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REVEGETATION OF SKI RUNS IN SERBIA: CASE STUDIES OF MTS. STARA PLANINA AND DIVČIBARE

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Abstract - Revegetation is the most sustainable method of soil stabilization at ski runs. In order to establish a stable plant community, it is recommended to use native species. However, non-native species are most often used. In this paper the revegetation of ski runs at two ski resorts is investigated: Divčibare and Stara Planina. Seven species were used for the revegetation of the ski run at the Divčibare ski resort of which six species were native. Six species were used for the revegetation of the Stara Planina ski resort, of which two species were native. It was established that the plant species used in the seed mixtures were suitable for erosion control at the investigated ski resorts.

Key words: Revegetation, ski runs, autochthonous plants, seed mixture, MT. Divčibare, MT. Stara Planina.

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INTRODUCTION

The construction of ski resorts is considered a major factor in environmental degradation in the world's mountainous regions (Titus and Tsuyuzaki, 1998; Urbanska, 1995; Ruth-Balaganskaya and Myllynen-Malinen, 2000; Wipf and others, 2005). The development of alpine skiing and mountain tourism has contributed to several negative impacts on mountain ecosystems (Pintar et al., 2009). Winter tourism today represents one of the most important economic sectors in a large part of the world's mountain areas (Abegg et al., 1997; Elsasser and Messerli, 2001; Rixen et al., 2003). Several ski resorts are influenced by both winter and summer tourism. In winter the soil and vegetation are affected by ski-run preparation and especially snowpack compression, machine grading and leveling (Ruth-Balaganskaya and Myllynen-Malinen, 2000). In particular, machine grading for winter sports causes important problems such as erosion that has a negative effect on biodiversity (Chambers, 1995). Soils are disturbed by the construction of ski-runs and ski-lifts, by the passage of skiers and snowcats managing the snow (Ferrari, 2005). Damage caused by skiers is more clearly seen in the middle of the ski runs (Ries, 1996), where the machines create undesirable effects over the entire soil surface. The high level of snow compaction produces a denser snow layer, with a reduction in snow-insulating properties, a higher probability of soil freezing, a decrease in gas permeability, alteration of bio-geochemical cycles, and a decrease in micro-porosity (Gros et al., 2004; Wipf et al., 2005). All of these changes can dramatically affect the vegetation of ski runs (Rixen et al., 2003).

To rehabilitate these areas, the degraded ecosystem must be compared with its undisturbed state to determine pre-disturbance soil properties and vegetation cover. These pre-disturbance attributes can be used to frame target outcomes for rehabilitation and inform the selection of plant species, soil treatments and mulching requirements (Good, 2006).

Revegetation is the most cost-effective and environmentally sustainable method of stabilization. The rehabilitation of a disturbed site should aim to minimize the length of time the site is exposed to potential erosion and sedimentation. Work areas should be progressively stabilized and revegetated immediately following any earthworks (Argenti et al., 2004; Good, 2006). Rapid reconstitution of the vegetation cover is desirable.

To establish a stable plant community it is recommended to use seeds from local natural populations (Mortlock, 2000) or from species adapted to the intervention site. However, non-native species, mostly grasses, are commonly used to revegetate ski runs as they are less expensive than native plants and have the ability to quickly establish a sufficient vegetation cover for erosion control (Kangas et al., 2009). On the other hand, these commercial mixtures are often not suitable to local conditions (Ruth-Balaganskaya and Myllynen-Malinen, 2001; Urbanska and Fattorini, 2000; Krautzer et al., 2001).

Construction of new, and the improvement of existing, ski resorts are very attractive activities in the transition societies of the Balkan region (Serbia, Montenegro, Bulgaria), but they involve numerous environmental violations during and after work (Ristić et al., 2007; Matto, 2007).

The aim of this paper is to provide baseline information on the species used for the revegetation of ski runs on the Divčibare and Stara Planina ski resorts in Serbia. Also, attention has been focused on the impacts of revegetation on the native vegetation and vice versa, investigating if the plant species used in the seed mixtures have invaded the native ecosystems from the ski runs.

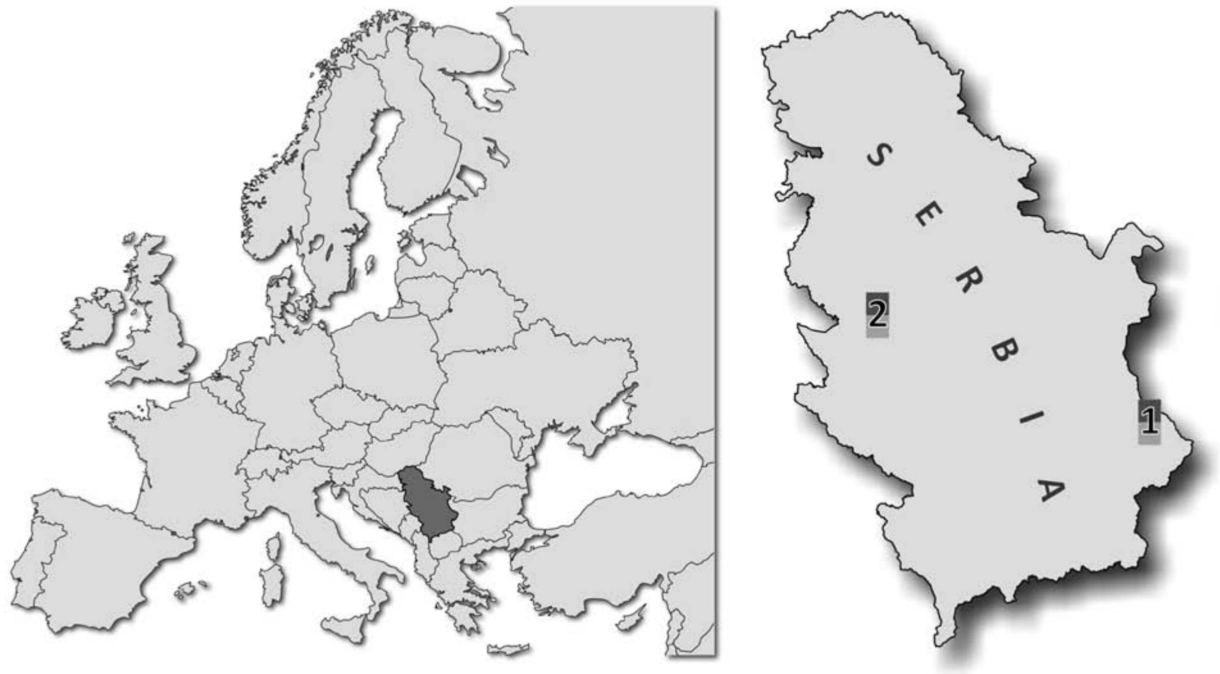
MATERIALS AND METHODS

Study area

The study was conducted on the Stara Planina ski resorts. The Stara Planina ski resort is being built on the largest mountain in eastern Serbia – Stara Planina, which spreads along the Serbian-Bulgarian border (Fig. 1). In this region the mean annual air temperature is 6.1°C. Mean precipitation is 1090 mm per year. Three ski slopes 3,700 m in length, and the appropriate installations (water reservoir for artificial snow making, 10,000 m^3; 3 km of pipeline, snow guns) were completed during the first phase of construction. In December 2007, a new detachable quad chairlift and one ski lift started to function. The total value of these investments is over € 20 million. Two ski runs were investigated at the Stara Planina ski resort: Konjarnik 1 and Sunčana Dolina.

The Konjarnik 1 (K_1) ski run is built on Cambrian green schists and Quaternary diluvium and alluvium, and the Sunčana Dolina (S) ski run is built on Permian red conglomerates (Nikić 2007). The greatest portion of the topsoil at the locations of the ski runs was removed during construction. The soils have similar mineralogical composition to the underlying materials. We observed dystric cambisol and dystric leptosol. Both soils are built of sand (62.8-80.9%), silt (10.9-24.6%) and clay (8.2-16.6%) fractions. The organic matter content varies from 2% to 11% in the dystric cambisol and between 2% and 5% in the dystric leptosol. The watershed area of the Zubska river has a land cover which consists of 57.06% forest surfaces, 15.82% meadow-pasture surfaces and 24.86% anthropogenic bare land (ski run, ski lift corridor, access road, parking lot), up to the profile immediately downstream from the end of the Konjarnik 1 ski run.

Divčibare is a mountainous tourist location in western Serbia. The mean air temperature is -2.4°C in February and 17.3°C in July; the mean annual air temperature is 8.87°C. Mean precipitation is 972.5 mm per year and the number of days with snow cov-



er is 67 for the same period. Construction of a new ski slope was started in the proximity of the locality Divčibare on Maljen mountain in 2006 (Fig. 1). By the end of 2006 the construction of the 850m-long ski slope with a double chairlift had been finished, reaching a total investment of nearly €1,500,000. At the Divčibare ski resort the Crni Vrh ski run was investigated. The working area (ski run and gravitating slopes) has a land cover which consists of 27.82% forest surfaces, 18.76% meadow-pasture surfaces and 53.42% anthropogenic bare land, up to the crossing of the ski run and the Bela Kamenica local stream. The greatest portion of the topsoil at the location of the Crni Vrh ski run was removed during construction. Eutric leptosol is developed on harzburgite. The soils are built up of sand (49.6-53.9%), silt (22-36.3%) and clay (14.1-24.1%) fractions. The organic matter content varies from 3.26% to 14.26%.

The main physical characteristics of the investigated ski runs are presented in Table 1.

During the establishment of the ski runs, the forest was clear-felled. Vegetation and the top soil were removed and machine-leveled. After the construc-

Table 1. Main physical characteristics of the investigated ski runs.

Ski resort	Ski run	Parameters					
		Area	Peak point	Lowest point	Length of ski run	Mean slope of ski run	Exposition
		km^2	m.a.s.l.	m.a.s.l.	km	%	
Stara Planina	Konjarnik 1	0.049	1548	1230	1.134	28.04	NW
	Sunčana Dolina	0.039	1724	1544	0.566	31.80	NE
Divčibare	Crni Vrh	0.042	1091	910	0.790	22.91	N

Table 2. Description of the studied ski runs.

Ski slopes		Year of revegetation	Mixture used	Seed rate (kg/ha)
Divčibare	Crni Vrh	2008	*Festuca rubra* (30%) *Festuca arundinacea* (35%) *Elymus repens* (15%) *Poa pratensis* (5%) *Lolium perenne* (5%) *Lotus corniculatus* (5%) *Trifolium repens* (5%)	200 kg/ha
Stara Planina	Konjarnik 1	2008	*Festuca rubra* (30%) *Festuca arundinacea* (10%) *Elymus repens* (5%) *Agrostis stolonifera* (15%) *Festuca ovina* (20%) *Trifolium repens* (20%)	200 kg/ha

tion, the ski runs were revegetated using a seed mixture. The species and their proportions in the seed mixture used for the experimental part of this study are presented in Table 2. All ski runs were revegetated in the same year (Tab. 2).

Floristic research

Floristic research of the Stara Planina and Divčibare ski resorts was performed in the period from June to September, 2010. The collection of plant material is deposited in the Herbarium of Faculty of Forestry in Belgrade. For plant identification relevant literature was used: Javorka and Csapody (1934), Josifović (1970-1977), Tutin et al. (1964-1980), Sarić and Diklić (1986) and Sarić (1992).

The similarity of the floristic composition between the sown and natural sites was assessed by the Jaccard index (Magurran 2004), which measures the coefficient of similarity between two sample sets of data using the following formula (eqn. 1):

$$J=c/(n+r-c)$$

where ***c*** is the number of species common to both sites and ***n*** and ***r*** the number of species found in natural and revegetated sites, respectively. Thus, the comparison was carried out only on the floristic lists of the two areas, without taking into account the abundance of each species.

Erosion processes

The erosion processes were surveyed from the beginning of April until the end of August, 2007 (when the restoration of ski runs started), at the most endangered spots (the Stara Planina and Divčibare ski resorts). Area sediment yield and intensity of erosion processes were estimated on the basis of the Erosion Potential Method (EPM). This method was created, developed and calibrated in Serbia (Gavrilovic, 1972) and is still in use in all countries that originated from former Yugoslavia. It is marked by a high degree of reliability of calculation of sediment yield, transport and reservoir sedimentation.

According to Gavrilovic (1972), the analytical equation for determining the annual volume of detached soil due to surface erosion is:

$$W_{year} = T \cdot H_{year} \cdot \pi \cdot \sqrt{Z^3} \cdot F$$

W_{year} is the total annual erosion (m^3/year), T is the temperature coefficient, H_{year} is the average yearly precipitation (mm), F is the catchment area (km^2) and Z is the erosion coefficient.

The soil erosion coefficient (Z) can be estimated using corresponding tables or calculated from the equation:

$$Z = Y \cdot X \cdot (\phi + \sqrt{I})$$

Where Y is the soil erodibility coefficient, X is the soil protection coefficient, ϕ – the erosion and stream network development coefficient, and I is the average slope of the study area.

RESULTS

In the Divčibare ski resort, the Crni Vrh ski run was constructed in the zone of *Pinus nigra* and *P. sylvestris* forest. Partly, the run passes through phytocenoses that can be characterized as a dry herbaceous community of pasture character. This herbaceous phytocoenoses has a secondary character. In the vegetation survey, a total of 61 species were identified in the autochthonous vegetation, and 34 at the ski run. The dominant species in the autochthonous vegetation are native trees and grasses: *Pinus nigra, P. sylvestris, Sesleria rigida*. On the ground floor of plants the most numerous are: *Anemone nemorosa, Cynosurus cristatus, Brachypodium sylvaticum, Sesleria rigida, Cytisus hirsutus, Daphne blagayana, Deschampsia flexuosa, Erica carnea, Festuca rubra, Melica cilliata, Galium pseudaristatum, Potentilla erecta, Vaccinium myrtillus,* etc. The species from the seed mixture, *Festuca rubra* and *Lotus corniculatus,* are also recorded in the native vegetation. Generally, the ski run was dominated by grasses *Festuca rubra* and *Festuca arundinacea*, but in one part *Trifolium repens* was the dominant species. In addition to the species used in the seed mixture, there were 26 other grass and herb species at the ski runs which were from native vegetation, e.g., *Rubus hirtus, Pteridium aquilinum, Galium corrudifolium, Verbascum lychnitis, Euphorbia cyparissias, Veronica officinalis, Lathyrus pratensis, Leucanthemum vulgare, Thlaspi praecox, Achillea millefolium, Rumex acetosella, Scabiosa columbaria, Melica cilliata,* etc. One species, *Cirsium arvense*, which was absent from the native vegetation, was described at the ski run. According to these data, the Jaccard index is 0.42.

In the ski resort on Mt. Stara Planina, the ski runs Konjarnik 1 and Sunčana Dolina have been constructed in the zone of *Ass. Fagetum submontanum*, *Fagetum submontanum luzuletosum* and *Luzulo-Fagetum serbicum*.

In the floristic survey of the Konjarnik 1 ski run, a total of 45 species were identified in the autochthonous vegetation, and 26 at the ski run. The dominant species in the autochthonous vegetation is *Fagus moesiaca*. On the ground floor, some of the recorded species are: *Asperula odorata, Athyrium filix-femina, Brachypodium silvaticum, Carex silvatica, Dryopteris filix-mas, Epilobium montanum, Euphorbia amygdaloides, Festuca heterophylla, Galium sylvaticum, Gentiana asclepiadea, Geranium macrorrhizum, Hypericum maculatum, Luzula luzuloides, L. sylvatica, Poa nemoralis, Vaccinium myrtillus, etc.* Two species from the seed mixture, *Festuca rubra* and *Trifolium repens,* are recorded in the native vegetation. Generally, the ski run was dominated by the grass *Festuca rubra.* In some parts of the Konjarnik 1 ski run *Festuca ovina* and *Trifolium repens* were the dominant species. In addition to the species used in the seed mixture, there were 26 other grass and herb species on the edges of ski runs which were from native vegetation, e.g., *Geranium macrorrhizum, Hypericum maculatum, Rubus hirtus, Leucanthemum vulgare, Achillea millefolium, Epilobium montanum, Trifolium pratense,* etc. These species are mainly developed near the edges of ski run. *Festuca arundinacea, Elymus repens, Agrostis stolonifera* and *Festuca ovina* (species from the seed mixture) are not described in the native vegetation. According to these data, the Jaccard index is 0.03.

In the floristic survey of the Sunčana Dolina ski run, a total of 28 species were identified in the autochthonous vegetation, and 6 at the ski run. Two species from the seed mixture, *Festuca rubra* and *Trifolium repens,* are recorded in the native vegetation. Generally, the ski run was dominated by grass *Festuca rubra.* Near the edges of ski run 12 species from native vegetation were described, such as: *Vaccinium myrtillus, V. vitis-idaea, Viola sp., Leucanthemum vulgare, Rumex acetosella,* etc. Also, *Festuca arundinacea, Elymus repens, Agrostis alba* and *Festuca ovina* (species from the seed mixture) are not described in the native vegetation. The Jaccard index is 0.06 which indicates a small similarity of floristic composition between the sown and natural site.

Table 3. Review of basic characteristics of erosion processes at the investigated ski runs.

Ski resort	Erosion forms	Specific annual sediment yield at the ski run before revegetation [$m^3 \cdot km^{-2}$]	Specific annual sediment yield at the ski run after revegetation [$m^3 \cdot km^{-2}$]	Specific annual sediment yield in the surrounding native vegetation [$m^3 \cdot km^{-2}$]
Stara Planina	deep gullies solifluctions sufosion systems of rills debris flows sheet erosion road erosion	5174.9	350	520
Divčibare	systems of rills debris flows sheet erosion road erosion	1711.1	280	417.5

The basic characteristics of the erosion processes at the investigated ski runs are shown in the Table 3.

DISCUSSION

In order to prevent erosion at ski runs it is very important to start revegetation immediately after earthworks with species that have the ability can quickly establish an adequate vegetation cover. For that purpose, non-native species, mostly grasses, are commonly used, because they are less expensive than the native plants. For this reason, the impacts of revegetation on the native vegetation were investigated, in order to check if the plant species used in the seed mixtures invaded the native ecosystem from the ski runs (Kangas et al., 2009).

In order to control erosion by water on slopes with vegetation, it is recommended to use grass-legume mixtures. Nitrogen-fixing nodules produced by the legumes benefit the grasses, which would otherwise disappear from the plant community through a lack of nitrogen. Legumes, however, take two to three years to establish a complete cover. Low-growing sod-forming grasses which spread rapidly by stolons above ground or rhizomes below ground are an essential requirement of any species mix (Morgan and Rickson, 1995).

Out of 7 species used for revegetation of the ski run at Divčibare, only one species, *Lolium perenne,* was not described in the autochthonous vegetation. This species has not invaded the native ecosystem from the ski run. Usage of native species for revegetation at this ski run has led to establishing a stable plant community, which is confirmed by 26 other grass and herb species found at the ski run which were from the native vegetation. Also, the Jaccard index indicates significant similarity of the floristic composition among the sown and the natural sites.

At the ski runs on Stara Planina, out of 6 species used for revegetation, only two are found in the autochthonous vegetation. The Jaccard index is low at both ski runs on Stara Planina and indicates little similarity of floristic composition among the sown and natural sites. Future investigation will be aimed at analysis of the stability of the new plant community and its impacts on natural vegetation. It is important to emphasize that four allochthonous species used in the seed mixtures have not invaded the native ecosystems from the ski runs.

Serbian ski resorts were formed on very steep terrains in the headwaters of local streams (Stara Planina, mean slope of terrain Sm=47.6% and Divčibare, Sm=23.7%), after massive construction activities.

Clear-cuttings, trunk transport, access road construction and large excavations on steep slopes put very strong pressure on the environment. Among many of the consequences are compaction of the surface soil layer, reduction of the infiltration capacity, destruction or degradation of the vegetation cover, intensifying of the surface runoff and development of erosion processes. Also, legal nature-protection standards were poorly implemented in the Serbian ski resorts (Ristić et al., 2009).

The soil and geology characteristics of the investigated ski runs are unfavorable, with small water infiltration-retention capacity, intensive erosion processes and sediment yield.

For Serbia, south of the Sava and Danube rivers the average value for sediment yield is 538.16 $m^3 \cdot km^{-2} \cdot year^{-1}$ (Ristić and Nikić, 2007). Results of specific annual sediment yield on the ski runs at the investigated ski resorts indicate strong erosion. In the region of Stara Planina, sediment yields were nearly 10 times bigger (5174.9 $m^3 \cdot km^{-2} \cdot year^{-1}$) at the disturbed ski run soil than at the undisturbed soil in the surrounding (native) beech forest (520 $m^3 \cdot km^{-2} \cdot year^{-1}$). In the Divčibare ski resort 1711.1$m^3 \cdot km^{-2} \cdot year^{-1}$ of sediment yield was produced on the disturbed ski run soil on harzburgite and 417.5$m^3 \cdot km^{-2} \cdot year^{-1}$ on the undisturbed soil in the surrounding, native pine forest. The lack of erosion control activities in the ski resorts, during construction (between June and October of 2007) increased the intensity of degradation processes (Ristić et al., 2008a, 2008b, 2008c). Restoration and erosion control works have stopped degradation processes and helped re-establish vegetation and rehabilitate landscape appearance and function. After the completion of restoration and erosion control measures at the ski runs, the intensity of erosion was stabilized at the levels of 350 $m^3 \cdot km^{-2} \cdot year^{-1}$ (Stara Planina) and 280 $m^3 \cdot km^{-2} \cdot year^{-1}$ Divčibare, respectively.

For rapid soil stabilization at the Crni Vrh ski run on the Divčibare ski resort, apart from the usage of autochthonous species, it is important to take into account the characteristics of these species. All 7 species (Tab. 1) used for revegetation of the Crni Vrh ski run are suitable for erosion control in a temperate climate (Morgan and Rickson, 1995). The grasses are rhizomatous and widely soil tolerant.

Species from the seed mixture for the two ski runs in the Stara Planina ski resort are suitable for erosion control in a temperate climate (Morgan and Rickson, 1995). However, only two species are native for that area. In the seed mixture only one species is a legume.

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