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APPLICATION POSSIBILITIES OF DOUGLAS-FIR IN EROSION CONTROL

Vera Lavadinović[1*], Zoran Miletić[1], Vukan Lavadinović[2], and Zoran Poduška[1]

[1]Institute of Forestry, Belgrade, Serbia. E-mail: veralava@eunet.rs
[2]Albert Ludwig University of Freiburg, Germany.

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Abstract

Erosion should be controlled with the programme of the National Strategy, which includes the use of biotechnology and afforestation. Protective afforestation should primarily provide quick establishment of plantation canopy. This prevents the direct influence of erosion agents on land surface. The establishment of forest canopy simultaneously results in the establishment of full hydrological function of forests, by reducing the probability of occurrence of surface runoff and extending the period of water concentration from the basin to the channel. Douglas-fir, as a fast-growing species, meets all requirements, which should be met by a species used in protective afforestation. Different Douglas-fir provenances under the same site and stand conditions in Serbia do not use the habitat production potential in the same way, i.e. the rates of canopy establishment are not the same in all Douglas-fir provenances. This means that the rate of establishing the protection and hydrological functions of Douglas-fir plantations depends largely on the provenance. In order to test the potential of fast-growing conifer Douglas-fir, experimental fields of this tree species were founded in Serbia. The test represented a variety of provenance from the natural range in North America. The insufficient research and the lack of reliability in the introduced tree species result in the fact that exotic species are rarely applied in such circumstances, for fear of their difficult adaptation to the changes of site conditions. To be able to meet the demands, the planting material should be: adequately chosen, correctly selected species at the level of the provenance, capable of providing the long-term stabilization of degradation processes, reproductively invasive, widely adaptive, with developed root system, more effective, less expensive and, of course, popular in the market. The paper presents the results of long term investigations of Douglas-fir value for erosion control in Serbia.

Key words: Douglas-fir, introduction, provenances, erosion control.

Introduction

It is widely accepted that soil erosion under forests is much less than under other forms of vegetation cover such as pasture, as trees have deeper stronger root systems (Knowles 2006).

Douglas-fir [*Pseudotsuga menziesi* (Mirb.) Franco], which originates from North America, is the most frequently introduced species in Europe and New Zealand, one of the most important and most quality conifers (Little 1979, Bradley et al. 2005). Germany is the leading country in the percentage of the introduction, establishment of the plantations and number of

researches, followed by France and New Zealand (where Douglas-fir is the second most common conifer, and *Pinus radiata* D.Don is the most common). The introduced species have to prove by their high quality that they were rightly introduced. Douglas-fir is the fast-growing, easily adaptable conifer, since it thrives on the degraded sites and meets the advertising requirements of the market. Douglas-fir is very important for the erosion control, but it is rarely used owning to the insufficient knowledge on species' biology and poor selection of the provenance. Douglas-fir is the tree which can be very efficiently used as the windbreak on the adaptable site, and it is the excellent species for the regeneration of eroded soil, watershed management, and mine soil reclamation (USDA-NRCS 2002). The value of the vegetation and reforestation in the erosion control is reflected in the long-term stabilization of the area. If the autochthonous species cannot meet the requirements of the protection programme, they can be very effectively replaced by the fast-growing species, which are ecologically adaptable. However, best results are achieved if in the first phase introduced species are combined with autochthonous ones, since the associations of Douglas-fir and broad-leaved and conifer species are very effective.

Douglas-fir provenance in test plantations are subject to long-term research in Serbia in many aspects: ecological adaptation, erosion control, anatomy, physiology, dendrometry ... (Lavadinović et al. 2001, 2011a, 2011b; Lavadinović and Isajev 2005).

In Serbia, judging from the multi-annual researches conducted by Miletić (2004), on the open pit mines of the Mining-Energy-Industrial Complex "Kolubara", the effect of the Douglas-fir monoplantations on the mine soil characteristics was much better than the effect of other conifer plantations. The dense canopy, which is formed by this mesophilic species, completely provides the hydrological and protective functions of the forest, and Douglas-fir litter fall has a favourable effect on the fertility and productivity of the mine soil. Also, as a result of the decomposition of its litter fall, the characteristics of the mine soil on which the erodibility, i.e. the ability of soil to resist the eroding agents, improve. The humus content and stability of the microstructural aggregates increase, which during the occurrence of the surface runoff prevents the mobility of the soil substances and their transformation into the suspension. On the clay mine soil in the differential soil porosity, under the influence of Douglas-fir, the percent of the coarse gravitation pores increases. As a result, the infiltration of precipitated water in the soil is accelerated and there is less likelihood of the occurrence of the surface runoff.

The influence of the Douglas-fir plantations of soil characteristics, upon which its ability to resist the eroding agents depends, is conditioned by the initial soil characteristics, prior to the reforestation by this species. In addition, the intensity of the influence of the Douglas-fir on the soil depends on the general site conditions, which determine the conditions for the activity of the soil microorganisms and rate of the decomposition of the soil organic litter. The chemical nature of the products of decomposition, which affect the soil, also depends on the site conditions and type of the saprophytic microorganisms which decompose the nutrients.

Thirty years after the substitution of mountain beech forests in Jelova gora,

Douglas-fir did not cause the important changes in the soil, i.e. the erodibility under Douglas-fir plantations was similar as under the original beech forests (Miletić et al. 2003). Nevertheless, on Hungarian and Turkey oak sites with hornbeam in Bogovaća under Douglas-fir plantation somewhat greater soil erodibility than under the original forest was reported (Miletić et al. 2010).

Douglas-fir adapts to the wide range of soil types and structures, but it thrives best on the soil of clay and powdery texture (Washington State University. 1979). The depth of soils, on which it adapts best, ranges from very shallow on the steep slopes and ridges to the deep colluvial sediments. The variance *menziesii* thrives best on the well-aerated (loose) deep soils, with the pH values from 5 to 6.

Douglas-fir is characterised by the great horizontal range on its natural site (Campbell 1979). Generally speaking, variety *glauca* is located at much higher altitudes than the sea variance at the respective latitudes. The altitudinal limit of Douglas-fir in central British Columbia is 760 meters above the sea level, whereas it is located at 1250 meters above the sea level in the Vancouver Island. In Washington and Oregon, this species generally ranges from the sea level up to 1520 meters, but it can occupy much higher altitudes at some places. In South Oregon Cascades and Sierra Nevada, the altitudinal zone ranges from 610 to 830 meters. In river valleys and canyons, this species is mainly located at altitudes ranging from 240 to 270 meters.

At the border southern parts of the altitudinal zone in Sierra Nevada, this species is located at 2,300 meters above the sea level. The continental variance is located at altitudes ranging from 550 to 2,400 in the northern part of the zone. In the central part of the Rocky Mountains, Douglas-fir is mainly found at the altitudes ranging from 1830 to 2590 meters, and in the southern Rocky Mountains at the altitudes ranging from 2440 to 2900 meters. At some sites of south and central Arizona, Douglas-fir can be found in the canyons, located at 1550 meters. The highest altitude where Douglas-fir grows in the Rocky Mountains is at 3260 meters, on the ridge of Graham Mountain in southeastern Arizona (Hermann1985, 1987).

The high adaptability of Douglas fir to the different soil and bedrock is also the result of the well-developed root system. Although Douglas-fir is a species with deep root system, its root morphologically varies, depending on the type of the bedrock and soil. If there are no obstacles, Douglas-fir first forms taproot, which enables the fast growth in the early youth. It was reported that on the deep soils (from 69 to 135 cm) the root system reaches about 50 % of its final depth, over first 3 to 5 years, and even 90 %, from the age of 6 to the age of 8. However, rocks or hard bedrock on the soil surface leads to the fast proliferation (extension) of the original taproot. When Douglas-fir develops on the shallow or extremely wet soils, the plate-shaped root system is developed.

Material and Method

Erosion is the gradual wearing away of the land surface as a result of uncontrolled wind and water energy. Sedimentation is the result of transport and delivery of eroded soil particles, deposited at some point. Erosion and sediment control is a complex interaction of soils, engineering water management, agronomic and horti-

cultural practices (Gaffney and Dickerson 2005).

The protective function of forest is reflected in the decrease of erodibility of the eroding agents, i.e. in the reduction of their mobility and ability to move the soil material. In the case of pluvial erosion, this function is performed by the vegetation canopy (Djorović et al. 2003). Douglas-fir is mesophilic species of the very dense canopy and the closed plantations completely provide the protective function. The rate of the canopy formation is crucial for the fast reduction of the effects of eroding agents on the soil and on the decrease of their erodibility. Height, as the element of estimation of forests, is the most reliable indicator of the effectiveness of the species on certain site, as well as of the rate of the canopy formation. In order to test the adaptability and ecological capability of the introduced species, two provenance tests in central and eastern Serbia were set. The sample plot "Juhor" is located in the management unit "Juhor I" of the forest district Jagodina, between 660 and 700 meters above the sea level.

The sample plot in Juhor is located in the association of mountain beech (Ass. *Fagetum submontanum* Rud.) on acidic brown soil.

Sample plot Tanda is in the management unit Stol of the forest district Bor, on the site of Hungarian oak and Turkey oak (*Quercetum frainetto-cerris* Rud.).

The material for the experiment originates from the collection of seeds from 27 Douglas-fir provenances collected by the Centre for Forest Seed in Georgia (USA) from the entire natural area of the species (Table 1).

At the age of fifteen, in the provenance test, plant heights were measured as indicator of the rate of canopy formation and protective function of forests. Sample plot Tanda is located on the site of Hungarian oak and Turkey oak (*Quercetum frainetto-cerris* Rud.), at elevation of 370 m, south-east exposure.

Results of Research

At the age of fifteen, plantations of all provenances on both sample plots formed the dense canopy (0.9–1), and, thereby, completely provided the protective function of forest and decrease of the eroding agents on the soil. The height of trees of observed provenances reflects on the rate of canopy formation.

Average plant height of all provenances in Tanda is 4.00 m, standard deviation 0.94 m, and the coefficient of variation 23.5 %. Provenance 19 (Washington 204-09) has lowest height (2.11 m), and trees of provenance 31 (Washington 205-02) are the highest (5.47 m). There are significant differences between tree heights (Lavadinović and Isajev 2005).

Average plant height in all provenances on Juhor was 4.65 m, standard deviation 0.86 m, and coefficient of variation 18.5 %. The lowest height (2.82 m) was that of provenance 9 (Washington 204-07), and provenance 3 (Oregon 202-27) was the highest (5.58 m). There are significant differences in the attained heights between the provenances. (Lavadinović et al. 2001).

The measurement of height of Douglas-fir (at the age of fifteen) of different provenances, in the experiment in eastern and central Serbia, showed significant differences.

Mean height of Douglas-fir in Tanda varies from 2.11 m (prov. 19, Washington 204-09) to 5.47 m (prov. 31 Washington

205-02). Mean height is 4.00 m, standard deviation is 0.94 m, and the coefficient of variation 23.5 %.

Mean plant height in all provenances in Juhor varied between 2.82 m (provenance 9, Washington 204-07) and 5.58 m

Table 1. Geographic characteristics and plant height of tested Douglas-fir provenances.

Provenance		Our sign	Latitude, °	Longitude, °	Altitude, m	Plant height, m	
						Tanda	Juhor
Oregon	205-15	1	43.7	123.0	750	3.90	5.16
Oregon	205-14	2	43.8	122.5	1200	4.01	5.17
Oregon	202-27	3	45.0	122.4	450	4.81	5.58
Oregon	205-38	4	45.0	121.0	600	4.77	4.99
Oregon	204-34	6	45.0	121.0	1050	4.95	-*
Oregon	205-16	7	44.0	123.0	150	4.87	-*
Washington	205-31	8	48.8	121.5	450	4.93	-*
Washington	204-07	9	49.0	119.0	1200	2.53	2.82
Oregon	205-13	10	43.8	122.5	1050	4.20	5.06
Oregon	205-18	11	44.2	122.2	600	4.63	5.24
Oregon	202-22	12	42.5	122.5	1200	3.91	4.72
Oregon	202-21	14	42.4	123.7	300	3.99	-*
Washington	202-17	15	47.6	121.7	600	4.31	5.16
Oregon	201-10	16	44.5	119.0	1350	2.98	3.53
Washington	204-06	17	49.0	120.0	750	2.82	3.48
Oregon	202-19	18	45.3	123.8	300	4.84	5.37
Washington	204-09	19	49.0	119.3	900	2.11	-*
Oregon	205-11	20	45.0	123.0	150	4.75	5.10
Oregon	205-45	21	44.0	122.0	900	4.48	-*
Oregon	202-31	24	44.3	118.8	1500	2.39	2.86
Oregon	205-29	26	42.6	122.8	900	3.98	4.86
Oregon	205-08	27	42.7	122.5	1050	3.46	4.63
Oregon	205-22	28	45.0	121.0	750	4.49	-*
Oregon	204-18	29	44.5	119.0	1500	2.24	-*
Oregon	204-04	30	45.0	121.5	900	3.67	4.69
Washington	205-02	31	47.7	123.0	300	5.47	5.29
Oregon	205-17	32	44.0	124.0	450	4.59	-*

* Provenances which are not included in experiment on Juhor.

(provenance 3, Oregon 202-27). Mean height in all Douglas fir provenances was 4.65 m, standard deviation 0.86 m, and coefficient of variation 18.5 %. It is interesting that the height of 50 % of the provenances is greater than 5.00 m.

Based on the observed heights on both sites, provenances 31 (Washington 205-02) in Tanda and provenance 3 (Oregon 202-27) in Juhor can be singled out as promising ones.

Almost all studied provenances on mountain beech site are characterized by faster growth, since at the age of fifteen they are higher than the provenances on the oak site in Tanda (Fig. 1). It implies that majority of studied Douglas fir provenances, used in the protective reforestation, is more favourable for the beech sites than for the oak ones.

The exception to the rule is the provenance Washington 205-02, which is higher on the oak site. As a result, it is more favourable for the protective reforestation on oak sites.

Conclusion

The key to successful afforestation is well and carefully selected plant material. The fast-growing species have the aims to connect complex forming soil structure and help to control erosion of endangered habitats. The goal of the introduced fast-growing species is to “occupy” habitat and stop erosion process in short term.

A combination of superior wood quality and high productivity has made Douglas-

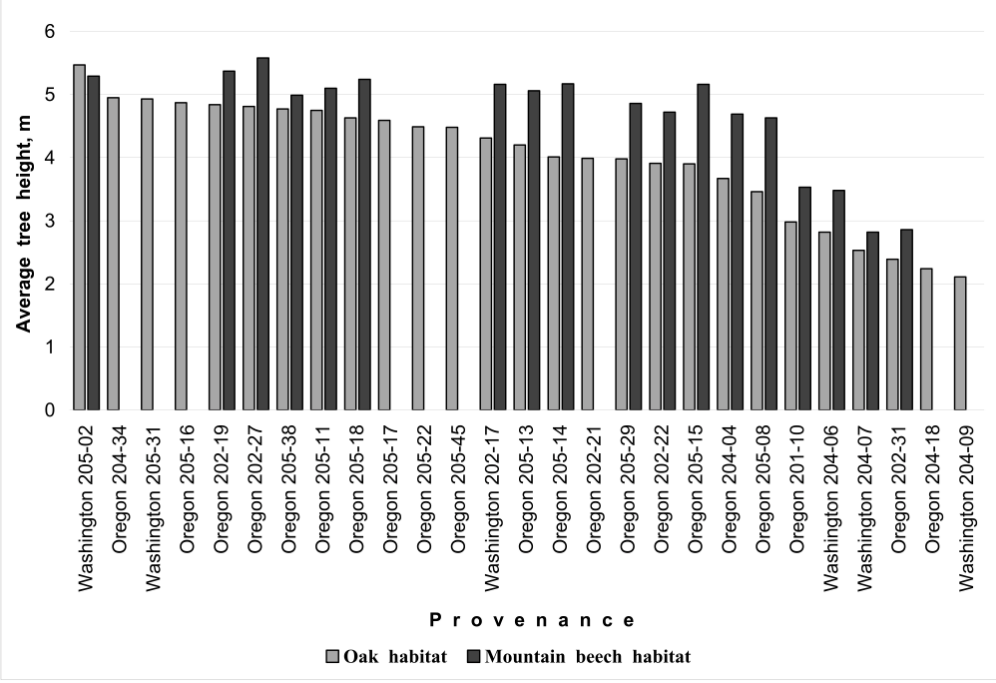

Fig. 1. Height of tested Douglas-fir provenances.

fir [*Pseudotsuga menziesii* (Mirb.) Franco] one of the premier timber trees in the world (Hermann and Lavender 1999).

Douglas-fir is the fast-growing species, whose plantations form complete canopy shortly after reforestation and thereby decrease the erodibility of the eroding agents.

Plant height is one of the reliable dendrometric parameters for assessing the productivity of provenances.

The mean height of the tree of studied provenances of the same age reflects on the rate of growth and canopy formation, thereby the rate of the establishment of protective and hydrological functions of the forest. Almost all studied provenances on beech site (*Fagetum submontanum* Rud.) establish the protective and hydrological functions of the forest faster than the forests on oak site (*Quercetum frainetto-cerris* Rud.).

In contrast to the influences on the decrease of the erodibility of the eroding agents, which is completely reflected in the canopy formation, the influence of Douglas-fir on soil erodibility can vary to a great extent. It depends on the general site conditions, and mainly from the initial characteristics of the soil, before reforestation. Genecological variations, which are most often reflected in the introduced material, as the modification variability of the quantitative and qualitative characteristics, are the result of interactions between introduced material and environmental conditions, in the place where the transfer was made. The range of variation of characteristics are conditioned by climate, edaphic and coenological characteristics of the sites to which the trees are introduced, as well as by the influence of altitude and geographic co-ordinates of the original origin of the population, from which the introduced material originates. The possibilities and future directions of the intensive use of introduced material depend on the knowledge on the interaction of the above mentioned elements. The results obtained by this paper contribute to:

Determination of the ecological parameters, which are important for the selection of Douglas-fir provenances for its transfer from North America to the sites in Serbia;

Gaining knowledge on the range of variation of economically important quantitative characteristics, as the selection criterion for the ranking of adaptive and productive provenances for growing in Serbia;

Reliable selection of Douglas-fir provenances for its directed use in Serbia during the establishment of special purpose plantations, in the erosion control activities.

Douglas-fir is an excellent tree species for restoring eroded lands, watershed management, and strip-mined areas reclamation.

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