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ASSESSMENT OF SOIL PROPERTIES UNDER DEGRADED FORESTS: JAVOR MOUNTAIN IN REPUBLIC OF SRPSKA − A CASE STUDY

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Abstract – This paper presents the main characteristics of soils under degraded beech forests on Mt. Javor and the possibility of the reintroduction of the spruce and fir that had been cut during previous negative human activity. Research into forest soil characteristics before reforestation is not common practice in the Republic of Srpska, and very often is not successful because it has not been established which soil environment conditions are most appropriate for a particular tree species. Soil degradation has been attributed to improper management and the unplanned deforestation of some parts of the Javor Mountain. Degraded parts were initially colonized by bushes and herbaceous vegetation, but despite this and due to the steep slopes, soil erosion has occurred. The restoration of degraded forests usually requires reforestation in order to reduce soil erosion and convert low to high forests. The aim of this study was the assessment of soil properties for the reintroduction of *Picea abies* (Karst.) and *Abies alba* (Mill.) on degraded parts of Mt. Javor, as one of the ways to protect the forest soil from erosion. According to the World Reference Base we determined the following soil types: Albic Acrisol, Dystric Cambisol and Mollic Leptosol. All analyzed soils can meet the demands of fir and spruce due to their characteristics.

Key words: Soil properties, soil erosion, *Picea abies*, *Abies alba*, reintroduction.

INTRODUCTION

The civil war left serious consequences and had an important impact on forests and land use in Bosnia and Herzegovina. Unplanned cutting of forests brought about the degradation of numerous plant species as well as excessive erosion (Tosic, 2011; Kapovic et al. 2010). Soil degradation has largely been attributed to improper management and unplanned deforestation of some parts of Javor Mountain. Degraded parts were initially colonized by bushes and herbaceous vegetation, but despite this and due to the steep slopes, soil erosion has occurred. The restoration of degraded forests usually requires reforestation practices (through the introduction of forest tree species) in order to reduce soil erosion, increase biological diversity and convert low to high forests. Reforestation not only alters aboveground vegetation, but also leads to significant changes in the physical and chemical properties and biochemical cycles of soils (Alriksson and Olsson, 1995; Paul et al., 2010b), and can successfully restore soil nitrogen stocks (Silver et al., 2005). The physical and chemical properties of soil, particularly in the rooting zone, plays a very important role in shaping vegetation (Bednarek et al., 2005).

Rehabilitation programs for the reduction of soil erosion can be carried out simply by planting trees whereby erosion processes will be arrested (Trac et al., 2007; Wang et al., 2007). The relationships between erosion and vegetation are complex since the soil-vegetation system has feedback mechanisms that regulate soil formation, plant development, and erosion/sedimentation processes (Kirkby et al. 1998). Research into forest soil characteristics before reforestation has not been common practice in the Republic of Srpska (Bosnia and Herzegovina), and is very often not successful because the conditions in the soil environment that are most appropriate for a particular tree species are not known. For this reason, it is very important to explore soil properties before deciding which tree species could be the most adaptable to certain conditions. Vegetation reduces water-promoted erosion by intercepting rainfall, increasing water infiltration on associated soil-fertility islands, intercepting runoff at soil surface level and stabilizing the soil by roots (Bochet and Garcıa-Fayos, 2004). The aim of this study was the assessement of physicochemical and morphological properties of soils for the reintroduction of *Picea abies* (Karst.) and *Abies alba* (Mill.) on degraded parts of Javor Mountain in Bosnia and Herzegovina, as one way to protect the forests soil from erosion. The results of this work will open up a new view regarding degraded forests and areas where excessive erosion is present. This approach will show the possibility of better use of soil productivity and conversion of a degraded beech forest into a high beech, fir and spruce forest.

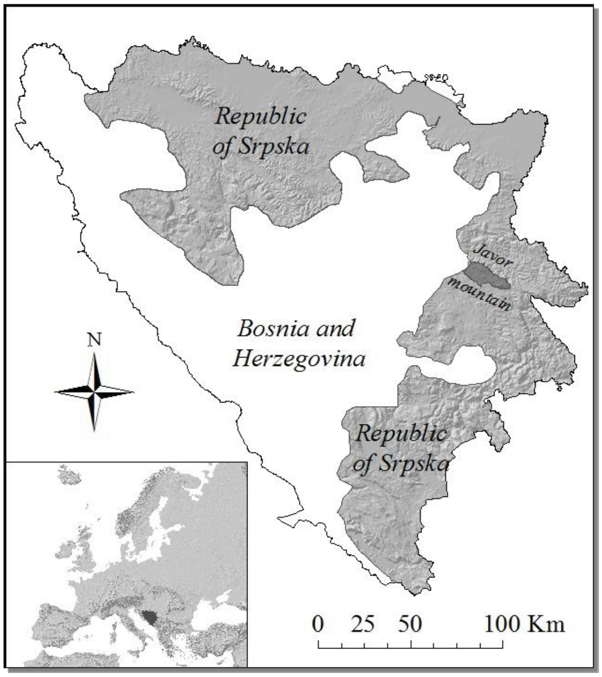

Fig. 1. Location of study area – Javor Mountain (Republic of Srpska, Bosnia and Herzegovina)

MATERIALS AND METHODS

Study area

The study area is located in southeastern Europe, 44°10´54″ N and 44°03´09″N, 18°52´15″ E and 19°06´15″ E, and encompasses 110 km^2. The whole study area of Javor Mountain belongs to the mountain/valley region of the Republic of Srpska (Bosnia and Herzegovina). The terrain ranges from 900 to 1537 m above sea level.

This area is covered with limestone, red siliceous limestone, sandstone, chert and claystone. The geological structure together with all other factors has caused the appearance of karstic process and karstic relief as the dominant one, especially at higher altitudes. The climate is mountainous with continental influence from east and northeast. The average annual temperature is 5.6°C. Average annual precipitation is 1010 mm. According to the Thornthwaite method (1957), this area has a high humidity climate – type B_4, which is characterized by high forests. With altitude increase, the climate becomes perhumid. Water deficiency only in July (12 mm), August (23 mm) and September (13 mm). Most of Javor Mountain is fully dominated with climate-regional high beech, spruce and fir forests (*Piceo-Abieti-Fagetum*). Beech forest in a degradational stage dominates the north and northeastern slopes of Javor Mountain.

Soil samples were taken from six soil profiles on different parent rocks, all in degraded beech forests and areas where surface and linear erosion is noticeable. We took 12 disordered soil samples from every genetic soil horizon. Soil samples were brought to the laboratory of the Faculty of Forestry in Belgrade. Stones, roots and other recognizable plant parts contained in the samples were removed and the soil was dried, homogenized and separated through a 2 mm sieve. Soil texture was determined by combined pi-

Table 1. Selected morphological characteristics of soil profiles

Horizon	Depth (cm)	Altitude (m)	Slope (°)	Aspect	Texture class	Boundary	Structure	Consistence	Erosion/ Erosion degree	Parent rock
Profle I Albic Acrisol										
AE	0-11	1093	23	N	SL	aw	1 mgr	so fr st pd	WS/S	sandstone
Bt	11-63				CL	cw	2 msbk	sh fr ss ps	-	
Profile II Dystric Cambisol										
A	0 - 16	1192	40	N	L	cw	3mgr	sh fr ss sp	WS/S	siliceous limestone sandstone
Bw	16 - 69				CL	dw	3mabk	h fr st pt	-	
Profile III Dystric Cambisol										
A	0 - 14	1238	13	NE-N	L	cw	3mgr	so vfr so po	-	sandstone-hornstone-claystone
A_2	14 - 37				L	dw	3mdgr	sh fr ss ps	-	
Bw	37 - 75				SCL	dw	2mdabk	h fi ss pt	-	
Profile IV Dystric Cambisol										
A	0 - 15	1269	12	N	L	cw	2mgr	so fr st ps	-	sandstone-hornstone-claystone
Bw	15 - 65				L	gw	2 mdabk	h f ss pt	-	
Profile V Mollic Leptosol										
A	0-34	1231	29	N-NI	SL	aw	2fgr	so vfr so po	WS/S	limestone
A_2	34-38				L	aw	3mgr	so fr ss po	-	
Profile VI Mollic Leptosol										
A	0-28	1200	42	S-SI	SL	aw	2 fgr	so vfr so po	WS/M	limestone

Structure: 1 weak, 2 moderate, 3 strong, sg single grain, m massive, f fine, vf very fine, md medium, c coarse, gr granular, pr prismatic, abk angular blocky, sbk subangular blocky. **Texture:** SL – sandy loam; L – loam; CL – clay loam; SCL – sandy clay loam. **Boundary:** a: Abrupt, c: Clear, d: Diffuse, g: Gradual, s: smooth; w: Wavy, i: Irregular. **Consistence:** Dry so:Soft, sh:Slightly hard, h:Hard; Moist lo:Loose, vfr:Very friable, fr:Friable, fi:Firm; Wet so: Nonsticky, ss:Slightly sticky, st:sticky, po:non-plastic, ps:slightly plastic, pt:plastic. **Erosion:** WS sheet erosion. **Erosion degree**: S slight; M moderate. **Abundance of rock fragments:** M many (15-40%).

pette and elutriation method with sieves according to Atteberg (JDZP, 1997). The pH values (active and substitution) of the soil samples were measured in a water and $CaCl_2$ suspension using a soil:solution ratio of 1:2.5 (w/w). A laboratory pH meter was used for pH determination in the aqueous phase (methodology of Soil Survey Staff, 1992); hydrolytic acidity and the sum of adsorbed bases were determined by Kappen's method (Kappen, 1931); total capacity of adsorption was calculated and cation exchange capacity by Hissink's method (JDPZ, 1997); content of humus and carbon by Tjurin, retrospectively Simakov (Simakov and Cipljenikov, 1960), content of nitrogen by Kjedahl's method (Bremmer and Mulvaney, 1982) and the content of phosphorus and potassium by the AL method (Egner, et al., 1960). The position of these soil profiles and their altitude were determined using a GPS device (cartographic view and digital elevation model (DEM); ArcGIS 9.3) Soil types are classified according to the World Reference Base classification (FAO/ISRIC, 2006).

RESULTS

The soils of Javor Mountain are influenced by homogeneous vegetational and climate conditions, so the morphological variability is mostly conditioned by parent rocks and relief characteristics. Soil profile No. 1 was developed on sandstones with a depth of 63 cm. Textural differentiation is highly expressed with depth. Deposition of clay is the most intense in Argiluvic B horizon. The soil structure is granular in surface horizons, but in deeper parts of the profile becomes subangular blocky. Soil structure aggregates are well formed and stable. The soil horizon's transitions are clear and irregularly shaped. The main rea-

Table 2. Soil particle size distribution (texture)

Profile No.	Horizon	Depth (cm)	Particle size distribution (%)							
			2.0 -	0.2 -	0.06 -	0.02 -	0.006 -	less than	Total	
			0.19 mm	0.06 mm	0.02 mm	0.006 mm	0.002 mm	0.002 mm	Sand	Clay
Albic Acrisol										
1	AE	0 - 11	10.30	31.80	12.50	19.70	10.10	15.60	54.60	45.40
	B	11 - 63	4.10	10.80	12.30	24.40	11.90	36.50	27.20	72.80
Dystric Cambisol										
2	A	0 - 16	30.00	6.10	10.70	25.40	11.00	16.80	46.80	53.20
	Bw	16 - 69	23.80	9.10	6.20	21.30	9.10	30.50	39.10	60.90
3	A	0 - 14	8.90	20.30	22.40	23.90	6.40	18.10	51.60	48.40
	A_2	14 - 37	21.80	14.10	12.80	19.90	8.70	22.70	48.70	51.30
	Bw	37 - 75	22.10	18.40	10.90	16.50	9.30	22.80	51.40	48.60
4	A	0 - 15	9.20	16.40	25.70	19.60	6.70	22.40	51.30	48.70
	Bw	15 - 65	11.70	6.60	23.30	27.80	7.00	23.60	41.60	58.40
Mollic Leptosol										
5	A	0 - 34	0.70	41.20	23.80	18.30	6.80	9.20	65.70	34.30
	A_2	34 - 38	1.10	31.50	13.80	19.00	13.30	21.30	46.40	53.60
6	A	0 - 28	0.60	30.20	29.70	23.10	5.70	10.70	60.50	39.50

son for the absence of a typical humus horizon lies in soil erosion that takes the soil litter simultaneously and does not allow the accumulation and deposition of organic matter. The high content of stones and other fragments larger than 2 mm derives from the parent rock due to its mechanical disintegration. As regards the clay soil texture, these fragments are desirable because they improve the water-air regime in deeper parts of the soil profile. According to the World Reference Base, this soil profile is classified as Albic Acrisol.

Soil profile No. 2 is developed on silicified limestone-sandstone, and morphologically is very different from soil profiles No. 3 and 4 which are developed on sandstone-chert parent rock. Soil profile No. 2 is characterized by the presence of soil erosion in correlation with steep slope. A moderate granular structure is expressed in surface horizons with highly stable aggregates. Clay content increases with depth, so the structure transits from blocky angular to blocky subangular. The main diagnostic horizon is Cambic with typical characteristics, and depth from 38-53 cm. This is a silty soil. According to WRB classification, this is Dystric Cambisol. Profiles Nos. 3 i 4 are also classified as Dystric Cambisols. Texture is prevalently loam with an increase of clay content in deeper part of the profiles. The structure is moderate granular in the A horizons, and moderate angular blocky in Bw horizons, with a lot of rock fragments. Soil profiles No. 5 and 6 are developed on limestone that is very poor in clay, and soil texture is sandy-silt. Structural aggregates are well formed, very small and granular shaped. Because of these characteristics, the soils are highly water-permeable but at the same time at risk from soil erosion because they are connected to steep slopes and degraded beech forest, sometimes without any vegetation protection. According WRB classification these are Mollic Leptosols. Textural differentiation between horizons is highly pronounced only in soil profile No.1 (on sandstone), while the other soils profiles have similar texture at all depths.

Chemical properties of the soil types differ. Active acidity ranges from very acidic to moderately alkaline (pH is 4.17 to 7.63). Albic Acrisol has the

Table 3. Selected chemical characteristics of soil profiles

Profile No.	Horizon	Depth (cm)	pH		Hydrolytic acidity Y1 mL NaOH/ 50g	Adsorption complex		CEC	Humus content	Organic C	N	Content of	
						S	T					P_2O_5	K_2O
			H_2O	$CaCl_2$		cmol/kg		(%)	(%)	(%)	(%)	mg/100g	
Albic Acrisol													
1	AE	4 - 11	4.27	3.47	62.50	0.00	40.63	0.00	7.07	4.10	0.30	1.80	8.70
	Bt	11 - 63	4.56	3.85	68.75	0.00	44.68	0.00	1.22	0.71	0.00	0.20	8.70
Dystric Cambisol													
2	A	8 - 16	4.46	3.76	56.50	2.40	39.13	6.13	6.50	3.77	0.56	4.40	9.70
	Bw	16 - 69	5.38	4.28	38.01	4.60	29.31	15.69	1.92	1.11	0.22	0.60	6.30
3	A	3 - 14	4.17	3.71	114.66	3.40	77.93	1.28	16.87	9.78	0.83	3.40	22.00
	A_2	14 - 37	4.60	4.10	73.00	0.00	47.45	0.00	6.43	3.73	0.35	0.80	8.00
	Bw	37 -75	5.28	4.40	45.00	2.20	31.45	6.99	2.36	1.37	0.15	0.50	14.50
4	A	5 - 15	4.20	3.57	124.92	2.20	83.40	2.64	30.55	17.72	1.13	5.50	24.70
	Bw	15 - 65	4.64	4.10	87.44	0.00	56.84	0.00	14.89	8.63	0.65	2.50	12.50
Mollic Leptosol													
5	A	6 - 34	7.14	6.90	6.25	95.80	99.86	95.93	39.31	22.80	1.66	9.10	15.50
	A_2	34 – 38	7.63	7.25	2.50	86.00	87.63	98.14	12.17	7.06	0.80	1.50	9.70
6	A	7 - 28	6.79	6.54	12.50	93.40	101.53	91.99	30.45	17.66	1.50	9.40	16.50

CEC: Cation Exchange Capacity; S: Base saturation; T: total capacity of cation adsorption;

lowest pH while Mollic Leptosol is the highest. Hydrolytic acidity is inversely proportional to pH. Humus content decreases with depth. Cation exchange capacity ranges from 0.00 to 98.14%, and it is directly connected with the content and quality of humus and clay content. Maximum values of CEC (Cation Exchange Capacity) are found in profiles No. 5 and 6, and the lowest CEC in profile No. 1 where the humus horizon is very eroded. Base saturation is also the highest in profiles 5 and 6. Clay content is also one of the very important factors that affect the degree of base saturation and CEC. Total capacity of cation adsorption is high but at the same time depends on soil acidity as well as quantity and quality of humus. The concentration of nutrition is correlated with the character of soil organic matter and soil texture. The nitrogen content is correlated with soil organic matter and decreases with depth. Nitrogen is very important for plant growth and vitality as a macronutrient. The pronounced acidity of soil profile No.1 is caused by the loss of Ca, Mg and K due to leaching processes, which usually lead to modification of the structure of soil biocenoses as well as nutrition disturbance, primarily of nitrogen. Phosphorus content in all soil profiles was low and mainly related to surface horizons and organic matter. Vegetation structure influences these processes, so it is very important to consider not only plant species that are dominant, but also their proportion in order to calculate the time required for the circulation of certain nutrients more precisely. The analyzed soils are usually well supplied with potassium especially in the surface horizons, and its content decreases with depth.

According to the WRB we determined the following soil types: Albic Acrisol (Profile 1), Dystric Cambisol (Profile 2, 3 and 4) and Mollic Leptosol (Profile 5 and 6).

DISCUSSION

This paper presents the main characteristics of soils under degraded beech forests (*Fagus sylvatica*) on the Javor mountain in the Republic of Srpska, and the possibility of the reintroduction of spruce and fir that had been cut due to negative human impact through unsustainable management of forests in a previous period. The soils are developed on different parent rocks under mountain climate (humid-perhumid type). Water deficiency in the soils is minimal, so nutrient mobilization is undisturbed during the whole year. The soils on the limestone are found on steeper slopes and at higher altitudes. Their characteristics are prevalently conditioned by the parent rocks and relief. The soils that have developed on acidic siliceous rocks are deeper and exhibit various characteristics of the adsorption complex because of the difference in humus quality and content. A low content of phosphorus characterized all soil types. Low phosphorus content and its availability in the soil can be explained in three ways. First is soil acidification (Foy et al., 1978); under a low pH the solubility of phosphorus is reduced due to the immobilization of Al and the increased sorption capacity of Fe for P. The cycling of P is delayed and reduced also because of a lower degree of mineralization of organic phospohorus (Carreira et al., 1997). Second, a high deposition of atmospheric nitrogen increases the nitrogen content in the organic litter, decreases the degree of mineralization of organic matter in the final stage of decomposition and also potentially reduces the availability of phosphorus from organic matter (Meiwes et al., 2002). Third, an increase in phosphorus supply and its immobilization in plant mass leads to an imbalance of phosphorus content and/or reduction of its plant availability (Spiecker et al., 1996; Wardle et al., 2004). Soil texture is very important for many chemical soil properties. Experiments with sandy-loamy and loamy soils show that nitrate leaching depends on humus and clay content in the soil (Pociene and Pocius, 2005). Soil texture is recognized as one of the most important factors influencing potassium leaching (Alfaro et al. 2004) and losses are almost two times lower in clay than in sandy soils. The clay content increases gradually with depth but all analyzed soil types had a "lighter" texture that is more appropriate for spruce and fir. Spruce is one of the most adaptable coniferous tree species and is successfully grown even outside of natural range (Stojanović et al. 2008; Pintarić 1991). In the Republic of Srpska, spruce is found at different altitudes, and its growth and development requires a large amount of precipitation, atmospheric moisture or a humid and very humid climate. Areas with a large amount of rainfall, where a significant part is snow, are appropriate for spruce, so Javor Mountain meets these demands due to its mountain type of climate. Spruce grows on soils formed on different geological substrates. It can withstand a low soil pH values and soil poverty, but does not tolerate dryness, high clay content or very wet soils. Structure, permeability and loam texture are characteristics that should be taken into consideration before the reintroduction of spruce. Spruce requires a higher nutrient content than most of the other broadleaf trees, but compared to fir and other conifers, spruce is more modest. Fir is a shade-tolerant species, and fir seedlings are very sensitive to extremely low temperatures and drought. It prefers deep and fresh, well-structured soils with good water-air regime and sand-loamy or loamy texture. Slightly acid soils are the most favourable ones because fir does not tolerate a very low pH as spruce does. All the analyzed soils can meet fir and spruce demands due to their characteristics. However, we can distinguish Mollic Leptosols whose productivity significantly depends on depth and climate condition. Because of the mountain climate type, the pedoclimatic dryness of shallow forms of Mollic Leptosols is not highly expressed. The researched soils represent an untapped potential for the reintroduction of fir and spruce and their gradual conversion into high mixed forests. Forestry engineers should bear in mind that the soils of ridges and steep slopes (such as Mollic Leptosols) are at risk of erosion and as such require additional specific attention and management. A permanent canopy would have a beneficial effect on the vegetation on these soils. In addition, the maintenance of soil productivity and protection from erosion through the introduction of coniferous trees (spruce and fir) would be a successful management measure. In this way we could achieve a triple effect: greater utilization of the productive potential of soils, further protection from erosion impact (especially on steep slopes) and the conversion of degraded beech forests into high broadleaf-coniferous forests that are wide spread on Javor Mountain.

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REFERENCES

Alfaro, M.A., Jarvis, S. C., and *P. J.* Gregory (2004). Factors affecting potassium leaching in different soils, *Soil Use Manage* **20**, 182-189.

Alriksson, A. and *M.T. Olsson* (1995). Soil changes in different age classes of Norway Spruce (Picea abies (L) Karst) on afforested farmland. *Plant Soil* **168**, 103-110.

Bednarek, R., Dziadowiec, H., Pokojska, U., and *Z. Prusinkiewicz* (2005). Badania ekologiczno-gleboznawcze (Soil–Ecological Research). PWN, Warszawa.

Bochet, E., and *P. Garcia-Fayos* (2004). Factors controlling vegetation establishment and water erosion on motorway slopes in Valencia, Spain. *Restor Ecol* **12**,166-174.

Bremmer, J.M., and *C.S. Mulvaney* (1982). Nitrogen – Total In: Methods of Soil Analysis, Page, A.L., R.H. Miller and D.R. Keeney (Eds.). ASA and SSSA, Madison, WI., USA., 595-624.

Carreira, J.A., Harrison, A.F., Sheppard, L. J., and *C. Woods* (1997). Reduced soil P availability in a sitka spruce, *Picea sitchensis,* Bong. (Carr.) plantation induced by applied acid-mist: significance in forest decline, *Forest Ecology and Management* **92**, 153-166.

Egner, H., Riehm, H., and *W. R. Domingo* (1960). Untersuchungen über die chemische Bodenanalyse als Grundlage für die Beurteilung des Nährstoffzustandes der Böden II. Chemische Extraktionsmethoden zur Phosphor und Kaliumbestimmung. Kungl. Lantbrukshögskolans Annaler, vol 26.

FAO/ISRIC (2006). World References Base for Soil Resources, World Soil Report, No.103, Rome, 128.

Foy, C. D., Chaney, R. L., and *M.C. White* (1978). The physiology of toxicity in plants, *Annual Review of Plant Physiology*, **29**, 511-566.

Kappen, H. (1931). Die Bodenazidität in ihrer Bedeutung für den Bodenfruchtabarkeitzustand sowie die Methoden ihrer Erkennung und der Bestimmung des Kalkbedarfes der sauren Böden, Berlin.

JDPZ, (1997). Metode istraživanja i određivanja fizičkih svojstava zemljišta, Jugoslovensko društvo za proučavanje zemljišta, Novi Sad, Srbija.(In Serbian).

Kapovic, M., and *M. Knezevic* (2010). Characteristics of black soil on Javor mountain limestones in the Republic of Srpska, First International Congress of Forestry, University in Belgrade Faculty of Forestry, Belgrade, 257-263.

Kirkby, M. J., Abrahart, R., Mcmahon, M.D., Shao, J., and *J.B. Thornes-Medalus* (1998). soil erosion models for global change. *Geomorphology* **24**, 35-49.

Meiwes, K.J., Meesenburg, H., Bartens, H., Rademacher, P., and *P.K. Khanna* (2002). Akkumulation von auflagehumus im solling – mögliche ursachen und bedeutung für den nahrstoffkreislauf, Forst&Holz 75, 428-433.

Paul, M., Catterall, C.P. Pollard, P.C and *J. Kanowski* (2010b). Recovery of soil properties and functions in different rainforest restoration pathways. *For. Ecol. Mange.* **259**, 2083-2092.

Pociene, A., and *S. Pocius* (2005). Relationship between nitrat amount in ground water and natural factors, *J Environ Engineer Landscape Manag.* XIII (1), 23-30.

Pintaric, K.. (1991). Uzgajanje šuma - Tehnika obnove i njege sastojina, Svijetlost, Sarajevo.(In Serbian).

Silver, W.L., Thompson, A.W., Reich, A., Ewel J.J., and *M.K. Firestone* (2005). Nitrogen cycling in tropical plantation forests: potential controls on nitrogen retention. *Ecol. Appl.* **15**, 1604-1614.

Simakov, V.N., and *V.P. Cipljenikov* (1960). Modifikacija objomnovo metoda opredeljenija gumusa (dlja masovih analizov). *Počvovedenije,* br. **4.** Moskva.

Soil Survey Staff (1992). Procedures for collecting soil samples and methods of analysis for soil survey. Soil Survey Investigation Report No. 1, US Government Printing Office, Washington, DC., USA.

Spiecker, H., Mielikäinen, K., Köhl, M., and *J.P. Skovsgaard* (1996). Growth trends in European forests - studies from 12 countries, European Forest Research Institut, Report 5, Springer Verlag, Heidelberg.

Stojanovic, L., Krstic, M., Vukin, M., and *Z. Govedar* (2008). Proredne seče kao mere nege veštački podignutih sastojina crnog bora. Seminar Prorede u kulturama bora, Divčibare - Bukovi, 17. oktobar, Beograd: Šumarski fakultet, Štampani materijal, 1-17.(In Serbian).

Thornthwaite, C.W and *J.R. Mather* (1957). Instructions and tables for computing Potential Evapotranspiration and the water balance. Publications in Climatology, John Hopkins University. V. 10, No. 3.

Tosic, R., Dragicevic, S., Kostadinov, S., and *N. Dragovic* (2011). Assessment of soil erosion potential by USLE method: Case study, Republic of Srpska – B**iH,** *Fresenius Environmental Bulletin***, 20 (8),** 1910-1917.

Trac, C.J., Harrell, S., Hinckley, T.M., and *A.C. Henck* (2007). Reforestation programs in Southwest China: reported success, observed failure, and the reasons why. *Journal of Mountain Science* **4**, 275-292.

Wang, F.X., Wang, Z.Y., and *J. Lee* (2007). Acceleration of vegetation succession on eroded land by reforestation in a subtropical zone. *Ecological Engineering* **31**, 232-241.

Wardle, D.A., Walker, R.L., and *R.D. Bardgett* (2004). Ecosystem properties and forest decline in contrasting long term chronosequences. *Science*, **305**, 509-513.