# Afforestation on bare lands – example of Ibar Gorge, Serbia

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## Abstract

The afforestation of bare lands, sandstone, and skeletal terrains are one of the biggest challenges forestry scientists face. These terrains are characterized by specific ecological conditions that are generally unfavorable for the growth of woody species. These are usually shallow soils, unstable, and poor in nutrients and moisture. The characteristics of these habitats make said terrains unfavorable for the regeneration of forest vegetation. It is therefore crucial for the success of afforestation to gain detailed knowledge and understanding of environmental conditions. Only after the detailed research and study of field conditions can the selection of species for afforestation, including selection of species characteristics and technology of planting, begin. Mistakes made during previous establishments of green areas are one of the main reasons some species of vascular flora have disappeared. This alone expresses the undeniable importance of knowledge on habitat specifics, work schedule, and selection of species for afforestation. With the aim to implement the future afforestation within the planned scope, it is necessary to organize an effective nursery production of seedlings with characteristics that will suit the environmental conditions of bare lands, sandstones, and skeletal terrains whose afforestation is planned.

## Keywords

Ibar Gorge, Barren Soil, Afforestation, Seedlings

## Contents

# 1 Bare lands in Serbia

The cause for the occurrence of bare lands, as well as large areas of degraded forests, in Serbia is in a series of historical, socio-political, economic, cultural, and climatic factors (Ratknić et al. 2007). The fight against soil erosion caused by deforestation and destruction of vegetation should be considered seriously because these are huge damages. Serbia is among the countries that are very endangered by erosion, which is best confirmed by the fact that many areas of our country lost loose soil.

Due to destroying vegetation, primarily by deforestation, improper treatment of steep slopes, deterioration of physical and chemical characteristics of soil, etc., humans have become a major factor in the general degradation of soil and the environment. With aggressive actions, humans contributed to the acceleration of the process of erosion. Erosion processes especially endangers mountain areas due to the ruggedness of terrains with very steep sides and deep slit streams. The degradation of pastures in the Pester plateau, on mountain Zlatibor, mountain Kopaonik, Ibar gorge, and the mountain complexes around Vlasina Lake, formed eroded skeletal barren soils.

Investing in afforestation is a long-term investment with a difficult assessment of investment risk. The specificity of afforestation of degraded areas is reflected in the limiting factors for the development of vegetation. The main limiting factors to restore the forest ecosystems are primarily physical characteristics of soils and shallow depth of solum that disable proper root development of trees. When there is low humidity, all physiological processes slow down, while during the longer dry periods these processes completely irrupt which leads to plant dieback. Therefore it is important to research complex, interrelated ecological factors and determine which one has the greatest impact on vegetation for maximum reduction of adverse effects.

The tempo of afforestation of deforested areas and bare lands in Serbia shows variability at different time periods. 519,824 ha of land were afforested in our country between 1945 and 1990 (Dražić 1992; Šmit et al. 1996). According to data from the Program of Protection and Improvement of Forests, from 1996-2000 in Serbia over the last thirty years (until the end of 2001) 155,135 ha of land owned by the state were afforested and ameliorated, of which 105,000 ha are bare lands (Medarević et al. 2002). In Serbia, 19,000 ha were afforested in 1982, but only 2,000 hectares were afforested in 2001 (Ćirković-Mitrović et al. 2011).

# 2 Ibar Gorge

Gorges are narrow, deep valleys with steep sides and cut in rocks (Janković et al. 1984). They represent refugia of rare and relict vegetation due to their specific climate and other environmental conditions, which enabled the preservation of the flora. Inversion of vegetation is one of the peculiarities of the gorges. The inversion of vegetation is conditioned, among other things, by the inversion of the climate – cold air descends to lower elevations and warm air goes to a higher elevation - on top of the gorges. Many gorges are characterized by the appearance of various geomorphological forms on the same side of steep slopes. Such relief affects a specific layout and diversity of vegetation on small areas – a mosaic of various ecosystems on small areas and at small distances.

The Ibar River is 65 km long and flows through the municipalities of Raška and Kraljevo, carving its way through the Ibar gorge (Fig. 1).


Figure 1. Basin of Ibar River in Serbia

Ibar gorge is located in southwest Serbia and it is one of the largest areas of serpentine soil in this country. This soil covers great areas of the Balkan Peninsula. The area with blocks of serpentine rocks in the Ibar gorge is larger than in any other part of Europe (Stevanović et al. 2003). It stretches from Kosovska Mitrovica to Kraljevo. In comparison to other serpentine areas, it had large areas of bare lands. Its deforestation was directly affected by long-term anthropogenic activities that caused irreversible negative effects on the previous forest ecosystems. Ibar gorge is characterized by specific ecological characteristics. In ecological and vegetation terms, thermophilus communities of oak and pine forests characterize this area. Soil in this area is characterized by shallow solum (under 20 cm), lack of moisture, and instability. The habitat is characterized by expressed orography with steep slopes and severe inaccessibility due to poorly developed road infrastructure. These characteristics of the Ibar gorge habitat are very unfavorable for forest regeneration and establishment.

## 2.1 Climate

The most intensive afforestation in the Ibar gorge was performed in the period from 1979; the analyzed climatic parameters are from 1979 to 1989. We tried to analyze the effect of different environmental factors on the selection of planting techniques, the scope, and success of afforestation in that period of time.

The processed data are from the Republic Hydrometeorological Service of Serbia for the weather station Kraljevo regarding average air temperatures, average annual and monthly sums of precipitation, and wind strength and frequency.

The average annual air temperature in the studied period was 10.9°C, and its value in the vegetation period was 17.5°C (Tab. 1). In the warmest month of the year (July) the average air temperature was 20.8°C, and in the coldest month (January) it was -0.5°C. The range of the mean annual air temperature in the studied period was from 10.3°C (in 1980) to 11.5°C (1983).

Table 1. Average air temperature (°C) recorded in the meteorological station Kraljevo (1979-1989)

| Year | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1979** | -1.2 | 3.3 | 9.6 | 10.4 | 16.1 | 20.4 | 19.6 | 19.3 | 16.2 | 10.2 | 7.1 | 4.5 | 11.3 |
| **1980** | -2.0 | 2.5 | 6.5 | 9.2 | 13.8 | 18.5 | 20.2 | 19.8 | 16.0 | 12.6 | 5.9 | 0.2 | 10.3 |
| **1981** | -2.6 | 1.5 | 9.2 | 10.9 | 15.8 | 20.2 | 19.9 | 19.6 | 17.4 | 13.2 | 3.8 | 2.5 | 11.0 |
| **1982** | -1.3 | -0.1 | 5.4 | 8.8 | 17.3 | 21.0 | 20.7 | 20.7 | 20.0 | 13.1 | 4.9 | 4.7 | 11.3 |
| **1983** | 3.8 | 2.0 | 8.5 | 14.4 | 18.0 | 18.2 | 21.5 | 20.6 | 16.3 | 10.8 | 3.1 | 0.9 | 11.5 |
| **1984** | 1.0 | 0.5 | 4.9 | 10.0 | 16.5 | 18.1 | 19.3 | 19.2 | 17.2 | 13.4 | 5.6 | 0.7 | 10.5 |
| **1985** | -4.4 | -3.0 | 5.5 | 12.4 | 18.1 | 17.7 | 21.7 | 22.1 | 16.3 | 10.4 | 5.0 | 4.3 | 10.5 |
| **1986** | 0.9 | -1.2 | 5.3 | 14.3 | 17.6 | 18.3 | 19.0 | 21.3 | 16.7 | 10.9 | 5.7 | -0.1 | 10.7 |
| **1987** | -2.9 | 2.5 | 1.5 | 11.2 | 14.3 | 20.0 | 23.5 | 20.0 | 20.2 | 12.0 | 7.6 | 2.8 | 11.1 |
| **1988** | 3.2 | 4.3 | 5.9 | 10.8 | 16.4 | 18.4 | 23.5 | 22.5 | 16.9 | 10.6 | -0.2 | 1.4 | 11.1 |
| **1989** | 0.3 | 4.7 | 9.3 | 14.1 | 14.7 | 17.0 | 20.3 | 20.3 | 15.9 | 10.7 | 4.7 | 0.5 | 11.0 |
| **Average** | -0.5 | 1.5 | 6.5 | 11.5 | 16.2 | 18.9 | 20.8 | 20.5 | 17.2 | 11.6 | 4.8 | 2.0 | 10.9 |

Data on pluviometric regime are shown in Table 2. The annual precipitation in the region of Kraljevo during the studied period was 771.2 mm of rainfall, ranging from 585.3mm (1982) to 932.3 mm (1981). During the vegetation period (April-September), the average precipitation was 421.3 mm, which represents 54.6% of the total annual precipitation. The least precipitation in the vegetation period compared with the annual amount, 48.2% was in 1988, and the highest precipitation of 72.7% was in 1989. June was the month with the highest precipitation of 103.1 mm and the least precipitation, 38.6 mm, was averagely in September.

The pluviometric regime of air temperature and the climate index calculated by Thornthwaite (Thornthwaite 1948, 1955) was analyzed for each year of the studied period. Using a complex computation method, which today is presented by a special computer program, based on the average monthly air temperature and average monthly precipitation, taking into account the latitude of the studied location and the length of daylight, the caloric index (i) and the annual caloric index (I) were calculated first. Using a special logarithmic nomogram, the uncorrected potential evapo-transpiration (PE), the actual evapotranspiration (SE), and the lack of water in the soil (M) was then calculated. The final result represents indices of the humidity (s) and aridity (Ia), and the climatic index (k) based on which the character of the climate for the analyzed area, according to the classification laid down in this method, had been determined. Thus, calculated climate index is a result of basic climatic factors (air temperature and precipitation regime) in conjunction with the basic orographic factors (geographical coordinates of the studied location and the length of daylight). The average value of the general climate index in the region of Kraljevo from 1979 to 1989 is 26.6394. The climate was mild and humid (B1). Excess moisture in the soil of a total of 170 mm occurs in the beginning of the year, in January, February and March, but also in December (it does not occur in the vegetation period so it is of less importance for plants). Lack of water of only 13 mm occurs in September (Tab. 3, Fig. 2).

Table 2. Monthly and annual precipitation (mm) recorded in the meteorological station Kraljevo (1979-1989)

| Year | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1979** | 72.5 | 36.6 | 14.1 | 50.4 | 69.5 | 69.5 | 52.4 | 84.6 | 45.7 | 53.1 | 112.3 | 33.8 | 694.5 |
| **1980** | 77.8 | 51.4 | 70.9 | 62.5 | 177.3 | 106.3 | 61.2 | 22.3 | 24.2 | 66.1 | 72.6 | 133.0 | 925.6 |
| **1981** | 67.9 | 23.1 | 93.6 | 40.8 | 67.4 | 99.1 | 102.8 | 60.5 | 102.7 | 88.2 | 124.8 | 61.4 | 932.3 |
| **1982** | 35.3 | 25.3 | 84.3 | 59.7 | 26.2 | 44.1 | 107.3 | 64.5 | 18.9 | 38.1 | 22.4 | 59.2 | 585.3 |
| **1983** | 31.2 | 45.3 | 30.5 | 39.2 | 60.2 | 146.7 | 99.4 | 22.8 | 63.7 | 24.7 | 49.8 | 101.1 | 714.6 |
| **1984** | 94.6 | 131.2 | 63.7 | 87.1 | 101.6 | 94.9 | 53.1 | 73.5 | 44.7 | 34.5 | 37.8 | 18.7 | 835.4 |
| **1985** | 71.9 | 67.7 | 30.3 | 81.8 | 52.0 | 72.6 | 20.3 | 133.3 | 4.5 | 27.8 | 150.9 | 35.4 | 748.5 |
| **1986** | 66.4 | 101.1 | 47.0 | 31.1 | 86.5 | 141.0 | 166.3 | 70.5 | 3.9 | 47.5 | 14.2 | 34.1 | 809.6 |
| **1987** | 108.1 | 8.3 | 67.6 | 72.0 | 165.0 | 50.2 | 63.4 | 52.9 | 20.3 | 45.2 | 113.8 | 91.6 | 858.4 |
| **1988** | 41.6 | 48.6 | 118.2 | 47.3 | 39.8 | 163.9 | 8.4 | 14.5 | 53.3 | 34.9 | 54.7 | 53.7 | 678.9 |
| **1989** | 1.5 | 17.9 | 30.6 | 41.6 | 92.9 | 145.6 | 108.0 | 81.8 | 43.2 | 42.2 | 51.5 | 49.1 | 705.9 |
| **Average** | 60.8 | 50.6 | 59.2 | 55.8 | 85.3 | 103.1 | 76.6 | 61.9 | 38.6 | 45.7 | 73.2 | 61.0 | 771.7 |

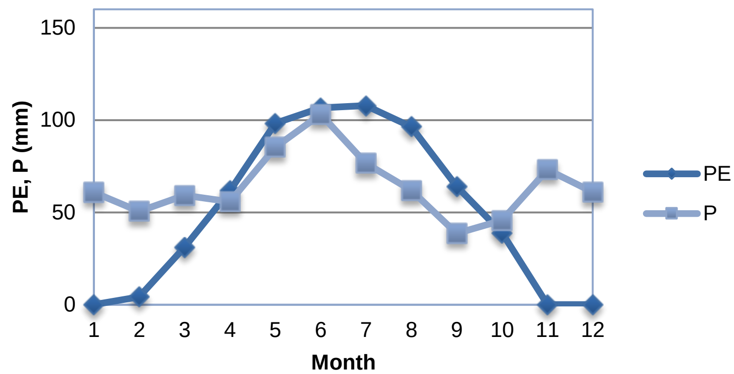


Figure 2. Climate diagram after Thornthwaite for the meteorological station Kraljevo

Table 3. Monthly and annual precipitation (mm) recorded in the meteorological station Kraljevo (1979-1989)

| | T °C | i | (PE) | PE | P | R | SE | M | V |
|---|---|---|---|---|---|---|---|---|---|
| **I** | -0.5 | 0.00 | 0 | 0 | 61 | 100 | 0 | 0 | 61 |
| **II** | 1.5 | 0.17 | 4 | 4 | 51 | 100 | 4 | 0 | 46 |
| **III** | 6.5 | 1.49 | 24 | 31 | 59 | 100 | 31 | 0 | 28 |
| **IV** | 11.5 | 3.53 | 48 | 62 | 56 | 94 | 62 | 0 | -6 |
| **V** | 16.2 | 5.95 | 74 | 98 | 85 | 81 | 98 | 0 | 0 |
| **VI** | 18.9 | 7.48 | 89 | 107 | 103 | 78 | 107 | 0 | 0 |
| **VII** | 20.8 | 8.68 | 100 | 108 | 77 | 46 | 108 | 0 | 0 |
| **VIII** | 20.5 | 8.46 | 98 | 96 | 62 | 12 | 96 | 0 | 0 |
| **IX** | 17.2 | 6.49 | 79 | 64 | 39 | 0 | 51 | 13 | 0 |
| **X** | 11.6 | 3.59 | 49 | 39 | 46 | 7 | 39 | 0 | 0 |
| **XI** | 4.8 | 0.95 | 17 | 0 | 73 | 80 | 0 | 0 | 0 |
| **XII** | 2.0 | 0.26 | 6 | 0 | 61 | 100 | 0 | 0 | 41 |
| **YR** | **10.9** | **47.04** | | **609** | **772** | | **596** | **13** | **170** |
| **V.P.** | **17.5** | | | **535** | **421** | | **521** | **13** | **-6** |
| **In.hum.=27.9658, In.arid. =2.21066, Cl. ind.=26.6394** | | | | | | | | | |
| **CLIMATE: *HUMID AND MILD - (B1)*** | | | | | | | | | |

i – caloric index, (PE) – uncorrected potential evapotranspiration, PE – potential evapotranspiration, P – precipitation, R - Reserve moisture (water) in the soil, SE – actual evapotranspiration, M – the lack of water in the soil, V – excess moisture (water) in the soil

Usually wind comings from the east and the west, while the lowest frequencies have winds from the south (Fig. 3).

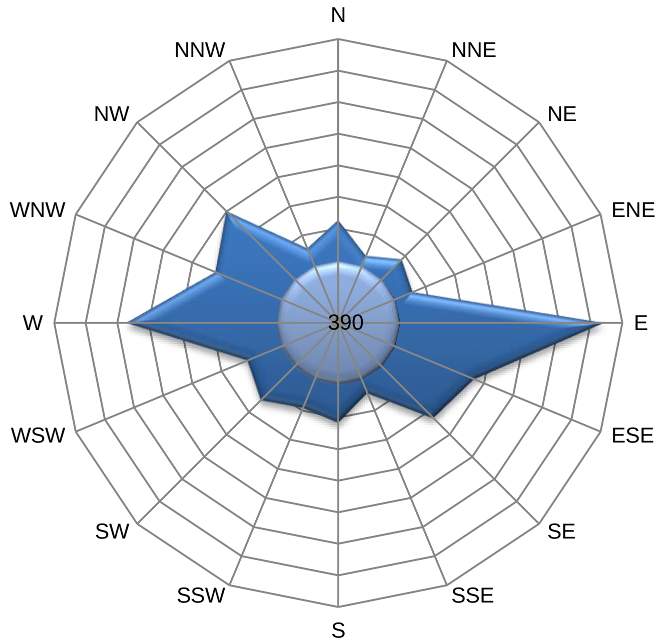


Figure 3. Wind rose of researched area.

## 2.2 Vegetation

Data collected by Tatić (1969) were used for the purpose of studying the vegetation of Ibar gorge. Preserved natural forests can only be found on small areas in hard-to-reach, privately owned fields mainly at higher elevations and colder climates. The reason for this situation is the destruction of forests over a long period of time. Destroyed forests and degraded habitats prevented the natural regeneration of forests.

In the studied area, the following forest communities were found: *Quercetum confertae-cerris* Rudski (40) 1949*, Pinetum nigrae serpentinicum* Pavlović 1951*, Quercetum montanum* Černjavski & B. Jovanović 1953 and *Fagetum moesiacae montanum* B. Jovanović 1953.

Within these communities appear more transitional forms conditioned primarily by the topography of the terrain. Forests consisting of Hungarian and Turkey oak – *Quercetum confertae-cerris* Rudski (40) 1949 have been determined only in Popova reka and near Polumir. The most represented species are: *Quercus cerris* L.*, Quercus farnetto* Tenore*, Quercus petraea* (Mattuschka) Lieblein and *Acer campestre* L.

Austrian pine forests – *Pinetum nigrae serpentinicum* Pavlović 1951. In the area of Gokčanica these forests were destroyed and only individual trees remain. The presence of *Erica carnea* L. and *Euphobia glabriflora* Visiani, along with stumps of cut down trees, shows that Austrian pine previously dominated in this area. On Pogrebine preserved natural Austrian pine forests can be found with very well developed saplings.

Sessile oak forests – *Quercetum montanum* Černjavski & B. Jovanović 1953. stretch from 400 to 1,000 m above sea level, depending on aspect. Tatić (1962) identified three sub-associations on Studena Mountain: *Ericeto vciccinietosum* on gentle slopes, *Spireetosum ulmifoliae* mostly on rocky soils, and *Seslerietosum rigidae* on slopes and plateaus at higher elevations. All these forests are severally degraded and with sparse canopy.

Balkan beech forests – *Fagetum montanum* Černjavski & B. Jovanović 1953 can be found in fragments on cold aspects. Many areas are covered with common bracken which indicates that beech was much more widespread in these areas.

Tatić (1962) identified the following grass communities on Studena Mountain: *Molinietum coeruleae* Koch 1926, *Agrostideto chrysopogonetum grylli* Kojić 1959, *Bromus fibrosus-Chrysopogon gryllus* Tatić 1969, and *Poeto molinierii-Plantaginetum carinatae* Pavlović 1959. Pavlović (1974) had identified the plant community Koelerio-Danthonietum calycinae in the zone of oak forests and in transitional zones between oak and beech forests, which in the area of Gokčanica occupies considerable areas inhabiting the steeper slopes and gentler terrains with deeper soil.

*Molinietum coeruleae* Koch 1926 inhabits only wet grounds in river valleys. *Poeto molinierii-Plantaginetum carinatae* Pavlović 1959 occupies large areas on shallow soils. In the community, the most represented are Mediterranean elements, but the presence of Balkan Illyrian floral elements is also noted. Grazing, which accelerates erosion processes and land degradation, is responsible for the degradation of these plant communities. This is the most represented plant community in the Ibar gorge.

*Agrostideto-Chrysopogonetum grylli* Kojić 1959 is a much represented community. It occupies deeper and richer soils on gentler slopes on elevations from 400 to 700 m. Areas covered with this community fall into a more favorable terrain for afforestation.

*Bromus fibrosus-Chrysopogon gryllus* Tatić 1969 – This community occupies terrains on elevations between 400-700 m and has a very xerothermic character, but it does not cover large areas. It appeared after the disappearance of Austrian pine on steeper terrains, and sessile oak on gentler terrains. Xerophytic species with Mediterranean floral elements can mostly be found in this community, which indicates a warmer and drier habitat.

In this area, degradation of grass communities that are symbolically represented and have no practical significance also occurs. It can be concluded that the geographic position of this massif enabled the development of a large number of plant species, but they are all plant communities in degradation under the influence of anthropogenic factors.

Forest and grass vegetation of Stolovi Mountain were mapped and studied by Vučković and Topalović (1987, 1996). In addition to the mapped forest communities and meadow-pasture, communities that were identified on Stolovi Mountain by Slavković (1976) and on Studena Mountain (next to Stolovi Mountain) by Tatić (1962) are forests of Hungarian and Turkey oak, sessile and Turkey oak, and Sessile oak forests, which in their composition have subpont species *Potentilla alba* L., on Stolovi Mountain were specifically studied.

Forests of Hungarian oak, Turkey oak and *Potentilla alba* L. (*Quercetum frainetto-cerris potentilletosum albae* Vučković et Topalović 1987) – These forests are especially significant because *Potentilla alba* has not been noted in the lower zones of oaks in our other regions that lack serpentine soil. This sub-association of Hungarian oak and Turkey oak forests was developed on vertisols in Neogene sediments within which redeposited serpentine material can also be found. In terms of their composition and basic environmental conditions, these are transitional phytocenoses of Hungarian and Turkey oak forests to Sessile and Turkey oak forests.

Forests consisting of Sessile oak, Turkey oak and *Potentilla alba* L. (*Potentillo albae-Quercetum petraeae-cerris* Vučković et Topalović 1987) – This phytocenosis forms on Stolovi Mountain a subzone between Hungarian and Turkey oak forests and Sessile oak forests in the range of 250-450 m (550 meters of elevation) at cold aspects. This is the final plant community, primarily edaphically conditioned. Soils mostly belong to more developed types of serpentine-peridotite soils. In the floral, genetic, and ecological terms phytocenoses of Sessile oak, Turkey oak and *Potentilla alba* on serpentine substrate are closely connected to the serpentine phytocoenoses of Sessile oak and *Potentilla alba* L.

Forests of Sessile oak and *Potentilla alba* L. (*Potentillo albae-Quercetum petraeae* Pavlović 1951 em Ht. 1959) – Stands of associations of Sessile oak forests and *Potentilla alba* L. take up the largest areas on Stolovi Mountain. The remaining forests and their degradation phases with different grass communities occupied habitats at all aspects, leaving stands of beech, Sessile oak, hornbeam, and stands of hornbeam and Sessile oak the only sheltered places with lower parts of the slopes or habitats near water access.

Sessile oak forests on Stolovi Mountain show variability in composition beside uniform activity of serpentine soil conditions. These differences in composition and distribution of Sessile oak forests arise from local and regional climate impacts as well as impact of soil conditions, primarily the differences in moisture regime, while differences in the level of soil development do not have this importance. That is why these forests, in terms of occurrence and composition, have been divided into lower systematic units (mainly sub-associations): *caricetosum silvaticae, aceretosum pseudoplatani, luzulo-vaccinetosum, typicum, caricetosum hallerianae, sedetosum maximi, seslerietosum rigidae, cotinetosum, brachipodietosum pinnati,* and *dictamnetosum albi*.

## 2.3 Geological substrate and soil types

Geological substrate of Ibar gorge is made of peridotites at different stages of serpentinization. The largest area is occupied by harzburgites, rocks consisting mostly of minerals olivine and pyroxene with small amounts of $SO_2$. On smaller areas, there are dacite-andesite, sericite-chlorite schists, granodiorite and quartz diorite porphyries minerals.

In the studied area, soil from the initial phase of the formation to genetically developed soil types can be determined. This is typical for serpentine areas that, for various reasons, had become bare lands. Due to expressed ruggedness and denudation of the terrain, the gravitational and water erosion is constant in these areas, therefore, the developed soils are often significantly disturbed. The characteristics of soils formed under these conditions are expressed skeletal structure, shallow profile, and the presence of colluvium processes (Tab 4 and 5).

The soils of the Ibar gorge are almost all types of soil on serpentine. These are lithosols, rankers, brown rankers and skeletal brown soil.

Rocky soils – They are presented in the studied area. They occur both on steep slopes and in their foothills and arise with the removal of small particles of land in the processes of erosion. In the areas of steep slopes, except triturated material, blocks of serpentine also appear and emerge to the surface and can occupy large areas. In the existing conditions, these areas cannot be used in regular production.

Table 4. Textural soil composition at research area (Šmit et al. 1997).

| Location | Soil type | Depth (cm) | Grain size composition (%) | | | | | | Grain size composition classification |
|---|---|---|---|---|---|---|---|---|---|
| | | | Corse sand 2-0.2 mm | Fine sand 0.2-0.02 mm | Dust 0.02-0.002 mm | Clay <0.002 mm | Total sand | Total clay | |
| **Gokčanica department 58** | ranker | 0-49 | 29.00 | 41.80 | 20.40 | 8.80 | 70.80 | 29.20 | sandy loam |
| **Gokčanica department 64** | brown ranker | 0-35 | 14.50 | 36.90 | 31.30 | 17.30 | 51.40 | 48.60 | loam |
| **Studenica-Polumir department 5** | brown soil | 0-32 | 13.00 | 25.20 | 47.30 | 14.50 | 38.20 | 61.80 | loam |
| **Gokčanica department 65** | ranker | 0-34 | 26.00 | 26.50 | 30.00 | 17.50 | 52.50 | 47.50 | loam |
| **Studenica-Polumir department 27** | brown ranker | 0-41 | 26.00 | 26.90 | 27.50 | 19.60 | 52.90 | 47.10 | loam |
| **Studenica-Polumir department 53** | brown ranker | 0-36 | 30.50 | 21.40 | 22.90 | 25.90 | 51.90 | 48.10 | loam |
| **Gokčanica department 84** | ranker | 0-39 | 30.50 | 35.70 | 25.20 | 8.60 | 66.20 | 33.80 | sandy loam |
| **Gokčanica department 86** | brown ranker | 0-39 | 36.50 | 43.70 | 12.40 | 7.40 | 80.20 | 19.80 | loamy sand |
| **Gokčanica department 75** | brown soil | 0-29<br>29-89 | 19.50<br>28.00 | 42.50<br>28.80 | 23.10<br>20.70 | 14.90<br>22.50 | 62.00<br>56.80 | 38.00<br>43.20 | sandy loam<br>sandy loam |

Eutric rankers – The depth of this soil type ranges from a few centimeters to about 50 centimeters, but it is usually about 25 centimeters deep. On steep slopes with damaged vegetation and expressed erosion shallow rankers dominate. In areas with lower slopes and grass, there are medium deep rankers. Soil profile depth of about 50 cm usually occurs under forest vegetation.

Rankers are black soils with humus content of 14%. Related to grain size composition, they are sandy loam to loam. They are loose, permeable, and porous soils. The root system of plants is developed throughout the whole depth of the profile.

Chemical characteristics of rankers are a slightly acidic reaction of soil solution (pH 6.4 to 6.7) and saturation of soil adsorption complex of above 70% by alkali cations. Soil provision with total nitrogen is high (0.38 to 0.75%), while forms of phosphorus and potassium in small quantities are easily available to plants.

Rankers of the studied area have a low production value if they are shallow. Unfavorable conditions for afforestation are shallow soil depth, presence of skeleton, and expressed xerothermic vegetation.

Brown rankers – The soil has the same profile structure as the typical ranker, only difference being that the humus-accumulative horizon has a brownish color and contains less humus (4.5-6.5%). Profile depth ranges from 35 to 40 cm. Compared to grain size composition, brown rankers are loam. The root system of plants is developed throughout the whole depth of profile.

Chemical characteristics of brown rankers are slightly acidic to neutral reaction of soil solution (pH 6.6 to 7.1) and saturation of soil adsorption complex of above 80%

by alkali cations. Soil provision with total nitrogen is high (0.22 to 0.28%), while forms of phosphorus and potassium in small quantities are easily available to plants.

The brown rankers of the studied area occur on gentle slopes and plateaus. They have the same production value as typical rankers. The production value mostly depends on the depth of usable soil layer.

Skeletal brown soils – The characteristic of these soils are the presence of skeletons on the soil surface and in the profile and that presence increases in deeper layers. In the studied area, these soils are damaged and often without the typical humus-accumulative horizon, which was removed by erosion.

Chemical characteristics of skeletal brown soils are weakly to moderately acidic reactions of soil solution (pH 5.9 to 6.6) and saturation of soil adsorption complex of above 60% by alkali cations. The humus content is about 3% and the soil provision with nutrients is poor to moderate.

Production value depends on the degree of preservation and the depth of usable soil layer. Deeper soils with fewer skeletons are very suitable for afforestation, while shallower variations are unsuitable.

Table 5. Chemical soil characteristics (Šmit et al. 1997).

| Location | Depth cm | Soil absorption complex | | | | $Y_1$ | pH | | Humus | Nitrogen | Easily available | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | T | S | T-S | V | | $H_2O$ | KCl | | | $P_2O_5$ | $K_2O$ |
| | | mil/ckv | | | % | ccm | | | % | | mg/100 g soil | |
| **Gokčanica department 58** | 0-49 | 21.14 | 50.50 | 20.69 | 70.98 | 31.75 | 6.4 | 5.5 | 13.97 | 0.75 | 4.0 | 5.5 |
| **Gokčanica department 64** | 0-35 | 36.11 | 30.42 | 5.69 | 84.24 | 8.75 | 6.6 | 5.9 | 5.46 | 0.27 | 15.0 | 5.6 |
| **Studenica-Polumir department 5** | 0-32 | 50.82 | 27.74 | 23.08 | 54.58 | 35.50 | 5.9 | 5.2 | 3.23 | 0.17 | 16.0 | 3.8 |
| **Gokčanica department 65** | 0-34 | 50.66 | 41.56 | 9.10 | 82.03 | 14.00 | 6.7 | 5.6 | 13.86 | 0.63 | 9.2 | 11.5 |
| **Studenica-Polumir department 27** | 0-41 | 41.22 | 36.28 | 4.94 | 88.02 | 7.60 | 6.9 | 6.1 | 4.75 | 0.24 | 8.0 | 13.5 |
| **Studenica-Polumir department 53** | 0-36 | 47.32 | 42.38 | 4.94 | 89.56 | 7.60 | 7.1 | 6.2 | 5.83 | 0.28 | 4.0 | 12.5 |
| **Gokčanica department 84** | 0-39 | 40.46 | 31.44 | 9.02 | 77.71 | 13.88 | 6.6 | 5.8 | 10.83 | 0.38 | 4.0 | 3.7 |
| **Gokčanica department 86** | 0-39 | 38.62 | 27.16 | 11.46 | 70.33 | 17.63 | 6.7 | 5.6 | 6.48 | 0.22 | 4.0 | 6.0 |
| **Gokčanica department 75** | 0-29 | 33.57 | 21.30 | 12.27 | 63.45 | 18.88 | 6.6 | 5.4 | 3.04 | 0.20 | 10.2 | 13.0 |
| | 29-89 | 45.87 | 29.38 | 16.49 | 64.05 | 25.37 | 6.6 | 5.9 | 1.70 | 0.09 | 4.0 | 9.5 |

T – cation exchange capacity, S – base content, T-S – hydrological acidity, V – base saturation $Y_1$ – Hydrolytic acidity – all by Kappen (1929)

***Soil water content*** – The amount of available water in the studied soil types is highly variable. Lithosols, as the shallowest soils, contain very little available water (less than 10 mm). Soil moisture primarily depends on precipitation because it can change situation from point of wilting to field water capacity in this soil type. Success of afforestation of these soils is closely connected to the distribution of precipitation because that is the only way to alleviate the discrepancy between increment and decrement of water.

In rankers and brown soils, the retention of available water is greater than in lithosols, but does not exceed 50 mm. A longer period without rain does not always cause wilting moisture. Soil drainage is a common occurrence in the unfavorable hydrological years and the duration of such occurrences depends on soil depth, characteristics of habitat, and primarily on aspect. Deep serpentine soils that in the area of the Ibar gorge occur on small areas are characterized by considerable reserve of available water. Gravitational water occurs in the profile during, and immediately after, precipitation. When moving through the profile, the gravitational water changes into available water and losses are far lower than in the previous soil types. This soil type drains only during dry periods, but that process happens slower than in shallow soil types.

### 2.4 Causes of forest and habitat degradation of the Ibar Gorge

In medieval Serbia mining was highly developed. As the melting of the ore required a large amount of wood, it is assumed that one of the main causes of forest and habitat degradation was the exploitation of wood for the ore processing. In addition to the mining, the animal husbandry as a main economic branch of that era had further influenced the deforestation. Another important factor that contributed to deforestation was the production of charcoal. In the second half of the nineteenth century, the population migration and settlement of areas around the Ibar gorge caused additional negative anthropogenic impact on the already unstable forest ecosystems in the area. Due to centuries of continuous forest degradation and the appearance of barren soils, the processes of erosion have been intensified.

## 3 Afforestation of the Ibar Gorge

One of the characteristics of the Ibar gorge is a big negative anthropogenic influence that led to the degradation and deforestation of large areas. According to Ulrich (1976), the ecosystems on ultrabasic rocks, in terms of stability, can be classified as weak, which upon making significant changes cannot return to its original stable state. Due to this reason, the process of afforestation and restoring vegetation on deforested areas is a very complex process that requires the study of different environmental characteristics and a certain level of interdependence to acquire knowledge for more successful afforestation.

Tree dieback reaches catastrophic proportions when the technology of afforestation is not particularly adapted to adverse environmental conditions. The success of afforestation depends on a series of procedures applied in the production of seedlings, as well as on applied measures of care and protection after planting.

Bare lands of Ibar gorge have represented a challenge for afforestation since the establishment of the first forest services in Serbia. However, the first attempts of afforestation date from the late nineteenth century.

Figure 4. Panoramic photography of planted forests in the valley of the Ibar River (Photo by Šmit et al. 1997).

In early 1973, the Institute of Forestry in Belgrade had mastered the technique of production of plant material with protected root systems and, among the first in this part of Europe, begun afforestation during the vegetation period (June-September). These activities led to the afforestation of large areas of the most unfavorable eroded bare lands through mass actions. Approximately 20,000 hectares of bare lands were afforested annually (Ratknić et al. 2007).

## 3.1 The selection of areas for reforestation, tree species and work method

The plan for the selection of areas for afforestation was to focus on larger areas of bare lands. A review of areas for afforestation is given in Table 6. It shows that for afforestation, a total of 6,457 hectares of different categories of soil were selected.

Table 6. Areas of bare lands planned for afforestation (Šmit et al. 1997).

| Forest Management Unit | Categories of areas in hectares | | | |
|---|---|---|---|---|
| | Total | I | II | III |
| Gokčanica | 3,111.80 | 72.30 | 605.50 | 2,433.10 |
| V.Vlah Treska | 2,906.30 | 106.40 | 999.70 | 1,800.20 |
| Željin | 158.80 | 9.80 | 60.30 | 88.70 |
| Studenica Polumir | 280.20 | - | 21.30 | 258.90 |
| Total | 6,457.10 | 188.50 | 1,686.80 | 4,580.90 |
| Percent of share in total area | 100.0 | 2.9 | 26.1 | 71.0 |

Categorization of areas planned for afforestation was carried out based on soil conditions and the possibility of applying certain work technologies. The basis for the categorization of areas in terms of the work conditions were the depth of the soil, the content of the skeleton throughout the profile, surface stoniness, slope, and how much the area is overgrown with grass (Dražić 1988).

Based on these criteria, areas for afforestation were divided into three categories:

*The areas of the first category* are bare lands with deeper soils with a small percentage (10%) of skeletons throughout the profile, minor surface stoniness (to 10%), and a slope of up to 30%. In these areas land preparation is mostly made possible by mechanized ripping.

*The areas of the second category* are bare lands with soil up to 30 cm deep, with 10-30% of skeleton throughout the profile, and surface stoniness from 0 to 30%. These are disturbed soils, usually located on hills with slopes over 30%. On a part of the areas of this category, the soil preparation for planting can be done by digging holes using machines, but mostly by manual preparation of cells or, on mild slopes, by ripping.

*The areas of the third category* are highly eroded bare lands with more than 50% of skeleton throughout the profile and surface stoniness of more than 40%. Soil layer is not continuous, but the soil is kept in “bunches” between stones. Due to the predominantly steep slopes, movement is difficult, and due to large stoniness the preparation for planting is difficult as well. Therefore, in these areas land preparation for planting has to be done manually.

The results of categorization of bare land areas that was supposed to be afforested, presented in Table 6, show that 71% of the areas are in the third category, and that less than 3% of the areas had conditions for using mechanized operations in the preparation of soil for afforestation (Tab. 6).

In the selection of species for afforestation, most attention was paid to the ecological conditions of habitats. Proper selection of species ensures success in the afforestation and sustainability of forest ecosystems, especially in degraded habitats. The results of the analysis of climate, soil, and potential vegetation show that the conditions for the forest establishment are very unfavorable. Due to long periods without forest, the microclimate and soil conditions have been changed.

Table 7. Review of planned areas related to forest species (Šmit et al. 1997).

| Forest Management Unit | Projected area (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | Austrian pine | Scots pine | Common spruce | European larch | Cedar | Douglas-fir | Mahaleb cherry |
| Gokčanica | 3,110.80 | 1,390.90 | 1,319.20 | 314.10 | 12.40 | 15.30 | 17.40 | 42.50 |
| V.VlahTreska | 2,906.30 | 1,218.20 | 905.00 | 668.70 | - | 27.00 | 42.30 | 45.10 |
| Željin | 158.90 | 55.60 | 38.60 | 49.30 | 15.40 | - | - | - |
| Studenica Polumir | 280.30 | 228.60 | 35.80 | 15.90 | - | - | - | - |
| Total | 6,456.30 | 2,893.30 | 2,298.60 | 1,048.00 | 27.80 | 42.30 | 59.70 | 87.60 |

Climate conditions are quite extreme, with severe lack of moisture. High mean and extreme air temperature values, as well as their frequency in the vegetation period, are limiting factor for the development of many tree species.

The occurrence and effects of erosion are quite expressed and the soil is severely degraded. All this led to the removal of the humus layer thus, the largest part of the area are shallow soils (lithosols and rankers on serpentine or eroded brown rankers and brown soils). Easy mechanical composition, shallow depth with the high content of skeleton throughout the profile, and large surface stoniness (50% or more), as well as adverse water-physical characteristics, point to unfavorable soil conditions for plant development.

Having in mind that the environmental conditions in which afforestation was planned are very unfavorable, the selection of species has too been restricted. Austrian and Scots pines are the species that can grow on habitats with unfavorable environmental conditions, so for that reason, they have been usually used for afforestation of large areas.

## 3.2 Seedling production

Mass production of forest seedlings for intensive actions of bare land afforestation and amelioration of coppice forests was especially expressed in the 1970s. In that period, the Institute of Forestry in Belgrade had started the production of container seedlings, in addition to the production of seedlings in Dunemann beds. The selection of species for afforestation and work technology was based primarily on field research of areas for afforestation, together with studying all past experience of scientific research activities – seedling nurseries of The Institute of Forestry, beside a productive character, also had scientific and research characters (Šmit et al. 1997).

In Serbia, the experimental production of plants in containers began in 1965 with applying the Jiffy *pot* system. Since 1973, the Institute of Forestry has begun with the experimental production of seedlings in container types *Paperpot* and Kopparfors. Then, the Institute had started using seedlings for afforestation via Hasselfors AB, Multicomp, Spencer-Lemaire etc. (Šmit et al., 1997) systems. For the afforestation of Ibar gorge bare lands, beside the abovementioned containers, container types Plantagrah I and II (which are made of hard plastic) were also used. Before planting seedlings in the field, seedlings were watered abundantly in order to avoid a sudden loss of moisture in the peat around the root system.

Annual seedling production of species *Pinus nigra* Arnold, *Pinus sylvestris* L. and *Picea abies* Karst. in seedling nurseries of The Institute of Forestry that have been used for mass afforestation (during abovementioned period of intensive afforestation actions) was about eight million pieces. Seeds meant for production of seedlings for the Ibar gorge afforestation were collected in seed facilities on Zlatibor Mountain and in the Ibar gorge (seed of Austrian and Scots pine), and on Golija Mountain (seed of common spruce) (Šmit et al., 1997).

Austrian pine (*Pinus nigra* Arnold) is a species that is characterized by a very modest need for water, nutrients, and especially soil depth. Analysis of environmental factors indicated Austrian pine as the dominant species to be used in the afforestation of such terrains. It tolerates high insolation; therefore it can grow on southern aspects as well.

Scots pine (*Pynus silvestris* L.) has slightly greater demands compared to Austrian pine, but it is also a modest species regarding the issue of environmental conditions. It is a very adaptable species in terms of soil pH and it can grow at higher elevations. Thus it is planned to plant the Scots pine in more favorable habitats at elevations above 800 m.

Mahaleb cherry (*Prunus mahaleb* L.) is used for the creation of mixed populations with pine monopopulations, for fixing soil conditions, and in the blooming period it contributes to landscape appearance.

Common spruce (*Picea abies* Karst.) is a species that has high demands in terms of habitat. It needs high relative humidity of air and soil, and it is sensitive to high air temperatures during the vegetation period. Therefore, its planting is planned at northern aspects and at higher elevations (above 1,300 m) where best preserved soils can be found, which with their structure, depth, and humus content maintain the necessary moisture.

European larch (*Larix decidua* Miller), Douglas-fir (*Pseudotsuga taxifolia* Britton) and cedar (*Cedrus atlantica* Man.) are species planned and recommended for planting on smaller areas for experimental purposes only. After some period of monitoring the growth and development of these species, the decision for their use in afforestation of degraded habitats can be made.

For afforestation of Ibar gorge, planting was planned during the vegetation period. In order to achieve such work, it was necessary to carry out mass production of seedlings with protected root systems. For this purpose, The Institute of Forestry mastered the technology of production and established the capacities for the appropriate scope of production. Given that this area was large and time for work short, youth work actions were organized for the afforestation of the Ibar gorge.

## 3.3 Selection of methods and technology of afforestation

The planting process of seedlings was specific because of field conditions. Classical planting was not possible because of the rapid drying of the removed soil due to direct insolation. A method for forming cells for planting was based on digging soil to a depth of 30 cm and a diameter of 40x40 cm or 40x60 cm on very steep slopes, without ejection of soil outside the cell in order to preserve existing moisture. In the areas with a higher content of skeleton, skeleton was ejected and packed on the bottom edge of the cell. If there was not enough fine soil, more was collected from the vicinity of the cell in order to cover seedlings and provide more favorable conditions for survival of seedlings. In prepared cells, seedlings were planted along the top edge or in the deepest part of the cell. Peat pot with the root was placed a few centimeters below ground level, covered with soil and stepped on. Just before planting, the peat pot has to be wet to the point of saturation.

In addition to the fact that they can be planted during the vegetation period, seedlings with protected roots are preferred for planting because in this way they bring organic matter that later provide nutrients and keep moisture in plants, which is often crucial for survival of seedlings in afforestation. Using the mentioned methods and techniques of work, in 1980 the afforestation of Ibar gorge had begun. Different container systems were used for the production of seedlings (Kopparfors, Jukosad, Gora, and Plantagrah). Reviews of afforested areas in the Ibar gorge from 1979-1989 are shown in Table 8.

Table 8. Review of afforested areas from 1979-1989 (Šmit et al. 1997).

| Year | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Afforested area (ha) | 147 | 516 | 1,143 | 982 | 638 | 367 | 651 | 400 | 124 | 277 | 341 | 5,586 |

### 3.4 Afforestation techniques and techniques for preparation of habitats for planting

When afforestation of the Ibar gorge had begun, different techniques of planting were applied depending on site conditions. Attention was paid to the reduction of the intensity of surface warming, evaporation, and transpiration in the vicinity of the seedlings, and thus to mitigation of the negative impact of unfavorable water regime of soil on the survival of seedlings (Bratić et al. 1990).

According to Bratić et al. (1990) the method of planting was designated as “deep planting” and “classic planting”. Preparation of habitat for afforestation was carried out manually and with machinery - using a bulldozer. “Gradoni” terraces, contour trenches and terraces for afforestation were built.

## 4 Analysis of afforestation success

Koprivica et al. (1996) showed the results of the completed afforestation in the Ibar gorge. These results present the overall success of afforestation with container seedlings during the vegetation period. Table 9 shows the review of percentage of seedling survival.

Table 9. Review of percentage of seedling survival (Koprivica et al. 1996).

| Tree species | Area (ha) | Percentage of seedling survival | | | | | |
|---|---|---|---|---|---|---|---|
| | | Below 50% | | Above 50% | | Above 70% | |
| | | ha | % | ha | % | ha | % |
| **Austrian pine** | 3,616 | 696 | 19.2 | 2920 | 80.8 | 1880 | 52.0 |
| **Scots pine** | 1,481 | 342 | 23.1 | 1139 | 76.9 | 742 | 50.1 |
| **Common spruce** | 177 | 115 | 65.0 | 62 | 35.0 | 58 | 32.8 |
| **Total** | 5274 | 1,153 | 21.9 | 4,121 | 78.1 | 2,680 | 50.8 |

Seedling survival below 50% is highest represented in Common spruce (65%) and lowest in Austrian pine (19.2%). If the survival below 50% can be considered unsatisfactory, it can be concluded that supplementary planting of seedlings should be made on the area of 1,153 hectares or 21.9% of the total afforested area. Seedling survival above 50% is highest in Austrian pine (80.8%) and lowest in Common spruce (35%). Afforestation success above 70% was determined on the area of 2,680 ha, or 50.8% of the total area, thus it can be considered very good having in mind the environmental conditions. Research results of Bratić et al. (1990) can be used as recommendations for supplementary planting of seedlings. When planning works on supplementary planting of seedlings, those technological solutions should be applied for soil preparation and planting of seedlings that in the given circumstances provide better seedling survival and development. It is desirable to introduce deciduous tree species that correspond to the environmental conditions in order to increase the stability of the plantations (Koprivica et al. 1996).

Table 10 shows a review of afforested areas in terms of selected species related to orographic factors. 80.7% of areas afforested with Austrian pine are located at elevation levels of 400-900 m, 94.5% of areas afforested with Scots pine are located at elevation levels of 800-1200 m, and 50.8% of areas afforested with Common spruce are located at elevation above 1,300 m. 90.8% of areas afforested with Austrian pine are terrains with a slope of 15-25 %, 86.9% of areas afforested with Scots pine are terrains with a slope of 15-35 %, 46.8% of areas afforested with Common spruce are terrains with a slope of 15-25 %. 78.8% of areas afforested with Austrian pine are exposed to south, southwest and northwest locations. 82.3% of areas afforested with Scots pine are exposed to south, southeast and southwest locations. 97.7% of areas afforested with Common spruce are exposed to northwest and northeast locations (Koprivica et al. 1996). Based on this data, it can be concluded that during afforestation projects were based on bio-ecological characteristics of tree species and habitat conditions.

Table 10. Review of afforested areas related to orographic factors (Koprivica et al. 1996).

| Orographic Factor | Austrian pine (%) | Scots pine (%) | Common spruce (%) |
|---|---|---|---|
| **Elevation (m)** | | | |
| **400-700** | 58.1 | 5.5 | - |
| **800-900** | 22.6 | 44.4 | 28.3 |
| **1000** | 9.0 | 15.2 | 18.6 |
| **1,100-1,200** | 10.3 | 34.9 | 2.3 |
| **1,300** | - | - | 50.8 |
| **Slope (%)** | | | |
| **7,5** | 3.8 | 3.2 | 46.3 |
| **12,5** | 4.5 | 9.2 | 4.6 |
| **17,5** | 31.7 | 60.7 | 28.2 |
| **22,5** | 51.9 | 16.5 | 18.6 |
| **32,5** | 0.9 | 10.4 | 2.3 |
| **Aspect** | | | |
| **N** | 5.3 | 1.7 | - |
| **NW** | 25.0 | 4.4 | 69.5 |
| **NE** | 9.9 | - | 28.2 |
| **E** | 4.2 | 1.9 | - |
| **S** | 35.8 | 24.0 | - |
| **SW** | 18.0 | 41.0 | - |
| **SE** | 0.9 | 17.3 | - |
| **W** | 0.9 | 9.7 | 2.3 |

## 5 Discussion and conclusions

The selection of Ibar gorge as an example where the afforestation of bare lands had been conducted is justified due to large areas of bare lands and unfavorable habitat conditions with much expressed erosion. This paper presents a review of papers of The Institute of Forestry in Belgrade that deal with multidecadal work in the Ibar gorge ranging from planning, afforestation, and analyses of success of these works.

Unfavorable conditions for the afforestation of this area were primarily created by erosion. The serpentine-peridotite substrate tends to decay on the surface layer therefore created debris is easily movable. The terrain features of this area are quite expressed, with large elevation differences in a small space, so in these conditions the erosion is intense. Rain runs down steep slopes, lack of vegetation enhances the speed and force of the water, which swills out the already impoverished soil. The geological substrate is peridotite at different stages of serpentinization. The soil is characterized by the skeletal structure, the shallow soil profile, and the lack of water and nutrients.

Vegetation has been being destroyed for years, without the possibility of natural regeneration.

By detailed analysis of habitat conditions, 6,457 ha were selected for afforestation. The largest part of that area, about 71%, was in the third category in terms of adequacy for afforestation. Having in mind the habitat conditions, as a dominant species for afforestation Austrian pine (*Pinus nigra* Arnold) was selected because it is one of the least needy species in terms of habitat demands. For the afforestation of areas where the elevation is above 800 m, plantation of Scots pine (*Pinus silvestris* L.) was planned and at elevations above 1,300 m on northern aspects and preserved soils it was agreed to plant common spruce (*Picea abies* Karst.).

During the vegetation periods between 1979 and 1989, 5,586 ha of bare lands were afforested with container seedlings by organizing youth work actions. The analysis of spatial distribution and orography of the terrain that was carried out after afforestation showed that during the operation the detailed design that was made based on bio-ecological characteristics of species and habitat conditions was fully respected.

Analyses of the success of afforestation were carried out in 1996. It was found that the percentage of seedling survival below 50% is 21.9% of the total afforested area. At 78.1% of the total area the percentage of seedling survival is above 50% and at 50.8% of the total afforested area the percentage of seedling survival is above 70%. Having in mind the very unfavorable habitat conditions, the results of the Ibar gorge afforestation are considered to be very good. Experience and work technology gained here can be used for operations on similar terrains.

The following authors have also confirmed the research of environmental conditions and ameliorative effects that afforestation has in areas with intensive erosion processes in their researches in the Grdelica gorge; Soljanik (1955), Filipović and Nikodijević (1957(1972)), Krstic (1961), and recently Kostadinov et al. (2000), Zlatic et al. (2001), Lukić (2013), Braunović (2013), Lukić et al. (2015) etc.

These are the reasons why forests, as a renewable natural resource, should be constantly improved. Only a biologically stable and healthy forest is a multifunctional complex system that can "perform" its function.

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