver	St.D.	Error	V, %	p, %	WC	CM
Pu R	4.56	171	125	30	4.64	1.11	0.20	24	4.3	100	–
Pu 40	5.63	154	120	30	6.37	1.15	0.21	18	3.3	90	10
Pu 80	4.15	178	130	30	4.35	1.05	0.19	24	4.4	95	5
Pu 150	3.43	196	140	30	3.84	0.83	0.15	22	3.9	100	-
AqA R	4.35	268	210	30	8.76	2.20	0.40	22	4.1	75	25
AqA 40	5.75	266	210	30	9.75	2.06	0.38	19	3.5	95	5
AqA 80	4.05	283	215	30	8.32	2.18	0.39	18	4.7	100	–
AqA 150	3.25	267	215	30	4.37	1.12	0.20	25	4.6	90	10

Symbols: Pu – two-component polyurethane varnishes (Pu-683/50+B-640); AqA – Acrylic water dilute varnishes "Aquis"; R – planed down surface; 40 – surface, polished with sandpaper No 40; 80 – surface, polished with sandpaper No 80; 150 – surface, polished with sandpaper No 150; M_{dc} – weight of dry coat; δ –thickness of the dry coat; R_a – roughness of wood; WC – destruction between wood and coating; CM – destruction between the coating ant the metal punch.

N.mm^{-2} and series with index Pu 150 with roughness values 3.43 μm had adhesion 3.84 N.mm^{-2}. Similar tendency was observed with coatings formed with acrylic varnish, but these coatings had higher adhesion towards *Ailanthus* wood. For example, series with index AqA 40 with roughness values 5.75 μm had adhesion 9.75 ± 0.38 N.mm^{-2} and series with index AqA 150 with roughness values 3.25 μm had adhesion 4.37 N.mm^{-2}.

Conclusions

As a conclusion we can state that *Ailanthus altissima* is a fast growing species with high quality wood. The wood of trees grown under controlled conditions had very good physical and mechanical properties, some of which were comparable to the very expensive walnut wood. Therefore it can be used for manufacturing articles with different functions, including furniture. Based on our results we can recommend further studies directrd to establishment of experimental plantations in different growing conditions (climate and soils) and the possible uses of wood. They will confirm whether *Ailanthus altissima* can be successfully used as a fast growing species for quick production of valuable or energy source wood in Bulgaria. Yet, strict control in the plantation locations should be applied in order not to contaminate environmentally important protection areas, in which the invasive character of *Ailanthus altissima* may be a major threat.

Acknowledgements

This study was carried out within the framework of contract No 44/13.04.2009 with Scientific Research Department of University of Forestry – Sofia, Bulgaria.

References

Alden H.A. 1995. Hardwood of North America (pdf document), 12 p. *Ailanthus altissima* – General Technical Report FPL-GTR-83 United States Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, USA, 136 p. Available: www.cnr.vt.edu/DENDRO/dendrology/woodgrain.cfm

Enchev E. 1975. Wood science. Zemizdat-Sofia 1975, 360 p. (in Bulgarian).

Hoshovsky M.C. 1988. Global Invasive Species Team. The Nature Conservancy – *Ailanthus altissima* (Mill.) aswingle (*A. glandulosa* Desf – Family Simaroubaceae) – Common Names-Tree of heaven, *Ailanthus*. Available: http://wiki.bugwood.org.

Hu Shiu-ying 1979. *Ailanthus altissima*. Arnoldia 39 (2): 29–50.

Kowarik I., Saumel I. 2007. Biological flora of Central Europe: *Ailanthus altissima* (Mill.) Swingle. Perspectives in Plant Ecology, Evolution and Systematics 8: 207–237.

Lawrence J.G., Colwell A., Sexton O. 1991. The Ecological Impact of Allelopathy in *Ailanthus altissima* (Simaroubaceae). American Journal of Botany 78 (7): 948–958.

Moslemi A.A., Bhagwat S.G. 1970. Physical and mechanical properties of the wood of tree-of-heaven. Wood and Fiber. 1 (4): 319–323.

Swearingen J.M., Pannill P.D. 2009. Fact Sheet: Tree-of-heaven. Plant Conservation Alliance's Alien Plant Working Group. Retrieved 2010-02-07.

FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

INVESTIGATION OF DOUGLAS-FIR PROVENANCE TEST IN NORTH-WESTERN BULGARIA AT AGE 20

Krassimira Petkova

Department of Sylviculture, Faculty of Forestry. University of Forestry. 10 Kliment Ohridski Blvd. 1756 Sofia. Bulgaria. E-mail: kpet@abv.bg

UDC 630.232

Received: 05 October 2010
Accepted: 21 November 2011

Abstract

The aim of the study wais to make a comparative analysis of the growth rate of 54 Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) provenances. The provenance test was established in the spring of 1990 with 3-year-old (3+0) seedlings planted in a 2x2 m plot design and two replications. The provenances originated from the North America and were separated into Coastal, Continental and Western Cascade groups. At age 20 growth rate was studied in terms of height and diameter, and stem volume. Coastal provenances demonstrated the best growth parameters, followed by Western Cascade Mountains and continental provenances. The provenances showing fastest growth provenances were Bremerton, of the coastal group, and Darrington, Newhalem and Idanha of the Western Cascade group. These provenances possessed also high resistance to fungal pathogens. Ten continental provenances had the lowest growth rate and productivity and were highly susceptible to the fungal pathogens *Rhabdocline pseudotsugae* and *Phaeocryptopus gaumannii*. Darrington from the Western Cascades in Washington is the recommended provenance for future afforestations with Douglas-fir in Bulgaria.

Key words: adaptation, disease susceptibility, seed sources, tree growth, provenances, *Pseudotsuga menziesii.*

Introduction

Douglas-fir was introduced in Europe in 1827 when the Scottish botanist David Douglas imported seeds of this tree species into England and Scotland. A century later Douglas-fir had already been introduced in almost all European countries. The rapid growth and wood quality of Douglas-fir attracted the attention of many researchers. The majority of studies focused on its growth and productivity and the role of soil and climatic conditions (Tyler et al. 1995, Dundari et al. 2002, Feliksik and Wilczynski 2004). The choice of appropriate provenances quickly became the main research goal of many European studies (Veen 1951, Ruetz 1981, Ruetz and Foerst 1984, Ruetz 1989, Ballian et al. 2002, Zas et al. 2003, Govedar et al. 2003, Perić et al. 2009). Superior growth of the coastal provenances and these from the western side of the Cascade Mountains in the states of Washington and Oregon have been reported in most studies

(Lally and Thompson 1998, Schultze and Raschka 2002, Rau 2005).

Douglas-fir was introduced in Bulgaria a century ago, but it became widespread only in the late 1950s and during the 1960s. Nowadays, plantations of this species occupy about 6714 ha. In many plantations, the species has demonstrated good adaptability (Petkova 1989, Popov 1991, Grozev et al. 1995). However, in some plantations diseases have been found caused by the fungi *Rhabdocline pseudotsugae* Syd (Rosnev 1978, Rosnev 1983a), *Phomopsis pseudotsugae* Wils (Rosnev 1983b) or *Phaeocryptopus gaumannii* (T. Rohde) Petr. (Rosnev and Petkov 1986, Rosnev 1987). Most plantations are of unknown seed origin, which could be one of the main causes of the emerging problems. Twenty years ago provenance tests of 55 Douglas-fir provenances were established in Bulgaria (Popov 1995, Petkova 1999, Popov and Petkova 2003), and these are a rich source of information on the various provenances' growth rate and ability to adapt to the natural conditions in the country. Earlier measurements of these plantations (at age 8 and 16) have indicated that the coastal provenances and the provenances from the Western Cascade Mountains of the states of Washington and Oregon have the best growth rate (Popov 1995, Popov 2001, Petkova 2004). The diseases found on part of these plantations caused by the fungi *Rhabdocline pseudotsugae* Syd. and *Phaeocryptopus gaumannii* (T. Rohde) Petr. (Georgieva and Rosnev 2008, Georgieva 2009) will contribute to the selection of the most tolerant and adaptive provenances for future afforestations with this valuable tree species in Bulgaria. Additional information on the use of Douglas-fir will be obtained from the new provenance tests established in 2006 with seeds from highly productive stands in Germany, Bulgaria and the USA (Petkova et al. 2008).

The aim of this study was to analyze the growth rate of 54 Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) provenances at age 20.

Material and Methods

The Douglas-fir provenance test is located on the lower northern slopes of the Western Balkan Mountain and is one of 4 field trials established with the aim of studying the adaptability of this species to different climates of Bulgaria. The trial was established on flat terrain facing East, at an altitude of 600 m, latitude of 43°14' N and longitude of 23°09'E. The soil is Orthic luvisol (FAO), mixed sandy and clay, slightly stony, and very deep. The habitat is medium rich to rich. The climate in the region is temperate with an average annual temperature of 10.2°C and annual precipitation of 1004 mm. The duration of the vegetation period is about 6 to 6.5 months.

The provenance test was established in the spring of 1990 with 3-year-old seedlings (3+0), which were planted in a 2x2 m plot design in two replications. Forty to forty-eight seedlings were planted on each plot. The experimental area was prepared by ploughing and the Douglas-fir seedlings were planted with an earth auger. Due to unfavourable environmental conditions in the northern part of the provenance test (waterlogging and swamping) some of the individuals in the second replication died, leaving just 23 provenances in the experiment.

The 54 provenances studied originate from natural stands of Douglas-fir in North America (Fig. 1), and were classified into three groups: continental (26), Western Cascade Mountain (22) and coastal (6) provenances. The continental group includes 21 Oregon provenances, 3 Washington provenances, 1 Montana provenance and 1 New Mexico provenance.

The following indices were determined when the trees reached the age of 20: average diameter at breast height (DBH), average height and stem volume. The average diameter (DBH) for each provenance and replication was determined after measuring the diameters of all trees on the plot. It was calculated according to the Formula 1:

$$D = \sqrt{\frac{4G}{\pi N}} \text{ [cm]}, \qquad (1)$$

where: $G = \Sigma n_i.g_i$ [m^2] is the total basal area of the trees in the provenance, n_i is the number of trees in the respective diameter class, g_i [m^2] is the basal area in the respective diameter class, N is the number of trees in the provenance.

The average height (H) of each provenance was calculated as the arithmetic mean of the heights of 15–25 individual trees, distributed into diameter classes.

The stem volume was calculated according to the Formula 2:

$$V = G.HF \text{ [m}^3\text{]}, \qquad (2)$$

where: G [m^2] is the total basal area of trees in the provenance; HF is the height form factor for *Abies alba* Mill., as presented in table 3 (Poryazov et al. 2004).

Statistical parameters (arithmetic mean, standard deviation and standard error) were assessed for the analyzed height and diameter at breast height per provenance. The differences among provenances were tested by analysis of variance (ANOVA). Since a lot of individuals in the second replication had been lost due to unfavorable environmental conditions, the design of the experiment did not allow testing a full factorial model. Instead, two analyses of variance were done on the height. In the case where the provenances were represented by two replications (23 provenances), the analysis considered the effects of groups, replications and provenances, and in the other case, the analysis considered only the effects of groups and provenances (54 provenances). This inconvenience did not affect testing the effect of the main factors, but rather the interactions among them.

The model for ANOVA (Formula 3) was:

$$Y_{ijkl} = \mu + G_i + P_j + R_k + e_{ijkl}, \qquad (3)$$

where: Y_{ijkl} is the value of the l^{-th} individual of the j^{-th} provenance of the i^{-th} group measured in the k^{-th} replication; μ is the overall mean; G_i is the effect of the i^{-th} group (i = 1, 2, 3); P_j is the effect of j^{-th} provenance (j = 1, 2, ..., 54); R_k is the fixed effect of the k^{-th} replication (k = 1.2); e_{ijkl} is residual error.

To assess the health status of trees of the individual provenances (Georgieva 2009) the degree of crown defoliation was determined according to the European methods for environmental monitoring of forest ecosystems (Eichhorn et al. 2007). Phytopathological surveys were carried out to identify the fungal diseases *Rhabdocline pseudotsugae* and *Phaeocryptopus gaumannii*.

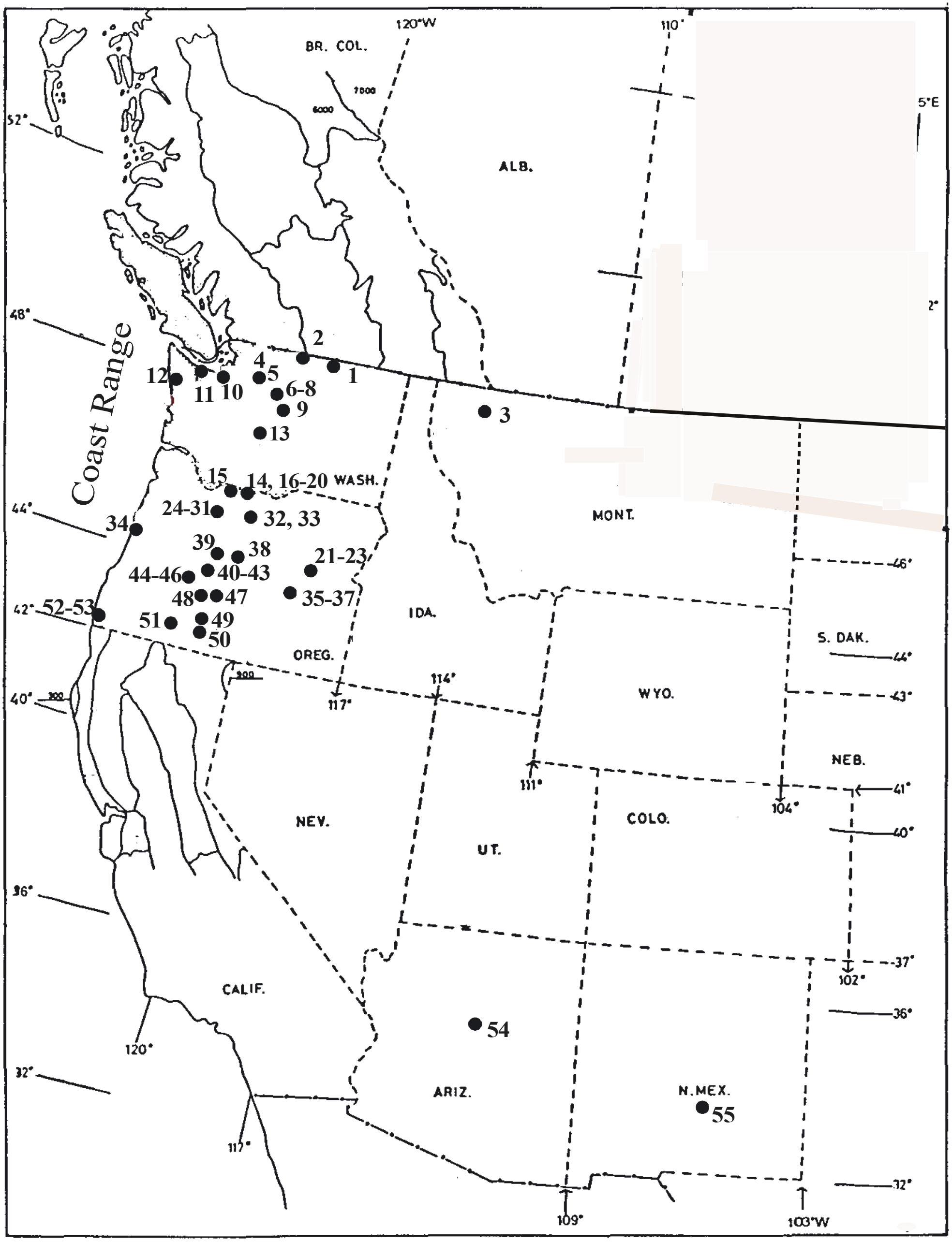


Fig. 1. Geographical location of Douglas-fir provenances (Georgieva 2009).

For each provenance, the coefficient of susceptibility to these pathogens was determined according of Chumakov`s formula No 4 (1974):

$$K = \frac{\sum(Q_n x P_n)}{N}, \quad (4)$$

where: K is the coefficient of susceptibility; Q_n is the degree of crown defoliation (from 0 to 4); P_n is the number of trees by respective degree; N is the total number of the investigated trees.

Depending on the value of the coefficient of susceptibility (K), provenances were categorized as:

– resistant – with coefficient of susceptibility from 0 to 1;

– less susceptible – with coefficient of susceptibility from 1 to 2;

– medium susceptible – with coefficient of susceptibility from 2 to 3;

– very susceptible – with coefficient of susceptibility from 3 to 4.

Results and Discussion

The overall mean height at age 20 was 10.4 m, ranging from 4.7 to 13.3 m depending on the provenance. Coastal provenances had reached the greatest height, followed by Western Cascade and continental provenances. Western Cascade provenance 7 (Darrington) and coastal provenances 10 and 11 (Bremerton) (Fig. 2) demonstrated particularly rapid height growth. These provenances were also found to be the most rapidly growing in previous studies of the same provenance test (Iliev and Petkova 1995, Petkova 1999, Petkova 2004).

The slowest height growth was registered in the case of 10 continental provenances: 1 (Greenwood) and 2 (Keremeos), Washington, 3 (Whitefish), Montana, 21, 22, 23 (Bates), 35, 36, 37 (Canyon City), Eastern Oregon and 55 (Alamogordo), New Mexico. These provenances were evaluated as very susceptible to fungal pathogens *Rhabdocline pseudotsugae* and *Phaeocryptopus gaeumanii*, causing needle cast (Georgieva 2009). Diseases were detected on trees at age 17 and were observed until the trees reached age 20.

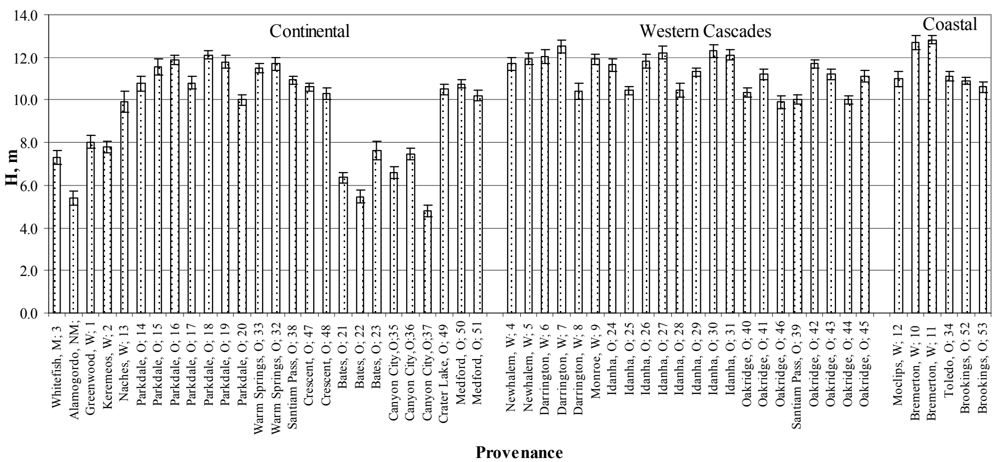


Fig. 2. Averrage height of 20-year-old Douglas-fir provenances planted at 1990 in Bulgaria.

Over the four years of observation, a decline was witnessed in the health status of this provenance group as the coefficient of susceptibility increased from 2.0 to 2.9. The main reason for the poor health status of these provenances was the combined development of the two fungi, *Rhabdocline pseudotsugae* and *Phaeocryptopus gaeumanii*. Most other provenances were attacked to a varying extent by *Phaeocryptopus gaeumanii* only (Georgieva 2009).

Results from studies of other provenance tests in Bulgaria using the same provenances (Popov 1995, Popov 2001) showed that the Washington coastal provenances (Bremerton and Moclips) and some of the Washington and Oregon Western Cascade provenances (Newhalem, Darrington, Monroe, Idanha, Oakridge) kept the best growth rate. These provenances were also characterized by very good growth in the provenance test subject to this investigation (Fig. 2), and in addition, they demonstrated very good resistance. The coefficient of susceptibility of provenances 7 (Darrington) and 43 (Oakridge) for the whole four-year observation period was 0.0. The other provenances were less affected by *Ph. gaeumanii* and were therefore categorized as less susceptible, with K = 0.2–1.6 (Georgieva 2009).

In testing the differences in height among provenance groups, when only 23 provenances were considered (the provenances being presented in 2 replications), the group effect proved not statistically significant ($p = 0.078$), however, it was statistically significant when all 54 provenances were included in the analysis ($p = 0.004$). The provenance effect was highly significant in both cases ($p < 0.001$). Replication effects were not significant (Table 1).

Table 1. ANOVA for the height.

Source of variation	DF	Mean squares	F-ratio	P-value
I. Number of provenances = 23				
Group effect				
Group	2	175.8	11.805	0.078
Replication	1	6.15	0.495	0.545
Provenance effect				
Provenance	23	72.224	23.166	<0.001
Replication	1	0.151	0.05	0.825
II. Number of provenances = 54				
Group effect				
Group	2	345.057	266.752	0.004
Replication	1	24.254	11.478	0.008
Provenance effect				
Provenance	53	78.136	20.529	<0.001
Replication	1	0.085	0.029	0.866

The average diameter of the provenance test at age 20 was 11.8 cm. With respect to this index, the highest values were again recorded on coastal provenances, followed by Western Cascade and continental provenances. The biggest average diameter was measured on Western Cascade provenance 7 (Darrington), 14.3 cm, and the smallest one, on continental provenance 37 (Canyon City), 4.7 cm. Testing the group, provenance and replication effect on diameter growth proved all effects as statistically significant (Table 2).

Table 2. ANOVA for diameter.

Source of variation	DF	Mean squares	F-ratio	P-value
Group effect				
Group	2	470.8	37.663	<0.001
Replication	1	996.2	79.45	<0.001
Provenance effect				
Provenance	53	181.9	7.11	<0.001
Replication	1	747.4	34.95	<0.001

For the entire provenance test, the average value of stem volume was 138.4 $m^3.ha^{-1}$. The highest stem volume was calculated for provenance 15 (Parkdale) – 223.2 $m^3.ha^{-1}$ and the lowest, for provenance 37 (Canyon City), only 4.5 $m^3.ha^{-1}$. The following provenances deserve particular attention, too: 5 (Newhalem), 6 and 7 (Darrington), 24 and 30 (Idanha) of the Western Cascade group and coastal provenances 10 and 11 (Bremerton). Their stem volume exceeded 200 $m^3.ha^{-1}$, which confirms the great potential and viability of these Douglas-fir provenances. The Darrington provenance has been reported as high-performing in the region of Sarajevo (Bosnia and Herzegovina) with a stem volume of 235 $m^3.ha^{-1}$ at age 37 (Ballian et al. 1999). In the Western Balkan Mountain, this provenance manifested better its growth potential since as early as age 20 its stem volume was 211 $m^3.ha^{-1}$, which is comparable to the volume achieved by the same provenance at almost double that age in Bosnia and Herzegovina. Along with its high performance, the Darrington provenance in the provenance test in this study was characterized by the highest resistance to the fungal pathogens *Rhabdocline pseudotsugae*, and *Phaeocryptopus gaeumanii*, as its coefficient of susceptibility for the entire four-year observation period was K=0.0 (Georgieva 2009). In the Western Balkan this provenance manifested itself in full growth potential, since at the age 20 its stem volume was 211 $m^3.ha^{-1}$, which is two times greater comparable to the same provenance at two times greater age in Bosnia and Herzegovina. Along with its high performance the provenance Darrington was characterized by the highest resistance to fungal pathogens *Rhabdocline pseudotsugae* and *Phaeocryptopus gaeumanii*, proven by the coefficient of susceptibility for the entire four-year observation period K=0.0 (Georgieva 2009).

The Darrington provenance was defined as very well growing by Günzl (1984), based on measurements and observations in multiple provenance tests in Austria. According to Rau (2005) Douglas-fir provenances of the Western Cascade were also characterised as particularly fast-growing in Hesse (Germany). Based on studies of 7 experimental Douglas-fir plantations in Germany, Kleinschmit et al. (1979) reported that Washington coastal provenances were the best according to a number of indicators.

Conclusions

1. The best growth parameters (height, diameter and stem volume) were found in the group of coastal provenances, followed by the Western Cascade group and the continental group.

2. The most rapidly growing provenances were the Washington coastal provenances (Bremerton), and the Darrington, Newhalem and Idanha provenances of the Western Cascades in Washington and Oregon. These provenances were characterized by high resistance to the fungal pathogens *Rhabdocline pseudotsugae* and *Phaeocryptopus gaeumanii*. For future afforestations with Douglas-fir in Bulgaria, Darrington provenances can be recommended as they combine rapid growth and high productivity with resistance to the fungal diseases.

3. The test revealed statistically significant effects of groups, provenances and replications with regard to growth in diameter and statistically significant differences between groups and provenances for growth in height.

4. The slowest growth and the lowest productivity were found in the continental provenances 1 (Greenwood) and 2 (Keremeos) of Washington, 3 (Whitefish) of Montana, 21, 22, 23 (Bates), 35, 36, 37 (Canyon City) of eastern Oregon and 55 (Alamogordo) of New Mexico, which also proved very susceptible to *Rhabdocline pseudotsugae* and *Phaeocryptopus gaeumanii* and should be excluded from future afforestations with Douglas-fir in Bulgaria.

References

Ballian D., Mikić T., Pintarić K. 1999. Analiza uspijevanja pet provenijencija zelene duglazije (*Pseudotsuga menziensii* Mirb. Franco) u pokusu Batalovo brdo. Šumarski list 9–10: 423–430.

Ballian D., Mikić T., Pintarić K. 2002. Provenance trials with Douglas fir (*Pseudotsuga menziensii* (Mirb.) Franco) at Blinje site near Kreševo, Works of the Faculty of Forestry, University of Sarajevo, No 1: 9–18.

Chumakov A.E. 1974. Basic methods of phytopathological research. Moscow, 189 p. (in Russian).

Dundari A., Dhubhain A.N., Bulfin M. 2002. The productivity of Douglas fir in Ireland. Forestry 75: 537–545.

Eichhorn J., Roskams P., Ferretti M., Mues V., Szepesi A., Durrant D. 2007. Visual Assessment of Crown , Condition and Damaging Agents. 49 p. Manual Part IV. In: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. UNECE ICP Forests Programme Coordinating Centre, Hamburg. Available: http://www.icp-forests.org/Manual.htm

Feliksik E., Wilczynski S. 2004. Dendroclimatological regions of Douglas fir (*Pseudotsuga menziesii* Franco) in western Poland. European Journal of Forest Research 123: 39–43.

Georgieva M., Rosnev B. 2008. Resistance of Douglas-fir (*Pseudotsuga menziensii* (Mirb.) Franco) to Swiss needle cast. Nauka za gorata, No 4: 41–50. (in Bulgarian with Engl. abstract).

Georgieva M. 2009. Diseases on Douglas-fir (*Pseudotsuga menziensii* (Mirb.) Franco) and their influence on the species introduction in Bulgaria, PhD thesis, Forest Research Institute – BAS, Sofia, 134 p. (in Bulgarian).

Govedar Z., Ballian D., Mikić, T. Pintarić K. 2003. Success of different Douglas fir provenances (*Pseudotsuga menziesii* (Mirb.) Franco) in the scope of IUFRO programme on the test area "Crna lokva" near the Gradiška. Šumarstvo 3–4: 61–74.

Grozev O., Yonov N., Popov E. 1995. Status of some Douglas-fir plantations in the Region of Sofia. Proceeding of a Jubilee Symposium "100th Anniversary of acad. B. Stefanov (1894–1979)", 2–3 June 1994, Vol. II: 248–252.

Günzl L. 1984. Herkunftsemphehlungen aus den Douglasien-Provenienzversuchen der Forstlichen Bundesversuchsanstalt, Der land- und forstwirtschaftliche Betrieb, Heft 1 und 2: 1–5.

Iliev S., Petkova K. 1995. Comparative studies on growth in height of Douglas fir provenances (*Pseudotsuga menziesii* Mirb. (Franco), Jubilee Scientific Session 70 years of Forestry Education in Bulgaria. Sofia, Vol. I: 144–152.

Kleinschmit J., Svolba J., Weisgerber H., Jestaedt M., Dimpflmeier R., Ruetz W., Dieterich H. 1979. Ergebnisse aus dem internationalen Douglasien-Herkunftsversuch von 1970 in der Bundesrepublik Deutschland. Silvae genetica 28 (5–6): 226–245.

Lally M., Thomson D. 1998. Best seed origins for Douglas-fir. Coillte Research & Development, Information note No 17, Newtownmountkennedy, Co. Wicklow.

Perić S., Jazbec M., Tijardović M., Margaletić P., Medak J. 2009. Provenance studies of Douglas fir in the locality of "Kontija" (Istria). Periodicum Biologorum Vol. 111, No 4: 487–493.

Petkova K. 1989. Studies on Establishing Douglas-fir (*Pseudotsuga menziesii* Mirb. (Franco) Plantations in Some Regions of the Balkan Mountains. PhD thesis, University of Forestry, Sofia, 190 p. (in Bulgarian).

Petkova K. 1999. Comparative assessment of the height growth of 55 provenances of Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco). Forestry ideas 2: 48–59. (in Bulgarian with Engl. abstract).

Petkova K. 2004. Der Douglasienanbau in Bulgarien – Ergebnisse der Herkunftsversuche. Forum Genetik – Wald – Forstwirtschaft. Ergebnisse forstgenetischer Feldversuche und Laborstudien und ihre Umsetzung in die Praxis. 20–22. IX.2004. Teisendorf. Tagungsbericht: 82–95.

Petkova K., Ruetz W., Popov E., Tasheva S. 2008. Testing of American, German and Bulgarian Douglas-fir progenies in experimental plantations in Bulgaria. Austrian Journal of Forest Science 125 (2): 135–156.

Popov E. 1991. Studying the result of the introduction of Douglas-fir (*Pseudotsuga menziensii* (Mirb.) Franco) into Dimovets place – Kazanlak National Forest. Nauka za gorata 28: 10–18. (in Bulgarian with Engl. abstract).

Popov E. 1995. First results of eight years continuing provenance trial with Douglas-fir (*Pseudotsuga menziensii* (Mirb.) Franco) in the State Forestry Estate "Kostenec". Proceedings of Anniversary Scientific Session "70 Years Forestry Education in Bulgaria" 7–9 VI. Sofia, Vol. I: 230–238. (in Bulgarian with Engl. abstract).

Popov E. 2001. First results of eight years continuing provenance trial with Douglas-fir (*Pseudotsuga menziensii* (Mirb.) Franco) in the State Forestry Estate "Kjustendil". Third Balkan scientific conference, "Study, Conservation und Utilization of Forest Resources". Proceedings, Volume II, 2 Bulgarian 6 October 2001, Sofia: 60–68. (in Bulgarian with Engl. abstract).

Popov E., Petkova K. 2003. Growth in height in experimental plantations of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Proceedings of the International scientific conference "50 years University of Forestry", Sessions Forestry, Landscape Architecture: 92–95. (in Bulgarian with Engl. abstract).

Poryazov Y., Tonchev T., Dobrichov I. 2004. Handbook of forest measurement. Bulvark, Sofia, 419 p. (in Bulgarian).

Rau H.M. 2005. The international Douglas fir provenance trial in Hesse – Results up to age 27, Forst und Holz 7: 291–294.

Rosnev B. 1978. *Rhabdocline pseudotsugae* Syd. – fungus causing needle cast on Douglas-fir. Gorsko stopanstvo 10/11: 50–52. (in Bulgarian).

Rosnev B. 1983a. On the resistance of various species and forms of Douglas-fir, grown in our country against the fungus *Rhabdocline pseudotsugae* Syd. Reports of second national symposium of plant immunity. Plovdiv, vol. III: 227–234. (in Bulgarian with Engl. abstract).

Rosnev B. 1983b. On certain cases of withering of the Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) in our country. Nauka za gorata, vol. XX, No 2: 47–52. (in Bulgarian with Engl. abstract).

Rosnev B., Petkov P. 1986. Pathologic causes for deteriorating the state of health of certain coniferous plantations in Bulgaria. Nauka za gorata, vol. XXIII, No 3: 74–82. (in Bulgarian with Engl. abstract).

Rosnev B. 1987. *Phaeocryptopus* (*Adelopus*) *gaumannii* – fungus causing needle cast on Douglas-fir in Bulgaria. Proceedings Fourth National Conference of Botany: 204–207. (in Bulgarian with Engl. abstract).

Ruetz W. 1981. Douglasien-Herkunftsempfehlungen – ein Vorschlag für Bayern. Allgemeine Forstzeitschrift 41: 13–15.

Ruetz W. 1989. Die Übertragung wissenschaftlicher Erkenntnisse in die Praxis am Beispiel Provenienzforschung bei der Douglasie. Allgemeine Forstzeitschrift, Sonderheft 22/23: 563–565.

Ruetz W., Foerst K. 1984. Grundsätze für den Anbau der Douglasie in Bayern. Bayerisches Staatsministerium für Ernärung. Landwirtschaft und Forsten, 17 p.

Schultze U., Raschka H.D. 2002. Douglasienherkünfte für den „Sommerwarmen Osten”. Österreichs Ergebnisse aus Douglasien-Herkunftsversuchen des Institutes für Forstgenetik BFW-Wien. Forstliche Bundesverzuchsanstalt Wien: 126–195.

Tyler A., Macmillan D.C., Dutch J. 1995. Predicting the yield of Douglas fir from site factors on better quality sites in Scotland. Annals of Forest Science 52: 619–634.

Veen B. 1951. Herkomstenonderzoek van de Douglas in Nederland. Provenance research of the Douglasfir in the Netherlands, 130 p.

Zas R., Merlo E., Diaz R., Fernández-López J. 2003. Stability across sites of Douglas-fir provenances in Northern Spain. Forest Genetics 10 (1): 71–82.

FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

FOREST CADASTRE AND ENVIRONMENTAL IMPACT ASSESSMENTS IN THE SERVICE OF FOREST MANAGEMENT PLANNING

Vasileios C. Drosos

School of Forestry and Managment of the Environment and Natural Resources, Democritus University of Thrace, N. Orestiada, Greece / P.C. 682 00.

E-mail: vdrosos@fmenr.duth.gr

UDC 630.6

Received: 13 May 2010
Accepted: 14 December 2011

Abstract

The main concern of a forester is to be able to collect and maintain accurate and detailed data in order to cope successfully with current needs but also to anticipate future situations. Generally speaking, the Cadastre is a tool for planning, rationalization and development of the country and environmental protection. The development of mountain areas consists of the development of anthropogenic influences, which – like every form of economic development – is usually accompanied by negative environmental impacts. Thus it is necessary to define the criteria considering Environmental Impact Assessment (EIA). The aim of this paper is to investigate and to clearly demonstrate the contribution of forest cadastre and EIA in Forest Management Planning. Forest cadastre, which is a special cadastre, should be in line with the technical specifications of the National one. The total cost is not just techno-economic, but also environmental, all of which constitutes the cost of the work. We must develop practical and objective methods in order to assess the environmental impacts in alternative solutions in order to determine the location that makes the work compatible with the natural environment. There can be no development and rational management of the forest without a forest cadastre. On the other hand, however, most of the country's forests are degraded and of low productivity and most of them play a protective role. So the EIA is essential for the planning of any work.

Key words: compatible construction, Environmental Impact Assessments, Forest cadastre, Forest Technical Works, rational management.

Introduction

Forest ecosystem produces many goods and services without the intervention of human management. But ever since human began to administrate forests intensively, the relationship between goods and production has changed. The current on forests and forest land has a direct impact on the system of human society which will increase further in coming years. Indeed, the effort to regenerate and create forests today (artificial or natural) will bear fruit after 60–70 years when the climatic conditions will have deteriorated. Concern of the forester is to be able to collect and maintain accurate and detailed data and information in order to enable him to cope successfully with current needs but also anticipate future situations.

In order to design a specific forest policy and one rational development planning and a successful decision making; an accurate knowledge of the real condition of forests in our country and the consequences of any attempt to use them is considered to be necessary.

In general, the Cadastre is a tool for planning, rationalization and development of the country and for the protection of the environment. Regarding the zoning planning, it is a strategic tool for sustainable development, with respect to the environment.

The development of mountain areas is related with anthropogenic influences, like any form of economic development, and is usually followed by negative environmental impacts. The peculiarity lies in the fact that this anthropogenic action often degrades the natural and constructed environment, which is also a raw material for its development. Thus it is necessary to define the general principles of zoning planning in mountain areas and the criteria governing Environmental Impact Assessments (EIA).

Environmental Impact Assessment is a thorough and documented scientific work and research aiming to assess the effects of certain public and private projects on the environment, in order to obtain a balanced development of national space which will become an easy and effective effort to prevent pollution and environmental degradation by evaluating the direct and indirect impacts of projects and activities (Source: N. 1650/1986).

The vast majority of onshore natural environment of Greece is forests and woodlands. The most effective tool available today to enhance the definition and future management of these areas are the forest maps.

On these maps:

- The boundaries of forests and forest areas in general of every region are accurately surveyed.

- The grass and other areas not covered by forest law are surveyed.

-The boundaries of all other areas which are currently used for other purposes (agricultural land, settlements, etc.) are surveyed.

These maps are approved by the proper public services, and when approved, it gets posted, so that every citizen can make any objections to any patch of land has any different view.

Once finalized their form, these are official public documents, available both to citizens as well as to anyone else might be interested. The “Forest Cadastre” established by the Law 248/1976.

The effort failed in the process, for three main reasons:

1. The crews did not have the means or the know-how which are currently available (no orthophotomaps, appropriate hardware and software, etc.).

2. The design that was made did not allow the rapid development of the project (those crews did in fact cadastre, which elaborated the same time and the titles of property owners who have parcels within or on the edges of forests lands).

3. The maps would be held by civil servants, a situation which leads to delays and cutbacks in recruitment, spe-

cific working hours, constant changes of Heads, Directors, Ministers, etc.

The last major effort which was made in our country concerning the preparation of forest maps is under the studies of the National Cadastre.

In this context it is indicated that apart from the purely cadastral information in open cadastre, it can be registered at any time in the future along with additional information as a tool to pursue particular objectives of rationalization and development of the country.

The success of an integrated cadastral system depends on the successful meeting of the objectives of forest land protection, forest environment and on how much it would provide secure information useful in all areas of forestry activities and for the rational development of forestry policy.

The implementation of these require the establishment of cadastral offices, which will be accommodated by the organization, collection and processing of information by creating data bank and land information system.

The term bank means the gathering, in an organized way, of all technical, legal and economic (forestry) data for each cadastral unit.

Land Information System (LIS) is a unified geodetic reference system consisting of the collection, updating, processing, distribution and integration of data among themselves and with other systems that contain land data (e.g. Environmental), so that is a decision support tool, both for legal, administrative and financial issues, and design and development that the bank is part of the system.

A G.I.S. (Geographical Information System) is an integrated system of collection, storage, management, analysis and performance information relating to events taking place in geographical space.

The management of cadastral information, and related topics, such as inventory, mapping and forest management with the current state of technology of computers are relatively easy to place. The digital topographic charts and tables represent the digital file, which should follow the standards of digital data transfer in a Geographic Information System (GIS). The file generated by digitizing with certain standards of accuracy and resolution and proved to be accurate by putting the produced to the original map.

The D.T.M. and GIS have a wide range of applications in forestry operation with main representative the cadastre as well as environmental impact assessments (EIA), etc.

The aim of this paper is to investigate and to clearly demonstrate the contribution of forest cadastre and EIA in Forest Management Planning.

Material and Methods

Regarding the creation of forest maps of a region

a. Usage and interpretation of the available aerial photographs (starting from 1945 aerial photographs, which are the oldest available aerial photographs covering almost the entire country and recent aerial photographs (A/P) according to the requirements of National Cadastre and comparison of those with the past ones in order to find differences in borderlines).

b. Extensive earthly inspections on the spot are taken place in order to investigate on the ground, the results of the interpretation.

c. Take into account and survey all final administrative acts issued by public services and identify particular plots of land (e.g. land declared to be reafforested, forest lands allocated for agricultural use, etc.) and finally.

d. With the help of Geographic Information Systems (GIS) process all this information and create the corresponding maps (in both printed and digital form), and also create the corresponding databases. All these are now assigned to each parcel of land that is characterized by the parameters (for example, traditionally forest lands, traditionally agricultural areas, land that was in the past forests and then changed use, etc.).

Finally, it should be pointed out that once the forest maps of an area are drawn up, at the same time the best and most modern topographic base that can be available to a scientist is available for this area (Digital Terrain Model and orthophotomaps-scale 1:5000) (Figure 1) in order to manage these specific areas (to organize the fire protection, to design in space and time the individual contributions, etc.).

Therefore, the old and the current dispute could have wide swath of forest land up to 30 meters. Next step is to quest for ways to reconcile the results of the previous and current situation and focus on the most recent borderlines whose application to land is more accurate, easier and "causes fewer reactions". Even for the boundaries alignment which in bushy vegetation reaches five meters at the expense of forest land.

Regarding EIA

Steps in the Environmental Impact Assessment are:

- Analysis of the environmental effects of the opening.
- Analysis of the criteria affecting the design and construction of individual forest road.
- Analysis of the criteria for impacts of road construction absorption.
- Evaluation of the criteria using terrain measurements data, photogrammetry and photointerpretation assessments and GIS.
- Grading the criteria with objective score, namely any factor that affects the impact of highly rated (100) when it does not affect at all.
- Assessment from a number of alternatives that has the highest percentage score and met the compatibility coefficient of work with the environment.

For the achievement of the research goals we used:

Digital orthophotomap of the research area and the respective digital terrain model (DTM) that resulted from the photogrammetric process of a pair of aerial photographs in a digital photogrammetric station were used. So the digitization of the land uses and the forest road network make possible and finally the inference reliable measurements regarding to the accurate estimate of the area for each land use and the length of the existing forest road network (Drosos et al. 2006).

The last management plan of the forest from which we utilized factors such as harvesting, management form, the already existing forest species, tree age etc.

The method, which would be applied, should be practical, effective and easy to

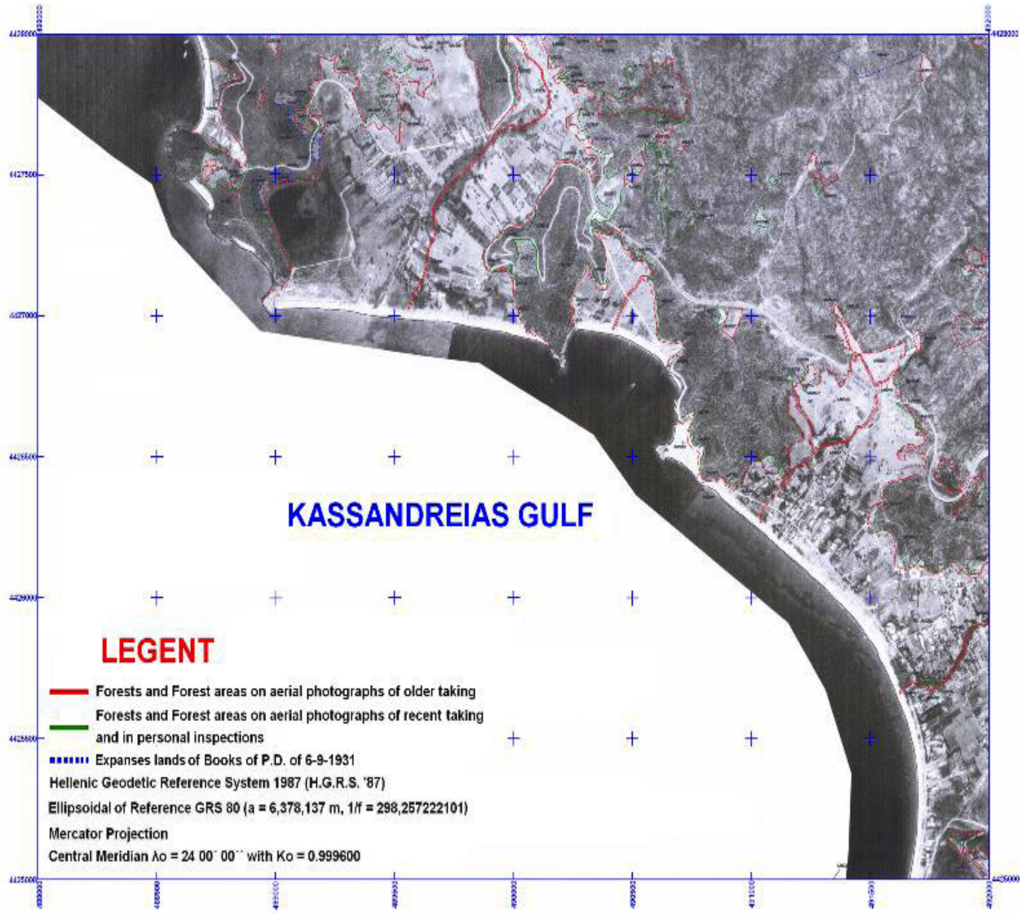


Fig. 1. Digital Orthophotomap of Toroni in Chalcidice Prefecture.

use. For this reason we have set a number of absorbency and intensity criteria.

The grading of these criteria depends on the following principle:

We accepted a situation as ideal (=100%) for the forest protection by road construction. The percentage of deviation from this ideal situation will be subtracted from 100%. The result will be the grading of the criteria.

In order to define the intensity of the human impact of the existing forest opening-up works and the exploit of the forest to the natural environment, we used respective criteria (Buwal 1990, Mader 1990, Heinimann 1994, Doukas 2004). At the same time, the absorbency and intensity criteria and their weights came from a questionnaire sent to specialist scientists (Giannoulas 2001). More specifically, the intensity criteria were used are shown in Table 1.

The next parameter studied was the capacity of the forest ecosystem to ab-

Table 1. Criteria of intensity and absorbency.

	INTENSITY			
	Criteria	**Grad, %**	**Weights**	**Sum**
1	Road density			
1.1	Skidding with draught or load animals		3	
1.2	Skidding with mechanical means or combination from animals and mechanical means		3	
2	**Percentage of tractors use in opening up**		2	
3	**Percentage of opening up**		3	
4	Skidding direction		1	
5	**Traffic frequency and motor vehicle types**			
5.1	Exceeding percentage of traffic frequency		2	
5.2	Exceeding percentage due overloading		2	
6	Forest roads' categories		2	
7	**Position of roads**			
7.1	Distance of water flows		3	
7.2	Distance of forest boundaries		3	
7.3	Problematic (unstable) soils		3	
	Total			
	Average value $C_I = \sum(I \times W_I) \times (\sum W_I)^{-1}$			
	ABSORBENCY			
	Terrain conditions			
	Forestry criteria			
1	Kind of coverage		3	
2	Forestry species		3	
3	Management form		3	
4	Age		3	
5	Tree height		3	
6	Productivity		3	
	Topographical criteria			
7	Slope of ground		2	
8	Exposition		2	
9	Relief		2	
	Social criteria			
10	**Distance from**			
10.1	Tourist recreation area		1	
10.2	National road network		1	
10.3	Railway		1	
10.4	Archaeological site		1	
10.5	Adjacent big city		1	
10.6	Adjacent village		1	
10.7	European path		1	
10.8	Natural or artificial lake or river		1	
	Total			
	Average value $C_A = \sum(A \times W_A) \times (\sum W_A)^{-1}$			

sorb the impact of the works. By absorbency, we mean the extent to which the effect will be absorbed by the ecosystem with time, as well as the number of the recipients of the effect.

The absorbency criteria are divided into 3 categories: 1st forestry criteria, 2nd topographic criteria and 3rd social criteria. The weights of the criteria are: three (3) for the forestry criteria, two (2) for the topographical criteria and one (1) for the social criteria (Table 1).

The final grading of intensity (I) for each criterion is provided by the product of each criterion value multiplied by its weight coefficient in order to find the barycentric mean. Similarly, the absorbency (A) of the forest ecosystem is calculated by each criterion value multiplied by the respective weight coefficient with a view to find the barycentric mean.

The value (%) that estimates the impact of intensity (I), which is not negative, is multiplied by the respective weight coefficient (W_I) and is divided by the sum of the weight coefficient values so as to extract the barycentric mean:

$$C_I = \sum(I \times W_I) \times (\sum W_I)^{-1} \qquad (1),$$

where $\sum(I \times W_I)$ and $\sum W_I$ are the sum of the estimate impact of intensity multiplied with the respective weight coefficient (W_I) and the sum of the weight coefficient values, respectively, for matrix as size %.

Likewise, the absorption (A) of the forest ecosystem is multiplied by respective weight coefficient (W_A) and is divided by the sum of the weight coefficient values with a view to extract the barycentric mean:

$$C_A = \sum(A \times W_A) \times (\sum W_A)^{-1} \qquad (2),$$

where $\sum(I \times W_A)$ and $\sum W_A$ are the sum of the absorption's estimate multiplied with the respective weight coefficient (W_A) and the sum of the weight coefficient values, respectively, for matrix as size %.

The rates C_I and C_A represent the indexes concerning the compatibility degree of the forest opening-up works with the natural environment.

Results and Discussion

1. Analogical forest maps should be gradually replaced by digital. In the meantime, however, the training of personnel in the forest service on the creation of a digital silvicultural map that will come from the digitization of the existing silvicultural map would be appropriate. Also, we should bring on the cadastral boundaries from photogrammetric process and field inspections, to make better use from employees and citizens that have become accustomed to the use of traditional silvicultural map.

2. The cadastral data held on Cadastral offices are not only technically and legally, but also additional information as a tool to pursue particular objectives and organizational development of the country. Particularly for forests and woodland forest maps, these are themselves a centralized information material of the forest ecosystem. The rational management, the readjustment, the protection of these data in the context of a multidimensional cadastre as intended to be the "National Digital Cadastre" is a forestry subject. The sheer volume of valuable data and information gathered from the forest service for all areas of the country under forest cadastre can be better and more effective if

added to the proprietary data bases of cadastral offices.

3. The national spatial planning of land uses, assumes that given the nature of the lands in this country, and based on this character designed and adopted for future use. For this reason, one of the most valuable "tools" of the final boundary is and the forest maps.

4. Apart from their contribution to the national land use planning is an important contribution of the cadastre and in protecting the natural environment:

i. The forest maps are the only means available to the Greek government to map and protect its land assets.

Features mentioned that the only essential property statements made by Greek government in the studies to date cadastral survey were based on forest maps.

ii. The preparation of forest maps in a region practically means the end of all underground transactions and all the corruption that can exist today in the forest or non-identification of individual areas of this region. Everyone knows now (officially proclaimed) the nature of each area and it does not change and deteriorate with any kind of promise or interventions.

iii. The existence of forest maps in an area stopped most of the suffering, and the continued litigation in this matter, both citizens and all relevant services.

iv. Finally the forest maps are an explicit constitutional obligation of the state, both by the Constitution of 1975 and the Constitutional Review of 2000. Nevertheless, we continue to be here for 34 years (since the passage of Law 248 of 1976) the only EU country in which there is currently no forest cadastre (Register, forest maps, borderline), for its entire territory.

In the era of revolution of knowledge/technology, when knowledge rapidly is considered to be old and new one is created "in the blink of an eye", the importance of the parameter "lifelong learning" in the effort to link research to production is obvious. An education with more theoretical training in many fields and more practice in technology, which enables foresters to be more flexible, efficient and competitive in the Greek market on close, is necessary. It is wrong to reduplicate uncritically standards which are effective in other countries.

A key consideration for any industry scientist is to survey and study the parameters affecting the link between research and production activities in every country.

Specifically with regard to the forest engineer there are two items that require linking research to production, i.e. continuous education:

- Forest cadastre and
- Environmental impact assessment on Forest works, particularly in opening up and road construction.

Therefore, sufficient knowledge of technology is required, both on technical training, and subsequently at the Cadastral office in order to create land data bank.

Regarding the EIA, it should be noted that the writing out of EIA in accordance with EU directive is mandatory in every assessment project, that changing land use. The total project cost is no longer just technical, economic and environmental, all of which constitutes the total cost of the project.

We therefore propose practical and objective methods for assessing the environmental impact of alternative solutions in order to determine the location that makes the project compatible with the natural environment.

The most important benefit, however, expected to result from the development and dissemination of EIA, is the public awareness towards environmental problems. The process of approval of a study published causes of environmental problems, and discussion about them. Dealing with environmental problems train a social class conscious, and ultimately leading to improved EIA why the authors should meet the criteria of informed consumers.

It is important, however, to stress that while the proper use of the concept of EIA only benefits may have on the site, misuse can cause various problems. For example, the risk that EIA a bit of a pointless bureaucratic process is important. Still, there is a risk to use EIA by interests that want to thwart any development project. By far the operation of the institution has reported several weaknesses, which are believed to be eliminated in the future.

The designer of environmental impacts should be targeted, that ultimately provide protection to the natural environment because the source – the basis for economic sustainable development, social improvement and prosperity.

Furthermore, it should be reassured that certain principles for the rational construction of Forest works will be maintained, but this will not damage the environment; on contrary, it will contribute to a sustainable management and development of forest areas.

Environmental protection should begin on the basis of established principles of forestry and nature protection, the premeditation and continued in the design and construction and not for the first time after construction or during construction of a project.

The various criteria and the review procedure described above constitute a useful manual on forestry practice that tries to interpret the overall effect of an opening up network in the environment, so that the opening up can be conducted as friendly as possible to the environment.

Development has been the flag of every country in the world. But what development is meant? We meant the residential development or the qualitative one or by the way the touristic development or sustainable one?

In order to achieve the suitable development necessary land planning use and forest cadastre (forest maps) is needed, meaning the essential foundation for development and instrument of land policy exercise. The aim of the cadastre should be the encouragement with respect to the environment with the help of land use maps and zoning plan, in order not to cut the branch (Forests and woodlands, ecosystem) on which the development sits.

References

Buwal Hg. 1990. Umweltverträglichkeit–sprüfung (UVP) bei Meliorationen. Wegleitung und Empfehlungen. Mitteilungen zur Umweltverträglichkeitsprüfung (UVP) No 3. Bundesamt für Umwelt, Walt und Landschaft. Bern.

Doukas A-K. 2004. Forest Constructions and Natural Environment. Giaxoudis Publishing. Thessaloniki.

Drosos V.C., Giannoulas V.J., Doukas A–K.G. 2006. General forest opening up works by the use of modern technologies: An evaluation of the intensity and absorbent capacity. In: Proceedings of the first International Conference titled: "Sustainable Management and Development of Mountainous and Island Areas", vol. 2: 229–233.

Giannoulas V. 2001. Forest opening-up with modern machinery. Technico-econmic, enviromental effects. Dissertassion, Aristotle University of Thessaloniki.

Heinimann H. 1994. Umweltverträgli–chkeit forstlicher Erschließungen. Konzept für die Abwicklung, die Analyse und die Bewertung. Schweiz. Z. Forstwegs 145: 139–157.

Mader H-J. 1990. Ökologische Aspekte des Waldwegebaues. Österreich AFZ 46/47: 1184–1187.

FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

GEOINFORMATICS – RECORDING AND PROCESSING SPATIAL AND NON SPATIAL INFORMATION

Vasileios C. Drosos* and Liampas G. Sarantis-Angelos

School of Forestry and Managment of the Environment and Natural Resources, Democritus University of Thrace, Ath. Pantazidou 193, P.C. 682 00, Orestiada, Greece. *E-mail: vdrosos@fmenr.duth.gr

UDC 004

Received: 13 May 2010
Accepted: 24 December 2011

Abstract

The rapid development of technology and the broad use of computers during the recent years have resulted in new emerging opportunities across all technical domains. Thus, there have been developed the ambitious Digital Terrain Models (DTMs) to exploit these opportunities and leverage their capabilities for the common good. The DTMs provide the basis for developing a wide range of applications related to earth sciences. To be more specific, the former in Geoinformatics enable the possibilities of modelling, analysis and performance measurement of spatial phenomena related to topography or other technical areas with similar spatial properties. The DTMs can be used in conjunction with the Geographic Information Systems (GIS) in order to create a system which could be able to provide analytical data and information over terrain properties. In this essay a combination of DTMs with Geographical Information Systems (GIS) is undertaken, in an effort to create a hybrid out of these technologies. The initial thinking was to create a digital database that could provide comprehensive information over the number of fires, land areas and living species and finally the reaction time of the forest office commissions for the entire Greek state. What is more, a secondary objective was to monitor the efficiency degree of land exploitation by using DTMs in a targeted area. To a further extent, the combination of DTMs' information data such as vegetation, air temperature and wind direction, can contribute better in more efficient ways of forest fires prevention and suppression. In addition, the combination of the former along with the lands' efficient exploitation offers unlimited possibilities of spatial planning applications within the national digital cadastre. Subsequently, there are in our disposability unlimited scheduling capabilities to reduce arbitrary structure, violation of forest and other public territories, and an urban and regional environmentally friendly planning. To sum up, the DTMs assist us in a better and more rational development, protection and enhancement of mountainous areas.

Key words: digital database, digital terrain model, forest fires.

Introduction

The concept of land exploitation by human is to meet his diverse needs such as nutrition, housing, relaxation, financial activities, and cultural, educational, religious and other purposes (Arvanitis 2004). The existence of cadastral maps, cadastral records and mortgage consolidation is necessary for the synthesis of cadastre and especially for the inclusion of changes in land use of one area (Resnik and Bill 2003).

In general, digital terrain models are the mathematical approach to the natural terrain. Characteristic tools include the contour diagrams of elevation, but in a digital format suitable for computing processing. Initially the methodology and the creation of 3D digital terrain models were developed from Miller and Laflamme (1958). The necessity to import the obtained data of ground and topographical diagrams into GIS and CAD programs led us to the digital terrain models which are widely used nowadays (De-Cambray et al. 2007).

The technological progress and the increasing role of computers have created new possibilities for harnessing the conventional-analogue model (i.e. diagrams and orthophotos) into the digital model. The digital model is defined as the automation in the identification of the original data, and the organization of the latter to form a database, which results in a set of known data with ground provision in a square grid (grid) or triangular irregular network.

Within the frame of Geoinformatics, DTMs enable surface modelling and performance analysis of spatial phenomena related to topography or other areas with similar spatial characteristics. Modelling procedure and digital data processing of the earth's natural surface can be seen as extensive components of GIS products that are independent from the plane data components without being relevant to the conventional processing functions (e.g. topology of polygons, networks or manipulation of normalized data).

It is worth mentioning that because the non-spatial data describe some characteristics of an object / component, they are also known or referred to as descriptive data. The descriptive data may be non-spatial characteristics of a spatial object, such as name, classification, colour, and can be either quantitative or qualitative.

The "spatial address" of a property (x, y) can be identified easily, thus it is classified as spatial data and its position remains unchanged. However, the owner of the property can change over the time and thus it is classified as descriptive data. Through its operating structures and the variety of available GIS software capabilities, there is in our disposal an interactive relationship between spatial and descriptive data. It is an appropriate way to present the geographic objects in precise patterns. However, this is not the recommended way for data that is characterised by a continuous distribution in a surface.

In Greece, during the last 25 years, forest fires have increased in terms of conflagrant area volume. It is disappointing that the overall burned areas increased on average three to five times more than in the last century. It is observed that careless operations and audacious activities (42.8%) are to be blamed for forest fires. The majority of these activities constitute of the burning of stubble after harvest period, the burning of dried tree branches and weeds in fields, orchards and gardens. It is worth mentioning that 20 years ago the burning of fields and weeds constituted only the 24% of these unfortunate events. This problem also exists to other countries as the act of burning stubble fields, etc. is also mentioned as a significant cause of fires in Spain and Great Britain. The factors that determine the risk coefficients of fire are divided in two categories. Firstly, there are the permanent factors (i.e. climate, sun radiation, natural hazards, topographic configuration, type of forest combustible materials, and exposure to prevailing wind). Secondly, we have the variable factors (i.e. climatic factors, barometric pressure, state of vegetation, fuel moisture, availability and homogeneity of burning material, initial proliferation capacity, inflammable sources and other external factors). In Figure 1 there is a model of forest fires' risk profile, which is provided by Kailidis and Karanikola (2004).

In this work has been an attempt for recording and processing spatial and non spatial information with the combination of DTM and Geographical Information Systems (GIS), within the scope of Geoinformatics.

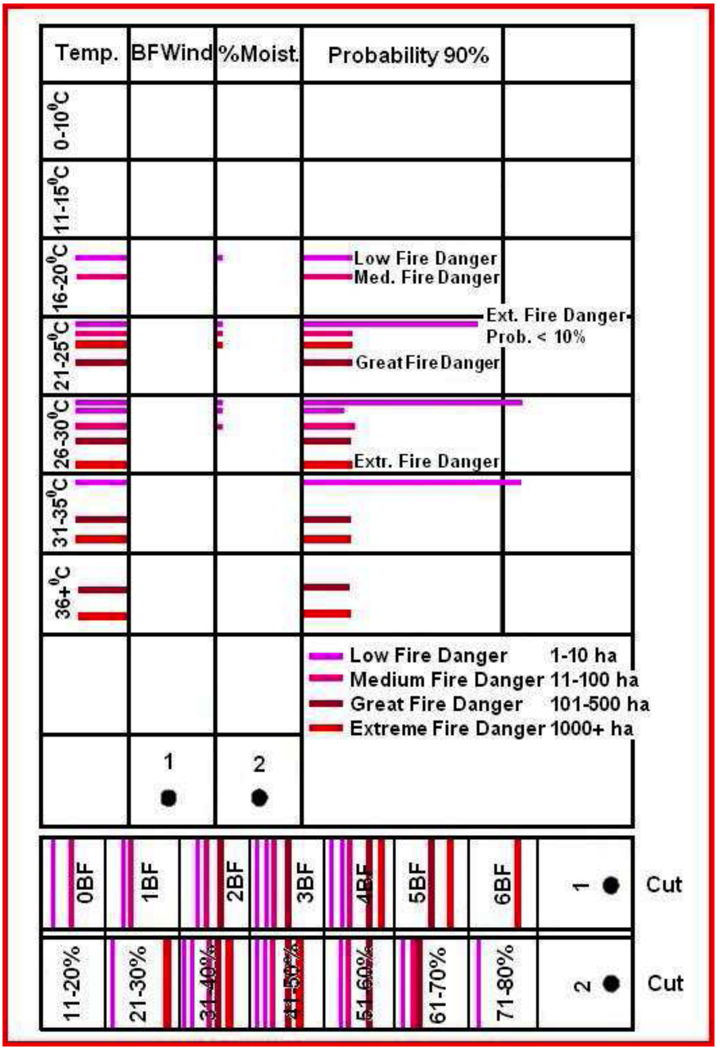


Fig. 1. A model of forest fires' risk profile.

Material and Methods

In order to create a digital database that could provide comprehensive information over the number of fires, land areas and living species and finally the reaction time of the forest office commissions we were used as research area the entire Greek state. Furthermore, the development and processing of three-dimensional digital model of the suburban forest of

Thessaloniki (Seix-Sou) was made using the software package Civil 3D of Autodesk corporation. The suburban forest of Thessaloniki, known as Seix-Sou, extends over the hills surrounding the city between 50–450 m above the sea level. This forest area is extended in a total area of 30,000 acres and it primarily consists of coniferous species (Figure 2). However, in July 1997, the suburban forest of Thessaloniki suffered a terrible ecological disaster, as 55% of its total area (16,640 acres) was burned. The identification of the area being researched was defined with the use of digital photogrammetric method.

A set of aerial photographs (A/P), which had been taken in 1994, were used for the project. After getting digitized (scanned) by a special photogrammetrical scanner, they were edited using the software package Leica Photogrammetry Suite (LPS 9) of Leica Geosystems Corporation.

The relative automated generation of a Digital Terrain Model (DTM) was realized through the application of automatically correlated homologous pixels using the standard frames of the radiometric values of the pixels (area based matching). This method is commonly used in the digital photogrammetry (Wolf and Dewitt 2000). What is more, LPS 9 software allows the generation and the use of the digital images' pyramids in order to improve the final results. The images' pyramids form a helpful tool for identifying the appropriate initial values which are used to further determine the best possible solution to the problem of digital correlation (Kraus 1996). The final derivatives of the photogrammetric process of the aerial photographs (within a research area), are the digital orthophotos for the year 1994. These derive from the differential regression of A/Ps, by eliminating the positioning errors that are entailed due to the terrain morphology/variations. The production of digital orthophotos is the first, fully automated digital procedure in digital photogrammetry (Baltsavias 1996). Then, the researchers created geographic vector data (polygons and lines), based on the interpretation of the study area. These, later, were associ-

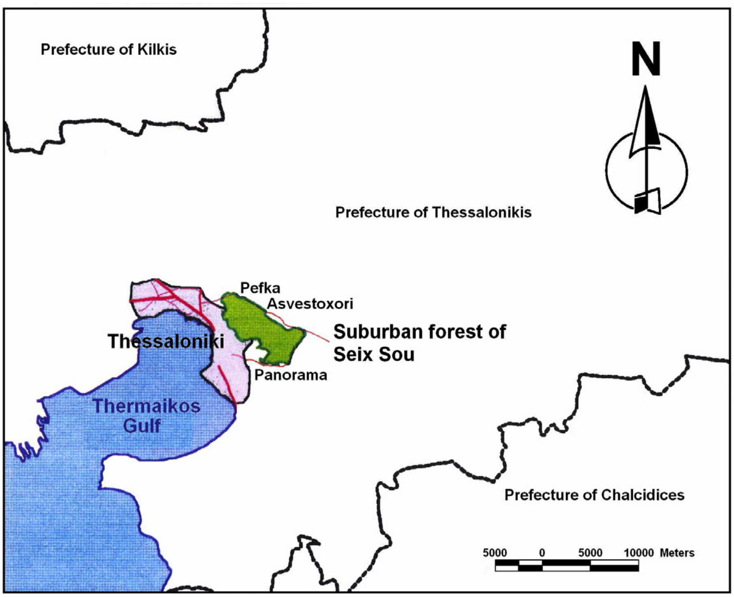


Fig. 2. Orientation map of study area.

ated with the descriptive data within the geographical database of Civil 3D. After defining the relevant topology, the planimetry of the polygons was carried out and the total area for each land use was calculated. Then, the production of the final orthophotomap was followed.

The Civil 3D is an integrated software application of Autodesk for mapping and development of GIS within the environment of AutoCAD. It combines the design capabilities of GIS and the use of surveying efficiency, calculation and design tools of digital terrain models. These characteristics are referred to the specialists of applied design GIS systems, and to surveying and design of technical works.

The ArcView Spartal Analyst package provides an effective way of presenting and analysing geographical objects of this type (It sounds a bit strange to use the term "objects", but is an appropriate one). Instead of being designed as shapes, they are separated on the surface-edge of an anaglyph on which they are represented in an identical size of rectangular cells. Each cell is filled with a numerical exponent that stores the value of the object in the site. So, if there is represented the average daily temperature in Celsius degrees (°C), the cells would have values like 13, 20, 26 etc.

Results and Discussion

With the help of Arc view GIS, classification of the burned species due to forest fires during the years 1992–1997 measured in 1,000 sqm per forest office in Greece is presented. This classification depicts grassy areas and areas with evergreen broadleaves vegetation. Furthermore, classification of the burned areas measured in 1,000 sqm per Greek prefecture throughout the years 1999–2002 is presented, according to the statistics of the fire brigade. The classification is presented through graded color shades of red, which appear in serial number.

As far as the evergreen broadleaves vegetation is concerned, the areas, which have been in danger for the period 1993–1997 (Figure 3), are mainly Southern Greece, Crete and some parts of Western Greece. Large expanses of grasslands have been burned down over the period 1993–1997 (Figure 4) exclusively in Northern Greece, mainly in Northwestern Macedonia and Thessaly and less in Epirus, Thrace and the Islands. On the contrary, in Southern Greece (Central Greece and Peloponnese) the burned grassy areas are negligible.

The overall burned areas in Greece through the years 1999–2002 (Figure 5), according to the fire brigade's information, are differentiated (with the common feature of the quantity of fires).

As a result, in 1999 significant areas in Thrace and Thessaly have been burned down and Macedonia as well as the Northern Aegean Islands follows in this year. In 2000 extended areas in Central Greece, Peloponnese and the prefecture of Evros have been burned down. Finally, in 2001 and 2002 uniformity is presented, as the most burned areas are centralized in Peloponnese and Central Greece, but they differ in Thrace and Crete respectively.

The science of forest fires demands that we should avert the fire spread-

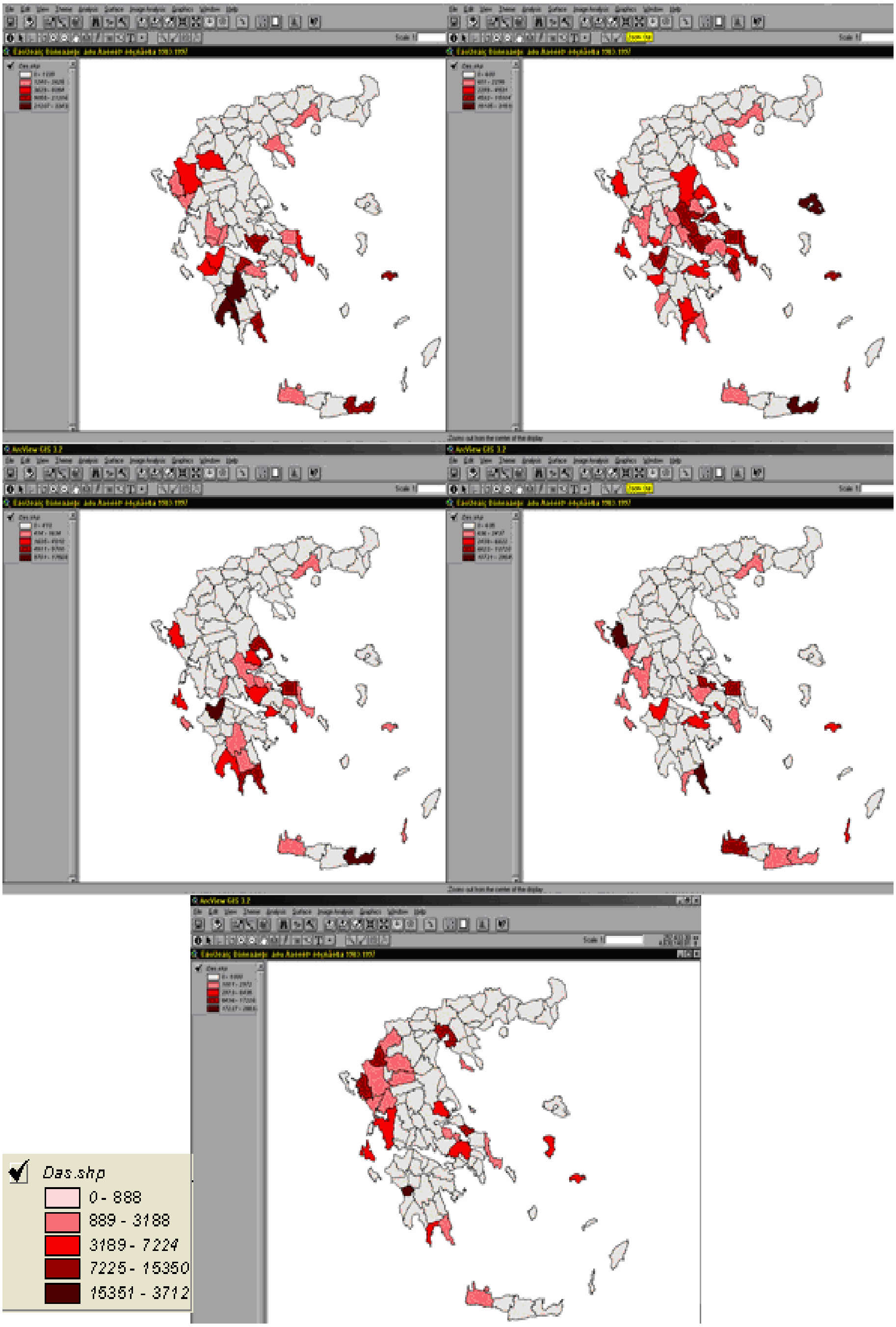


Fig. 3. Burned broadleaved evergreen 1993–1997.

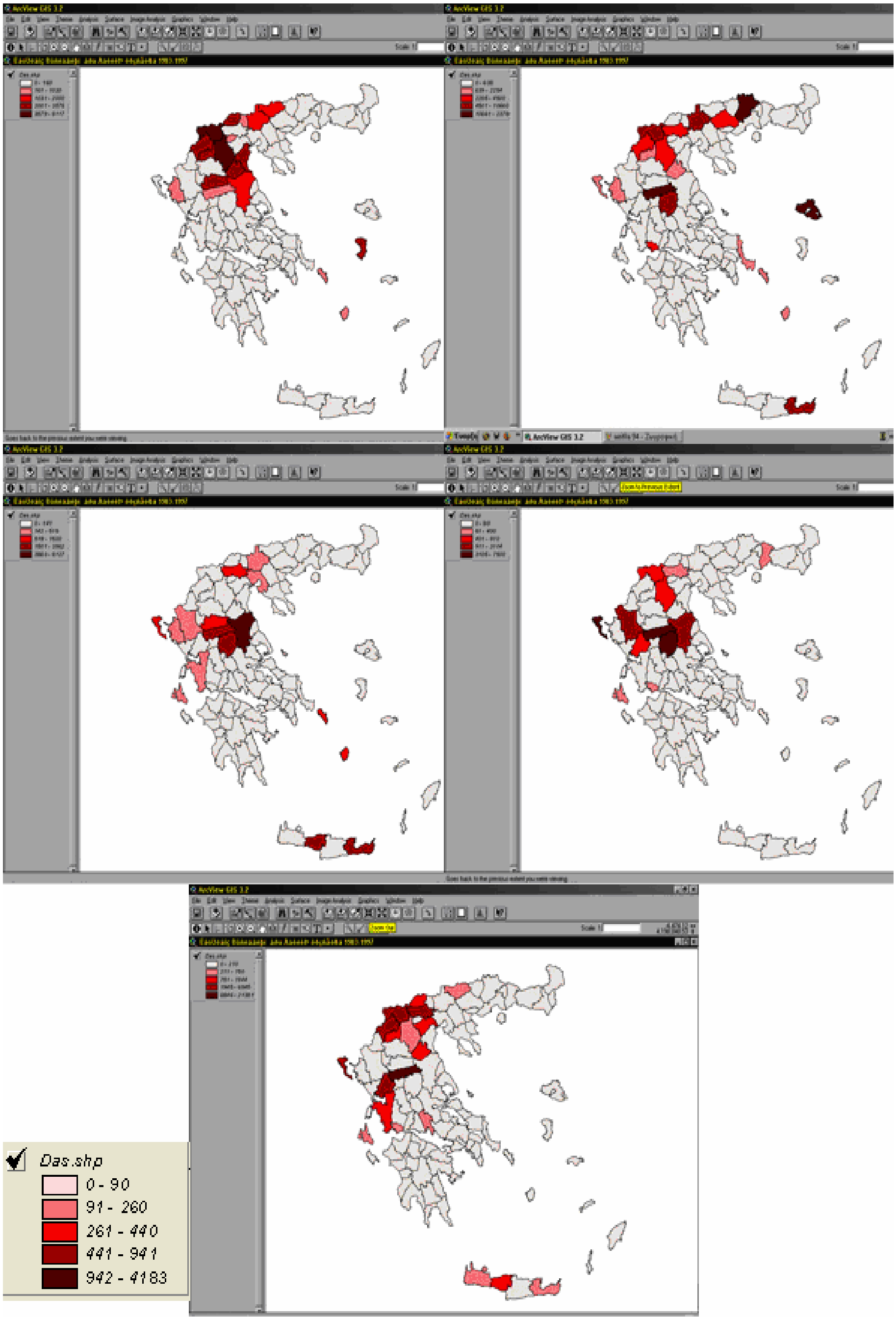


Fig. 4. Burned grassy areas 1993–1997.

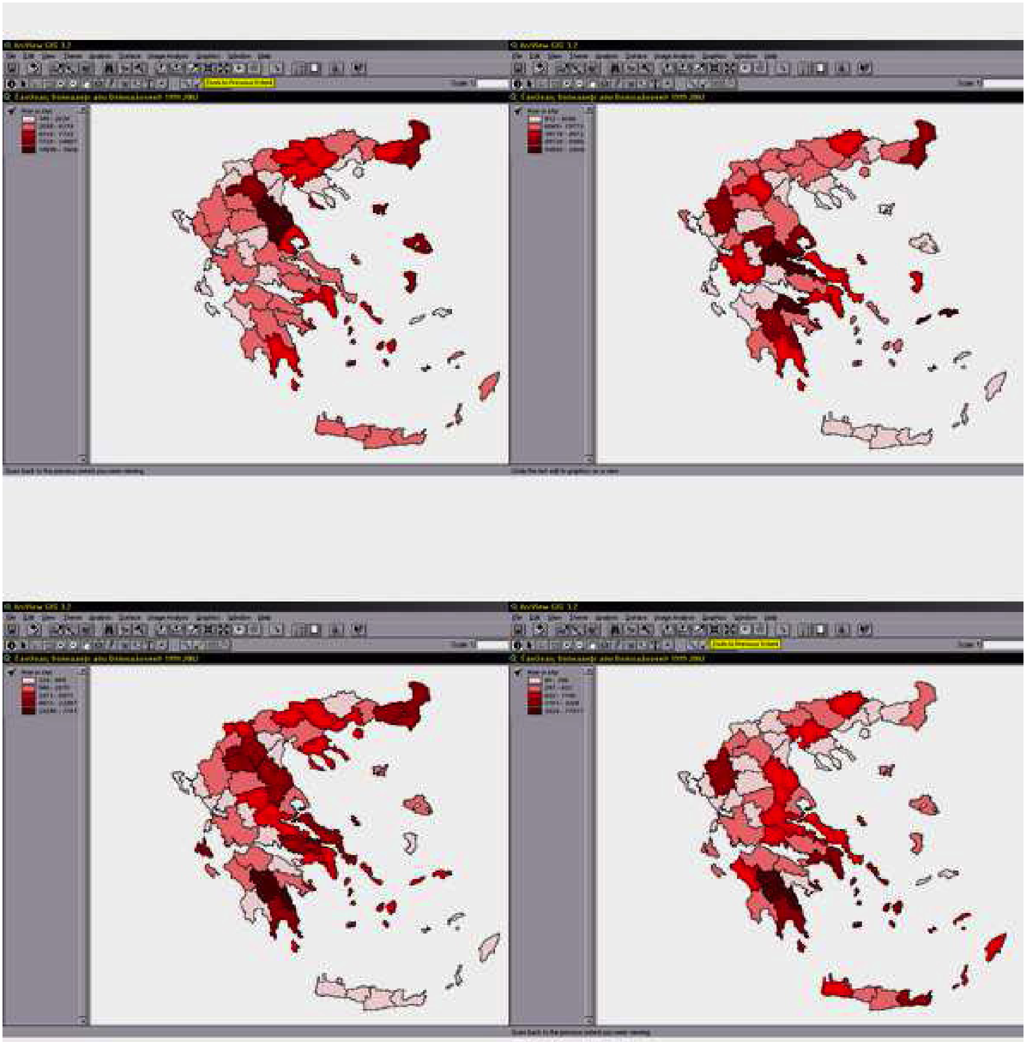


Fig. 5. Overall burned areas 1999–2002.

ing and extinguish small fires. This means, that we should arrive as soon as possible in the location of fire, as to put out a small fire. Given the fact that the fire is immediately or almost immediately noticed, the fire administration center or the nearest fire vehicle is notified; the appropriate vehicles are dispersed throughout the forest, in specific posts and not outside the fire brigade office. The first 15 minutes are considered to be the ideal time of reaction. Until then the extinguishing of fire should have been started. The firefighter crews should be well trained, so that they begin the extinguishing in just few minutes after their arrival in the location of fire. For example in 1983 the majority of fire administration centers were notified in 10–19 minutes but in 1993 in 19–27 minutes (Figure 6).

In Figure 7 we have the TINs model of the suburban forest as it is created from the digital photogrammetric procedure and in Figure 8 shows the three-dimensional representation of Seix Sou from the Civil 3D of AutoCAD. Particular emphasis is given to maps of land use in suburban areas as it is vital not

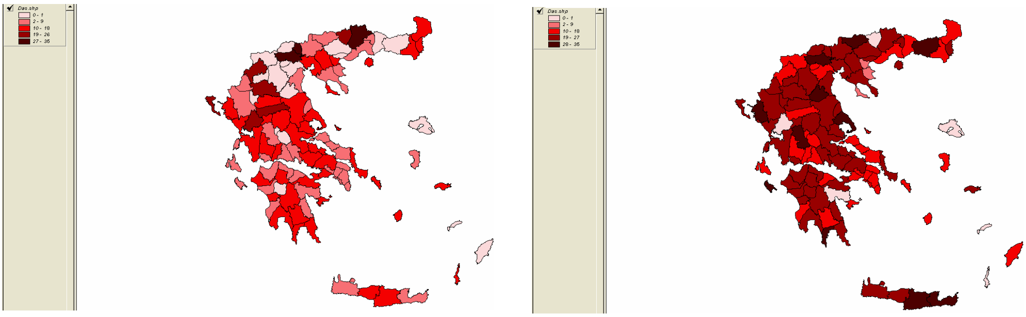


Fig. 6. Notified Fire administration center in 1983 and 1993.

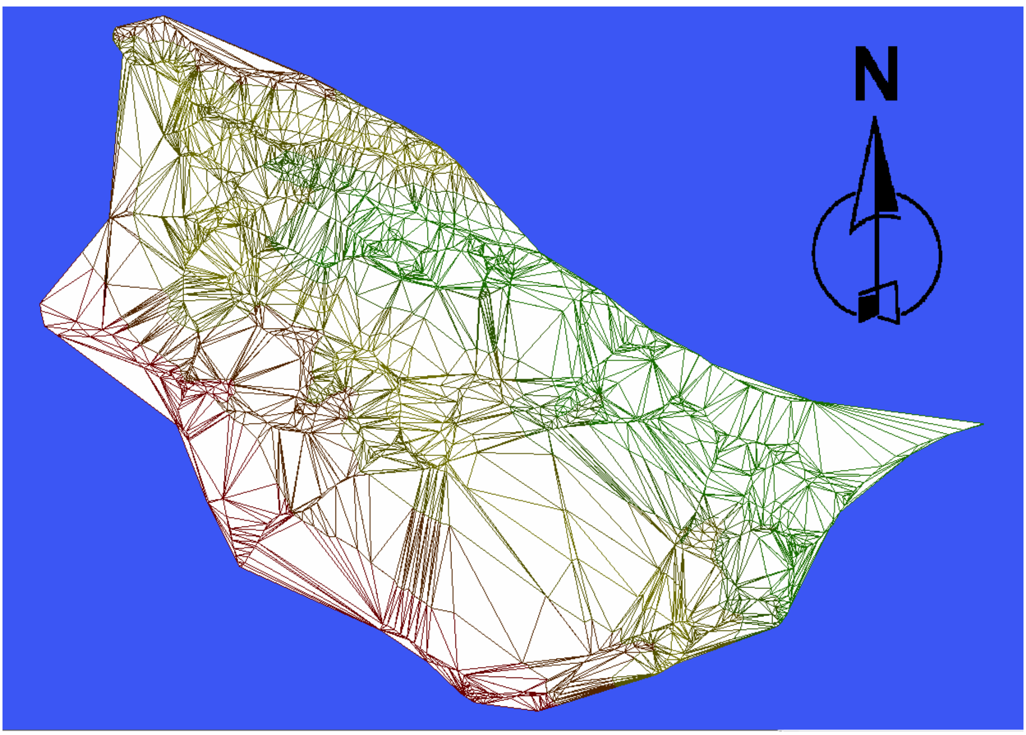


Fig. 7. TINs of Seix Sou forest.

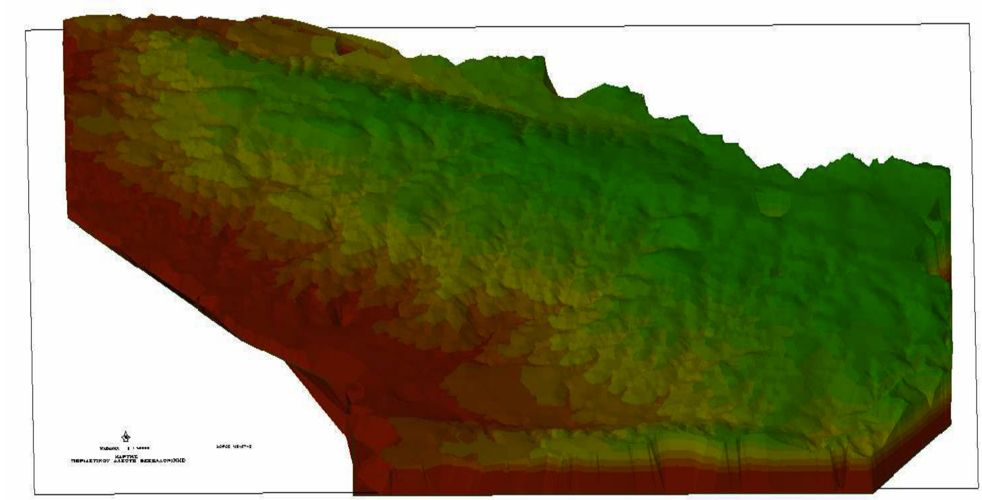


Fig. 8. Three-dimensional representation of Seix Sou.

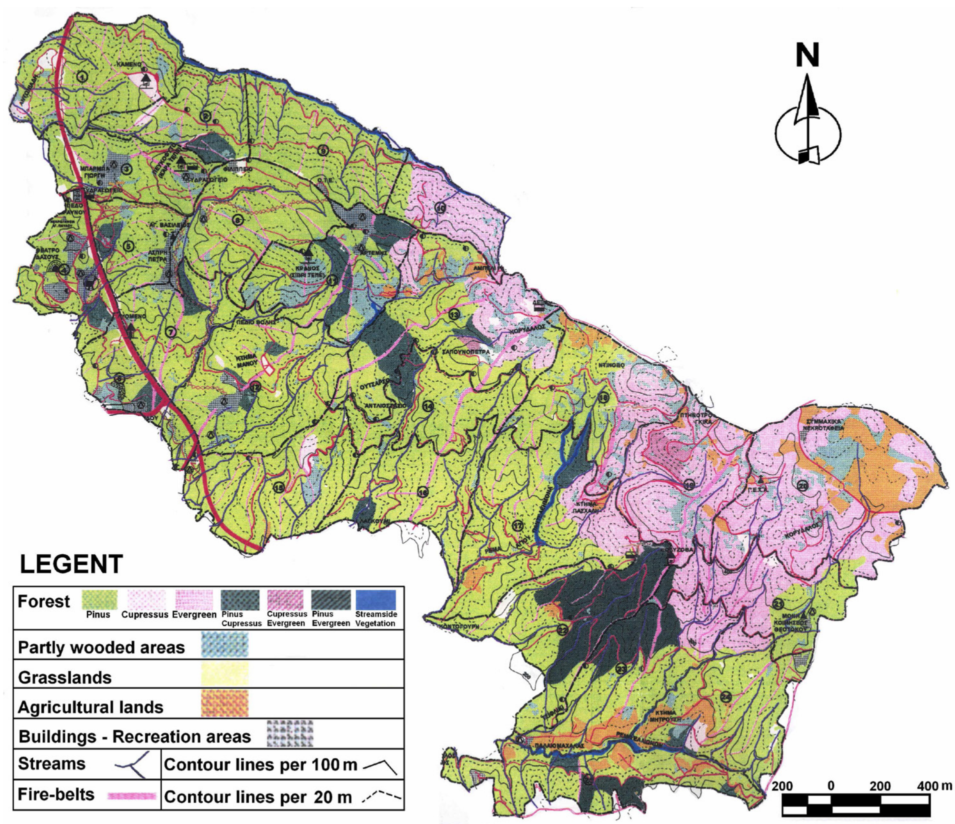


Fig. 9. Land uses map of Seix Sou.

only for the quality of life but the very lives of city's residents (Figure 9).

Conclusion–Suggestions

Within the scope of Geoinformatics, in essay, a combination of DTM and Geographical Information Systems (GIS) is undertaken to record and process spatial and non spatial information. The hybrid out of these technologies is a digital map which is created by specialists.

The protection of forest ecosystems (lifeline), in combination with the principle of exploitation, can only be based on digital maps of land use, by specialists, who will decide as an independent scientific body, if the existence of forest area in terms of forest cover by 15 or 25% or other use is more appropriate.

The digital maps of land use, in combination with the development plan, give a view of development, social cohesion and improving quality of life in the country. However the choices in land use are actually derived from the contemporary land policy. We need to comply with Article 24 of the Constitution, as these choices are the product of scientific investigation and imposed by the needs of society.

Land use maps are maps which provide information about land use. There is a number of different applications for such maps, and in many nations, land use maps are prepared by several government agencies, for a variety of reasons. Individual groups and organizations can also generate maps with land use information. Often, such maps are available to the public, so that people who are interested in land use trends can access them.

One form of land use map is a zoning map. Zoning maps are used to mark out areas designated for specific types of land use, so that people, who are associated with land development know, which kinds of uses will be allowed. The creation of zoning maps is part of the overall process of community planning, in which communities decide how they want to develop themselves into the future. Zoning decisions can include features such as setting aside green space, isolating industrial land, and so forth.

Another type of land use map is a map which shows utilization. Utilization maps are often used in zoning decisions to determine, whether zoning changes need to be made or not. If, for example, only 60% of the land designated for residential use, is in active use or under development, it would be suggested that scheduling more residential zoning is not necessary. Utilization land use maps exhibit, the way land is being used, and may also indicate historic utilization information, and provide information about the development of land use through different periods of time.

References

Arvanitis A. 2004. Cadastre. Ziti Publishing. Thessaloniki.

Baltsavias P.E. 1996. Digital ortho images-a powerful tool for the extraction of spatial- and geo-information. ISPRS Journal of Photogrammetry and Remote Sensing, 5: 63–77.

De-Cambray B., Delpy T., Zeitouni K. 2007. A Survey on 3D Data Models in Architecture and Civil. Available at: http://citeseer.ist.psu.edu/update/163073.

Kailidis D., Karanikola P. 2004. Forest Fires 1900–2000. Giaxoudi Publishing. Thessaloniki.

Kraus K. 1996. Photogrammetrie Band II. Verfeinerte Methoden und Anwendungen. Duemmler Verlag, Köln, 488 p.

Miller C.L., Laflamme R.A. 1958. The digital terrain model-theory and application. Photo–grammetric Engineering, 24(3): 433–442.

Resnik B., Bill R. 2003. Vermessungskunde für den Planungs-, Bau- und Umweltbereich, Wichmann Verlag, Deutschland, 303 p.

Wolf P., Dewitt B. 2000. Elements of Photogrammetry with applications in GIS. 3th Edition, McGraw-Hill, 606 p.

FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

DIGITAL TERRAIN MODELS – A HELPFUL TOOL FOR SUSTAINABLE MANAGEMENT AND DEVELOPMENT OF DEGRADED GREEK FOREST ECOSYSTEMS

Vasileios C. Drosos[1]*, Vasileios J. Giannoulas[2], and Christos C. Stamatiou[1]

[1]School of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, N. Orestiada, Greece / P.C. 682 00, Ath. Pantazidou 193 Str. *E-mail: vdrosos@fmenr.duth.gr, stamatioy@gmail.com
[2]Faculty of Forestry and Natural Environment, Aristotle University, Thessaloniki, Greece, University Campus, P.C. 541 24. E-mail: vgiannou@for.auth.gr

UDC 004

Received: 13 May 2010
Accepted: 25 December 2011

Abstract

Most of the ecosystems of our country are classified as degraded natural ecosystems, due to more or less human impact on the near or distant past. Many of these ecosystems are currently experiencing an evolutionary process, after their relief of adverse human activities, which mainly depends on the condition of the soil, the ecological diversity of the region and the rational and sustainable human management. The digital representation of the terrain, with software easy to handle, is a key task of the Geotechnical – Engineering Scientist. Furthermore, it is necessary for the upgrade of the existing environment that the current state of the ground (aspects, soil-cover) and the proposed one (roads, new soil-cover, micro-works) are depicted on three-dimensional intelligibly form. This process requires detailed surveying with geodesic station or GPS and automatic transfer into an appropriate software for processing – a comparison of existing and proposed state, through several options. Consequently, the following problem is raised: farming and sustainable management of the forest without road openings is unrealistic, on the contrary most of our country's forests are degraded and with low productivity. Therefore, it is difficult to find the golden mean between the services of the needs of the forest exploitation and protection and the principle of the optimization that should apply in all economic-technical studies. The aim of this essay is to examine the contribution of the digital elevation model and generally, the high technology, to setting a framework for sustainable management and development, which will contribute to the recovery of degraded forests in Greece. The background on which the modern analysis and design of the site takes place, is a digital design in two-dimensional and three-dimensional forms. In relation to the above both the design and construction of forest roads ought to depend on digital technology. It is the largest infrastructure work in the mountainous area and contributes to the intensification of forest exploitation in economic growth and gradual improvement of degraded mountain areas.

Key words: AutoCAD, sustainable development, geoinformatics, digital terrain model.

Introduction

The optimization of the opening up of the forest is to rationalize their management so that, in relation to forestry purpose, their better utilization, the on-time and effective protection against biotic and abiotic factors and the maintenance of the ecological balance of the region are satisfactorily achieved.

In productive forests, in particular, one of the main purposes of the opening up of the forest is the contribution to the sustainability of fruitfulness and the optimization of wood production, in quantitative and qualitative terms. The wood, which is produced from Greek forests, is categorized into stacker (crushed-wood and firewood) and technical (round). In productive forests, forests with wood stock (> 2 $m^3.ha^{-1}.year^{-1}$), the ratio for stacker to technical wood is about 60% to 40%, while in non-productive forests stacker wood amounts to 80–100% (Doukas 1984).

Most of the ecosystems of our country are classified as degraded natural ecosystems, due to more or less human impact on the near or distant past. Many of these ecosystems are currently experiencing an evolutionary process, after their relief of adverse human activities, which mainly depends on the condition of the soil, the ecological diversity of the region and the rational and sustainable human management (Doukas 2004).

The background on which the modern analysis and design of the site takes place, is a digital design in two-dimensional and three-dimensional forms. The digital representation of the terrain, with software easy to handle, is a key task of the Geotechnical – Engineering Scientist (De-Cambray et al. 2007). Furthermore, it is necessary for the upgrade of the existing environment that the current state of the ground (aspects, soil-cover) and the proposed one (roads, new soil-cover, micro-works) are depicted on three-dimensional intelligibly form. This process requires detailed surveying with geodesic station or GPS and automatic transfer into an appropriate software for processing – a comparison of existing and proposed state, through several options (Tsouxlaraki 1996).

The problem of the optimal opening up of the forest and the construction of forest roads in particular, is complex and in Greece, it is even further exacerbated by the steep slopes and the terrain generally, and the low productivity of most of our mountain forests (FAO 1998). Consequently, the following problem is raised: farming and sustainable management of the forest without road openings is unrealistic, on the contrary most of our country's forests are degraded and with low productivity. Therefore, it is difficult to find the golden mean between the services of the needs of the forest exploitation and protection and the principle of the optimization that should apply in all economic-technical studies.

The need to approach and access the forests and the mountainous areas, in general, is the beginning of the economic exploitation, the protection and the operation of all functions within the multipurpose forestry-science. Moreover, the opening up of the forest and the opening of forest roads, in particular, is a project with social implications, as they are the most important infrastructure work in the mountainous areas and contributes to the intensification of the forest exploitation, the economic growth and the gradual improvement of degraded mountain areas (Liu and Sessions 1993).

The aim of this essay is to examine the contribution of the digital elevation model and generally, the high technology, to setting a framework for sustainable management and development, which will contribute to the recovery of degraded forests in Greece.

Material and Methods

The public forest of Cithaeron mountain is located west of Athens at a distance of 60 km away from Egalaio area, where the office of the Forest Service exists, nearby the boundaries of Boeotia prefecture. The public forest of Cithaeron mountain extends to the S – SE slopes of the main ridge of Cithaeron mountain, and especially on the slopes which are N, NW and W of the town of Vilia among the coordinates (Figure 1):

Latitude North 38° 11΄ 30΄΄, South 38° 09΄ 00΄΄

Longitude East 23° 23΄ 00΄΄ West 23° 13΄ 00΄΄

It is a long stretch from E to W along and south of the Ridge of Cithaeron Mountain, about 16 km long, in central Greece, standing between Boeotia in the north and Attica in the south. The area that lies within these boundaries is 1,582.5 Ha, in accordance with the land uses as presented on Table 1 and Fig. 2.

The whole area on which lies the under study forest has a general south aspect. Due to the relief of the area, local slopes appear W, SW, E, NE and a little bit N aspect. The slopes of the ground differ from mild to moderate and to intense, with a higher coverage rate of 40.02% of the total surface slopes of 21–40%. The slopes are generally steeper on the west side of the mountain. The above

Fig. 1. The research area.

Table 1. Land use.

Land use	Coverage rate, ha
1. Wooded area	698.1 ha
2. Partially wooded area	57.2 ha
3. Scrubs - Evergreen Broadleaved	732.7 ha
4. Agricultural lands	27.8 ha
5. Bare - grassland	65.7 ha
6. Settlements	0.9 ha
Total	1582.5 ha

sea level starts at 420 m just above Vilia and reaches 1.407 m on the top of the Prophet Elias pick of Cithaeron Mountain. The entire area is strictly mountainous. It is mainly composed of limestone.

For research purposes, namely the contribution of digital terrain models in the sustainable management and development of degraded Greek forest ecosystems, DTM is created concerning a typical forest with low productivity (< 1 m^3 per year and ha), after having obtained the necessary forestry, technical and economic data from the forest management plan for Cithaeron forest for the years 2000–2009.

The maps of 1:50000 of the area were used with the help of the most modern tools such as powerful computers and programs i.e. the Geographic Information Systems (GIS), automated design (CAD) and Digital Image Analysis (Image Processing).

We placed the boundaries of the complex, the forest sectors and stands (Figure 3) and various land uses of the area (wooded, partially wooded land, agricultural lands, bare lands, evergreen broadleaved, grassland and settlements) and then became the area measurement

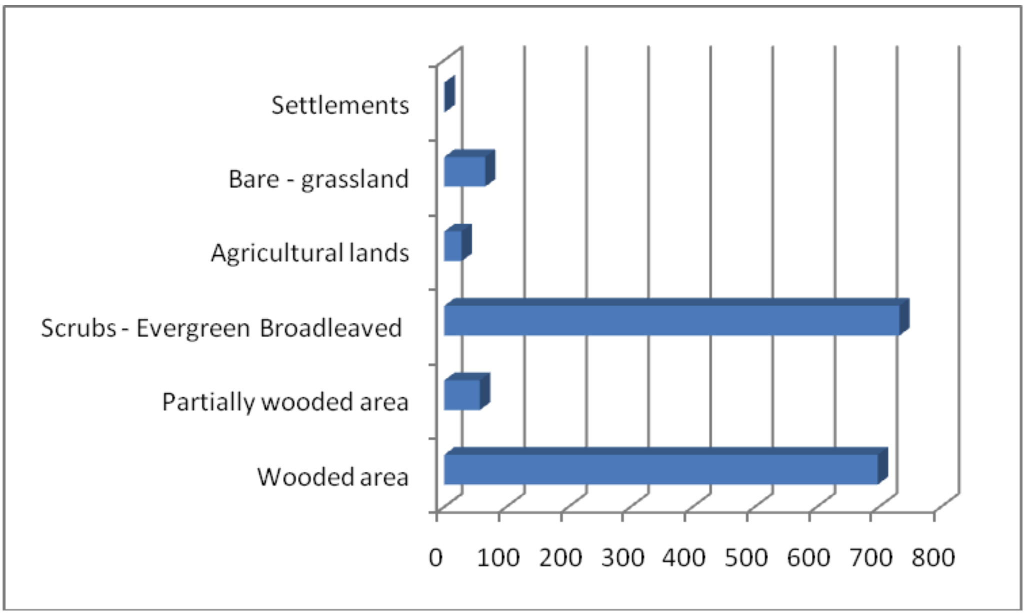


Fig. 2. Land use percentage of the study area.

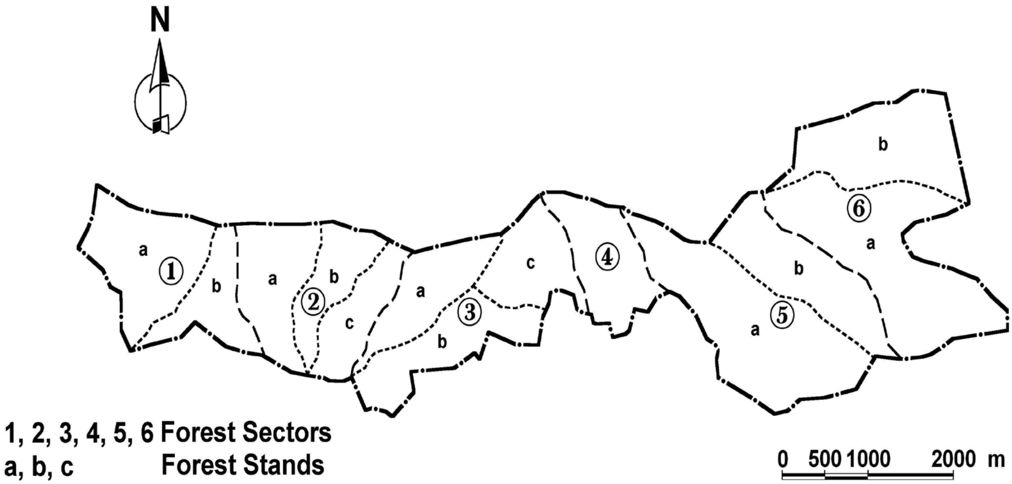


Fig. 3. Forest sectors and stands of the study area.

automatically by using a command of AutoCAD named: "lift". The current road density of the region was estimated by using the AutoCAD.

Digitization is the digital mapping of the characteristics of a map. Substantially through the digitization of the spatial features of an analogue map (points, lines, and surfaces) are converted into digital (x, y) which in turn are stored in specific files on the computer. Specifically a pair of coordinates (x, y) represents a point, while a series of points represents a line. One or more lines delimit a region using a label point represents a surface (Papadimitriou 1980).

On a practical level, as the map is pasted on the panel of digitization, points or lines that represent captured by the digitizing cursor. By activating the cursor, the computer records the position of the point he intended. A necessary condition is the digital encoding of digital records in a common reference system. Practical means to convert the local coordinates of the device in a common geographic reference system such as UTM coordinates or coordinate system H.G.R.S. 87. Most commercial GIS packages containing the software to convert the coordinates facilitating the cartographer to any changes they desire (ACSM 1988).

Results and Discussion

In Figure 4 we can see the under study area with contour lines of 100 m, roads and the control points of the digitization. In Figure 5 is shown the digital terrain or elevation model with the forest road network in 2-D and 3-D. In Figure 6 we can see the silvicultural map of the study area, with contour lines of 100 m and 20m, roads and streams. In figures 7, 8 and 9 are shown the diagrams of altitude percentage, slope percentage and aspects percentage of the study area.

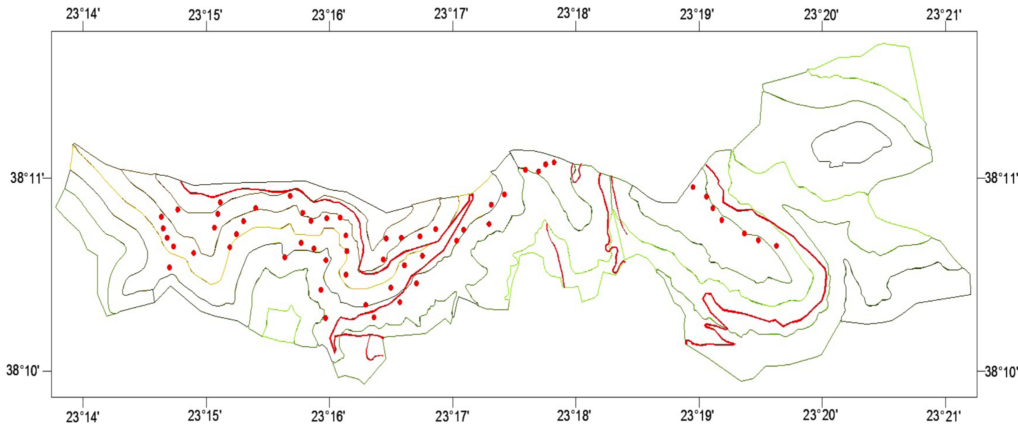


Fig. 4. Research area with contour lines of 100 m, roads and the control points of the digitization.

Finally in figure 10 is presented the research area with the points of interest.

Considering the facts that the wooded area is very small, the actual condition of the forest that is degraded, with very low wood stock and the proposed management which does not evaluates the wood production, but the protection, preservation and improvement of the forest, the protective, aesthetic, health, etc. effects should be considered and evaluated and appropriate measures for the protection of the existing forest and the improvement and expansion of it should be suggested.

Generally, it is not vital to apply specific restrictions on the management of the forest, accounting the hydronomic and protective nature of the forest and its health, aesthetic, etc. effects, except for the need for the durable existence of the forest, the improvement and the rational management, by stand, according to the forestry and biological requirements of the prevailing species.

Apart from the hydronomic and protective nature of the forest, the assessment of the healthy, aesthetic character of the forest is valuable and growing, both by local residents and tourists who come around during the summer months in the region and in transit to Porto Germeno resort.

The area is a resort for Athenians and those who originate from there. The forest offers the beauty of the Fir tree in the wider area covered with Pine trees. Finally, on the top of the Cithaeron Mountain remarkable view in every direction is provided. The Boeotia plain, Euboea, Parnitha Mountain and the other mountains of Attica, the Saronic islands, the mountains of the Peloponnese, much of the Corinthian Gulf and Parnassus Mountain can be observed from there.

The existence road density is:

D_{ex} = 18,848 m / 1,582.5 ha = 11.91 m.ha^{-1}

This is quiet efficient for a forest with hydronomic-protective role. This is the minimum required road density in the region, which has a key protective role.

In non-productive forests, road density that amounts to 12.5 $m.ha^{-1}$ should be achieved, which is the minimum one for the protection of forests from fires (Doukas et al. 1995) and may also contribute to the economic-technical skidding of the stacker wood. In case of forest areas with very low productivity, where the road opening should serve mainly the protection of these areas from fires, the road density is based on the technical capabilities of fire fighting-vehicles (with pipe-length of 450 m), the method of movement of fire-fighters (easier drive downhill than uphill) and the reaction time of the fire crews (about 15 min).In these circumstances, the road distance must be between 670–800 m, i.e., road density of 12.5 $m.ha^{-1}$ – 15

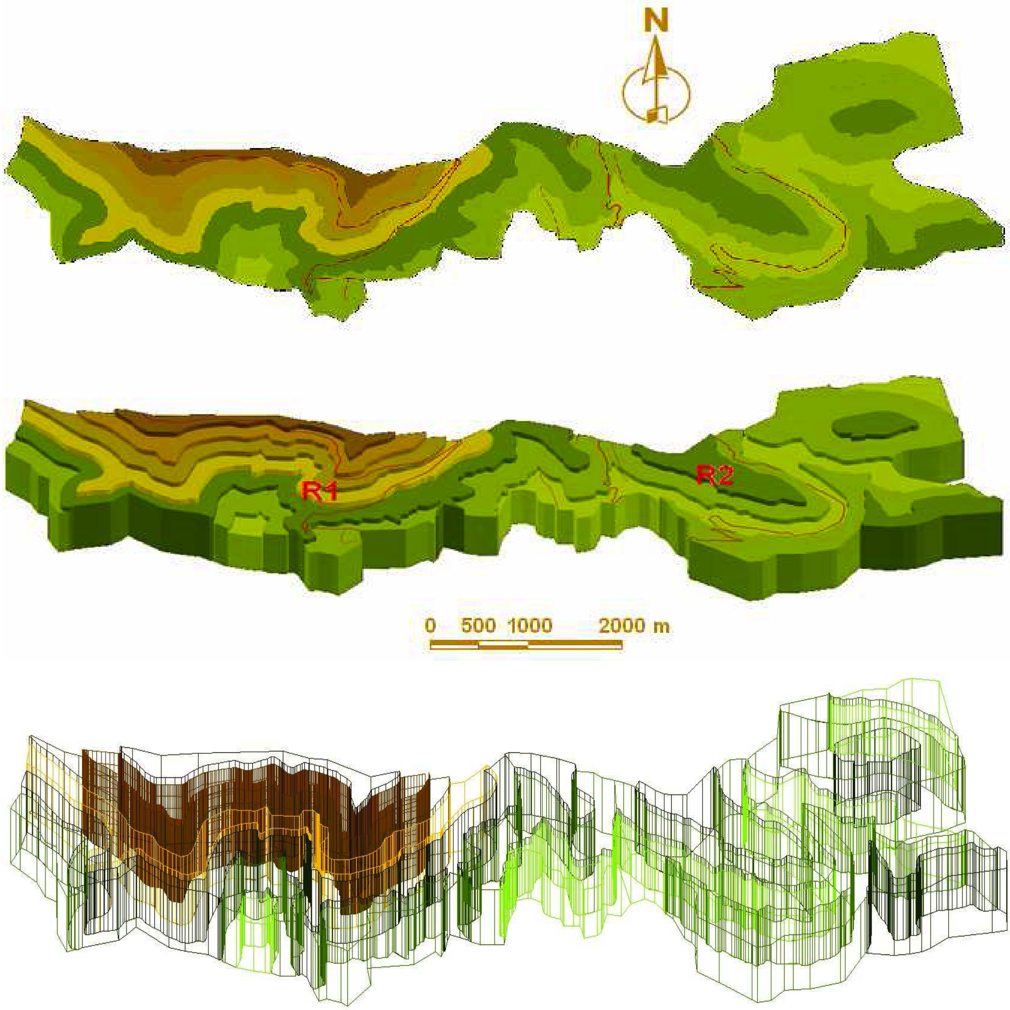


Fig. 5. DTM of the study area with forest road network.

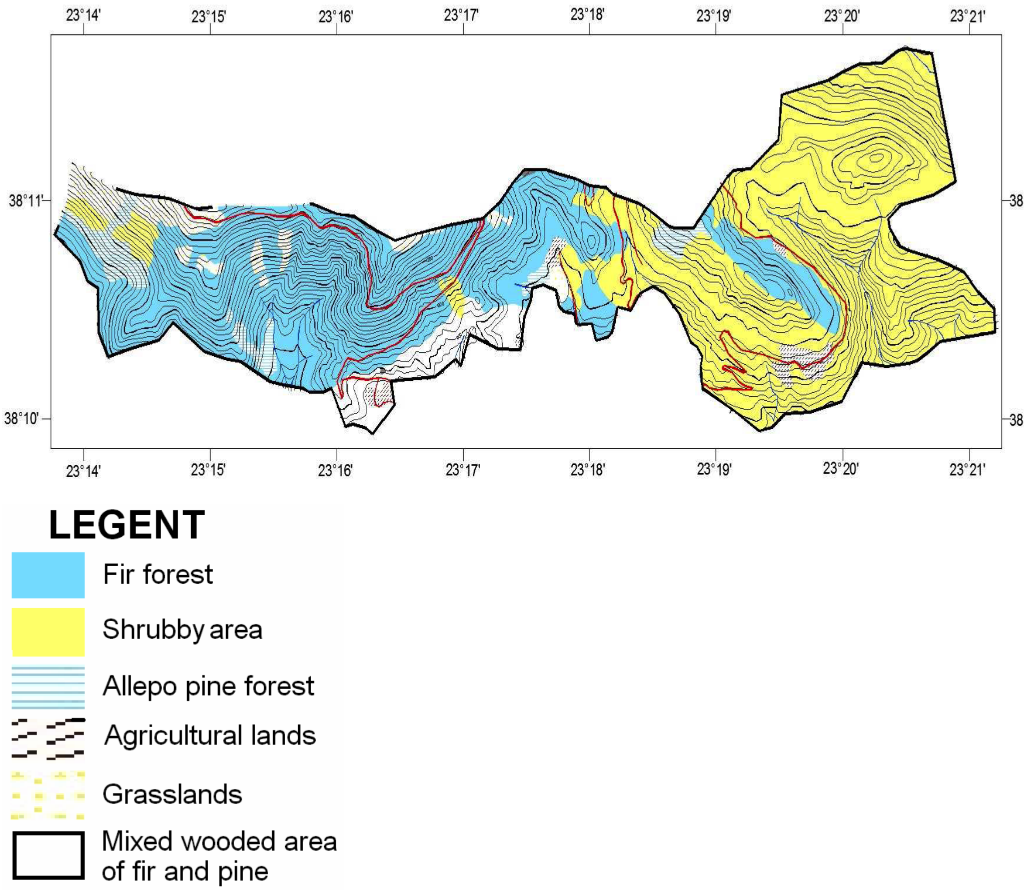


Fig. 6. Silvicultural map of the study area, with contour lines of 100 m and 20 m, roads and streams.

m.ha^{-1} (Rizopoulou and Bazigou 1990). Because of the low productivity, light traffic of vehicles is planned in the coming years for these forests. In the forests with productivity more than 2 m^3.year^{-1}.ha^{-1}, optimum road density should be calculated based on the forest exploitation data and technical and economic data of the area.

As shown in the forest map, with the help of Figure 3, forest stands 1a, 1b, 2a, 2b, 2c are not adequately served by the existing road network. A road with a start from the hairpin turn (also hairpin bend, hairpin corner or switchback) at the lower boundary of stands 2c and 3a and a general western direction to the western boundary of the forest in study would meet this need.

Conclusions

The forest, though, as mentioned above, will not be exploited for the production of forest products. The opening of a road, under the existing local conditions, will negatively affect the environment and cause damage on an already degraded forest.

The construction of another road, a little bit further, outside of the Fir-forest boundaries and through the Aleppo-Pine forest, would cover some needs of the

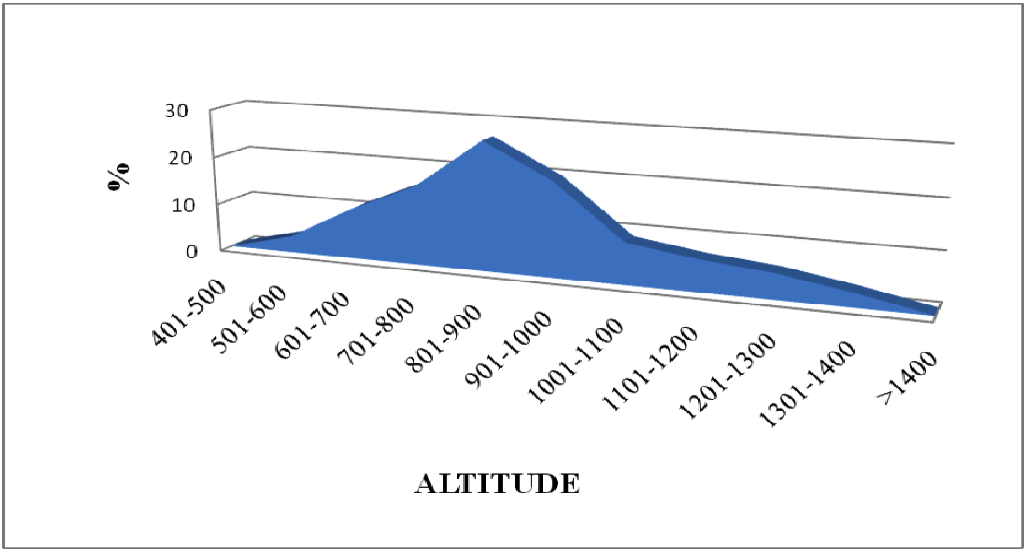


Fig. 7. Percentage distribution of altitude of the study area.

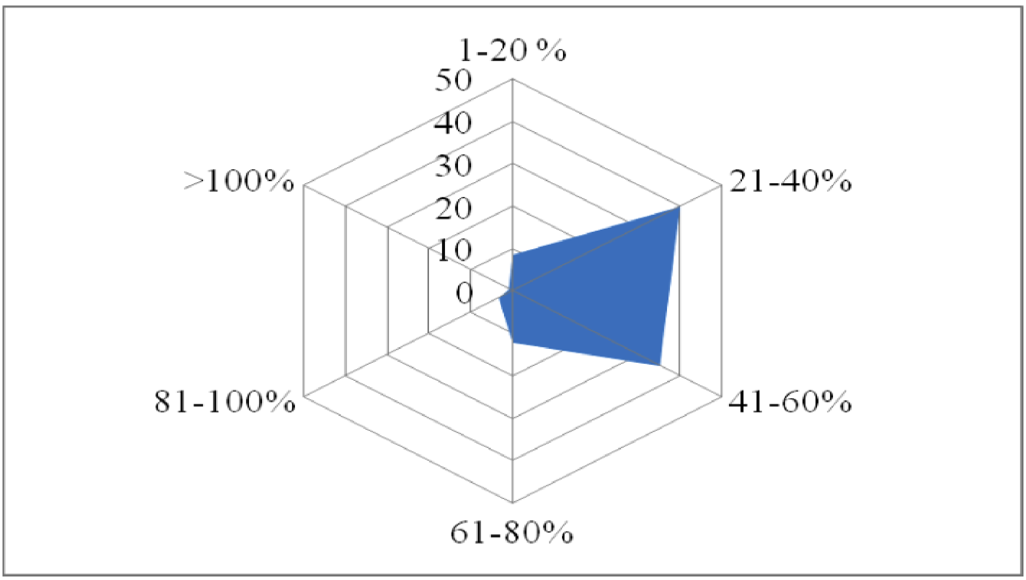


Fig. 8. Presentation of slope's percentage distribution in the study area.

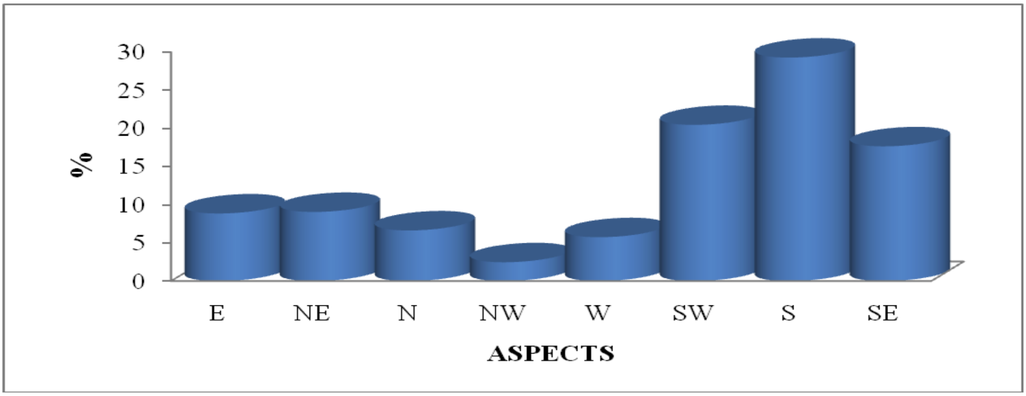


Fig. 9. Aspects' percentage distribution of the study area.

Fir-forest, while it would serve and the Aleppo-Pine forest.

As a consequence, the construction of any road is not suggested, nonetheless, we believe that the opening of a road in the area should be considered with the conditions which are developed above; the mutual service of the Fir-forest and the Aleppo-pine one.

It is not required to settle buildings and other facilities for the exploitation of the forest. The issue of the fire protection should be dealt with altogether for the entire region. Especially, in the hazardous forests that are endangered by fire, dead-end forest roads should be avoided, in order to eliminate the chance of the entrapment of forest fire-fighting vehicles.

Finally, the important issue of interventions in this area with the construction of various works that will serve the needs of mountaineers, tourists, forest recreation, etc. involving various bodies (local authorities, mountaineering clubs, hunting clubs, Forest Service, etc.), each one different and often conflicting priorities and views, must be addressed through true cooperation between these bodies and after a thorough study of all parameters and joint decision-making.

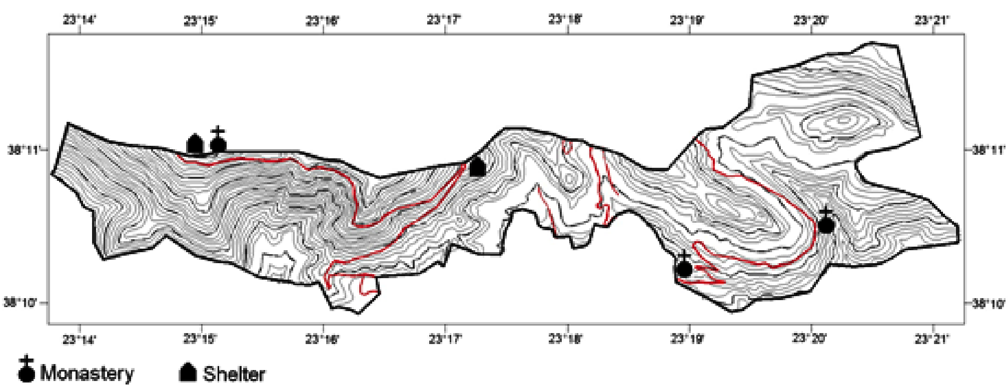


Fig. 10. The study area with contour lines of 100 m, roads and points of interest.

Whatever is concluded for this degraded forest, is a guide for the rest of the Mediterranean degraded forests of our country.

The digital elevation model is the base for the creation of utilization land use maps. Utilization maps can be very detailed and tremendously useful. They can highlight a variety of activities, including farming, mining, residential use, light industrial, heavy industrial, waste storage, and so forth so that people get a clear visual impression of how land in the area covered by the map can be used. Utilization land use maps can also be important from a development perspective because they provide data about historical use; land used for a tannery, for example, might not be a great place for a residential development and help in setting a framework for sustainable management and development, which will contribute to the recovery of degraded forests.

Land use maps, records, and archives are often kept in central government buildings for the purpose of maintaining a coherent record. Researchers who want to study land use or the history of a region can access these archives, as can developers who want to know more about their land use options, and government officials who monitor land use. These maps can become important in zoning and property disputes, as people may be able to use them to prove or argue their case.

We can use land use data derived from satellites and aerial photographs to study the historic change in Land Use/ Land Cover for a region and to model the possible impacts of climate change on these trends.

References

American Congress on Surveying and Mapping (**ACSM**) 1988. The proposed standard for digital cartographic data. The American Cartographer 15: 9–140.

De-Cambray B., Delpy T., Zeitouni K. 2007. A Survey on 3D Data Models in Architecture and Civil. Available at: http:// citeseer.ist.psu.edu/update/163073 (14 June, 2007).

Doukas K. 1984. The road network and the optimum road density in the forest district of Panteleimona-Skotina (Down Olympos). Scientific Annals of the Department of Forestry and Natural Environment, Aristotle University of Thessaloniki, Vol. KΣT/KZ: 284–295.

Doukas K. 2004. Forest Constructions and Natural Environment. Publications Giahoudi, Thessaloniki.

Doukas K., Karagiannis Ev., Karagiannis K., Kararizos P. 1995. Erschließung von Waldgebieten unter Sonderverh□ltnissen (dargestellt im Beispiel vom Heiligen Berg). 29 Internationales Symposium „Mechanisierung der Waldarbeit", FORMEC 95, vom 28.8.1995, Tagungsbericht, Druckerei der Universität für Forst- und Holzwissenschaften, Sopron, Ungarn: 40–57.

FAO 1998. A manual for the planning, design, and construction of forest roads in steep terrain. Draft. FAO, Rome. 188 p.

Liu K., Sessions J. 1993. Preliminary planning of road systems using digital terrain models. International Journal of Forest Engineering 4: 27–32.

Risopoulou E., Bazigou P. 1990. One method of improving the use of fire engines to extinguish forest fires. Geotechnical information. Thessaloniki. Issue 21: 55–56.

Tsouxlaraki A. 1996. Visual Digital Representation of Relief in the Analysis of Landscape. Technical Chronikal 3: 27–40.

Papadimitriou A. 1980. Digital terrain models. Technical Chronikal 3: 93–102.

HIGH TECHNOLOGY IN FOREST ENGINEER WORKS

Vasileios C. Drosos*, Apostolos Kantartzis, and Rigas Giovannopoulos

School of Forestry and Managment of the Environment and Natural Resources, Democritus University of Thrace, N. Orestiada, Greece / P.C. 682 00. Ath. Pantazidou 193 Str. *E-mail: vdrosos@fmenr.duth.gr, apkan2002@yahoo.gr, rigas_giovannopoulos@yahoo.gr

UDC 004

Received: 13 May 2010
Accepted: 26 December 2011

Abstract

Older methods and instruments were characterized by low accuracy or low productivity and high costs of fieldwork. From the 80^s appeared on the market new types of instruments identified to measure accurately, productively, with a small amount of field work, but large cost of purchasing the instrument and modified analytical methods and efficiency. The era that we are living is characterized by evolutions of great importance in the sector of space applications. Especially, in the field of geodesy science, the applications of position determination with the use of satellite systems in global scale offered valuable solutions in chronic problems while creating new prospects but also greater demands. GPS and GLONASS are continually improving and the European Galileo and Chinese Compass systems are emerging to provide additional benefits for world-wide users. The main target of this research is the investigation of the possibilities of the triple frequency GPS at field work for forest mapping. Previous works has been done by many researchers in all over the world. However, in this paper we concentrate on woodland area with receivers of two (2) frequencies (dual frequency) for both GPS and GLONASS satellites on. Also be able to receive signals from the third frequency GPS L5 and GALILEO, COMPASS satellites and the new L2C frequency for better and faster fixing in these environments. Finally are concluded proposals for the survey work in the forest cadastre, the forest opening up and the forest road construction, the study of temporal changes in the earth surface, for the measuring of forest data and for the civil engineer works.

Key words: frequency, field test, GPS, instrument, terrain condition.

Introduction

Older methods and instruments were characterized by low accuracy or low productivity and high costs of fieldwork. From the 80^s appeared on the market new types of instruments identified to measure accurately, productively, with a small amount of field work, but large cost of purchasing the instrument and modified analytical methods and efficiency.

In order to choose the correctly instrument it depends on follow factors: the cost of instrument, the existed available instruments, the terrain conditions, the method of the work and the desirable precision of the work.

The era that we are living is characterized by evolutions of great importance in the sector of space applications. Especially, in the field of geodesy science, the applications of position determination with the use of satellite systems in global scale offered valuable solutions in chronic problems while creating new prospects but also greater demands. GPS and GLONASS are continually improving and the European Galileo and Chinese Compass systems are emerging to provide additional benefits for world-wide users. NAVSTAR/G.P.S. (NAVigation Satellite Timing And Ranging – Global Positioning System) or just GPS is a satellite system with which we can determinate the position of one point of observation X, Y, Z, in relation to a point of reference. This new system's development started at the beginning of the 70s and its use started at the beginning of the 80s by the USA's Ministry of Defense.

It has been designed for the needs of navy and for military purposes and its main target was to allow knowledge of any position, with ±10–15 m accuracy, in real time. It soon became clear that it could be used for even more accurate calculations so its use also expanded to geodetic applications. Generally GPS covered a great gap in the field of position's determination.

GPS receivers are used for navigation, positioning, time dissemination, and other research.

- Navigation in three dimensions is the primary function of GPS.
- Precise positioning is possible using GPS receivers at reference locations providing corrections and relative positioning data for remote receivers. Surveying, geodetic control, and plate tectonic studies are examples.
- Time and frequency dissemination, based on the precise clocks on board the SVs and controlled by the monitor stations, is another use for GPS.
- Research projects have used GPS signals to measure atmospheric parameters.
- Georeferencing: that is assigning correct latitude and longitude to the control points of satellite imageries and topographic maps.

Many groups are now researching the advantages of the third civil frequency available with Modernized GPS and an entirely new Global Navigation Satellite System (GNSS), GALILEO.

Studies have shown that the integration of the two systems provides stronger geometry and more availability (O'Keefe 2001). These properties allow for better blunder detection and higher reliability of the overall system. The increased availability gives better precision in the position domain (Lachapelle et al. 2002) and can provide improved satellite geometry in the most difficult signal masking environments, such as urban canyons (O'Keefe et al. 2002).

Beginning around 2008, civilians will have access to three GPS signals: L1 (1575.42 MHz), L2 (1227.60 MHz), and L5 (1176.45 MHz) (Van Dierendonck 2000). Both L1 and L5 are for civil aviation safety-of-life services. L2 is for non-safety critical applications. The use of these additional frequencies is expected to enhance the performance (accuracy, integrity, continuity, availability) of GPS. There are several ways to take advantage of the new frequencies:

- Calculate ionosphere delay in the airplane. This might eliminate the grid which is used for ionosphere delay corrections in WAAS (Enge et al. 1996).

As a result, one would have fewer wide area reference stations (WRS). This system would be less expensive.

- When radio frequency interference (RFI) is present, one can use the additional GPS frequencies as a backup navigation method. This system requires WAAS to continue broadcasting the ionosphere grid.
- Combine the above two methods to form a more robust navigation system. This combined system is more preferable than the two above methods.

Three frequency systems allow for better modeling of atmospheric errors, especially in the case of the ionosphere, which is dispersive. Three frequencies will also allow for more variation in ambiguity resolution methods. The GPS widelane combination of L1 phase minus L2 phase has been shown to reduce measurement errors, in terms of cycles, which allows for faster ambiguity resolution. This widelane combination has also been used as an intermediate step in resolving individual L1 and L2 ambiguities. This process is called cascading ambiguity resolution, in which frequency combinations that reduce the effects of the atmospheric errors are resolved prior to attempting to fix more difficult, shorter wavelength, ambiguities. By using the fixed information, the frequencies combination is used to assist with ambiguity resolution of the shorter wavelength ambiguities in an attempt to resolve the ambiguities on the base frequencies.

The basis of GPS is trilaterate from satellites. To trilaterate a GPS receiver measures distance using the travel time of radio signals. To measure travel time, GPS needs very accurate timing, which it achieves with some tricks. Along with distance, it is needed need to know exactly where the satellites are in space. High orbits and careful monitoring are the secret. Finally you must correct for any delays the signal experiences as it travels through the atmosphere.

Position is calculated from distance measurements (ranges) to satellites. Mathematically we need four satellite ranges to determine exact position. Three ranges are enough if we reject ridiculous answers or use other tricks. Another range is required for technical reasons.

Our research motivation is the investigation of the performance of a triple frequency GPS at field work for forest mapping.

Material and Methods

The research area was at Asvestochori. The instrument we used was the LEICA VIVA GS15 (Figures 1 and 2).

The basic technical specifications of the triple frequency satellite positioning system are shown in Table 1.

These steps below describe briefly how to setup, operate, take down, and process data for a GPS-RTK survey.

1. Setting up the base station for an RTK survey.

1.1. Set up of base station antenna and tripod.

1.2. Set up base repeater radio.

2. Set up of RTK rover for RTK survey.

2.1. Setting up the rover receiver.

3. Set up of independent RTK repeater radio for RTK survey.

4. Configuring the RTK survey.

5. Creating a new job for the RTK survey.

6. Starting the base receiver for a RTK survey.

7. Starting the rover receiver for a RTK survey.

8. To survey a point.

9. Ending a RTK survey.

We must be careful if base or rover batteries fail during the RTK survey, survey data may be lost.

In order to take the ASCII output files of RTK data we used special software in order to export various GIS output files, and those interested in creating various GIS are referred to the manuals for further information.

Note that ASCII TEXT files contain WGS-84 latitude and longitudes, and height above ellipsoid elevations. We used special software (CO-ORDS) in order to transform them to HGRS '87 (Hellenic Geodetic Reference System '87). Then we input the ASCII file in AutoCAD and export the digital map of the area.

Results and Discussion

The Following figure 3 presents the surveying area with the contour lines. The main contour lines with red colour are

Fig. 1. Pieces of the instrument LEICA VIVA GS15 with the technical equipment.

Fig. 2. Case of the LEICA VIVA GS15.

Table 1. Basic technical specifications of satellite positioning system LEICA VIVA GS15.

System Differential GPS Corrections	
1.0	The GPS system consisting of two receivers interchangeable between each other with supporting accessories, software to perform all the required applications.
Receiver GPS GNSS	
2.0	Have receivers of four (4) frequencies for both GPS and GLONASS satellites on. Also be able to receive signals from the third frequency GPS L5 and GALILEO satellites and the new L2C frequency for better and faster fix.
2.1	Each receiver offers 120 channels and two frequencies L1 and L2 on simultaneous detection of up to 60 satellites at both frequencies. The receiver performs measurements of phase and frequency waves two carriers L1 and L2 code measurements and C / A and P in L1 and L2 frequencies. Each receiver has: • Sixteen (16) channels of continuous detection of the frequency of L1. • Sixteen (16) channels of continuous detection of the frequency of L2. • Sixteen (16) channels of continuous detection of the frequency of L1 GLONASS and sixteen (16) channels of continuous detection of the frequency of L2 GLONASS + (4) SBAS (WAAS, EGNOS, GAGAN, MSAS)
2.2	Ability to record observations in kinematic and static procedure for post-editing in the office.
2.3	The rate of measurements' recording to qualify by 0.05 sec to 300 sec. The angle of the satellite measurements for recordings (cut – off angle) to be eligible.
2.4	The refresh rate of the position to be eligible by 0.05sec (20 Hz) to 1 sec (1 Hz).
2.5	The system offers complete reference design parameters (availability of satellites, static figures Precision PDOP, GDOP, and azimuth angles of the satellites, sky map) all the data is tabular and graphical format.
2.6	Has built-in anti-jammining on both frequencies L1 and L2.
2.7	Have reliable technology of reception under trees.
2.8	The mobile receiver to receive network RTK corrections and supports networked RTCM messages type of issue until v3.1.
2.9	The receiver is controlled via the serial port to any other program that runs on any platform.
2.10	The data from both receivers are recorded in CF Compact Flash or SD cards in both the receiver and the keyboard with selectable by the user to register.
2.11	The ISDN cards have at least 1GB of memory
2.12	The mobile receiver (rover) communicates with Bluetooth built-in antenna for kinematic and REAL TIME applications.
2.13	The rover receiver (mobile) consists of the antenna, keyboard, batteries and pole with the support and its weight is not more than 3.5Kg.
2.14	The operating temperature range of the receiver is -30°C to +65°C.
2.15	The storage temperature range of the receiver is -40°C.
2.16	The resistance to humidity is 100% (total precipitation).
2.19	The RTK is fully integrated in receivers.

Table 1. Contination.

2.20	The integrated software of the receiver allows and the following measurements: • Surveying • Identification of reference systems • Mapping of all methods of orientation (north, sun, point, line, arrow navigation) • COGO applications for determining coordinate points with many geometric methods. Specifically: cuts straight to the field in straight distance calculations, arrows, shift, speed tracks, routes • Transformation etc. The user has the ability to create its own set of rules for all applications supported by the system and planning at the office before the field measurements.
2.21	The software has the ability to create lines and polygons as well as the possibility of introducing coding points, lines and polygons.
RTK performance	
3	The reliability of positioning should be better by 99.99%
3.1	For Real Time approach to achieving the following accuracies: Position 10mm +1 ppm; Elevation 20mm +1 ppm.
3.2	Continuously independent continuous control algorithms to resolve the ambiguity phase.
3.3	Equipment modem and GSM modem are removable from the receivers and not integrated.
3.4	To be making points with a frequency of 20Hz (0.05sec) without degradation of accuracy.
3.5	Time for On-the fly positioning in Real Time situation is 8 sec (typical) after connecting to satellites.
3.6	The display controller to display continuously the situation to resolve ambiguities.
3.7	The display controller to provide all information as the number of detectable satellites and the condition of the battery or memory card capacity.
3.8	The display controller to display graphic signs with engraving.
3.9	The system to read signs marking just ASCII files.
3.10	The scheme to import and export files onboard ASCII measurement sites offline with a program on a PC in a format of choice.
3.11	The system can import and export onboard DXF files points / lines / polygons without connection to program in a computer.
3.12	The system must support connection to GSM. The connection between the GPS receiver and GSM modem to be without power.
3.13	The system has the possibility of simultaneous wireless modem, and GSM modem in the body of the receiver.

every 2 m while the intermediate contour lines with green colour are every 40 cm.

In this paper we presented an overview of a GPS system, we mentioned its characteristics and some of its drawbacks. RTK method was briefly described. Measurement results showed that in open sky with the triple frequency GPS offered the most accurate and quick solution for the digital terrain model creation. When high precision and accuracy measurements are required for example in forest cadastre the triple frequency GPS is the answer. GPS L5 is the new third GPS frequency with GPS and GLONASS. Through higher power emission GPS L5 offers easy and faster signal acquisition and tracking. Advanced signal modulation schemes improve multipath rejection performance. Galileo will add another 30 satellites to the GPS and GLONASS constellation. This will provide an average of 20 satellites in view 24/7 and will further improve speed and accuracy. Also the new L2C frequency is another one frequency for better and faster fix in wooded environments. Also it can be able to receive signals from the Chinese COMPASS.

Especially G.P.S. in forest engineer works gives the following advantages:

Topography (Relief)

The high accuracy, which the measurements of carrier wave phases offer, constitutes an excellent tool for a series of geodynamic, geodetic and topographic applications (Seeber 1993).

G.P.S. system has been used by the laboratories of Superior and satellite geodesy, in order to support the Greek Trigonometric network and for the implementation of the new Hellenic Geodetic Reference System HGRS '87. It was used for the monitoring the small movements and deformations of the earth's crust or from dams, to accomplish hydrographic photographs and underwater wirings (Sakkos and Vorrias 1998).

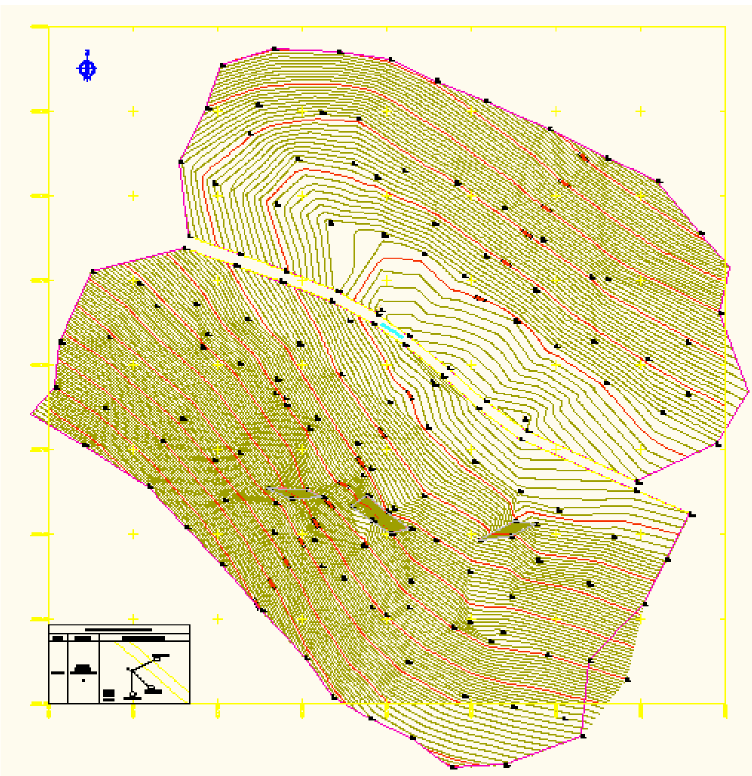


Fig. 3. The surveying area with the contour lines.

Forest cadastre

For the cadastre work the kinematic and semi-kinematic methodologies are applied as usual, while for the works of the triangulation use becomes of the static and semi-kinematic methods of determination. G.P.S. constitutes a valuable tool for the geographical information systems (G.I.S.), which connect phenomena with the geographical space. G.I.S. is the new trend in technology to collecting, storing, managing and analyzing data. Many companies in Europe manufacture G.I.S. – programs, in order to renew the cadastral maps, cadastral tables and delimitation of forest cadastre with the help of digital maps that are taken central via Internet and are cooperated with G.P.S. in the field.

Road construction

Afterwards the abolition of the Selective Availability, the global positioning system has an extended use in the road construction replacing the topography's classical methods that were based on the use of the total station, theodolite and level. G.P.S. – system can be a useful means for the survey engineer, which occupies the road's construction premeditations and designs (Varvanis and Vasiliadis 1996).

Except from the surveying, G.P.S. (the global positioning system) can also be used in other applications of road constructions, like way staking. In relation to the installation of gradient developed control systems in the earthwork machines, the exact place of the machine can be determined, being based upon the technology of G.P.S.

Management of forest – Harvest, skidding and transport of forest products

Simple in the use GIS-programs and suitable database help in the modern management of the forest (Sprenger 2003). During last years, the global positioning system has been useful as an application within forest management; as far as this instrument allows the researchers to clearly define the productivity of the machines that used in forest work. G.P.S.-system is more advantageous compared with the traditional methods of forest management, as it requires less work time and is extremely precise. One reaches this with the installation of receivers in the cultivation and harvesting machines. By the production of a road map one can define the route and speed of the vehicles and the ground pressure, which are practiced on the road, with computation of the traffic frequency.

Management of fire-fighting vehicles' fleet

The surveying of a forest area's roads gives the possibility of designing the suitable maps, in order to prevention or extinguish a fire faster. Great effect, particularly in Europe and Japan, finds also the combination of G.P.S. and electronic maps for the management of vehicle fleets, e.g. to fire brigade, police and ambulances. Each vehicle watches its travel on an electronic map, which provided with information about the direction change, the weather, and road and traffic conditions. With this manner the central station improving their route reaches the control of all vehicles' travel at any moment. This usefulness of G.P.S.-receivers gets a greater importance in extreme emergency situations, like the danger before fires, in extreme health circumstances, whereby the reaching of the fastest route is urgent.

Conclusion

It is a third generation instrument for measurements, that includes the most modern GNSS technology and tracks all existing satellite signals and those planned for the future. This includes GPS, GPS L5, Galileo, Compass, GAGAN, WAAS, EGNOS and MSAS. This state of the art equipment will contribute to an efficient and effective performance in the field.

GPS technology offers several advantages: First of all, the service is free worldwide in order to locate a position. Second, the system supports unlimited users simultaneously. Third, one of the great advantages of GPS is the fact that it provides navigation capability. By integrating the navigation, positioning, and timing abilities of GPS with other technologies such as GIS and data collection, electronic displays, and communications, a vast amount of applications can be created. Combining the GPS data with GIS allows for greater capabilities than what GPS and GIS can provide individually. With the combination of two technologies one is able to display the field/actual site on a PC and take serious decisions. In forestry there is no shortage of uses. In forest cadastre, forests opening up, forest road construction and landings, heavy equipment of recording and monitoring, and all sorts of field data collection application have already been initiated. Mechanical site preparation, juvenile spacing, mechanical brushing and planting, forest health (i.e. insect and disease tracking), forest fire monitoring, research plots and others are some of Forestry applications that the use of GPS brings a new era. Forestry applications that use GPS are continually changing. GPS can be used to create and maintain digital map databases for the forests we manage. In connection with the zoning plans we can sustainable develop the mountainous areas.

References

Enge P., Walter T., Pullen S., Kee C., Chao Y. C., Tsai Y. J. 1996. Wide Area Augmentation of the Global Positioning System, Proceedings of the IEEE, Volume 84, No 8: 1063–1088.

Lachapelle G., Cannon M. E., O'Keefe K., Alves P. 2002. How Will Galileo Improve Positioning Performance? GPS World, Volume 13 (9): 38–48.

O'Keefe K. 2001. Availability and Reliability Advantages of Galileo/GPS Integration. Proceedings of ION GPS-01, Salt Lake City, USA, 2001: 2096–2104.

O'Keefe K., Ryan S., Lachapelle G. 2002. Global Availability and Reliability Assessment of the GPS and Galileo Global Navigation Satellite Systems. Canadian Aeronautics and Space Journal, Canadian Aeronautics and Space Institute, 48 (2): 123–132.

Sakkos L., Vorrias E. 1998. Following of the small movements of the earth's crust within the earthquake range of Migdonia basin from two observation rows with G.P.S. Thesis work of the Sector for Geodesy and science of surveying. Aristotle University of Thessaloniki. (in Greek).

Seeber G. 1993. Satellite Geodesy, Foundations, Methods and Applications. Published by Walter de Gruyter. New York, 531 p.

Sprenger A. 2003. Forest – G.I.S. in the InterNet: Customers define their kind of condition. Forest newspaper, No 10: 12–13.

Van Dierendonck A.J. 2000. Signal Specification for the Future GPS Civil Signal at L5, Proceedings of ION Annual Meeting 2000, San Diego, CA, June 26–28.

Varvanis A., Vasiliadis Th. 1996. G.P.S.'s applications at the construction of roads. Thesis (diploma) of the Sector of Geodesy and Science of Surveying. Aristotle University of Thessaloniki. (in Greek).

FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

RELATIONSHIP BETWEEN COLOUR CHANGE AND SURFACE HARDNESS IN THERMALLY MODIFIED SESSILE OAK WOOD

Nebojša Todorović* and Zdravko Popović

University of Belgrade, Faculty of Forestry – Department of Wood Processing, Kneza Višeslava 1, 11030 Belgrade, Serbia. *E-mail: nebojsa.todorovic@sfb.rs

UDC 630.84

Received: 31 May 2010
Acepted: 28 December 2011

Abstract

The aim of this paper is to investigate the relationship between the surface hardness (Brinell's hardness) and colour change of thermally modified Sessile oak (*Quercus sessiliflora* Salisb.) wood. The material was taken from the coppice forests of the National Park Đerdap in eastern Serbia. Two groups of samples were selected from sapwood and from heartwood. The samples were heat treated at 170ºC, 190ºC and 210ºC for 4 hours. Radial hardness and CIELab (L*a*b*) coordinates of wood colour were investigated before and after the thermal treatment. The obtained results indicate that thermal treatment causes a reduction of CIElab coordinates and radial hardness whereas colour change (ΔE) increases with the rise in temperature. All the measured coordinates of the CIELab system have positive values in all the analyzed samples. The positive correlation between lightness (L*) and hardness was determined, whereas colour change has negative impact on radial hardness of oak wood. The results presented in this paper indicate that the colour can be used for assessment of hardness of thermally modified Sessile oak wood.

Key words: CIELab, thermally modified wood, Sessile oak, colour change, hardness.

Introduction

Thermally modified wood (TMW) is obtained by intensive treatment at extremely high temperatures. Thermal treatment of solid wood permanently changes large number of its properties (Jamsa and Viitaniemi 2001, Bekhta and Niemz 2003, Tjeerdsma and Militz 2005, Johansson and Moren 2006, Shi et al. 2007, Gonzales–Pena and Hale 2009).

This type of modification causes a change in hardness, which is a very important indicator of TMW quality and usability. Jamsa and Viitaniemi (2001) showed that hardness is most often an indicator of the quality of TMW surface. Shi et al. (2007) reached the conclusion that hardness in most thermally modified types of wood is higher than in the untreated ones e.g. by 7% in spruce wood, by 52% in pine wood, by 22% in birch wood and by 39% in cottonwood wood. The above listed research results do not give a clear picture of the impact of high temperatures on wood hardness. One of the possible reasons for that may lie in the fact that in some cases and in some types of wood the surface of wood hardens extremely, so that the results obtained using the Brinell method do not reflect the true state of hardness in the whole volume of the investigated sample (Popović et al. 2008).

Besides the change in hardness, heat treated wood obtains a darker tone of colour and the intensity of darkening increases with the rise in temperature. The colour of TMW is an indicator of its chemical properties (Esteves et al. 2007), equilibrium moisture content and shrinkage (Patzeit et al. 2003), as well as hardness (Johansson and Moren, 2006). So far there have been few researches of the relationship between colour and mechanical properties of TMW. Bekhta and Niemttz (2003) found strong correlation between colour change (ΔE) and bending strength in spruce wood thermally modified at 200ºC. Gonzales–Pena and Hale (2009) showed that in beech and pine wood colour change ΔE proved as the best parameter for the prediction of wood hardness, and in spruce wood that was the coordinate of wood lightness L*. The obtained results indicate that quantitative assessment of colour can serve as a good indicator of some mechanical properties of TMW.

Taking into account that fact that Sessile oak (*Quercus sessiliflora*) wood is wood the most significant hardwood industrial species in Serbia, besides beech, the main aim of this paper was to investigate the relationship between its colour and surface hardness (Brinell's hardness) after thermal modification at high temperatures and to obtain data which can be useful for industrial production and application. The relationship between colour and hardness was investigated for heartwood and sapwood. The investigation of the properties of such wood can contribute to the enhancement of the percentage of sapwood in the final product and consequently the enhancement of utilization in the production of thermally modified Sessile oak wood.

Materials and Methods

The material was taken from the coppice forests in the National Park „Đerdap" in east Serbia. In the forest management unit „Porečke šume", department 54, section „a", three trees were felled (D = 50 cm at 1.3 m). 18 logs with the length of 50 cm were cut, at height from 0.3 m to the first green branches, at every 2 meters. Logs at breast height (1.3 m) and in the middle of stem (5.3 m) were selected for this research (Figure 1).

The logs were transported to the sawmill where their conversion into radial planks of 27 mm thickness was carried out. The planks were transported to the laboratory where they were conditioned. They were cut into two groups of samples (heartwood and sapwood) with dimensions 12 x 22 x 35 mm (radial by tangential by longitudinal). The samples were cut along the longitudinal direction. The heat treatment was done in an oven for 4 h at 170°C, 190°C and 210°C. Three replicates were used for each combination of time/temperature of treatment (B, C and D). After treatment, the samples were cooled down in a dry environment and weighed. Untreated samples (A) were used as the control.

The density was determined in the samples using SRPS D.A1.044 standard and moisture content using SRPS EN 13183-1 standard. The moisture content of thermally treated samples was determined according to Akyldiz and

Ates (2008). Mass loss, as a significant indicator of the quality of thermally modified wood, was determined in all the examined samples (Esteves et al. 2007a).

Wood colour was determined in the CIELab system with the use of a BYK (BYK Gardner GmbH) colorimeter. Settings of the device were the following ones: light source D65 and 10º standard observers. The samples were measured with elliptical aperture, 8mm in diameter. The colour meter was calibrated using white calibration plate which is delivered with the device by the producer. During the measurement each sample was positioned on a flat plate for the sake of measurement stability and constant position in relation to the measuring device. Colour coordinates were measured on a tangential surface before and after the treatment at two measuring points and their average value was used. The following CIEL*a*b* coordinates were measured: L* (black-white), a* (green-red), b* (blue-yellow). Colour change in the CIELab system was determined according to the following formula:

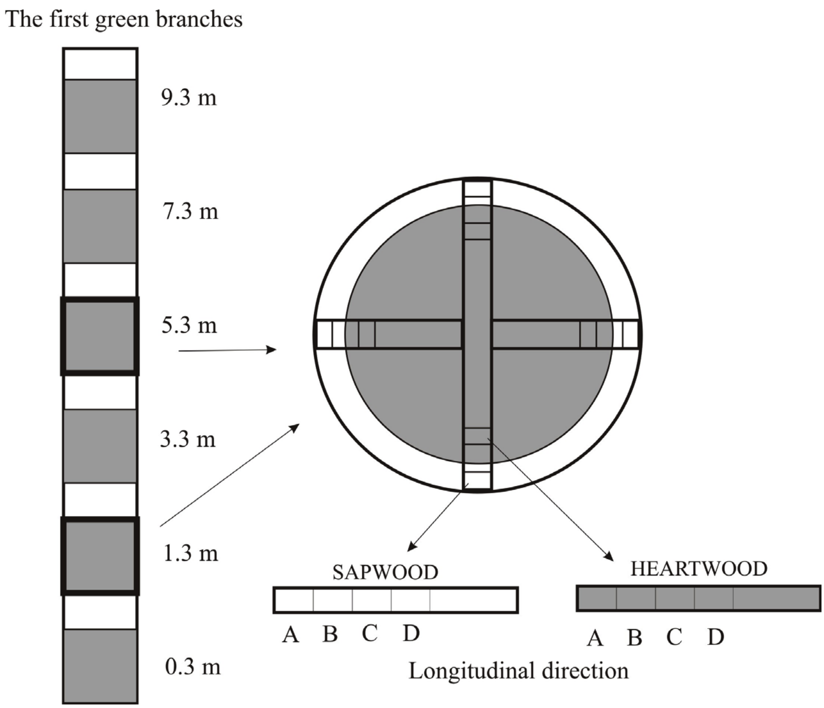


Fig. 1. The way samples were cut.

$$\Delta E = \sqrt{(L_0 - L_t)^2 + (a_0 - a_t)^2 + (b_0 - b_t)^2}$$

where:

L_t, a_t and b_t – CIELab coordinates of the samples after treatment,

L_0, a_0 and b_0 – CIELab coordinates of the samples prior treatment.

Wood surface hardness was determined using the Brinell's method (EN 1534) with the direction of the force parallel to wood rays (radial hardness) prior (untreated samples) and after heat treatment (heat treated samples). Radial hardness was determined at the same points as colour (Figure 2). After that, average values of these two measurings were determined.

The obtained data were submitted to an analysis of variance (ANOVA) and t-test.

Results and Discussion

Oven dry density, moisture content and mass loss

The average value of Sessile oak density in oven dry state was 0.715 g.cm^{-3} in heartwood with a 5.2%, coefficient of variation and in sapwood 0.590 g.cm^{-3} with a 7.4% coefficient of variation.

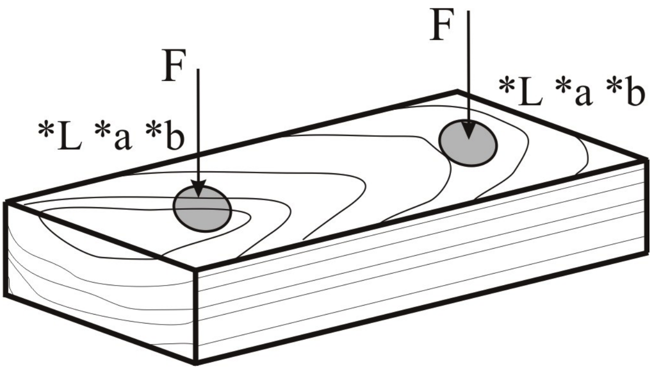


Fig. 2. Place on a sample at which hardness and CIELab coordinates were determined.

The obtained value of density is the approximate value to the one reported by Le Moguedec et al. (2002).

By conditioning the samples at temperatures from 22±2°C and 55±5%, humidity, untreated heartwood samples reached an average value of 10.8%, and sapwood 10.2%. The thermally treated samples were conditioned in the same conditions for 30 days, before colour and hardness recording and they reached the following values of moisture content: 170ºC: heartwood – 6.4%, sapwood – 6.6%; 190ºC: heartwood – 4.4%, sapwood – 4.6%; 210ºC: heartwood – 3.9%, sapwood – 4%. The obtained results show that thermal treatment contributes to the reduction of equilibrium moisture content in wood.

Mass loss increased with a rise in temperature. Mass loss of the heat treated samples was: at 170ºC: heartwood – 1.3%, sapwood – 1.6%; at 190ºC: heartwood – 4.1 %, sapwood – 6.4% and at 210ºC: heartwood – 10.7% and sapwood – 11.7%. The presented results indicate that the losses are higher in sapwood than in heartwood which can also be an indicator of significant changes in the physical properties of this part of oak wood.

Brinell hardness and colour change

The obtained values of radial hardness are shown in Table 1. In untreated samples radial hardness of heartwood was on average 36.1 N.mm^{-2}, and for sapwood 27 N.mm^{-2}. Variability of the analyzed data was higher for heartwood – 18.4%, whereas it was 12.7% for sapwood.

After thermal treatment there is a reduction in the radial hardness of wood. The analysis of variance revealed that there is significant difference in average values between the untreated and treated samples for both heartwood ($F=9.36$, $p<0.01$) and sapwood ($F=15.73$, $p<0.01$). T-test was used to reveal that at 170ºC the value of hardness does not differ from the untreated samples, as well as that there is no substantial difference among the values at temperatures between 190º and 210ºC. These results confirm the premise that the substantial reduction of wood hardness begins at temperatures over 190ºC.

Table 1. Brinell hardness of thermally modified Sessile oak wood.

Statistical parameters	Heartwood				Sapwood			
	Untreated	170°C	190°C	210°C	Untreated	170°C	190°C	210°C
N	24	24	24	24	24	24	24	24
X	36.1	34.2	31.4	28.4	27.0	24.8	20.9	20.9
σ	6.63	4.20	5.47	5.06	3.42	3.57	4.30	3.52
V	18.36	12.26	17.44	17.83	12.65	14.38	20.56	16.83
Max	48.10	41.00	44.50	41.32	33.18	32.38	34.97	27.00
Min	26.30	25.10	19.30	19.30	21.30	16.87	14.16	14.45

N – number of samples; X – mean, $N.mm^{-2}$; σ – standard deviation, $N.mm^{-2}$; V – variation,%; Max – maximum of values, $N.mm^{-2}$; Min – minimum of values, $N.mm^{-2}$.

Quantitative characteristics of the colour of Sessile oak TMW were determined according to the CIELab system (not shown). Wood lightness (L*) ranged from 77.7 in untreated sapwood to 27.7 for wood heat-treated at 210ºC. These values were lower for heartwood and were 67.5 for untreated to 24.9 for a treatment at 210ºC. Values of b* were positive but they had the same trend as L* i.e. they decreased with the rise in temperature. Colour change (ΔE), as a result of a thermal treatment increased with the rise in temperature. Colour change was the greatest at 210ºC, and it was 51.4 for sapwood and 46.4 for heartwood. In the other two treatments colour change was also slightly higher in sapwood which is a result of the increased wood mass loss.

Positive linear correlation was determined between hardness and CIELab coordinates in the form $y = b_0 + b_1x$. The impact of CIELab coordinates a* and b* on the hardness of thermally modified oak wood was very weak. Coefficients of determination (R^2) ranged from 0.145 to 0.275 for sapwood and from 0.276 to 0.395 for heartwood. The coordinate L* had the greatest impact on hardness which coincides with the results of Gonzales-Pena and Halea (2009). Table 2 shows the values of the coefficients of determination between L* and radial wood hardness. As shown, coefficients of determination for heartwood are higher than for sapwood, with the exception of the treatment at 210ºC. According to the analysis of variance significant difference was found between radial hardness and L* coordinate in all samples.

Taking into account the fact that the values of colour difference are only slightly different between sapwood and heartwood, the impact of colour change was investigated for both parts of wood together. Colour change ΔE had the opposite impact on the radial hardness of oak wood to CIELab coordinates. This trend was recorded in both heartwood and sapwood. Table 3 also shows the coefficients of the linear equation with the form $y = b_0 + b_1x$ and Fig. 3 and Fig. 4 the impact of L* and ΔE on the hardness of Sessile oak wood thermally modified at 190°C.

Table 2. Simple linear regression analysis to estimate Brinell hardness of thermally Modified Sessile oak wood using the colour coordinate L*.

Temperature of treatment	Part of wood	n	R^2	F (sig)	b_0	b_1	Std. error
170°C	Sapwood	20	0.425	13.30	- 31.75	+ 1.00	2.59
	Heartwood	20	0.522	19.67	- 34.97	+ 1.40	2.72
190°C	Sapwood	20	0.494	14.68	- 69.84	+ 2.78	3.07
	Heartwood	19	0.565	22.4	- 64.29	+ 3.07	3.84
210°C	Sapwood	20	0.423	11.01	- 135.6	+ 6.65	4.57
	Heartwood	22	0.250	6.35*	- 76.26	+ 4.23	4.79

n – number of samples; R^2 – coefficient determination of model; F – result of Fisher's test, significance at 99% level; model of the form: $y = b_0 + b_1x$; Std. error – the standard error of the estimate; *significance at 95%.

Conclusions

The results obtained in this research show that thermal treatment causes a reduction in radial hardness of oak wood. This change is not significantly different between thermal treatments at 210°C and 190°C, as well as between the untreated samples and the ones treated at 170°C. This was recorded in both heartwood and sapwood.

All the investigated coordinates of CIELab system (a*, b* and L*) were positive in both untreated and treated samples and they mainly decreased mainly with a rise in temperature. In the analysis of the impact of certain coordinates on wood hardness it was determined that only lightness (*L) has significant impact on it. Positive correlation was found between lightness and radial hardness. On the other hand, the calculated colour change (ΔE) had the opposite trend and its values increased with the rise in temperature. The analysis of the relationship between colour change and radial hardness revealed negative linear correlation.

According to the results presented in this paper, colour change of the thermally modified Sessile oak wood can be a

Table 3. Simple linear regression analysis to estimate Brinell hardness of thermally modified Sessile oak wood using colour difference (ΔE).

Temperature of treatment	R^2	F (sig)	b_0	b_1	Std. error	n
170°C	0.609	71.8	57.29	- 1.31	3.86	48
190°C	0.781	163.98	79.94	- 1.27	3.40	48
210°C	0.692	99.12	61.98	- 0.53	2.07	48

R^2 – coefficient determination of model; F – result of Fisher's test, significance at 99% level; model of the form: $y = b_0 + b_1x$; Std. error – the standard error of the estimate; n – number of samples.

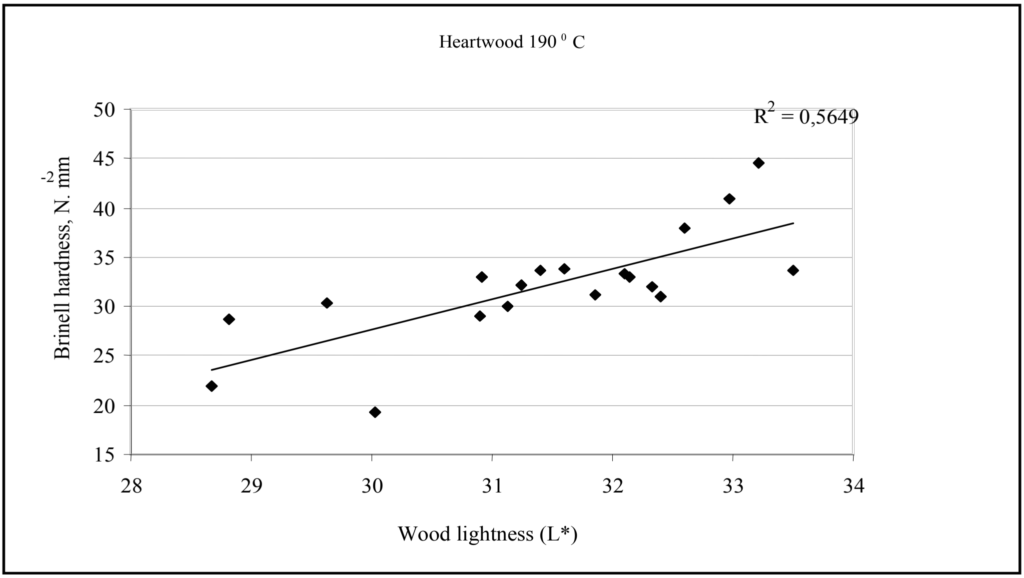


Fig. 3. Models for the prediction of TMW hardness (at 190ºC) using wood lightness (L*).

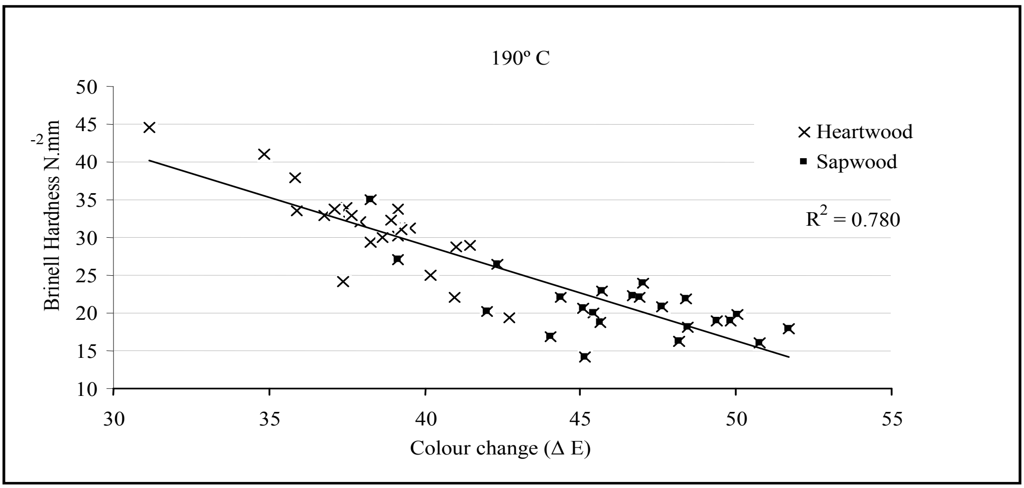


Fig. 4. Models for the prediction of TMW hardness (at 190ºC) using colour change (ΔE).

good indicator of its hardness. The obtained results can be applied in TMW production with mainly visually determined colour, which can significantly influence the application of the final product.

Acknowledgements

Authors would like to thank the company "Tarkett" d.o.o. Bačka Palanka – Serbia for technical support to carry out this research.

References

Akyldiz M., Ates S. 2008. Effect of heat treatment on equilibrium moisture content of some wood species in Turkey. Research Journal of Agriculture and Bilogical Science, 4 (6): 660–665.

Bekhta P., Niemz P. 2003. Effect of high temperature on the change in colour, dimensional stabilty and mechanical properties of spruce wood. Holzforschung, 57: 539–546.

Esteves B., Domingos I., Pereira H. 2007. Improvement of technological quality of eucalypt wood by heat treatment in air at 170–200°C. Forest Products Journal, 57 (1/2): 47–52.

Gonzales–Pena M., Hale M. 2009. Colour in thermally modified wood of beech, Norway spruce and Scots pine. Part 2: Property predictions from colour changes. Holzforschung, 63 (4): 394–401.

Jamsa S., Viitaniemi P. 2001. Heat treatment of wood – better durability without chemicals. In: Review on Heat Treatments of wood. Proceedings of the special seminar on heat treatments, 9 February 2001, Luxembourg: 17–22.

Johansson D., Moren T. 2006. The potential of colour measurement for strength prediction of thermally treated wood. Holz Roh Werkst, 64: 104–110.

Le Moguedec G., Dhote J.F., Nepveu G. 2002. Choosing simplified mixed models for simulations when data have a complex hierarchical organization. An example with some basic properties in Sessile oak wood (Quercus petraea Liebl.). Annals of Forest Science 59: 847–855.

Patzelt M., Emsenhuber G., Stingl R. 2003. Colour measurement as means of quality control of thermally treated wood. In: The First European Conference on Wood modification Ghent University Press, Ghent. Belgium, April 3–4, 2003: 213–218.

Popović Z., Todorović N., Gavrilović D. 2008. Compressive strength and hardness of thermally modified sessile oak wood. Prerada drveta, 21–22: 14–20 (in Serbian).

Shi L.J., Kocaefe D., Zhang J. 2007. Mechanical behaviour of Quevec wood species heat treated using Thermo Wood process. Holz als Roh- und Werkstoff, 65: 255–259.

Tjeerdsma B., Militz H. 2005. Chemical changes in hydrothermal treated wood: FTIR analysis of combined hydrothermal and dry heat-treated wood. Holz als Roh- und Werkstoff, 63: 102–111.

FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

EVALUATE AND DEVELOP AN EXISTING FOREST ROAD NETWORK BASE ON ENVIRONMENTAL FACTORS

Sattar Ezzati[1]*, Kyumars Mohammadi Sammani[2],
Akbar Najafi[1], and Hamid Hasangholipour[3]

[1]Department of Forestry, Tarbiat Modares University,
P. Box: 64414-356, Noor, Iran.
*E-mail: S.ezzati@modares.ac.ir, E-mail: a.najafi@modares.ac.ir
[2]Department of Forestry, Kurdistan University, Sanandaj, Iran.
E-mail: K.Mohammadi@uok.ac.ir,
[3]Department of Forestry, Guilan University, Rasht, Iran.
BSc gratuated in forestry. H.hasangholipour@yahoo.com

UDC 630.37

Received: 18 August 2010
Accepted: 10 January 2011

Abstract

Designing the forest road network is a complex and specialized process including route selection, field investigation, data analyzing, and finally determining the best variant coping with the site-specific road locations. The present study was designated to evaluate the existing forest road network and to develop the existing forest road network in the mountainous forests, north of Iran (Savadkoh district). In order to find appropriate options for road routing, firstly the effective environmental factors were identified such as slope, aspect and elevation layers. In the next step, the Geographic Information System (GIS) was applied to evaluate and develop an existing forest road network. The length and density of the existing road network were about 1.75 km and 10.14 $m.ha^{-1}$, respectively. The new variant was developed with regard to forest and physiographic conditions using PEGGER software. The length and density of new variant were 1.38 km and 8 $m.ha^{-1}$, respectively. The development of the existing road network has been increased the total road density from 10.15 to 18.16 $m.ha^{-1}$ and also could cover 55.5% of the forest area for timber harvesting operations. Approximately, 32.14% total length of the new variant was passed on 15–30% slope and 64% of the new variant was passed on 30–60% slope terrains, which is more likely to be minimal negative environmental impact. Moreover, the new variant has had a better performance than the existing road. The results showed that this method can be more helpful and road network can be designed quickly with less cost than traditional method. Also, it was confirmed by computer analysis that application of this system at such level can be effective in preparation of the optimum routes designing plans.

Key words: environmental impact, forest road network, GIS, PEGGER, Iranian forests.

Introduction

The Caspian forests located in the north of Iran cover the north facing slopes of the Alborz mountain ranges and are classified as temperate mountain forests. Consistent timber harvesting and protection of forests and making their direct benefits (economic, social, environmental etc.) (Gumus et al. 2008) available to public, primarily depends on a well arranged road network and transportation plan (Aykut et al. 1998). Forest functions are different in each country and depend on the culture and social life (Potocnik 1996), as shown in different studies (Hruza 2003, Demir 2007). Forest roads are the most important infrastructure for forestry operations, but without good plan, they could cause technical, economical and environmental problems (Demir and Oztork 2004). Therefore, in many studies there are attempts to compare the different variants of roads and finally to select the best one in order to enhance the accessibility of forest areas (Mohajer 2005). A suitable forest road network is necessary first to make a continuous forest harvesting and conservation, as well to use the direct benefits (Aykut et al. 1998). Timber harvesting being one of the main benefits, needs special attention during forest road network planning. Forest road network parameters change with regard to construction location requirements, different terrain conditions, particular technologies used and management activities. These requirements and the planning approach have to be related to management, economy and environmental ecology (Potocnik 1996). There are some other important factors that should be considered in forest road network design such as slope, elevation, aspect, type of bed rock, soil permeability and tree volume (Hosseini 2003). Not only costs has the main role in forest road planning, but also there are some other important factors, which should be considered such as forest road distribution, landscape patterns, forest hydrological role and soil conservation (Heralt 2002). The suitable distribution of the forest roads makes accessible all parts of the forest and thus all the processes like harvesting, plantation, silvicultural activities etc could be properly managed. The topographic condition is important not only for the design of the forest road network, but also can be effective for the forest road distribution among villages (ShiLiang et al. 2007). Appropriate and optimal distribution of forest road network from both economical and environmental viewpoint can help to meet the aims for sustainable development in forest management. A few of studies were conducted on the analysis of forest road network in the world. For example Akbari (1995) studied the existing forest roads in northern Iran and reported that the road density was 11.7 $m.ha^{-1}$, which was not enough to cover all district. Therefore, he proposed that road density should be developed to 16.5 $m.ha^{-1}$. Naghdi (2004) studied the planning of skid trail in planned and unplanned logging systems in a district in Mazandaran Province, nort of Iran, and found that the appropriate road density was 10.5 $m.ha^{-1}$. Pulkki (1992) described that the optimum road density in the different harvesting methods in Canada (log, tree length, whole tree) was 8.3–16.7 $m.ha^{-1}$. He stated that optimum skidding length was an effective factor on road structures. Picman and Pentek (1998) in Croatia stated that the optimum road density for ground skidding system was 14.7 $m.ha^{-1}$. Past studies developed forest road network with manual methods, while in the last few years the computer software and hardware is extensively and effectively used for the solutions of complex problem in forest areas, especially in the developed countries (Akay 2003, Rogers 2005, Demir 2007). Pentek et al. (2005) also analyzed the existing forest road network in Croatia investigating the mean skidding distance, its costs and suitable accessibility using GIS software. They showed that the average geometrical mean skidding distance was 158 m and the average existing real mean skidding distance was 250 m, whose factors of skidding wood assortment was 1.58. Today, the concepts like the digital map, digital terrain model, geographic information systems and the land information systems have gained an important role in design of the road network (Akay 2003, Demir and Oztork 2004, Aruga at al. 2005). The computer software is extensively used in many countries of the world for design of public and forest road networks. Thus, the aim of the present study was to investigate the forest road network with regard to road density and distribution, and to use this planning approach as a case study. Further, the aim was to compare the existing road network and new planned road segments according to environmental factors, to cover all studied district and to compare them by applying geographic information system.

Material and Methods

The study was carried out in a mountain temperate forest district covering 1722 ha of Mazandaran province, north of Iran. The area is located between 34°3′40″ and 35°1′00″ E, and 36°08′00″ and 36°11′40″ N (Fig. 1). The length of the existing road is 1.71 km. The road density was obtained refers to reference and road spacing was determined as theoretically road density

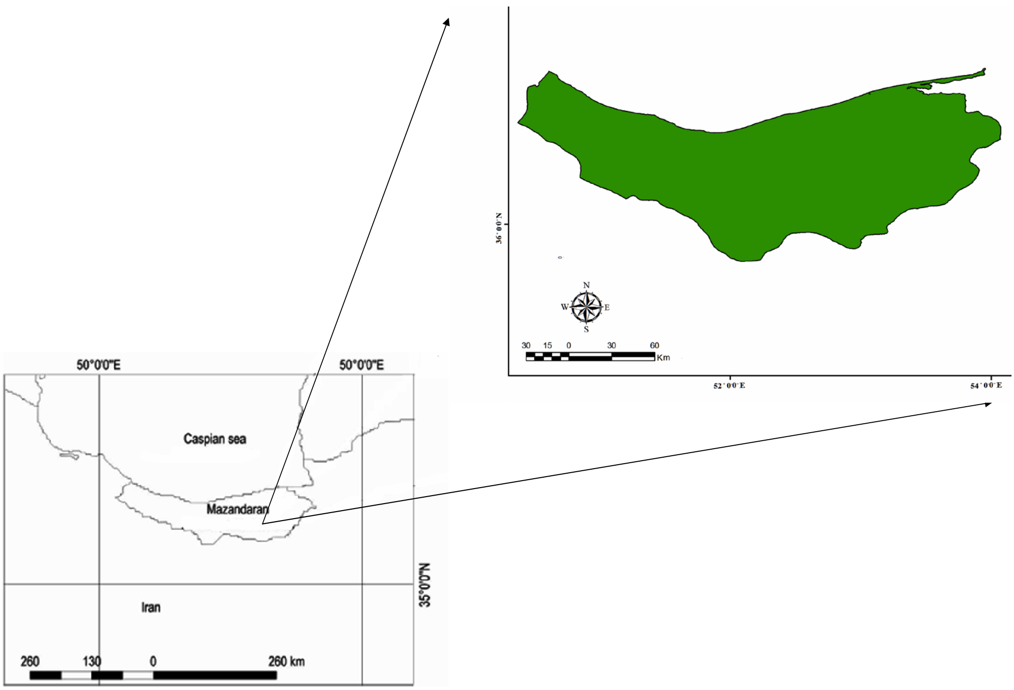


Fig. 1. General location of the study area.

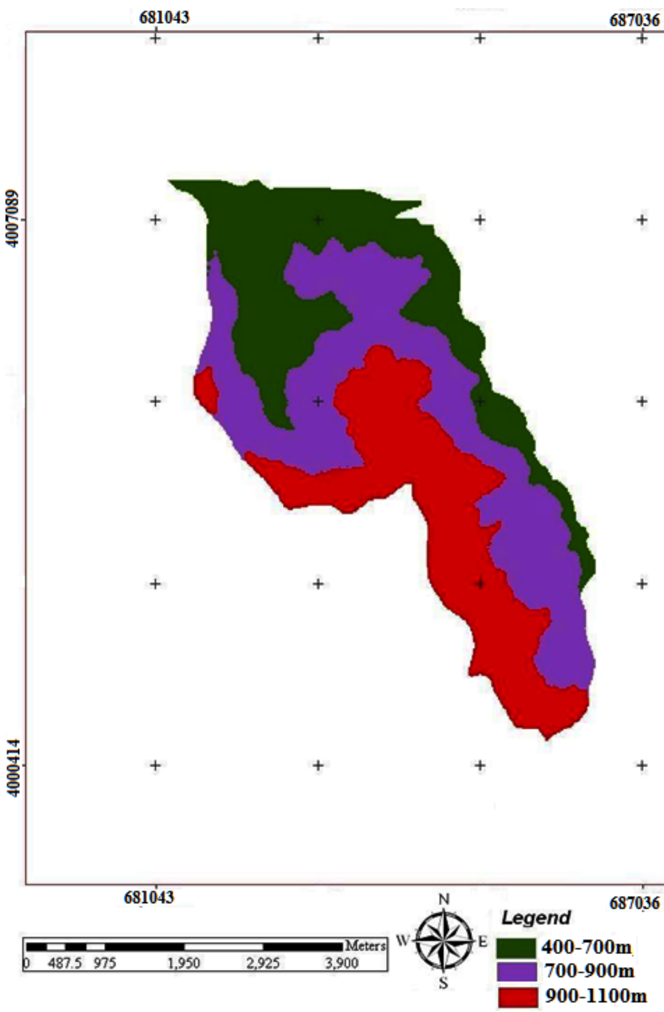


Fig. 2. Elevation map of the study area.

(Backmund 1968) and for the existing road it was 10.15 $m.ha^{-1}$. All road segments in the study area were recorded by reconnaissance using GPS (Garmin 60CX brand) and study of topographic maps. Then, by using Digital Elevation Model (DEM) in Geographic Information System (GIS), the affecting map factors were produced. In fact by using DEM, slope, aspect and elevation, also tree volume ($m^3.ha^{-1}$) maps were produced. The maps were elaborated by inventory data from field study. Tree volume ($m^3.ha^{-1}$) is one of the suitable factors for road density. In fact, when volume is less than 250 $m^3.ha^{-1}$ appropriate road density is 10 $m.ha^{-1}$ and when volume is more than 250 $m^3.ha^{-1}$, appropriate road density is 20 $m.ha^{-1}$ (Demir 2007). Majority of the study area had more than 250 $m^3.ha^{-1}$ volume. Therefore, the district studied needs about 20 $m.ha^{-1}$ road density. After determining of the existing roads (Pentek et al. 2005) new road segments were designed in accordance with the management plan. At this stage, the parameters were slope, aspect, stability maps overlaid and the critical points based on environmental considerations were determined. At the next stage, we tried using PEGGER software in GIS environment to propose the new variant additional to the existing road, which passes more positive and pass less negative points.

Results

To evaluate and develop the existing road, firstly the important maps e.g. (aspect, elevation and volume) were provided in GIS (Fig. 2, 3 and 4, respectively). In the next step, developed and existing road started. As you seen in the Fig. 5 the new variant has included two sections. First section is started almost in the middle of existing road, and another is started in the end of the existing road network. These two segments were previously planned to cover the uncovered part of the study area. Total the length of road 510 km (2.9 km) of the existing roads' longitudinal slope was more than 0–15%, while new variants do not pass such slopes.

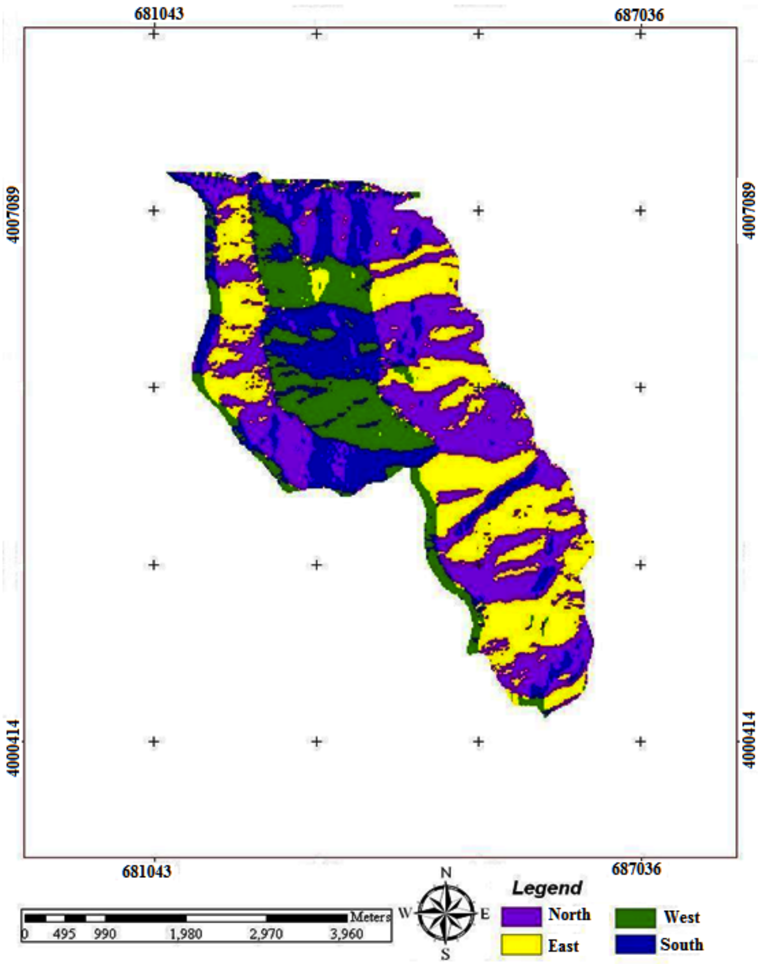


Fig. 3. Aspect map of study area.

The proportions of the existing and newly planned road network passing slope of 15–30% were 15.7% and 32.14%, respectively. Except these, 69.92% of existing roads and 63.90% of newly planned ones passed slopes 30–60% (Fig. 5 and Table 1). Finally, 11.47% of the existing roads' length and 3.96% of the new variant roads passed slopes more than 60% steep. The length and density of the existing road network was 1.75 km and 10.14 m.ha^{-1}, respectively. The new variant developed the road length to 1.38 m, and as consequence, the road density was 8 m.ha^{-1}. So total road density of the area was increased to 18.15 m.ha^{-1}. The total percent of road network (both existing variant and new variant) passing slopes of 0–15%, 15–30%, 30–60%

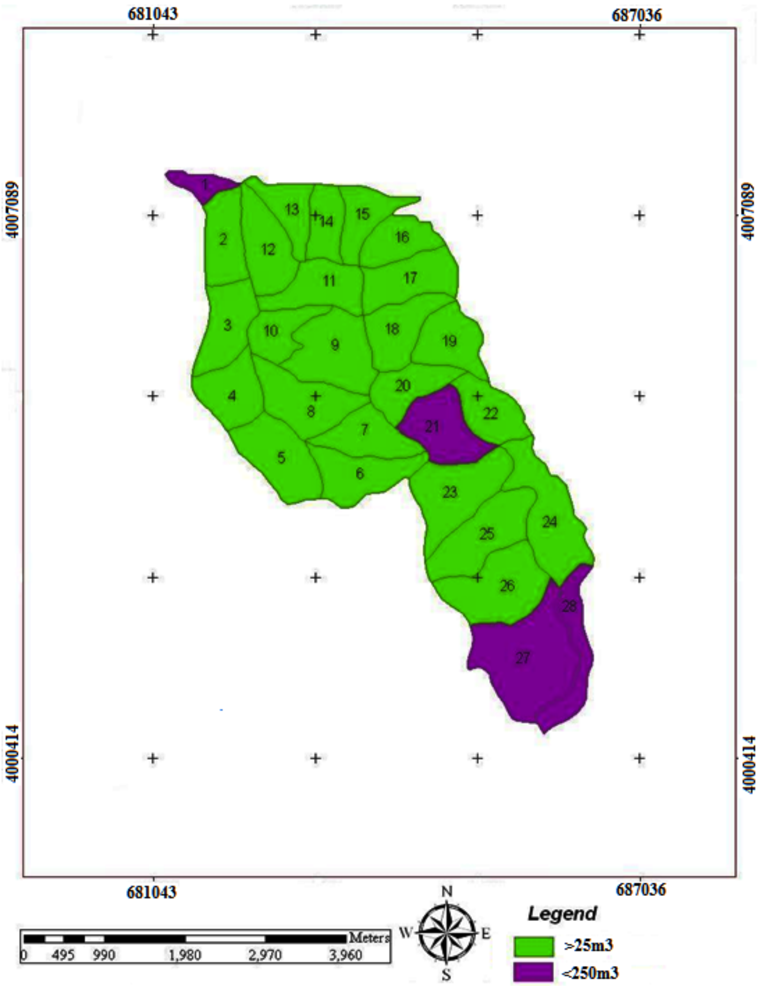


Fig. 4. Volume map of the study area.

and > 60% were 1.63%, 22.92%, 67.29% and 8.16%, respectively.

Discussion

The present study showed that environmental parameters such as longitudinal slope, aspect and elevations affected significantly the road network planning. When tree volume was less than 250 m^3.ha^{-1}, appropriate road density was 10 m.ha^{-1} and when volume was more than 250 m^3.ha^{-1}, appropriate road density was 20 m.ha^{-1} (Demir 2007). The existing road network plan is not capable of activating all management plan activities according to the calculations, moreover majority of study area has more than 250 m^3.ha^{-1} tree volume, and so the existing road density (10.15 m.ha^{-1}) is not enough. If the management activities were carried out within the existing area, the density of forest road network would be increased only with 18–20 m.ha^{-1} or a rate of 50% (Sobhani and Stuart 1991). In contrast, the new variant could increase the road density from 10.14 to 18.14 m.ha^{-1} and cover area by about 55%, which is more acceptable (Akbari 1995, Lotfalian 2001, Demir 2007). With the road network to be constructed, the forest will be used in the optimal way and through utilization at maximum level, could be very beneficial in terms of environment. Because, by way of digital terrain modeling and assessment of slope thereat, the usage of a land in an impropriate way will be prevented and besides, the most beneficial road will have been planned in technical, economical and ecological aspects. As it is obvious in Table 1, the new variant does not pass from 0–15% slope because of topographic condition. In fact, there is no area with 0–15% slope in this section of study area (Fig. 5). The areas with 15–30% slope have a good condition to road building and we should try to design the forest road in this slope (Hosseini 2003). New variant is passed on this segment about 32.14% more than existing road (15.7%), so new variant has been a better situation than the existing road in this segments. We should try to design the forest road in the safe area and low slope, because, when slope increase, not only the cost increase but also soil erosion occurs, as well as it cause the stability of road reduces (Lioyd and Swift 1985). Approximately 63.94% and 3.96% of new variant are passed on 30–60% and over 60% slopes, respectively. New variant was passed on more than 60% slopes less than existing road respectively 3.96% and 11.47%. In contrast new variant has the better design than existing road, which not only can cover the most study areas but also passed more than existing road in the gentle slopes than existing road network. Total road network (the exist-

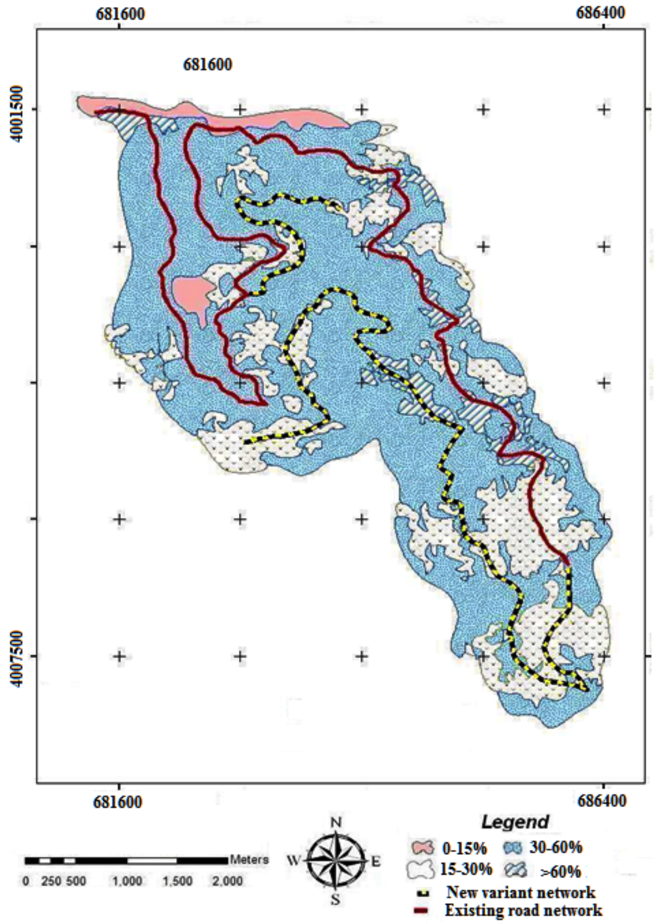


Fig. 5. The existing and new variant roads in different slope classes.

Table 1. The existing and new proposed road which are passed in different slopes.

Slope groups, %	Existing road			New variant			Change, %		Total road		
	Road length, km	Propo-rtion, %	Road density, m.ha^{-1}	Road length, km	Propo-rtion, %	Road density, m.ha^{-1}	Incre-ased (+)	Decre-ased (–)	Road length, km	Propo-rtion, %	Road density, m.ha^{-1}
0–15	0.51	2.91	0.29	0	0	0		2.96	0.51	1.63	0.29
15–30	2.746	15.7	1.59	4.422	32.14	2.57	16.4		7.168	22.92	4.16
30–60	12.229	69.92	7.1	8.816	63.90	5.11	5.98		21.045	67.29	12.20
>60	2.006	11.47	1.16	0.547	3.96	0.31		7.51	2.553	8.16	1.48
Total	17.491	100	10.14	13.785	100	8			31.276	100	18.14

ing and new variants) has 18.14 m.ha^{-1} road density which is acceptable for north forests of Iran (Sobhani and Stuart 1991, Lotfalian 2001). With propose a new variant and passing more in the low slopes and avoid from high slopes, now total road in 4 classes of slope 0–15%, 15–30%, 30–60% and more than 60% was passed 1.63%, 22.92%, 67.29% and 8.16% respectively which has better situation than existing road.

Conclusion

The new forest road network plan was achieved by the addition of a total of 3.13 km forest roads designed for successful timber harvesting activities. The development of the existing road network increased the total road density from 10.14 to 18.14 m.ha^{-1} and also covered 55.5% of the forest area available for logging. The length of new variants' longitudinal slope was more than 15–30% in about 32% of the cases. Comprehensive GIS database and research led to this success. Forest road networks aimed at enhancing timber operations must be implemented to meet the targets of the management plan. 20 m.ha^{-1} road density, which is a conservative measure need not be a criterion for forest network plans. A geographical information system should be more used as a tool for functionally based forest road network plans by reason of its geographical data storage, updating, and number of possible analyses.

References

Akay A.E. 2003. Minimizing total cost of construction, maintenance, and transportation costs with computer-aided forest road design. PhD thesis. Oregon State University, Corvallis, Oregon. 229 p.

Akbari H. 1995. Investigate the existing forest road network and determine the most suitable skid trails in Liresar Project in the north of Iran (district 2). MSc thesis. Faculty of Natural Resources and Marine Science, Tarbiat Modares University. 104 p.

Aruga K., Sessions J., Akay A.E. 2005. Heuristic planning techniques applied to forest road profiles. Journal of Forest Research 10 (2): 83–92.

Aykut T., Senturk N., Demir M. 1998. Situations of Turkish forest roads in 75th

years of the Republic of Turkey. Symposiums of the Turkish Forestry in 75th Years of the Republic of Turkey, Istanbul, Turkey.

Backmund F. 1968. Indices for the degree of accessibility of forest districts via roads. Schweizerische Zeitschrift für Forstwesen 119 (11): 445–452.

Demir M., Ozturk T. 2004. A Research on Forest Road Planning and Projecting by Inroads Software in Bolu Region of Turkey. American Journal of Applied Sciences 1 (4): 295–301.

Demir M. 2007. Impacts, management and functional planning criterion of forest road network system in Turkey. Transportation Research Part A, 41 (1): 56–68.

Gumus S., Acar H.H., Toksoy D. 2008. Functional forest road network planning by consideration of environmental impact assessment for wood harvesting. Environmental Monitoring and Assessment, vol. 142 (1–3): 109–116.

Heralt L. 2002. Using the roading system to design an optimum forest road variant aimed at the minimization of negative impacts of the natural environment. Journal of Forest Science 48 (8): 361–365.

Hosseini S.A. 2003. Forest road network planning using geographic information system technology in the Khiroudkenar forests (Noshahr, North of Iran). PhD thesis. Faculty of Natural Resources and Marine Science, Tarbiat Modares University, 148 p.

Hruza P. 2003. Optimization of forest road network under principles of functionally integrated forest management. Journal of Forest Science 49 (9): 439–443.

Lioyd W., Swift Jr. 1985. Forest road design to minimize erosion in the Southern Appalachians. In: Proceedings of forestry and water quality: A Mid-South Symposium. Little Rock, Arkansas, May 8–9, 1985. Edited by B.G. Blackman, University of Arkansas: 141–151. Available: http://coweeta.uga.edu/publications/2194.pdf

Lotfalian M. 2001. Investigate the effective factors to determine the optimum density of forest roads network (North of Iran – Mazandaran Province). PhD thesis. Department of Natural Resources, Tehran University, 130 p.

Mohajer M.M. 2005. Silviculture. Tehran University Publications, 387 p.

Naghdi R. 2004. Evaluation and comparison of tree length and log to present a appropriate model of forest road network in the north of Iran (case study Mazandaran province – Neka). PhD dissertation. Faculty of Natural Resources and Marine Science, Tarbiat Modares University. 310 p.

Pentek T., Picman D., Potocnik I., Dvorscak P., Nevecerel H. 2005. Analysis of an existing forest road network. Croatian Journal of Forest Engineering 26 (1): 39–50.

Picman D., Pentek T. 1998. The influence of forest roads building and maintenance costs on their optimum density in low lying forests of Croatia. In: Seminar on Environmentally Sound Forest Roads and Wood Transport in Sinaia, Romania. Rome, FAO: 87–102.

Potocnik I. 1996. The multiple use of forest roads and their classification. Proceedings of the Seminar on Environmentally Sound Forest Roads and Wood Transport, Sinaia, Romania, Proceedings: 103–117.

Pulkki R. 1992. Cut-to-Length, Tree-Length or Full Tree Harvesting? Lakehead University, Faculty of Forestry, 6 p. Available: www.Borealforest.com

Rogers L.W. 2005. Automating Contour-Based Route Projection for Preliminary Forest Road Designs using GIS. Ms.C. thesis. University of Washington. 87 p.

ShiLiang Liu, BaoShan Cui, MinXia Wen, Juan Wang, ShiKui Dong 2007. Statistical regularity of road network features and ecosystem change in the Longitudinal Range-Gorge Region (LRGR). Chinese science bulletin, vol. 52, Supp. II: 82–89.

Sobhani H., Stuart W.B. 1991. Harvesting system evaluation in Caspian forests. Journal of Forest Engineering 10 (1): 24–29.

FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

FIRST RESULTS OF RAPD-ANALYSES OF INTRASPECIFIC POLYMORPHISM OF DOUGLAS-FIR CULTIVATED IN BULGARIA AND BELARUS

Volha Chyzhyk[1], Tatsiana Antsipava[1]*, Vladimir Torchik[1], and Emil Popov[2]

[1]National Academy of Sciences of Belarus, State Scientific Institution "Central Botanical Gardens", Surganova Street-2b 220012, Minsk, Belarus. *E-mail: hbc@mserv.bas-net.by

[2]Forest Research Institute – Bulgarian Academy of Sciences 132 "St. Kliment Ohridski" blvd., Sofia 1756, Bulgaria. E-mail: emilpopov99@hotmail.com

UDC 630.232

Received: 13 May 2010
Accepted: 09 November 2011

Abstract

The aim of the research was to elucidate existing intraspecific polymorphism of Douglas-fir plantations in Bulgaria and Belarus using Random Amplified Polymorphic DNA (RAPD) markers and to estimate genetic similarities and distances. RAPD-primers that reveal high polymorphism were selected. Seven Douglas-fir populations from Bulgaria and one from the Central Botanical Gardens in Belarus were included in the study, and individual RAPD patterns for 8 primers were obtained. The obtained RAPD-patterns were used to calculate the genetic distances among the populations studied.

Key words: *Pseudotsuga menziesii* (Mirb.) Franco, genetic distance.

Introduction

High volume productivity and relative resistance to diseases, cold and drought of Douglas-fir made it one of the most broadly used exotic coniferous species in Europe. The introduction of Douglas-fir in Bulgaria for afforestation started at the beginning of the last century and nowadays the plantations occupy 6,714 hectares. In Belarus, the species was not widely used but also showed good growth and resistance to frost and diseases. The origin of almost all of the established plantations is unknown in both countries, except that of provenance tests in Bulgaria.

The aim of the present study was to examine existing intraspecific polymorphism of Douglas-fir plantations in Bulgaria and Belarus using Random Amplified Polymorphic DNA markers and to estimate genetic similarities and distances.

Materials and Methods

The plantations, from which samples have been collected, can be grouped as follows:

1. Provenance experimental plantations in Bulgaria established in the forest services of Kostenets and Kyustendil with known origin (Table 1 and Figure 1). The plantations are 20 year old and have been established with seedlings produced from seeds supplied by the National tree seed laboratory of the USA.

2. Plantations and groups of trees in Bulgaria and Belarus showing stable growth and health status without information about their origin (Table 1).

Total genomic DNA was extracted from Douglas-fir needles in liquid nitrogen using standard CTAB protocol (Dreiper et al. 1991). DNA concentration and purity was estimated using the Agilent 8453 spectrophotometer.

Polymerase chain reaction (PCR) mixture to amplify RAPD fragments (25 µl) contained 0.2 мM dNTP (Fermentas); 1× *Taq*-polymerase buffer (Fermentas); 3.5 мM $MgCl_2$ (Fermentas); 10 pmol primer; 1.5 U Taq- polymerase (Fermentas); 50 ng DNA. PCR was carried out in Mastercycler personal thermocycler (Eppendorf), using an initial "hot start" of 94°C for 4 min, followed by 44 cycles of 1 min at 94°C, 1 min at 38–40°C, and 2 min at 72°C, and terminated with a final extension at 72°C for 8 min.

Amplified fragments were resolved on 2% agarose gel in 1× TAE (tris-acetic acid-EDTA) buffer with ethidium bromide solution (final concentration – 0.5 µg.ml^{-1}) (Maniatis et al. 1982).

Table 1. The origin of *Pseudotsuga menziesii* (Mirb.) Franco.

Provenance number or name	Seed zone	Origin (region and state in the USA)	Latitude	Longitude	Elevation, m	Location
5	403	Newhalem, Washington	48°5′	121°5′	500	Bulgaria, State forest enterprise Kostenets
6	403	Darrington, Washington	48°0′	121°5′	1167	Bulgaria, State hunting enterprise Kyustendi
19	661	Parkdale, Oregon	45°5′	121°5′	900	Bulgaria, State forest enterprise Kostenets
23 a	482	Bates, Oregon	45°0′	118°5′	1333	Bulgaria, State forest enterprise Kostenets
23 b	482	Bates, Oregon	45°0′	118°5′	1333	Bulgaria, State forest enterprise Kyustendil
Minsk		Unknown	–	–	–	Minsk Belarus, CBG of NAS of Belarus
White water		Unknown	–	–	1400	Bulgaria, State hunting enterprise Alabak
Shipka		Unknown	–	–	800	Bulgaria, State forest enterprise Kazanlak

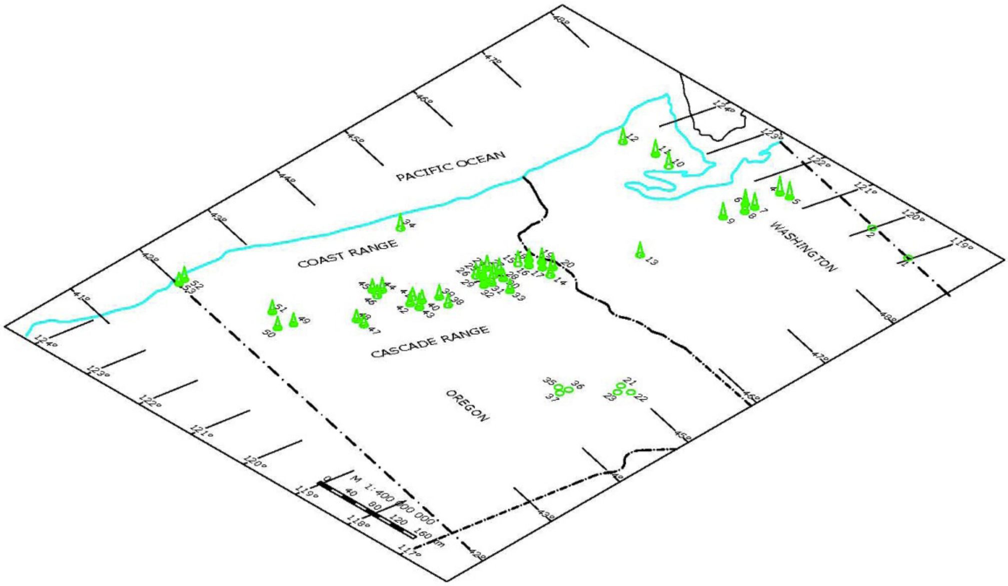


Fig. 1. Geographic location of Douglas-fir seed parents in Oregon and Washington (USA) used for provenance tests in Bulgaria.

Gels were visualized in transilluminator (Hoefer) and photographed. DNA banding patterns sizes were scored using the Phoretics™ 1D program (version 2003.02, Nonlinear Dynamics Ltd). Only distinct, discrete bands were used for analysis. A 100 kb DNA ladder (Fermentas) was used as molecular weight standard.

All analyses were repeated at least three times. Multilocus genetic profiles were composed for each tree using binary scores (1 – presence, and 0 – absence of a RAPD fragment, respectively). The MS Excel program was used to estimate parameters of diversity and differentiation between different samples.

The ability of the most informative primers to distinguish Douglas-fir samples was assessed by calculating their resolving power (**Rp**) according to Gilbert et al. (1999):

$$\mathbf{Rp} = \mathbf{\Sigma I_b},$$

where $\mathbf{I_b} = 1 - (2 \times |0.5 - p|)$, **p** – proportion of trees containing the certain fragment (Gilbert et al. 1999).

The genetic similarity between different samples (S) were estimated using the PHYLIP v. 3.63 program and formula by Nei and Li (1979):

$$\mathbf{S = 2a\ (2a + b + c)^{-1}},$$

where **a** – number of fragments amplified (shared) in both individual trees or samples 1 and 2; **b** – number of fragments amplified in tree or sample 1 but not in 2; **c** - number of fragments amplified in tree or sample 2 but not in 1 (Debnath 2007, Nei and Li 1979). From genetic similarity coefficients (S) the genetic distances matrixes were obtained. The similarity matrix was used as input data for cluster analysis using unweighted pair-group method with arithmetic averages (UPGMA), and the resulted dendrograms were drawn. To evaluate the robustness of the groupings formed, the binary data set was subjected to bootstrap using the TREECON software program.

Results and Discussion

RAPD-primers that reveal higher level polymorphism were selected. We tested 10 different primers developed by University of British Columbia (Canada) and successfully used for Douglas-fir population polymorphism analyses (Aagaard et al. 1998a, 1998b). From 10 primers tested, eight (UBC-234, -328, -336, -460, -570, -504, -330, -428) amplified discrete RAPD products and were used for further work.

The selected primers' characteristics are presented in Table 2. Seven Douglas-fir populations from Bulgaria and one from Belarus were studied, and individual RAPD patterns were obtained for 8 primers.

The amplicon sizes were in the range of 320-2000 bp. Amplicon number varied from 11 to 4 depending on a primer. The maximum number of polymorphic bands (8) was generated by the UBC336 primer, and minimum (3) – by the UBC570 and UBC428 primers, the average number of polymorphic loci per primer was five.

The ability of 8 most informative primers to distinguish between Douglas-fir genotypes was assessed by calculating Resolving power (**Rp**) parameter for each primer according to Gilbert et al. (1999). The **Rp** value was varied from 1.3 (for the UBC428 primer) to 5.0 (for the UBC330 and UBC336 primers) (Table 2).

We revealed 58 amplicons: 40 polymorphic (69%) and 18 monomorphic (31%), identified in all Douglas-fir gen-

Table 2. RAPD-primer names and sequences PCR amplified in Douglas-fir samples, the number of polymorphic, monomorphic and unique fragments per primer, the fragment (amplicon) size in base pairs (bp) and Resolving power (Rp) for all primers.

Primer	Sequence (5′-3′)	Total fragments	Monomorphic fragments	Polymorphic fragments	Unique fragments	Fragment size range (bp)	Resolving power (Rp)
UBC 234	TCCACGGACG	8	3	5	0	400–2000	3.5
UBC 328	ATGGCCTTAC	7	3	4	1	400–1200	2.3
UBC 336	GCCACGGAGA	10	2	8	1	320–900	5.0
UBC 460	ACTGACCGGC	11	6	5	0	350–1200	3.5
UBC 570	GGCCGCTAAT	5	2	3	0	420–900	1.5
UBC 504	ACCGTGCGTC	5	0	5	0	450–1200	3.0
UBC 330	GGTGGTTTCC	8	1	7	1	480–900	5.0
UBC 428	GGCTGCGGTA	4	1	3	0	900–1300	1.3

otype profiles (patterns) that can considered as species specific markers for *Pseudotsuga menziesii*. Some primers amplified unique sample specific fragments: 450 bp fragment in "Shipka" (amplified by the UBC328 primer), 600 bp (UBC336) and 610 bp (UBC330) in "Bates No 23b". This unique amplicons can be used for individual Douglas-fir genotypes identification. Douglas-fir total DNA amplification results with UBC570 and UBC504 primers are presented by Figure 2.

The binary (presence-absence) matrix of was inferred from the RAPD-pattern assuming that amplicons of the same size represent the same RAPD loci. Genetic patterns were compared between individual trees and samples. The genetic similarity and distance coefficients were calculated following the formula suggested by Nei and Li (1979) (Table 3).

The maximum genetic distance of 0.1895 was between Bates No 23a and No 19 samples (Bulgaria). The minimal genetic distance of 0.0310 was between Parkdale No 19 and Newhalem No 5 samples based on 58 RAPD loci. Genetic distances between the Central Botanical Gardens of NAS of Belarus populations and Bulgarian samples were within the 0.0855–0.126 range (Table 3).

Dendrograms representing phylogenetic relationships between Douglas-fir samples were generated using the UPGMA cluster analysis based on the similarity matrices and the Treecon program (Fig. 3). Darrington No 6, White water, Parkdale No 19 and Newhalem No 5 formed one cluster (A) in the dendrogram. Shipka and CBG of NAS of Belarus samples were placed next to this cluster. Bates No 23b and Bates No 23a samples formed a separate group in this dendrogram (cluster B). Bates 23 samples representing provenance from Oregon had shown low indexes of growth capacity and health status in previous assessments (Popov 1996, Georgieva 2009). Big differences were found between Bates 23 and the provenances from Cascade Range and coast range in terms of growth and disease resistance.

Numbers at the nodes are bootstrap

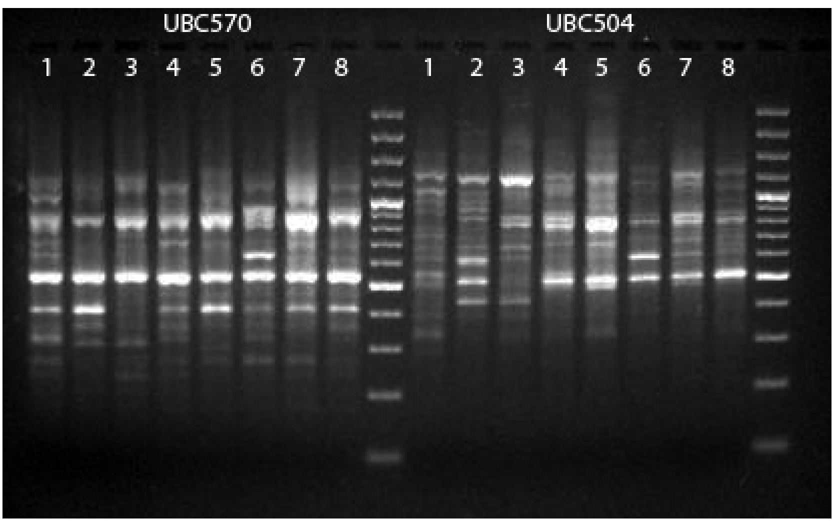


Fig. 2. RAPD pattern of Douglas-fir genotypes amplified using the UBC570 and the UBC504 primers.

Table 3. Matrix of the genetic distance coefficients (Nei and Li 1979) for eight Douglas-fir samples based on the RAPD genotypes.

	1	2	3	4	5	6	7	8
1	**0.0000**							
2	0.1296	**0.0000**						
3	0.1142	0.0685	**0.0000**					
4	0.1194	0.1705	0.1895	**0.0000**				
5	0.0946	0.1446	0.1789	0.0310	**0.0000**			
6	0.1102	0.1444	0.1446	0.0932	0.0833	**0.0000**		
7	0.0855	0.1442	0.1161	0.0598	0.0733	0.0644	**0.0000**	
8	0.1050	0.1395	0.1395	0.0520	0.0537	0.0568	0.0489	**0.0000**

Samples: **1** – Central Botanical Gardens of NAS of Belarus; **2** – Bates No 23b; **3** – Bates No 23a; **4** – Parkdale No 19; **5** – Newhalem No 5; **6** – Shipka (40 years); **7** – Darrington No 6; **8** – White water.

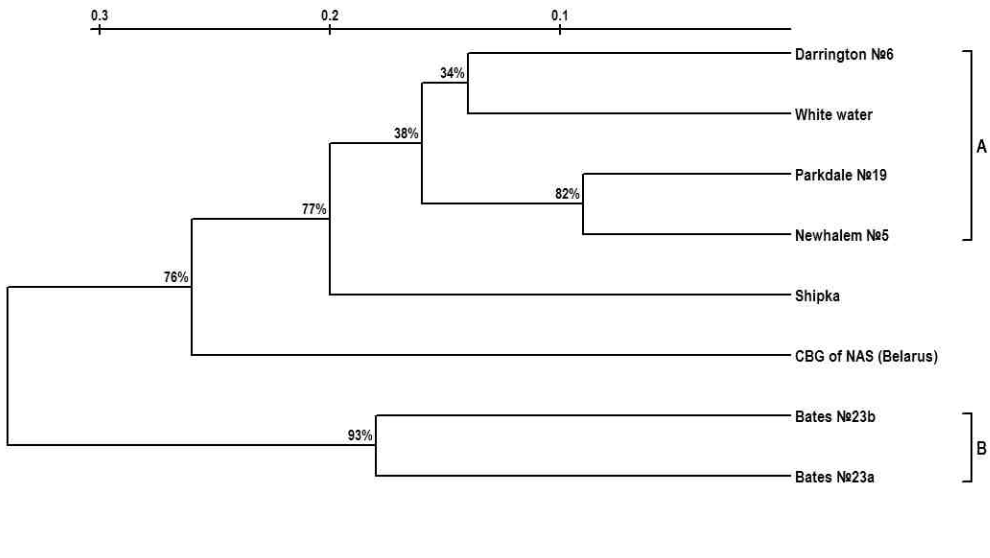


Fig. 3. Unweighted pair-group method with arithmetic averages (UPGMA) dendrogram based on similarity matrix between Douglas-fir samples.

values (%) obtained from 1000 replicate analyses.

In conclusion, RAPD- analysis on 8 primers and 58 loci allowed to differentiate Douglas-fir in Bulgaria from Belarus samples. Primers selected in this study can be used in further studies of Douglas-fir polymorphism.

Acknowledgments

The work is carried out within the scope of Bulgaria-Belarus Project "Assessment of Sylvicultural, Phenotypical and Biochemical Characteristics of Douglas-Fir (*Pseudotsuga menziesii* (Mirb.) Franco) for establishment of Fast-growing Plantations and Biodiversity Conservation".

References

Aagaard J.E., Krutovskii K.V., Strauss S.H. 1998a. RAPDs and allozymes exhibit similar levels of diversity and differentiation among populations and races of Douglas-fir. Heredity 81: 69–78.

Aagaard J.E., Konstantin V., Krutovskii K.V., Strauss S.H. 1998b. RAPD markers of mitochondrial origin exhibit lower population diversity and higher differentiation than RAPDs of nuclear origin in Douglas-fir. Molecular Ecology 7: 801–812.

Debnath S.C. 2007. Inter simple sequence repeat (ISSR) to assess genetic diversity within a collection of wild lingonberry (*Vaccinium vitis-idaea* L.) clones. Canadian Journal Plant Science 87: 337–344.

Dreiper J., Skott R., Armitidzh F., Uoldena R. 1991. Genetic Engineering of Plants: A Laboratory manual. Moscow, Mir, 408 p.

Georgieva M. 2009. Diseases on Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and their influence on the species introduction in Bulgaria, 138 p. (In Bulgarian).

Gilbert J.E., Lewis R.V., Wilkinson M.J., Caligari P.D. 1999. Developing an appropriate strategy to assess genetic variability in plant germplast collection. Theoretical and Applied Genetics 98: 1125–1131.

Maniatis T., Fritsch E.F., Sambrook J. 1982. Molecular cloning: A Laboratory manual. New York: Cold Spring Harbor Laboratory, 545 p.

Nei M., Li W.H. 1979. Mathematical model for studying genetic variation in terms of restriction endonuclease. Proceedings of the National Academy of Sciences USA 76: 5269–5273.

Popov E. 1996. A complex assessment of 55 Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) provenances. In: Proceedings Scientific Papers "Second Balkan Scientific Conference on Study, Conservation and Utilization of Forest Resources", 3–5 June, Sofia, I: 157–162. (In Bulgarian).

CREATING A DATABASE FOR THE DENDRARIUM IN THE TRAINING AND EXPERIMENTAL FOREST RANGE "PETROHAN" USING REMOTE SENSING AND GIS

Emil Galev

University of Forestry, Faculty of Ecology and Landscape Architecture, 10 Kliment Ohridski Blvd., 1756 Sofia, Bulgaria. E-mail: emil.galev@abv.bg

UDC 004

Received: 12 July 2010
Accepted: 22 November 2011

Abstract

Using Remote Sensing and GIS technologies as an aid for creating database for the dendrarium in the Training and Experimental Forest Range "Petrohan" is the focus of discussion in the paper. The cardinal study goal is illustrating a concrete instance of applying GIS technology in the landscape architecture survey. This paper describs the methodology of vegetation mapping using traditional method combined with remote sensing data. Creating graphical and attribute table databases is also useful in the education of students in the University of Forestry in Sofia. Making semester projects in academic discipline "Dendrology" the students have to learn and analyze the features of trees and shrubs. GIS software provids the capability to analyze large data sets containing features of coniferous and deciduous trees and shrubs in the dendrarium. In the other hand the purpose of the development of the vegetation mapping methodology is to provide an objective and cost-effective survey method utilizing satellite remote sensing for the vegetation mapping. Overall, these results confirm that satellite imagery data coupled with field observations and direct measurements can be used effectively for precise mapping of trees and shrubs.The result of the analysis shows that image objects extracted from satellite data provide a new opportunity to make detailed inventory maps of ornamental vegetation in parks. In such cases, it is imperative that such exploration technologies should be used, which are cost effective and provide greater accuracy. An integrated approach of remote sensing and GIS technologies can just suffice these requirements during exploratory efforts in difficult terrains.

Key words: satellite image, mapping, vegetation, coniferous, deciduous.

Introduction

Detailed mapping of tree and shrub species is often required in various landscape architecture design projects. This paper illustrates a concrete instance of the vegetation mapping using Google Earth Satellite Database, assuming the future use of satellite imagery data for the vegetation inventory information acquisition. A key requirement for the effective inventory of ornamental plants is the accuracy. Hand-mapping in the field is a technique commonly used in practice, but is inaccurate. In addition hand-mapping from field observation requires access to the site from the ground and visibility, a condition that does not exists always, especially on a very steep ground and in the presence of closely planted trees and bushes. Then measurement of distances is extremely time-intensive and often necessitates a large number of linear measurements. Because of these constraints, hand mapping is usually done on an as-needed basis, and comprehensive map that would support data base is done after taking dimensions of the terrain. There is need, therefore, to develop repeatable and reliable techniques for successive field and computer work, which allows mapping the vegetation objects, which can be accomplished using more conventional methods.

This study tested the suitability of the satellite imagery for improved mapping of plants in the parks. This work will be useful in future decisions about methods for detailed mapping of vegetation.

The objective of the investigation was to make a detailed dendrological inventory. The information it has provided might be useful insofar as directing future surveys or design projects. The graphical output serves as a basic plan to assess future activities in the park. The goals of this project were to map the spatial location of ornamental plants in the study area and to test the efficacy of satellite imagery for plant mapping.

Resolution of Google Earth data is about 1.00 m and provides enough information for distinguishing the majority of the trees. On the other hand, Google Earth imagery provides useful information such as diameters of the crowns. Therefore it is suitable for delineating trees in a quite precise manner.

Material and Methods

In this study, a detailed mapping from actual satellite data was conducted for a specific park area. The dendrarium in the Training and Experimental Forest Range "Petrohan" near the village of Barzia was chosen for the study area. According to (Kuneva et al. 2009) this area is characterized by a rich species diversity of trees and shrubs and dense wood massifs. The ground in the area is characterized by displacement and slope configuration by (Destan 2007).

Technical objectives of the research are:

– to conduct the inventory in a way that all trees and shrubs occurring at the park are documented with their location and size in a scientifically credible manner;

– to develop methodology to accurately identify the location of ornamental park vegetation using satellite imagery, image-editing software and graphic software;

– to test methodology in a study area marked by difficult access of terrain and dense vegetation within the AutoCAD environment;

– to assess the accuracy of the mapping.

For this study, traditional methods by (Rangelov 2003) were used in the beginning of the field work for initially mapping of the terrain data, which was recorded in a sketch and then transferred to the digital format. According to (Asenova 2009) the multispectral satellite data with a spatial resolution of 1.00 m allows identification of quite a number of vegetation objects and amend their location and size at a drawing.

The sketch-map was created for use as a tentative set. Using a combination of field photos and field notes hand-mapped trees, shrubs and massifs were adjusted on the display of the image data. Using distinguished and adjusted trees as pickets were conducted direct measurements in the field and small trees and shrubs were fixed in the drawing.

The final product was derived from the Google Earth data after conducting the field work and after some amendments in the drawing. This product will allow the resource manager of the park to make up to date, well informed management decisions with a detailed vegetation map in a relevant and efficient timeframe.

A detailed drawing for the plants is created in three stages. The investigation started with drawing up a field sketching map produced for the park including areas managed as a dendrarium. The investigation used standard floristic inventory procedures to identify and document all 116 plant species observed. Location of the existing plants was judged by sight at first and was recorded as coniferous and deciduous trees or shrubs. The locations were marked in the geodetic survey as points (for the ornamental trees) or as polygons (for woodlands and shrubs). The geodetic survey was updated and made more precise prior to conducting the first stage of field work at the park. The primary purpose of the conducted field inventory is to create a field sketching map, and also verify the current presence of already-documented species, provide information on relative abundance, provide distribution information on endangered or threatened species or species of concern. Positions of the plants on the sketching map were fixed by traditional methods, i.e. approximately. The vegetation of the sketch-map has been scanned and processed in a digitized form. The trees were delineated over the drawing like points and the shrubs – like polygons.

Results and Discussion

The study starts with the image conversion in derivative formats for CAD software, which allow to insert it into AutoCAD where is possible to delineate image objects. The conversion was done using image processing software. The satellite photo was not put under geometrical rectification. This was equilibrated with just a little deformation of the image in order to coinciding with the geodetic cadastre. The satellite photo was used for this study as a technical aid. Its purpose is to provide pickets for the following stage of work – detailed field observations. At this stage, using an electronic ranger had been fixed positions of small trees and shrubs toward amended by satellite photo trees. Image insertion implemented in the AutoCAD was used to improve and to specify the field sketching map.

The image was converted to a derivative format for AutoCAD and used to rectification of the location and size of the distinguished tree crowns. Thus the draft of vegetation map was obtained and was finalized and supplemented by subsequent field surveys (field observations and direct measurements). The map compilation took into account massifs and single trees conducted in the area. The method permitted to delineate areas of conifers and deciduous woodlands on an extremely steep and difficult of access terrain, and to identify precise location and size of many individual tree crowns.

Many image objects at this zoom level correspond to individual tree crowns, as well as other spatial objects including roofs of buildings, walks, retaining walls, etc. Some of the shrubs are smaller than the individual pixels. A research question is how to determine an optimal zoom level for identification of individual plants.

The purpose of the work was to obtain sound information on the locations and real sizes of the trees and shrubs in a digitized form. The initial objective was to travel all over the entire territory of the dendrarium, and to draw up a sketch of the existing vegetation over the geodetic survey.

Each graphical object in the hand made sketch needs to be amended, in accordance with the image (Figure 1). Some image objects in this study were relatively easy to be identified based on the spectral properties, and others are difficult to be determined only by the contextual information such as relative sizes, spatial relationships, texture, and so on. The Google Earth data used in this study was taken in spring, and vegetation–covered and non-vegetation areas were spectrally distinctive on the imagery. Among the conifer and deciduous trees, and grass areas showed relatively distinctive spectral properties on the photo so that their identification were easier after an arbitrarily variation of their color adjustment. On the contrary, instances of some vegetation classes were difficult to distinguish from other vegetation classes. For instance, some trees (both coniferous and deciduous) with loose crowns are very difficult to identify, but they cast clearly visible shadows on the ground so that property must be used for the determination rule. For distinguishing deciduous from coniferous trees, texture information of image objects appears to be useful. Sizes and shapes of image objects were also useful properties for distinguishing some trees such as high specimens with large crowns from others. Figure 2 shows a precise drawing illustrating conifer and deciduous trees as well as decorative shrubs within the dendrarium. Figure 3 shows developed GIS database concerning detailed graphical and attribute information for the dendrarium territory.

In comparison with traditional inventory methods the remote sensing data tend to produce better results representing vegetation cover. In the case of vegetation mapping using very high resolution satellite data, the results are useful in combination with traditional methods results, because the image provides additional information about the location and size of trees in the image objects delineated by the sketch. Anyhow some gaps in the drawing come into sight during the drawing amendment. To rectify these gaps, additional field work is needed, with an electronic telemeter.

Conclusions

Traditional methods for large scale vegetation mapping require expensive time intensive field surveys. The use of remotely sensed, high resolution, multispectral data for mapping vegetation provides a detailed, accurate product in a time and cost effective manner. For

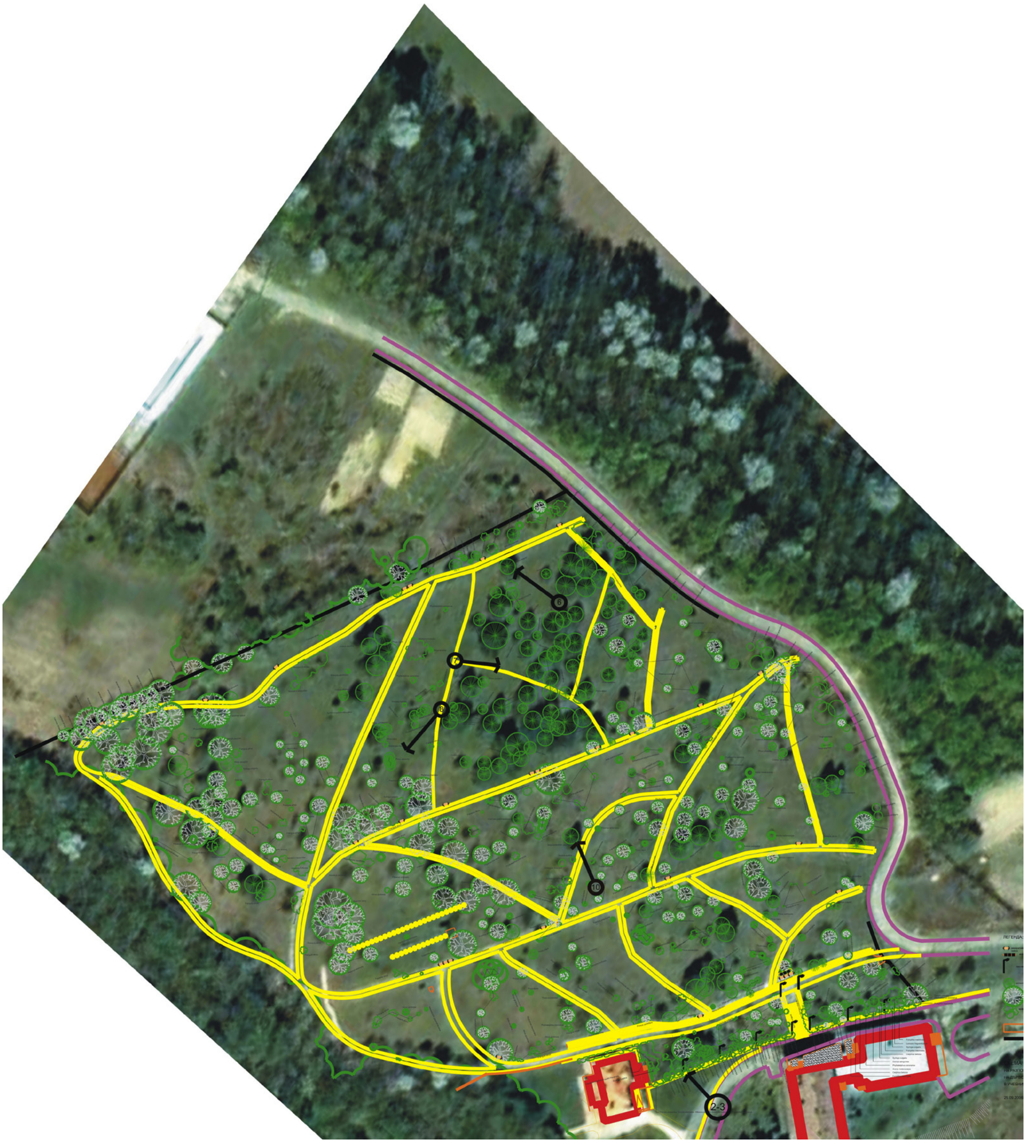


Fig. 1. Amendment of the drawing.

this project, applying a hybrid approach was developed a plant inventory map using imagery data.

The result of the hybrid approach and using Google Earth data in this study suggests that Google Earth data would be a useful additional information source for the vegetation mapping for the landscape architecture design projects.

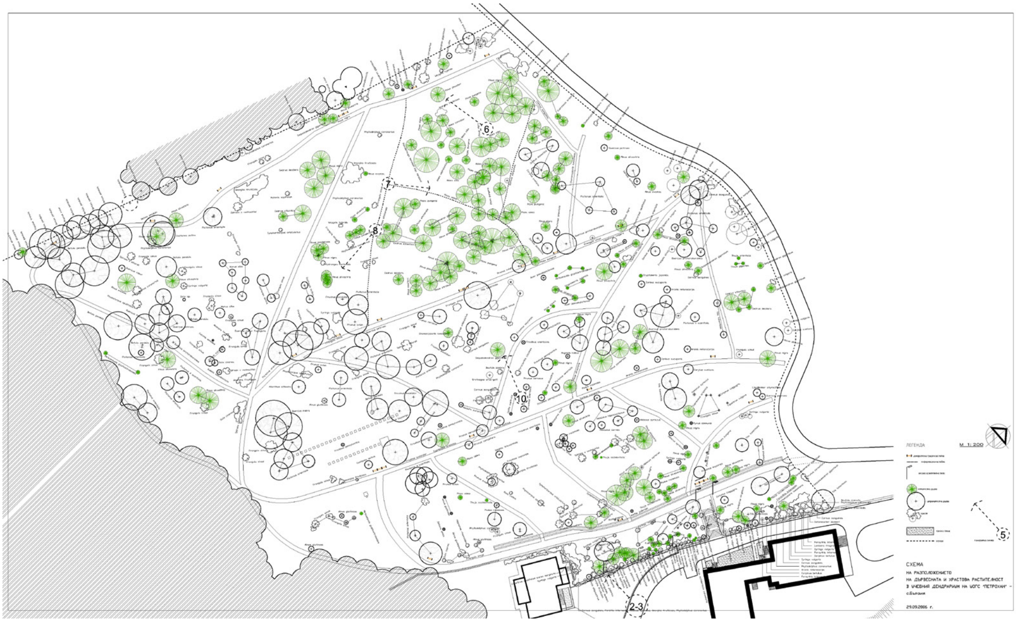


Fig. 2. Dendrological drawing of the object.

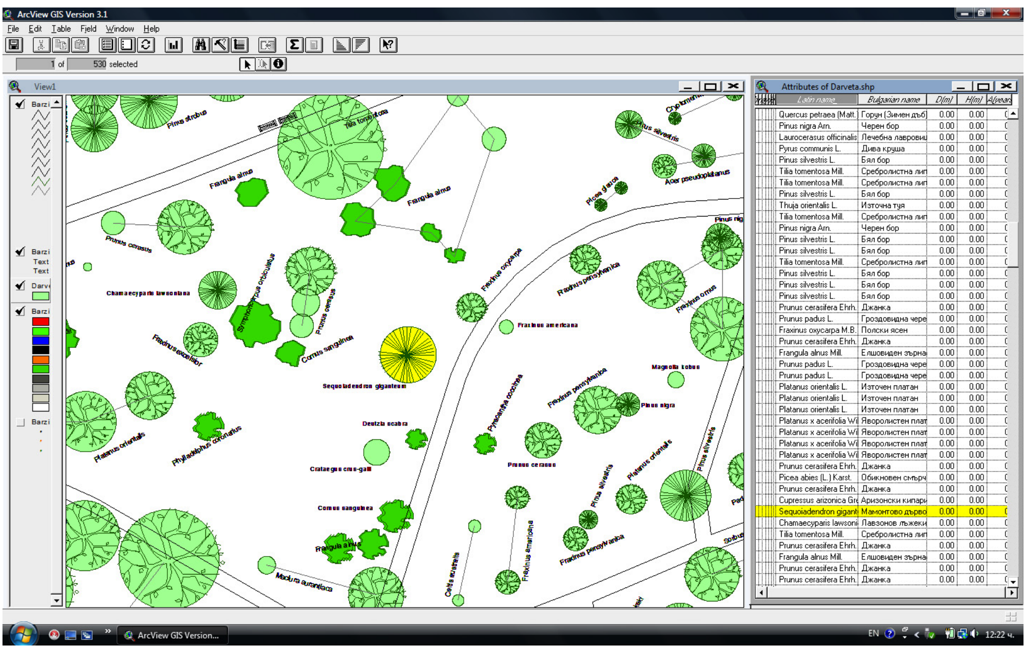


Fig. 3. GIS database for the dendrarium.

Very high-resolution satellite images are a useful information source for vegetation mapping, which is part of the design project data set.

Through this project, the spatial distribution of ornamental plants was mapped at a famous Bulgarian park in digital format.

The information collected through this effort will:

– increase the ability of landscape architects to analyze and map plants and non vegetative elements of the parks;

– serve as a baseline for long-term monitoring, assist with the characteristics of changes in parks over time and detect new elements there.

In addition, the data collected through this study will provide the basis for a plant inventory plan for the dendrarium in the Training and Experimental Forest Range "Petrohan" near the village of Barzia. This study shows that ornamental plants in the parks can successfully be mapped using satellite data and conventional methods. These techniques show promise as useful tools for vegetation inventory. This is especially applicable in the landscape architecture design projects because spatial extents and distribution of existing vegetation is very important and define the future plant composition of the parks.

References

Asenova M. 2009. GIS as an effective tool for forest management. Management & sustainable development, University of Forestry, Sofia, Vol. 22 (1): 94–101. (in Bulgarian).

Destan S. 2007. Importance of Maturity Concept in Determination of Functional Rotation in Forestry. Review of the Faculty of Forestry, University of Istanbul. Series B, Vol. 1, No 1: 52–53.

Kuneva Ts., Kabatliyska Z., Petrova R., Yancheva D. 2009. One year flowering meadows. "Avangard Prima", Sofia, 108 p. ISBN 978-954-323-326-7.

Rangelov V. 2003. Spatial characteristics significantly affect the appearance of park areas. Proceedings of the "Jubilee Scientific Conference 50 Years University of Forestry – Sofia", April 2003, Sofia, Bulgaria: 272–276.

FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

POSITIVE AND UNFAVORABLE VISUAL EFFECTS OF THE FOREST LANDSCAPES

Emil Galev

University of Forestry, Faculty of Ecology and Landscape Architecture, 10 Kliment Ohridski Blvd., 1756 Sofia, Bulgaria. E-mail: emil.galev@abv.bg

UDC 379.83

Received: 12 July 2010
Accepted: 23 November 2011

Abstract

Visual impact of forest landscapes is the focus of discussion in the paper. Their influence on passengers and onlookers sidelong roadways and trails is described in detail. A great number of practical examples have been examined with the purpose of drawing some general conclusions from this problem to the advantage of landscape design practice. The result of the analysis shows different degree of landscape damages visual impact over the observers. Using color photographs and taxation indices for the same forest stands the survey concludes that from the standpoint of aesthetics or recreation value forest products such as scenic beauty can be assessed either with psychophysical measurement procedures or with taxation indices of the forest subdivisions. Two such procedures are compared for convergence. The methods gave similar results with respect to their theoretical foundations and their independently derived scenic beauty metrics. It is hoped that the comparison of these procedures will facilitate needed discussion on their appropriateness and usefulness in multiple use forest management and planning efforts.

Key words: perception, forest landscapes, visual impact, design project, scenic beauty, aesthetics, landscape preferences.

Introduction

Every model of visual preference must be set within its theoretical context. The author believes that individuals have shifting visual preferences and that the judgments which people make are principally colored by their cultural background, active purpose and geography. The idea of a universal all-purpose all-condition preference scale seems to be an empty one.

The cultural context question was well stated by Kluckhohn and Murray (1967): "Every person is like all other persons and very person is like some other persons, and every person is like no other persons". The simultaneity is important.

Material and Methods

The research approach for identifying indicators and criteria for visual assessment of landscapes have to include detailed study of past research.

Visual perception of landscape accompanies all recreational activities and proper assessment of the aesthetic qualities of great importance for the organization of leisure, especially in mountainous forest regions. „Only in the mountains covered with forests one can admire beautiful natural landscapes that provide aesthetic delight the eye of the observer and make people even more to love nature and mountains. Forests are giving life to the mountains." (Tamamdzhiev 1940).

According to Destan (2001) forest landscapes should be regarded as a recreational resource and as such it is variable to be considered in decisions on land use.

Shafer and Brush (1977) claim that aesthetic qualities and beauty of the landscape are subjective categories and each person has their own opinion about them, but because people have a common evolutionary history and under the hypothesis of biofilia, feeling for nature is one of their innate instincts and genetically they are prone to exhibit preference for certain visual qualities of landscapes. Stoycheva and Tzolova (2001) and many other authors have tried to identify the specific preferences of the people and their criteria for picturesqueness and attractiveness of the landscape. It can be said that in our country there is a theoretical vacuum, but current research and practical developments are not particularly successful.

This study seeks to determine what exactly generates the attractiveness and the attractiveness of the landscape in forests and meadows and to assess the visual impact that specific forest landscapes have on the people.

According to Helliwell (1984) assessment of the landscape is individual and depends on personal taste and experience of the observer, but there are some basic rules for unity in the composition that have survived from ancient Greece. He believes that the lack of unity in the face of deteriorating quality of its landscape, because scattered and unrelated elements bring confusion in visual perception. Disparate elements also create confusing diversity and viewed within seconds while they create an unpleasant visual impression. The design according the author has three stages: creation of a balanced landscape with simple forms, combining elements and arrangement of plants in accordance with the environment without occasional contrasts of colors, shapes and habit.

Seung-Bin (1984) develops a scientific approach to the use of visual preferences of people in urban design. In the method applied by him called „assessment the beauty of the view" core elements that form people's preferences are the slope of the terrain, the vertical impact of building volume and degree of plant coverage.

According to the majority of authors most impact on human perceptions have shaped and sized forming plants that form forest landscapes. They create a general impression, but mainly in the detail are essential contours, colors, scents and even sounds that are characteristic of forest vegetation. Tere have also been made numerous surveys. Ulrich (1986) explores such psychological reactions in human comprehension of vegetation in the landscape and found that trees with thick stems and crowns are perceived positively by the observer, while those with thin stems and crowns developed only create bad feelings. Same opinion supports

Brivot (1982), regarding „... mighty old trees, their crowns are spread of tens of meters and attracts their shade in summer, while the effect of the game of light and shadow in their crown is an outstanding ...". There have been shown particularly spectacular specimens of various types, including forms of weeping beech. General rule the author is that the viewer should be given the opportunity to fully enjoy the magnificence of old trees, so they advised to leave in small groups where they can be the dominant element, and before them in all cases have a large open area. Veer (1986) considered „valuable vision" that all wood specimens are distinguished from others by highlighting the qualities decorated (mostly habit and beautiful crown) and the mapping out of 210,000 trees. Lewis (1973) and Sorensen (1982) highlight the decorative features of the bark of trees. Barely noticeable in other seasons, larval bark of trees is a major decorative element after defoliation in winter and especially in the morning and in the evening if sunbeams fall below lower angle and directly illuminate the tree trunks. The number of species whose bark is quite impressive is significant. Especially rich in this respect is a kind of Betula. Its representatives are suitable for almost all soils and climatic regions, making them versatile element in the landscape. White Pine is also mentioned as a species with spectacular bark. Stoycheva and Kabatliyska (2002) attempted to identify the total number of colors in the landscape that are seen by most visitors. Kouneva et al. (2009) have focused in their research mainly on the yellow hues of the vegetation in the landscape, describing a number of plants and their blooms during the period of performance, especially when planted in lit places. In the study of Breton (1981) has been investigated in more detail the issue of the nuance of the autumn wood-bush vegetation. They considered that a number of deciduous species in autumn become with extremely beautiful color of their leaves. These include beech and aspen, which are indigenous species in mountain regions and this gives reason to consider enhancing their participation in the outskirts of pure conifer plantations. Another possibility to diversify the periphery of the array is the planting of flowering tree species. Rangelov (2007) estimated high beauty and diversity resulting from the spring flowering trees and shrubs in the forest landscape. The same notes Kabatliyska (2007) determining that people are not impressed by some of the colors that make up the natural background in parks or in the landscape, namely blue, green and brown. Emotional impact of the white color of flowering trees and shrubs depends on surrounding objects. This impact is positive when it is white in combination with pale colors, but with bright and dark colors, it manifests itself in strong and striking contrasts that can cause fatigue. White colors on cloudy days make the landscapes more bright and pleasant. Another source of vivid effects in the forest landscape have the fruit colors of ornamental trees and shrubs. This aspect was studied by Vandevelde-Dassonville (1982). She described many species, some of which are frost-resistant and could be used in the mountain areas. Among these series of publications dealing with differentiated sensory feelings of people for the landscape should be mentioned and that of Quellet (1982). It indicates a favorable impact on human health and spirits, which have aromas emanating from certain trees, shrubs, grasses and flowers. There exist conditions for the development of so-called „aroma" as part of the phytotherapy.

Significant theoretical contribution to the development of the issue of visual assessment of the landscape is the study of Kurbatov (1988). He structured a set of visual characteristics and created a system of six indicators for evaluation including: size and size scale; canopy; configuration, visual barriers, visual magic tricks. Visual perception of the landscape by the author is a function of the plastic structure of the terrain and vegetation.

The Directives in respect of forest landscape design developed by the Forestry Commision (1994) recommended the design process to start with an assessment of the landscape as the main criterion to be visible, and those sectors which can be seen from most locations receive the highest score.

In the method of Shafer et al. (1969) for determining psychophysical preferences of people towards landscape key indicators are perimeter and area of distribution of its features, and more precisely – the correlations between these variables. A similar approach applied Petrov and Velchev (1980) in the definition of „factor of landscape diversity", only that they use the perimeters and areas of individual units.

Buhyoff (1986) developed statistical models for predicting the beauty of sight to the trees and within them. The same issue is addressed by Colvin (1973). He introduces an indicator called „sculpture of the green forms" which examines the spatial structure of tree-distances, but uses only visual criteria.

Brown and Daniel (1986) determine the aesthetic value of tree-distances using data from forest taxation. In their method landscape value is increased by the presence of highest trees, the existence of a group structure, the absence of fallen and rotting trees, and the existence of „living" soil cover.

To determine the aesthetic value of forest landscapes is developed the method of Daniel and Vining (1983), where subject to an assessment is the vegetation visual diversity.

Scales of aesthetic landscape assessments have been developed by Briggs and France (1980), which are based on: location and forms of relief, a combination of volumes and plant groups. Eringis and Budryunas (1975) use the following indicators: total gravity landscape; expression of relief, spatial diversity of vegetation, diversity and relevance of anthropogenic sites.

Bulev (1977) carried out an assessment of the aesthetic environment at regional level and local level. Indicators used include: relief conditions; mosaic pattern of vegetation, visual spatial relationships, architectural landmarks, protected natural areas and others.

Orland (1994) and a number of other authors used computer simulations of landscapes for their aesthetic evaluation.

In conclusion we can say that the attempts made to establish the psychological effects of different categories of visitors to the compositional elements and environmental conditions for relaxation (volume plant, flowers, water areas, architectural park elements, open spaces, panoramic views, etc.) have not made generally valid findings, it is impossible to formulate what all people can subjectively like in one place. However it seems pretty clear, how the landscape image remains in their minds, namely through visual memories for expression of relief, herbal and other natural and anthropogenic components of landscapes.

Conclusions

In conclusion we can say that the attempts made to establish the psychological effects of different categories of visitors to the compositional elements and environmental conditions for relaxation (for instance: plant capacities, flowers, water areas, architectural garden elements, open spaces, panoramic views, etc.) have not been made generally valid findings till now, because it is impossible to formulate what all people can subjectively like in a place. Seems pretty clear, however, how the image of the landscape remains in their minds, namely through visual memories for expression of relief, herbal and other natural and anthropogenic components of landscapes.

References

Breton L. 1981. Arboretum Allard: arbres et arbustes a l'automne. Jardins de France No 6–7, 240 p.

Briggs D. J., France J. 1980. Landscape Evaluation: A comparative study. Journal of Environmental Management 10: 263–275.

Brivot F. 1982. L'ombre des grands arbress. L'ami des jardins et de la maison No 685.

Brown T., Daniel T. 1986. Predicting Scenic Beauty of Timberstands. Forest Science No 2: 471–487.

Buhyoff G. 1986. Prediction of Scenic quality for Southern Pine Stands. Forest Science No 3: 769–778.

Bulev T. 1977. Criteria for evaluation of aesthetic environment. Sofia.

Colvin B. 1973. Land and Landscape. Ed. J. Murray, 414 p.

Daniel T.C., Vining J. 1983. Methodological Issues in the Assessment of Landscape Quality. In Behaviour and the Natural Environment (eds. Altman I. and Wohwill J.), Chapter 2: 39–83, Plenum Press.

Destan S. 2001. Management and functional characteristics and assessment of forest ecosystems in forest management activities. Ph. D. Thesis, Faculty of Forestry, Istanbul University. (In Bulgarian).

Eringis K., Budryunas A. 1975. Essence and methodology of ecological and aesthetic izssledovaniya landscapes. In: Prince. Ecology and aesthetics of the landscape. Vilnius, Publisher "Thought".

Forestry Commision 1994. Forest Landscape Design – Guidelines. HMSO, London.

Helliwell R. 1984. Growing a picture. GC HTJ, 195, No 9, 19 p.

Kabatliyska Z. 2007. Flowers in the bulgarian monasteries – interior and exterior, traditions and future. "Vita nova' Work Shop – Klissoura monastery, 10–21 July, 2007. Academia Danubiana, Vol. 5: 10–13.

Kluckhohn C., Murray H. 1967. Personality and person perception across cultures. In A History of Psychology in Autobiography, Vol. V, edited by Edwin G. Boring and Gardner Lindzey, New York: Appleton-Century-Crofts, 127 p.

Kouneva Tz., Kabatliyska Z., Petrova R., Jancheva G. 2009. Annual wild flowering (Moorish) meadows. Avangard Prima, Sofia, ISBN: 978954323326-7, 84 p.

Kurbatov Y. 1988. Architectural forms and natural landscapes – composite connection., Leningrad, University of Leningrad Publisher. (in Russian).

Lewis C. 1973. The barks of Trees. American Forests 79, No 11: 14–17.

Orland B. 1994. Visualization techniques for incorporation in forest planning geographic information systems. Landscape and Urban Planning 30: 83–97.

Petrov P., Velchev A. 1980. Principles and methods for assessing environmental systems for recreation. In: Geography and natural resources, Novosibirsk, Siberian Branch of USSR, No 2.

Quellet J. 1982. Les parfums des arleres. Foret conservation 49, No 6: 12–15.

Rangelov V. 2007. The monastery complexes – objects offering opportunities for recreation and alternative tourism. Forestry Ideas No 1–2: 73–94.

Seung-Bin Im. 1984. Visual preferences in enclosed urban places – an exploration of a scientific approach to environmental design. Environment and Behavior 16, No 2: 235–262.

Shafer E.L., Hamilton J.F., Schmidt E.A. 1969. Natural landscape preferences: a predictive model. Journal of Leisure Research 1: 1–19.

Shafer E.L., Brush R.O. 1977. How to measure preferences for photographs of natural landscapes. Landscape Planning, 4: 237–256.

Sorensen Ph. 1982. Jouez sur les ecorces. L'ami des jardins et de la maison No 689: 58–63.

Stoycheva M., Tzolova G. 2001. About some dynamic accents and their visual and aesthetic perception in nature landscape. Jubilee book, University of forestry.

Stoycheva M., Kabatliyska Z. 2002. Influence of floral compositions upon human psychological condition. ECLAS, Budapest conference.

Tamamdzhiev L. 1940. Forest and Tourism, Forest Review, Sofia 3: 129–132.

Ulrich R. 1986. Human responses to vegetation and landscapes. Landscape and urban planning 13, No 1: 29–44.

Vandevelde-Dassonville B. 1982. Arbres et arbustes & fruits decoratifs. Paysage actualites No 50: 52–55.

Veer A. 1986. The Geographical Distribution of Visually Strikinf Trees (VSTs) in the Rural Landscape of the Netherland. AJ 10, No 1: 53–61.

FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

STUDY OF THE RELIABILITY OF DISTANCES MEASURED WITH A REFLECTORLESS TOTAL STATION WITHIN FOREST LAND SURVEY, USING DIFFERENT TYPES OF MATERIALS-TARGETS

Apostolos Kampouris

Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, Thessaloniki, Greece.
E-mail: akambour@otenet.gr

UDC 630.5

Received: 13 May 2010
Accepted: 10 December 2011

Abstract

Distance measurements feature an inextricable section of applied forestry science from the Forester engineer and concern a great variety of technical procedures. In nowadays the technological explosion of surveying instruments make these measurements a matter of seconds and even faster. Also, new alternative measurements are considered, such as reflectorless measurements, a function that is offered by most geodetic total stations. The range and accuracy of this function type is different and depends on the type of the total station. However, not sufficient attention has been given to the many error sources contributing to the uncertainty of such measurements and especially the quality of each measurement. Among others, the type and the colour of the material are considered as very important parameters for errors in distance measurements. The aim of this study is to determine the influence of the type of the material and colour to the quality of distance measurements using the total stations reflectorless ability. Therefore, experiments were carried out using 8 different types of materials or colours and Trimble 5605DR$^+$ long range total station.

Key words: distance measurements reliability, forest land survey, reflectorless total station.

Introduction

In everyday scientific and professional activity of forester engineer, the surface distance measurements are a very important part of the Applied Science of Forestry for a wide variety of complex technical projects and processes such as, forest cadastre, surveying, forest alignments and torrent control works, roads, reforestation, rehabilitation of quarries, geodata collection for forestal and environmental studies, and others. The rapid technological development of surveying instruments, allows the development of new alternative methods of distance measurements, based on the possibility of measurement without using a prism reflector, which is very useful and even necessary in some cases, in the difficult and complex mountainous forest environment. The major advantages of reflectorless distance measurement are (Amann et al. 2001, Fidera et al. 2004, Lambrou and Pantazis 2006): 1) Ability to measure points which are inaccessible or very difficult to approach or with high risk to approach, points (slided embankments, quarries and mines); 2) Possibility to measure points in low light environments; 3) Possibility to measure points in monuments – protected areas without any damage; 4) Reduction of staff which perform measurements; 5) Reduction of measurement time and considerable precision in points detection.

Material and Methods

The process of measurements took place outdoors in premeasured control points created to adapt the experiment. The measurements were conducted under good conditions, with visibility >20Km, slightly overcast, no heat, moderate wind and ensured direction of the sun i.e. sun was not opposed. Also, knowing the nominal value of the distance and in combination with forced centering both total stations body and targets, the results are directly comparable. The procedure for each set of measurements is as follows: a) Total station is placed in the first control measured point, and in the second point the tripod with the special support base of material-targets, which is placed under a forced centering and on which are placed the prism and all the material targets; b) the distance between total station and the prism is measured with the precision provided by the station for this specific measurement; c) the body of total station remains stable without changing the target angle in order the measuring conditions for each material to remain constant. Therefore, the point of distance measurement remains stable, and hence, different results are directly comparable; d) all the targeted material are placed at the same point measured with prism.

Thus, five successive distance measurements were conducted, in eight different materials, and the surface of the specimens forms an angle in respect to the direction of sight line of instrument body 90°, 30°, 45° respectively. The change of target angle position was achieved by rotating the bases plate in their respective angles. This allow us to study the reflectivity of laser beam when the material is aimed not only at a vertically angle, which is often happens in reality (Boehler et al. 2003; Ingensand et al. 2003). It has to be noted that in all cases the instrument body was still encased in a stationary horizontal and vertical angles respectively.

The aim is to compare the value of the measured distance using a prism in each location with the one that was measured in the same position on the surface of each material and calculate their difference. This way allow us to examine whether the difference in distance measurement between total station and material target, with and without reflector, is more or less than the permitted 95% confidence level according to the measurement accuracy given by the manufacturers of institutions (Dermanis and Fotiou 1995, Rossikopoulos 2001). According to the above, ΔD is defined as the difference in the distance measurement with or without the use of reflector: $\Delta D = \beta_1 - \alpha_1$ – (1) where: β_1 measurement with reflector and α_1 measurement without reflector. According to the law of transmission errors: $\sigma\Delta D = \pm\sqrt{\sigma\beta_1^{\,2} + \sigma\alpha_1^2}$ – (2). In order the price difference of ΔD length to be eligible, it should be between the time intervals $-z\sigma_{\Delta D} \leq \Delta D \leq z\sigma_{\Delta D}$ – (3) where z value 1.96 for linear control for 95% confidence level. The audit was carried out for each material and each viewing angle.

In order to compare the reflector measured values with the one measured with the prism, specimens should be placed in a suitable arrangement in order to meet specific requirements. For this reason we have used an adequate base of support so that the measurement surface of the samples lie in this vertical plane containing the vertical axis passing through the centering point of the base, where it is horizontal and therefore its identical with the measuring point where the prism is positioned on the special base (Balodimos and Stathas 1993).

We have tried to cover a satisfactory range of materials and colors. Special attention was provided to materials which are considered ubiquitous in use and often encountered by forester engineer in the countryside. Some of these materials were collected in different colors in order to study the results of reflectivity of different colors of the same material (e.g. cement). Eventually, the following eight material with specimens dimensions 12 cm x 12 cm were selected and measured: 1) White Cement; 2) Cement Gray; 3) Rock; 4) Marble; 5) Iron; 6) Tile; 7) Asphalt; 8) Wood. All these materials were placed one after the other on the special support base and pegged in such a position so that the front surface of tangential links to the base and to implement correctly the vertical measurement. In order to perform the experimental measurements, the Trimble 5605RD+ total station is used and its special features are shown in Table 1 (Trimble 2003).

The experimental measurements were made in two distances, approximately 100 m and 400 m. The first one is a normal distance measured in the countryside, whereas the second one is resulted from measurements of laser beam divergence on a white board. Measurement that were conducted in distances larger than the second one, occur the fact that the imprint far exceeds from the size of the samples and

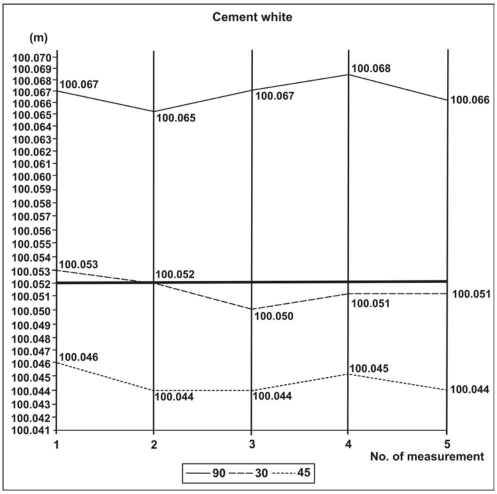
Table 1. Total station specifications

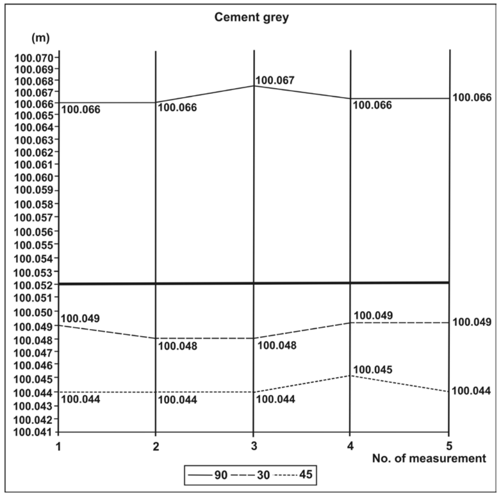
	TRIMBLE 5605RD+ Reflectorless ability. Measuring time: 3 sec. Weight: 6.6 kg. Range: up to 600 m reflectorless, 2500 m using 1 prism and 5500 m for long distance measurements (long range mode). Angle reading 1^{cc} and accuracy $\pm 15^{cc}$. Distance measurement accuracy: standard, ±3 mm ±3 ppm with prism and ±3 mm ±3 ppm (<200m) and ±5 mm ±3 ppm (>200m) reflectorless. Laser beam divergence 40 mm/100 m horizontal and 80 mm/100 m vertical.

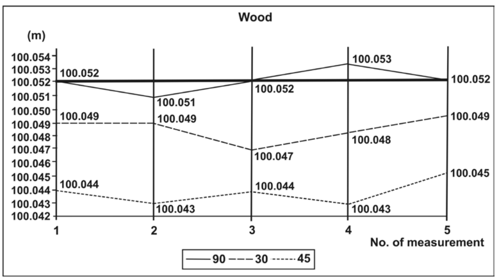
has caused serious problems in the measurements. The final precise distances in measurements with reflector were identified in 100.052 m and 400.140 m respectively.

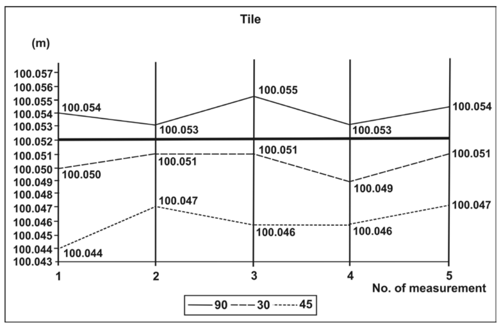
Results and Discussion

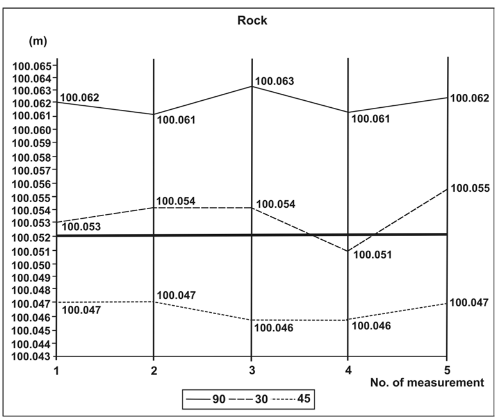
The making of the experimental measurements has revealed the following results diagrams shown in Figures 1 and 2.

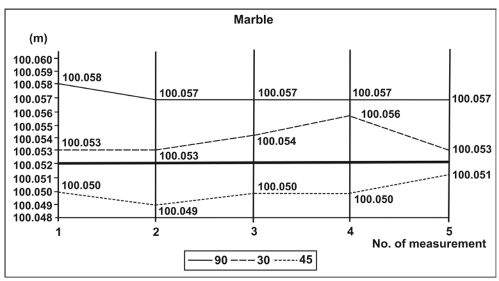












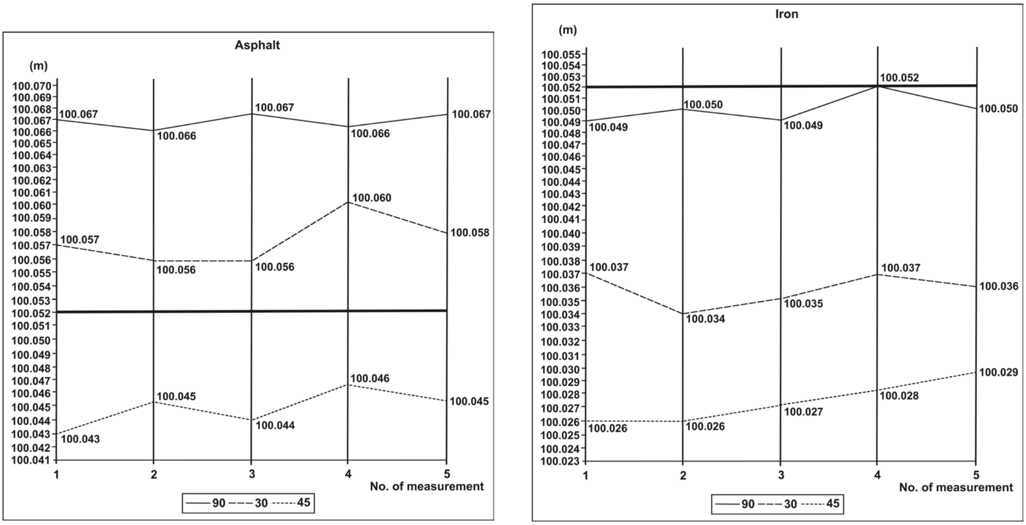


Fig. 1. Graphs of distance measurements with Trimble 5605DR+ total station at 100.052 m.

Then, tables for the evaluation and acceptance or rejection of the measurements have been set up. This way enables us to examine whether the difference in distance measurement between total station and target with and without reflector is acceptable for 95% confidence interval based on accuracies provided by the manufacturer. For Trimble 5605DR+ and according to the manufacturer the results are as follows: ±3 mm reflector and ±3 mm without reflector for measured lengths <200 m, and ±5 mm without reflector and ±3 mm reflector for lengths> 200 m. Thus, according to the equation 3, $\sigma\Delta D = \pm 4.2$ mm and finally to accept a measure of confidence level of 95% where $z = 1.96$, $z \cdot \sigma\Delta D = \pm 8.2$ mm, lengths while >200 m, $\sigma\Delta D = \pm 5.8$ mm and $z \cdot \sigma\Delta D = \pm 11.3$ mm. Table 2 shows the aggregated evaluation results of the measurements. Hence, the bold italic figures shown in the table are measurements that are not accepted within 95% confidence interval, the gray cell of the table show the measurements that except the fact that they are not accepted, they have presented large deviations compared to the originally measured with prism along, and symbol (-) indicates the impossibility of measurement.

Analyzing the results of the measurements we see that at the distance of 100 m all the material-targets are measured whereas in the 400 m distance was only four are measured. In the final two distances most of the conducted measurements were accepted at a confidence level of 95%. Especially in the 100 m 4 sightings out of 8 were accepted in the angle of 90° and 7 out of 8 in a angle of 30° and 45° respectively. In 400 m distance only one of all final measurements was not acceptable at a confidence interval of 95%, concerning the white cement at an angle of 90°.

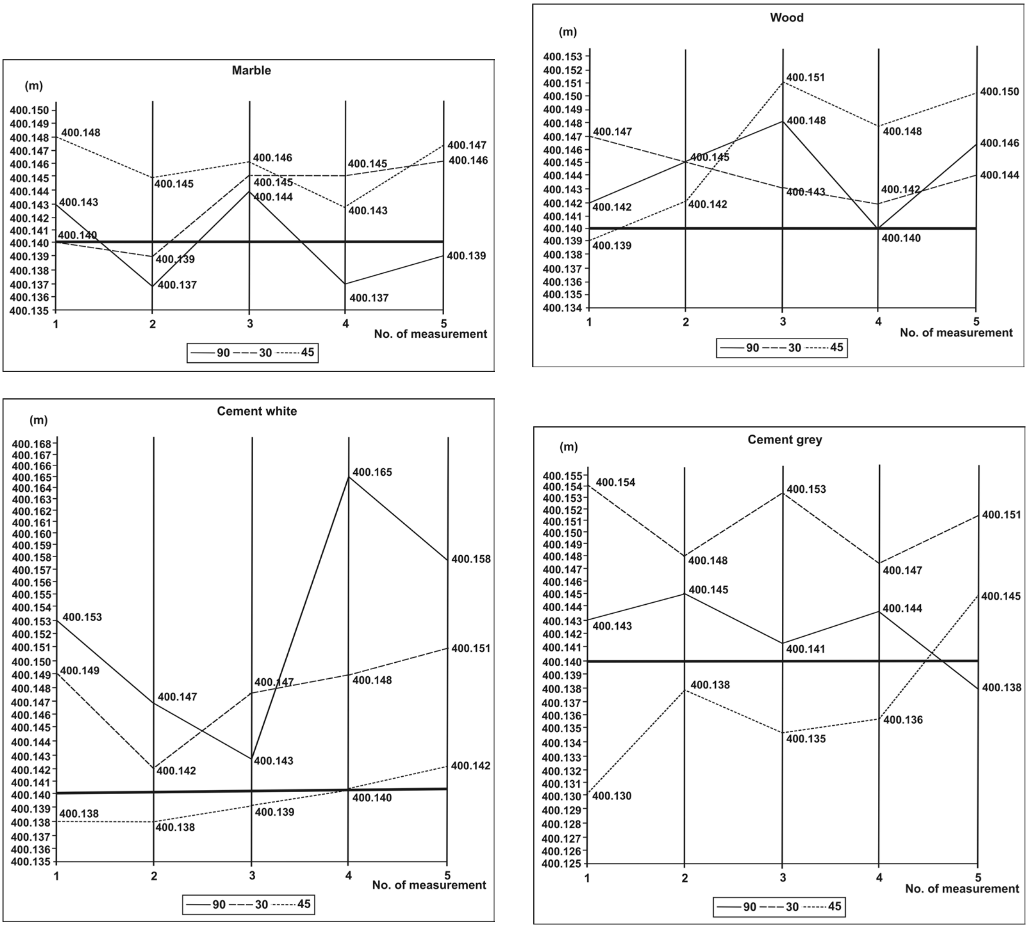


Fig. 2. Graphs of distance measurements with Trimble 5605DR+ total station at 400.140 m.

Also, while the target turns from the vertical angle, the distance value measured becomes less than the reflectorless measurement, which indicates that the angle of incidence is an important and decisive factor for the quality of measurements. The color is an important factor in the quality of measurements too. Generally colored materials have in general higher quality and more stable measurements. The texture and surface roughness of materials also affects the measurement results. Especially at a distance of 400 m, materials with a rough surface i.e. rock, asphalt, etc. either they made the measurements complicated or they were not measured at all. More measurements show a range of variation for both distance measurement 0–24.6 mm. The maximum difference was observed by measuring the distance value of the one measured with reflector in 100 m: 1) angle of incidence 90^{o}: 14.6 mm (cement gray, asphalt); 2) Turn on

Table 2. Measurements evaluation with Trimble 5605DR+ total station.

		Distance: 100.052 m			Distance: 400.140 m		
		ΔD, mm	ΔD, mm	ΔD, mm	ΔD, mm	ΔD, mm	ΔD, mm
A/A	**Material**	**90°**	**30°**	**45°**	**90°**	**30°**	**45°**
1	Cement white	***-14.6***	0.6	7.4	***-13.2***	-7.4	0.6
2	Cement grey	***-14.2***	3.4	7.8	-2.2	-10.6	3.2
3	Asphalt	***-14.6***	5.4	7.4	–	–	–
4	Iron	2.0	***16.2***	***24.8***	–	–	–
5	Wood	0	3.6	8.2	-4.2	-4.2	-6.0
6	Tile	-1.8	1.6	6.0	–	–	–
7	Rock	***-9.8***	1.4	5.4	–	–	–
8	Marble	-5.2	-1.8	2.0	0	-3.0	-5.8

30°: 16.2 mm (iron) 3) 45° move: 24.8 mm (iron). Similarly for the distance of 400 m were: 1) incidence 90°: 13.2 mm (cement white); 2) Turn on 30°: 10.6 mm (cement gray); 3) Turn on 45°: 6.0 mm (wood). For the distance of 100 m, best materials were wood, tile and marble and worse was cement gray, asphalt and iron. Similarly, for a distance of 400 m best material was marble and worse was cement white.

Utilizing on the conclusions drawn from all the experimental measurements and their effects on the use of these data and the further analysis of the status of reflection of a laser beam of modern total stations the following are proposed: a) To investigate the performance of the total stations reflectorless property at distances of 10 m by 20 m or so, in order to identify more precisely those distances from which the measurements can vary widely; b) To investigate the performance of total stations in the same material for different colors, so that to highlight the importance of color as a factor in the measurement and in return the same color for different materials to highlight the importance of such material as a factor affecting the measurements; c) To investigate the performance and reliability status of reflectorless total stations and specialized tests that are of particular interest as tariff measurements in various types, color, age bark roughness and forest species, different color, roughness and moisture and secondary wood products (chipboard, plywood, melamine, MDF, etc.), measurements on bare rocky and vegetative earthen embankments, with different types of rock and vegetation, respectively; d) To monitor the performance status of reflectorless property, total stations in experiments concerning the shooting at edges or sides of geometric elements, intersections levels, etc. and especially useful measurements on technical projects in rural areas (retaining walls, bridge abutments, culverts, buildings etc.); e) The application of experimental measurements to be made on actual field conditions and in different weather conditions.

References

Amann M.C., Bosch T., Lescure M., Myllyla R., Rioux M. 2001. Laser ranging: a critical review of usual techniques for distance measurements. Optical Engineering 40 (1): 10–19.

Balodimos D., Stathas D. 1993. Geodetic Instruments and Methods of Angles and Distance measurments. National Technical University of Athens Publications, 213 p.

Boehler W., Bordas M., Marbs A. 2003. Investigating laser scanner accuracy. Proc. CIPA XIXth Int. Symposium, 30 Sept. – 4 Oct., Antalya, Turkey: 696–702.

Dermanis A., Fotiou A. 1995. Methods and Applications of Observations Adjustment. Ziti publications, 348 p.

Fidera A., Chapman M.A., Hong J. 2004. Terrestrial Lidar for industrial metrology applications: Modeling, enhancement and reconstruction. XXth ISPRS Congress.

Ingensand H., Ryf A., Schulz T. 2003. Performances and experiences in terrestrial laser scanning. Proc. Optical 3D Measurement Techniques, 22–25 September, Zurich, Switzerland: 236–244.

Lambrou E., Pantazis G. 2006. A new geodetic methodology for the accurate Documentation and Monitoring of inaccessible surfaces. 3rd IAG / 12th FIG Symposium, Baden, May 22–24.

Rossikopoulos D. 2001. Surveying Networks and Computations. Ziti publications, 418 p.

Trimble 2003. Specifications manual, The 5600DR+ series.

Trimble R7/R8 GPS Receiver User Guide 2003. Version 1.00. Revision A. September 2003. 216 p. Available: http://facility.unavco.org/software/download_transfer/trimble/TrimbleR7-R8_UserGuide.pdf

FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

THE MELLIFEROUS PLANTS OF THE BULGARIAN FLORA – CONSERVATION IMPORTANCE

Alexander Tashev* and Evgenia Pancheva

University of Forestry, 10 Kliment Ohridski Blvd., 1756 Sofia, Bulgaria.
*E-mail: atashev@mail.bg, jeni_pancheva@abv.bg

UDC 630.28

Received: 19 March 2011
Accepted: 28 December 2011

Abstract

The paper presents a classification of 1010 species, belonging to 296 genera and 84 families of wild melliferous plants. A particular attention is given to the characteristics of the conservational importance of these plants at national and international level. Two hundred and one of these species belonging to 71 genera and 36 families were considered to have some conservational status in Bulgaria and Europe. Many of them are endemics for Bulgaria and/or Balkan Peninsula and are protected by the national Bulgarian legislation or by international conventions ratified by Bulgaria. The results indicate that substantial part of melliferous plant species of the Bulgarian flora is of high conservation value.

Key words: Bulgaria, flora, melliferous plants, conservation value.

Introduction

Melliferous plants are these, whose flowers are natural food source for honey-bee (*Apis mellifera* L.). Based on critical analysis of literature data, it was established that wild melliferous plants in Bulgaria are represented by 1010 species belonging to 296 genera, 84 families and two phyla (Tashev and Pancheva 2010). They represent 25.3% of the species, 31.7% of the genera and 54.9% of the families of the Bulgarian flora (Tashev 2008).

Being an integral part of the plant kingdom, the melliferous plants are charactrerized by different life-histories, different ecology and conservation status. The assessment of their conservation status is an important part of the modern concepts and practices of sustainable use of plant resources and conservation of plant diversity. Therefore, the aim of the present study was to characterize the conservation importance of the wild melliferous plants of Bulgarian flora. National and international documents were used for this assessment, with particular reference to the endemic taxa.

Material and Methods

For determining the national conservation status of the honeyberry plants from the Bulgarian flora, we used the Red Data Book of Bulgaria, Volume I – Plants (Velchev 1984), Red Data Book of Bulgaria, Volume I – Plant and Fungi

(Peev 2011). We used also the national legislation treating the legal protection of the plant species (Biodiversity Act; Anonymous 2007). Determining the international status of the analyzed species was based on the Red List of Endangered Plants of IUCN (Walter and Gillett 1998) as well as on the "List of Rare, Endangered and Endemic Plants of Europe" (Lucas 1983). We also used the CITES (Anonymous 1973) and the Convention on the Conservation of European Wildlife and Natural Habitats called also Bern Convention (Anonymous 1979). The Balkan and Bulgarian endemics were determined following Assyov and Petrova (2006).

Results and Discussion

Table 1 presents the conservation status of the honeyberry plant of Bulgarian flora.

The results showed that considerable part of melliferous plants of Bulgarian flora is important from conservation point of view and the species are included in the Red Data Book of Bulgaria, Volume I – Plants (Velchev 1984). They are total 112 species, or 11.1% of all species of this group. Among them with category "Rare" (R) are 78 species, and with category "Endangered" (EN) – 34 species. In percents, compared to the whole number of melliferous plants of the Bulgarian flora, the distribution is as follows: 7.7% "Rare" and 3.4% "Endangered". When compared to the number of all wild melliferous plants, included in the Red Data Book of Bulgaria, 69.6% are "Rare" and 30.4% are "Endangered".

In the new edition of the Red Data Book of Bulgaria, Volume I – Plants and Fungi (Peev 2011), the number of melliferous plants is reduced to 74 species (7.4%). This could be explained by the fact that many of the species included in the first edition of the Red Data Book (Velchev 1984) had category "Rare", which does not exist in the new edition. This is because it considers only IUCN threatened categories, i.e. "Extinct", "Critically Endangered", and "Endangered". A few species labeled as "Rare" in Velchev (1984) were included with the category "Vulnerable" in the Red List of Bulgarian vascular plants (Petrova and Vladimirov 2009). The new edition of the Red Data Book of Bulgaria includes 43 species with the category "Endangered" (EN), which accounts to 4.3% of all wild melliferous plants; "Critically Endangered" (CR) are 26 (2.6%) species, and "Vulnerable" (VU) are 5 (0.5%) species.

Comparison of the plant taxa in the two Red Data Book editions showed that 50 melliferous species are present in both of them. This means that in the period after the publication of the first edition (more than 25 years), 24 wild melliferous species have acquired conservation importance. Eighteen species were transferred from category "Rare" to category "Endangered"; 11 species from category "Rare" to category "Critically Endangered"; 2 species from category "Rare" to category "Vulnerable", and 5 species from category "Endangered" to category "Critically Endangered". This unequivocally means that the population status of the rare melliferous plants is getting worse.

Eighty-one (8%) species are protected by the Bulgarian legislation and are included in the Appendix 3 of the Biodiversity Act (Anonymous 2007).

Table 1. Conservation status of honeyberry plants of Bulgarian flora.

Family/Species	Conservation importance							Measures taken			No of dociments including the taxon*
	Red Data Book of Bulgaria (1984)	Red Data Book of Bulgaria (2011)	IUCN (1998)	Eur. List, (1983) BG status	Eur. List, (1983) EU status	Bulgarian endemic	Balkan endemic	Biodiv. Act (2007)	Bern. conv. (1979)	CITES Appendix 2 (1973)	
1	2	3	4	5	6	7	8	9	10	11	12
Acanthaceae											
Acanthus spinosus L.	R	EN	–	–	–	–	–	+	–	–	3
Acanthus balcanicus Heywood et Richardson	–	–	–	–	–	–	+	–	–	–	1
Alliaceae											
Allium angulosum L.	R	CR	–	–	–	–	–	+	–	–	3
Allium montanum F. W. Schmidt	EN	–	–	–	–	–	–	+	–	–	2
Allium rhodopaeum Velen.	–	–	–	–	–	+	–	–	–	–	1
Amaryllidaceae											
Galanthus elwesii Hook. f.	EN	EN	–	–	–	–	–	+	–	+	4
Galanthus nivalis L.	EN	EN	–	–	–	–	–	+	–	+	4
Leucojum aestivum L.	EN	–	–	–	–	–	–	–	–	–	1
Apiaceae (Umbelliferae)											
Anethum graveolens L.	R	EN	–	–	–	–	–	–	–	–	2
Heracleum angustisectum (Stoj. et Acht.) Peev	R	–	–	–	–	+	–	–	–	–	2
Heracleum verticillatum Panč.	–	–	–	–	–	–	+	–	–	–	1
Asteraceae (Compositae)											
Hieracium ančevii Szelag	–	–	–	–	–	+	–	–	–	–	1
Hieracium asenovgradense Jasiewicz & Pawl.	–	–	–	–	–	+	–	–	–	–	1
Hieracium belogradčense T. Georg. & Kitanov	–	CR	–	–	–	+	–	+	–	–	3
Hieracium divergens Naeg. & Peter	–	–	–	–	–	+	–	–	–	–	1
Hieracium dolopicum Freyn & Sint.	–	–	–	–	–	–	+	–	–	–	1
Hieracium ferdinandii-regis Zahn	–	–	–	–	–	+	–	–	–	–	1
Hieracium gregorii-bakurianii S. Bräut.	–	–	–	–	–	+	–	–	–	–	1
Hieracium heldreichii Boiss.	–	–	–	–	–	–	+	–	–	–	1
Hieracium heterogynum (Froel.) Gut.	–	–	–	–	–	–	+	–	–	–	1
Hieracium kittaniae Vladimirov	–	EN	–	–	–	+	–	–	–	–	2
Hieracium marmoreum Panč.	–	–	–	–	–	–	+	–	–	–	1
Hieracium mattfeldianum Zahn	–	–	–	–	–	+	–	–	–	–	1
Hieracium merxmulleranum S. Bräut.	–	–	–	–	–	+	–	–	–	–	1
Hieracium naegelianum Panč.	–	–	–	–	–	–	+	–	–	–	1
Hieracium nipholasum T. Georg. & Zahn	–	–	–	–	–	+	–	–	–	–	1
Hieracium olympicum Boiss.	–	–	–	–	–	–	+	–	–	–	1
Hieracium ossaeum Zahn	–	–	–	–	–	–	+	–	–	–	1

1	2	3	4	5	6	7	8	9	10	11	12
Hieracium pannosum Boiss.	–	–	–	–	–	–	+	–	–	–	1
Hieracium petrovae Vladimirov & Szelag	–	–	–	–	–	+	–	–	–	–	1
Hieracium pilosissimum Friv.	–	–	–	–	–	–	+	–	–	–	1
Hieracium pirinicola T. Georg. & Zahn	–	–	–	–	–	+	–	–	–	–	1
Hieracium pseuderiopus Zahn	–	–	–	–	–	–	+	–	–	–	1
Hieracium scardicum Bornm. & Zahn	–	–	–	–	–	–	+	–	–	–	1
Hieracium sericophyllum Nejčeff	–	–	–	–	–	–	+	–	–	–	1
Hieracium stefanofii Zahn	R	–	–	–	–	+	–	–	–	–	2
Hieracium tommassinii Rchb.	–	–	–	–	–	–	+	–	–	–	1
Hieracium urumoffii Nejčeff & Zahn	–	–	–	–	–	+	–	–	–	–	1
Hieracium villosum L.	–	EN	–	–	–	–	–	–	–	–	1
Hieracium virosum Pall.	–	EN	–	–	–	–	–	–	–	–	1
Berberidaceae											
Epimedium pubigerum (DC.) Morren & Decne	R	–	–	–	–	–	–	+	–	–	2
Boraginaceae											
Anchusa davidovii Stoj.	–	CR	–	–	–	+	–	+	–	–	3
Anchusa hybrida Ten.	R	–	–	–	–	–	–	–	–	–	1
Buglossoides arvensis (L.) I. M. Johnst.	R	–	–	–	–	––	–	–	–	–	1
Buglossoides grandulosa (Velen.) R. Fernandes	R	–	R	V	V	–	–	+	–	–	4
Buglossoides sibthorpiana (Griseb.) Czer.	R	–	–	–	–	–	–	–	–	–	1
Echium plantagineum L.	R	–	–	–	–	–	–	–	–	–	1
Echium russicum J. F. Gmel.	–	VU	–	–	–	–	–	+	–	–	2
Myosotis aspera Velen.	–	–	–	–	–	+	–	–	–	–	1
Myosotis jordanovii N. Andreev & Peev	–	–	–	–	–	+	–	–	–	–	1
Myosotis macedonica Velen. & Charrel	–	–	–	–	–	–	+	–	–	–	1
Myosotis orbelica (Velen.) Peev & N. Andreev	–	–	–	–	–	+	–	–	–	–	1
Myosotis rhodopea Velen.	–	–	–	–	–	+	–	–	–	–	1
Myosotis suaveolens Waldst & Kit.	–	–	–	–	–	–	+	–	–	–	1
Onosma heterophylla Griseb.	R	–	–	–	–	–	–	–	–	–	1
Onosma thracica Velen.	–	–	–	nt	–	–	+	–	–	–	2
Onosma rhodopea Velen.	EN	EN	R	I	R	–	+	+	–	–	6
Symphytum tauricum Willd.	R	EN	–	–	–	–	–	–	–	–	2
Trachystemon orientalis (L.) G. Don	R	–	–	–	–	–	–	–	–	–	1
Brassicaceae (*Cruciferae*)											
Alyssum cuneifolium Ten. var. *pirinicum* Stoj. & Acht.	R	EN	–	–	–	–	–	+	–	–	3
Alyssum pulvinare Velen.	R	–	–	–	–	–	–	–	–	–	1
Alyssum stribrnyi Velen.	R	–	–	–	–	–	–	+	–	–	2
Matthiola odoratissima (M. Bieb.) R. Br.	EN	CR	–	V	V	–	–	+	–	–	4
Caesalpiniaceae											
Cercis siliquastrum L.	R	–	–	–	–	–	–	–	–	–	1
Campanulaceae											
Campanula cochlearifolia Lam.	–	EN	–	–	–	–	–	–	–	–	1

1	2	3	4	5	6	7	8	9	10	11	12
Campanula euxina (Velen.) Ančev	–	EN	–	–	–	+	–	+	–	–	3
Campanula jordanovii Ančev & Kovanda	–	VU	–	–	–	–	+	+	–	–	3
Campanula lanata Friv.	–	VU	R	–	–	–	+	+	+	–	5
Campanula latifolia L.	R	EN	–	–	–	–	–	+	–	–	3
Campanula moesiaca Velen.	–	–	–	–	–	–	+	–	–	–	1
Campanula orphanidea Boiss.	–	EN	–	–	–	–	+	+	–	–	3
Campanula patula L.	–	–	–	–	–	–	–	–	+	–	1
Campanula scutellata Griseb.	–	–	–	–	–	–	+	–	–	–	1
Campanula sparsa Friv.	–	–	–	–	–	–	+	–	–	–	1
Campanula thyrsoides L.	–	EN	–	–	–	–	–	–	–	–	1
Campanula transsilvanica Schur ex Andrae	R	EN	R	R	I	–	–	+	–	–	5
Campanula trojanensis Kovanda & Ančev	–	–	–	–	–	+	–	–	–	–	1
Campanula velebitica Borbas	–	–	–	–	–	–	+	–	–	–	1
Campanula versicolor Andrews	EN	EN	–	–	–	–	–	+	–	–	3
Cistaceae											
Cistus salvifolius L.	R	EN	–	–	–	–	–	+	–	–	3
Elaeagnaceae											
Hippophae rhamnoides L.	EN	CR	–	–	–	–	–	+	–	–	3
Ericaceae											
Calluna vulgaris (L.) Hull	R	–	–	–	–	–	–	+	–	–	2
Erica arborea L.	R	–	–	–	–	–	–	+	–	–	2
Rhododendron ponticum L.	EN	–	–	–	–	–	–	+	–	–	2
Vaccinium arctostaphylos L.	EN	EN	–	R	R	–	–	+	+	–	5
Fabaceae (Papilionaceae)											
Anthyllis aurea Weld.	–	–	–	–	–	–	+	–	–	–	1
Chamaecytisus danubialis (Velen.) Rothm.	R	–	–	–	–	–	–	–	–	–	1
Chamaecytisus absimthioides (Janka) Kuzm.	–	–	–	–	–	–	+	–	–	–	1
Chamaecytisus calcareus (Velen.) Kuzm.	–	–	–	–	–	–	+	–	–	–	1
Chamaecytisus jankae (Velen.) Rothm.	–	–	–	–	–	–	+	–	–	–	1
Chamaecytisus frivaldszkyanus (Deg.) Kuzm.	R	EN	–	–	–	+	–	–	–	–	3
Chamaecytisus kovačevii (Velen.) Rothm.	R	EN	–	V	–	+	–	+	–	–	5
Chamaecytisus neičeffii (Urum.) Rothm.	R	–	VU	E	–	+	–	+	–	–	5
Chamaecytisus ratisbonensis (Schaeff.) Rothm.	EN	–	–	–	–	–	–	+	–	–	2
Genista germanica L.	–	CR	–	–	–	–	–	+	–	–	2
Genista pilosa L.	EN	EN	–	–	–	–	–	+	–	–	3
Genista rumelica Velen.	–	–	–	–	–	–	+	–	–	–	1
Genista subcapitata Panč.	–	–	–	–	–	–	+	–	–	–	1
Lathyrus grandiflorus Sibth. et Sm.	R	EN	–	–	–	–	–	–	–	–	2
Lupinus albus L.	R	–	–	–	–	–	–	–	–	–	1
Ononis adenotricha Boiss.	R	–	–	–	–	–	–	–	–	–	1
Ononis repens L.	R	CR	–	–	–	–	–	+	–	–	3
Trifolium affine C. Presl.	–	–	–	R	R	–	–	–	–	–	1

1	2	3	4	5	6	7	8	9	10	11	12
Trifolium dalmaticum Vis.	–	–	–	–	–	–	+	–	–	–	1
Trifolium heldreichianum Hausskn.	–	–	–	–	–	–	+	–	–	–	1
Trifolium pignantii Fauche et Chaub.	–	–	–	–	–	–	+	–	–	–	1
Trifolium trichopterum Panč.	–	–	–	–	–	–	+	–	–	–	1
Trifolium globosum L.	R	–	–	–	–	–	–	–	–	–	1
Trifolium spumosum L.	R	–	–	–	–	–	–	–	–	–	1
Trifolium ligusticum Balb. ex Loisel	EN	EN	–	–	–	–	–	–	–	–	2
Trifolium phleoides Pourr. ex Willd.	EN	CR	–	–	–	–	–	–	–	–	2
Trifolium physodes Stev. ex M. B.	–	CR	–	–	–	–	–	–	–	–	1
Trifolium rubens L.	EN	CR	–	–	–	–	–	–	–	–	2
Trifolium spumosum L.	–	CR	–	–	–	–	–	–	–	–	1
Trifolium squamosum L.	EN	CR	–	–	–	–	–	–	–	–	2
Trifolium squarrosum L.	EN	CR	–	–	–	–	–	–	–	–	2
Trifolium velenovskyi Vandas	–	–	–	–	–	–	+	–	–	–	1
Fagaceae											
Castanea sativa Mill.	EN	EN	–	–	–	–	–	–	–	–	2
Geraniaceae											
Erodium absinthoides Willd.	R	EN	–	–	–	–	+	+	–	–	4
Erodium hoefftianum C. A. Meyer	R	–	–	–	–	–	–	–	–	–	1
Grossulariaceae											
Ribes nigrum L.	R	CR	–	–	–	–	–	+	–	–	3
Hippocastanaceae											
Aesculus hippocastanum L.	EN	EN	–	–	–	–	+	+	–	–	4
Hypericaceae (*Guttiferae*)											
Hypericum androsaemum L.	R	EN	–	–	–	–	–	+	–	–	3
Hypericum calycinum L.	R	–	–	–	–	–	–	+	–	–	2
Iridaceae											
Crocus veluchensis Herbert	–	–	–	–	–	–	+	–	–	–	1
Lamiaceae (*Labiatae*)											
Marrubium friwaldskyanum Boiss.	R	VU	–	R	R	+	–	–	–	–	4
Salvia forskahlei L.	EN	–	–	–	–	–	–	+	–	–	2
Salvia pinnata L.	–	CR	–	–	–	–	–	+	–	–	2
Salvia ringens Sibth. & Sm.	–	–	–	–	–	–	+	–	–	–	1
Salvia scabiosifolia Lam.	EN	CR	R	R	R	–	–	+	–	–	5
Salvia verbenaca L.	R	–	–	–	–	–	–	–	–	–	1
Satureja rumelica Velen.	R	–	R	–	I	+	–	–	–	–	4
Satureja pilosa Velen.	–	–	–	nt	–	–	+	–	–	–	2
Teucrium botrys L.	–	–	–	–	–	–	–	+	–	–	1
Teucrium lamiifolium D'Urv.	R	–	–	R	R	–	–	+	+	–	4
Thymus albanus Heinr. Braun	–	–	–	–	–	–	+	–	–	–	1
Thymus atticus Čelak.	–	–	–	–	–	–	+	–	–	–	1

1	2	3	4	5	6	7	8	9	10	11	12
Thymus bracteosus Vis. ex Benth.	–	–	–	–	–	–	–	+	–	–	1
Thymus comptus Friv.	–	–	–	–	–	–	+	–	–	–	1
Thymus longedentatus (Degen & Urum.) Ronniger	–	–	–	–	–	–	+	–	–	–	1
Thymus perinicus (Velen.) Jalas	R	EN	–	–	–	+	–	+	–	–	4
Thymus stojanovii Degen	–	CR	–	–	–	+	–	+	–	–	3
Liliaceae											
Fritillaria pontica Wahlenb.	R	–	R	–	–	–	–	+	–	–	3
Menyathaceae											
Menyanthes trifoliata L.	EN	EN	–	–	–	–	–	–	–	–	2
Morinaceae											
Morina persica L.	R	–	–	–	–	–	–	+	–	–	2
Orchidaceae											
Platanthera bifolia (L.) Rich.	–	–	–	–	–	–	–	–	–	+	1
Paeoniaceae											
Paeonia mascula (L.) Mill.	EN	EN	–	–	–	–	–	+	–	–	3
Paeonia tenuifolia L.	EN	EN	–	–	–	–	–	+	+	–	4
Polygalaceae											
Polygala acarnanica (Chodat) Koz. et Petrova	R	–	–	–	–	–	+	+	–	–	3
Polygala amarella Crantz	R	EN	–	–	–	–	–	+	–	–	3
Polygala alpestris Reichenb.	–	EN	–	–	–	–	–	+	–	–	2
Polygala carniolica Kern.	R	EN	–	–	–	–	+	–	–	–	3
Polygala hospital Heuff.	R	–	–	–	–	–	–	–	–	–	1
Polygala monspeliaca L.	R	–	–	–	–	–	–	–	–	–	1
Polygala rhodopea (Velen.) Janch.	R	–	–	–	–	–	+	–	–	–	2
Polygala supina Schreb.	R	–	–	–	–	–	–	–	–	–	1
Primulaceae											
Primula deorum Velen.	R	VU	R	–	nt	+	–	+	+	–	7
Primula frondosa Janka	R	EN	R	–	R	+	–	+	+	–	7
Primula halleri G. F. Gmel.	R	–	–	–	–	–	–	+	–	–	2
Primula vulgaris Huds.	R	–	–	–	–	–	–	+	–	–	2
Ranunculaceae											
Adonis microcarpa DC.	–	EN	–	–	–	–	–	–	–	–	1
Adonis vernalis L.	R	–	–	–	–	–	–	–	–	+	2
Adonis wolgensis Stev. in DC.	R	–	–	–	–	–	–	+	–	–	2
Anemone narcissiflora L.	R	–	–	–	–	–	–	+	–	–	2
Anemone sylvestris L.	EN	–	–	–	–	–	–	+	–	–	2
Aquilegia aurea Janka	R	–	–	–	–	–	+	+	–	–	3
Aquilegia nigricans Baumg.	R	–	–	–	–	–	+	+	–	–	3
Caltha cornuta Schott	–	–	–	–	–	–	–	+	–	–	1
Caltha polypetala Hochst. ex Lorent	–	EN	–	–	–	–	–	+	–	–	2
Pulsatilla halleri (All.) Willd.	R	EN	–	–	–	–	–	–	+	–	3
Pulsatilla pratensis (L.) Mill.	R	–	–	–	–	–	–	+	–	–	2

1	2	3	4	5	6	7	8	9	10	11	12
Thalictrum foetidum L.	EN	CR	–	–	–	–	–	+	–	–	3
Trollius europaeus L.	R	–	–	–	–	–	–	+	–	–	2
Rosaceae											
Crataegus orientalis Pall. ex M. B.	–	–	–	–	–	–	–	+	–	–	1
Mespilus germanica L.	R	–	–	–	–	–	–	–	–	–	1
Potentilla chrysantha Trevir.	R	–	–	–	–	–	–	+	–	–	2
Potentilla emili-popii Nyarady	R	CR	R	–	–	–	+	+	+	–	6
Potentilla fruticosa L.	R	–	–	–	–	–	–	–	–	–	1
Potentilla montenegrina Pant.	–	CR	–	–	–	–	–	+	–	–	2
Potentilla nicicii Adam.	R	CR	–	–	–	–	–	+	–	–	3
Potentilla pirotensis (Borb.) Mark.	–	–	–	–	–	–	+	–	–	–	1
Potentilla palustris (L.) Scop.	R	–	–	–	–	–	–	+	–	–	2
Potentilla regis-borisii Stoj.	–	–	–	–	–	–	+	–	–	–	1
Pyracantha coccinea M. Roem.	EN	–	–	–	–	–	–	–	–	–	1
Rubus macrophyllus Weihe & Nees	EN	–	–	–	–	–	–	–	–	–	1
Rubus oblongoobovatus Markova	R	–	–	–	–	+	–	–	–	–	2
Rubus thyrsiflorus Wehe et Nees	EN	–	–	–	–	–	–	–	–	–	1
Rubus vepallidus Sudre	R	–	–	–	–	–	–	–	–	–	1
Spiraea crenata L.	EN	CR	–	E	V	–	–	+	–	–	4
Spiraea hypericifolia L.	EN	–	–	–	–	–	–	–	–	–	1
Spiraea salicifolia L.	EN	CR	–	–	–	–	–	+	–	–	3
Rutaceae											
Ruta graveolens L.	EN	EN	–	–	–	–	–	+	–	–	3
Salicaceae											
Salix pentandra L.	EN	CR	–	–	–	–	–	+	–	–	3
Salix rosmarinifolia L.	–	CR	–	–	–	–	–	+	–	–	2
Scrophulariaceae											
Pedicularis palustris L.	R	CR	–	–	–	–	–	+	–	–	3
Veronica austriaca L.	R	–	–	–	–	–	–	–	–	–	1
Veronica chamaedrys L.	R	–	–	–	–	–	–	–	–	–	1
Thymelaeaceae											
Daphne laureola L.	R	EN	–	–	–	–	–	+	–	–	3
Daphne pontica L.	R	EN	–	–	–	–	–	+	–	–	3
Tiliaceae											
Tilia rubra DC.	R	–	–	–	–	–	–	–	–	–	1
Valerianaceae											
Valeriana dioscoridis Sm.	R	EN	–	–	–	–	–	–	–	–	2

* Column 12 represents the number of different documents (Red lists, Red data books and different legislative documents) where the respective taxon is included.

Seventeen species (1.7%) are in the "European List of Rare, Endangered and Endemic Plants" (Lucas 1983). It defines the National (BG) and European (EU) status of the species. According to the national status, 6 species have category “Rare” (R), 3 species category “Vulnerable” (VU), 2 species category “Endangered” (E), 1 species category “Undetermined” (I), and 2 species “neither Rare, nor Endangered”. According to their European status 7 species have category “Rare” (R), 3 species category “Vulnerable” (V), 2 species category “Undetermined”, and 1 species category “neither Rare, nor Endangered” (nt).

Eleven melliferous species were included in the IUCN’s Red List of Endangered Species of 1997 (Walter and Gillett 1998). These are: *Buglossoides grandulosa*, *Onosma rhodopea*, *Campanula lanata*, *C. transsilvanica*, *Chamaecytisus nejčeffii*, *Salvia scabiosifolia*, *Satureja rumelica*, *Fritillaria pontica*, *Primula deorum*, *P. frondosa*, and *Potentilla emili-popii*.

Eight European melliferous species are strictly protected under the Bern Convention (Anonymous 1979), Appendix 2. These are: *Campanula lanata, C. patula, Vaccinium arctostaphylos, Teucrium lamiifolium, Paeonia tenuifolia, Primula deorum, P. frondosa, Pulsatilla halleri,* and *Potentilla emili-popii*.

Four species are listed in Appendix 2 of the Convention on International Trade in Endangered Species (Anonymous 1973, supplemented in 2003), and these are: *Galanthus elwesii, G. nivalis, Platanthera bifolia* and *Adonis vernalis* L.

Thirty-three species (3.3%) of the melliferous plants are Bulgarian endemics and 54 (5.3%) are Balkan endemics.

Conclusion

The data presented so far show that the melliferous plants of the Bulgarian flora amount 201 species from 71 genera and 36 families. This represents 20% of the species, 24.3% of the genera and 42.9% of the families with wild melliferous plants. With the highest conservation status among them are the Bulgarian endemics *Primula deorum* and *P. frondosa*, included in seven lists of conservation importance. They are followed by *Onosma rhodopea*, *Potentilla emili-popii* – present on six lists, *Campanula lanata*, *C. transsilvanica*, *Chamaecytisus kovačevii*, *C. neičeffii*, *Salvia scabiosifolia*, *Vaccinium arctostaphylos* – part of 5 lists, and *Aesculus hippocastanum*, *Buglossoides grandulosa*, *Erodium absinthoides*, *Galanthus elwesii*, *G. nivalis*, *Marrubium friwaldskyanum*, *Matthiola odoratissima*, *Paeonia tenuifolia*, *Satureja rumelica*, *Spiraea crenata*, *Teucrium lamiifolium*, *Thymus perinicus*, which are part of 4 list.

The results outline the high conservation importance of the Bulgarian honeyberry plants, both for the national and for the European flora.

References

Anonymous 1973. Convention on International Trade in Endangered Species (CITES) 1998. Available: http://www.cites.org/eng/app/appendices.php

Anonymous 1979. Convention on the Conservation of European Wildlife and Natural Habitats. Available: http://conventions.coe.int/treaty/en/treaties/html/104.htm

Anonymous 2007. Act for amendment and updating of the Biodiversity Act of Bulgaria. State Gazette, 94/2007. Available: http://lex.bg/laws/ldoc/2135456926 (in Bulgarian).

Assyov B., Petrova A. (eds) 2006. Conspectus of the vascular flora of Bulgaria. Chorology and floristic elements. Bulgarian

Biodiversity Foundation, Sofia, 454 p. (in Bulgarian).

Lucas G. 1983. List of Rare Threatened and Endemic Plants in Europe. Strasburg, 358 p.

Peev D. (ed.) 2011. Red Data Book of the Republic of Bulgaria. Vol. 1. Plants and Fungi. IBEI – BAS & MOEW, Sofia, 848 p.

Petrova A., Vladimirov V. (eds) 2009. Red List of Bulgarian vascular plants. Phytologia Balcanica, Sofia, 15 (1): 63–94.

Tashev A. 2008. Flora of the vascular plants of Bulgaria: history of studies, structure and problems of conservation. Ukrayinskyi Botanichnyi Zhurnal (Ukrainian Botanical Review) 65 (1): 41–57. (in Russian).

Tashev A., Pancheva E. 2010. Honey bearing plants of Bulgaria. In: Kordum E.L. et al. (eds.). Modern problems of the botany and ecology. International scientific conference of young scientists (21–25.09.2010), Yalta, Simferopol, "Arial" Publishers: 140–142.

Velchev V. (ed.) 1984. Red Data Book of Bulgaria. Vol. I., Plants. Bulgarian Academy of Sciences Publishing House, Sofia, 448 p.

Walter K. S., Gillett H. J. (eds) 1998. 1997 IUCN Red List of Threatened Plants. Compiled by the World Conservation Monitoring Centre. IUCN – The World Conservation Union. Gland, Switzerland and Cambridge, UK. LXIV + 862 p.