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The afforestation strategy of Republic of Serbia in torrential flood risk management

Стратегија пошумљавања Републике Србије у управљању ризиком од бујичних поплава

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Abstract

By setting the objective of increasing the afforestation level of the Republic of Serbia to 41.4% by 2050, the Serbian forestry has undertaken a number of tasks, among which afforestation, regeneration and improvement of the quality of existing forests are given the highest priority. The key criteria applied in the prior afforestation of barren land, as well as in amelioration of degraded and coppice forests were the scope of afforestation, i.e. the size of afforested areas and the highest possible wood mass yield obtainable in a short period.

The effects of different weather conditions, heterogeneous geological formations, topography, aspect and quality of forest ecosystems, as well as the negative impact of anthropogenic factors brought about intensive erosion processes in the previous period and occurrence of frequent torrential floods. They endangered human lives and caused losses to settlements, roads, agriculture, water management facilities, i.e. society in general. The results of the research performed in the area of Grdelička Klisura and Vranjska Kotlina confirmed significant effects of the performed erosion control works on the mitigation of the intensity of erosion and sediment yield and transport, and the necessity of a multidisciplinary approach to the questions of drainage basin erosion processes. The success of afforestation depends on the selection of suitable technical solutions (bench terraces and terraces), selection of suitable species, use of seedlings produced in the afforested area and the application of appropriate silvicultural measures in the established plantations.

The implementation of a new afforestation strategy, based on ecosystem preservation and sustainable development, will contribute to a more successful establishment of cultures and plantations and enhancement of other, generally beneficial forest functions.

Keywords: Serbia, risk management, afforestation strategy, torrential floods, erosion

Introduction

Afforestation, amelioration of forest habitats and reconstruction of degraded coppice forests, which were in the past decades carried out mainly through regular and often routine activities, were more or less successful. The main criteria were

the scope of afforestation (the size of forested areas) and the highest possible wood mass yield obtainable in a short period. The selection of species was reduced to a few native or introduced species: Austrian pine on the southern aspects, sometimes Scots pine at higher altitudes, spruce on the northern aspects, Douglas-fir and eastern white pine at beech forest sites, locust at lower altitudes, while Euro-American poplar plantations were established in alluvial plains. This proved successful in the afforestation of barrens with Austrian and Scots pine, partially successful in ameliorations, while the conducted reconstructions had considerable negative effects on potentially productive ecosystems of beech coppice forests, because they were carried out through mere substitution with pioneer species and spruce. Biodiversity centers of global importance were replanted with Scots and Austrian pines (Strešer, Besna kobila, etc). The habitats of rare endemic and relict plant species were destroyed in reforestation attempts to „shift up” the upper limit of vegetation.

Recent years have seen the development of scientific theories that elaborate systems of afforestation and amelioration taking into account habitat conditions. Unfortunately, none of them have come to life in practice, which is still aimed at increasing the volume of work and improving the technology. Moreover, most theories are based on the selection of species, or even intraspecific taxa and provenances, according to individual habitat factors (altitude, aspect, parent rock, heat factor, etc.). None of them takes into account the entire complex - ecosystem or ecological unit, which is defined not only by its edifying species, but also by natural vegetation and soil.

Grdelička klisura was an example of successful protection of soil against erosion. The first erosion and torrent control works in Serbia began in the late 19th century, in the area of Grdelička klisura. The area had been almost fully restored by the end of the seventies of the 20th century. By the early nineties, biological and biotechnical works had been conducted to rehabilitate over 1,200,000 ha of barrens, gullies and degraded land. Technical works performed in the torrential beds included several thousand of different objects (sediment storage dams, retaining walls, torrential riverbed regulations, inlet structures, etc.).

Strategy Concept and Objectives

The objectives of The Afforestation Strategy of Serbia are the following: provision of professional and scientific basis for the establishment of 1,000,000 hectares of new forest plantations; environmental quality improvement; protection and rational utilisation of forests and other natural resources; erosion control and water security; reduction in the emissions of harmful

gases; protection of the species and ecosystem components of biodiversity; biodiversity protection and preservation, etc.

The Afforestation strategy is harmonized with the relevant international agreements and conventions, applicable laws, regulations and policies that are implemented in the EU (Acquis communautaire) in the field of environmental protection. It also complies with the laws and regulations of the Republic of Serbia.

Specific objectives of the Afforestation Strategy are the following:

- Development of the operational planning systems – production of seedlings from source-identified seed (of recognised provenances) adapted the conditions of the selected habitat, with the choice of the best method of planting stock production and afforestation technology;
- Encouraging establishment of new forest plantations and enhancing the state of existing forests by applying the latest silvicultural measures aimed at conversion and reconstruction of coppice forests and anthropogenic scrubs into high forests;
- Minimising the conflicts between forestry and other land users;

Forest management planning should be aimed at preservation, protection and improvement of biodiversity at the level of ecosystems, species, genes, as well as at the habitat level. The maps and inventories of forest resources must include ecologically important habitats (protected, rare or sensitive forest ecosystems).

Natural regeneration must be a priority. In afforestation, the priority is given to autochthonous species of the most appropriate provenances. Tending and felling should be conducted in accordance with environmentally-friendly management principles, which do not disturb ecosystem functioning. Infrastructure construction must not cause damage to ecosystems (rare and sensitive, in particular) and genetic resources or threaten the habitats and migration routes of endangered and other important species.

In order to overcome the deficiencies of the current global climate forecasts, regional climate models and impact models are used. The results of these models are integrated into activities enabling timely adaptation to climate

change and its mitigation (if possible) (National Afforestation Strategy of the Republic of Serbia (2014-2018)).

Environmental Characteristics of Potential Afforestation Habitats

The Strategy is based on a detailed study of habitat environmental characteristics (parent rock, soil, climate, habitat type, erosion condition, etc.), whose understanding is the key to successful afforestation. Special attention is paid to the following: sensitivity of forest ecosystems to climate change; impact of climate change on biodiversity; sensitivity of species to climate change; importance of global climate change and possible creation of new species and subspecies adapted to the modified climate conditions; occurrence of weed and invasive species, insects, plant diseases, etc.

The expected effects of climate change on forest ecosystems, forest communities and tree, shrub and ground vegetation species are the following:

- some forests will change their latitude boundaries and shift up altitude limits;
- some forests will probably ‘lose the battle’ or ‘give up the race’ and eventually disappear;
- some forests will change their composition (some species will disappear and others will emerge) with the changes in their multi-storey structure and social position;
- some species will change their shade-tolerance;
- forest communities will be more exposed to various adverse effects that are directly or indirectly caused by climate change;

The above-mentioned effects, considered cumulatively, will directly affect preservation of biological diversity as well as the feasibility and intensity of sustainable forest management.

The total number of forest habitats in Serbia is 210. According to the climate model (Ratknic, M. 2010), a 1°C temperature increase would reduce the number of habitats to 198, while a 2°C temperature increase would bring the number of habitats down to 192. A 3° C temperature increase would reduce the number of habitats to 159, while a 4° C temperature increase would bring

the number of habitats down to 131. A 5°C temperature increase would reduce the number of habitats to 116, or by 44.8%.

Biodiversity

The Strategy stipulates that afforestation, in any of its segments, must not endanger ecosystem, species and genetic diversity. Potential afforestation areas must not endanger species and their survival or cause destruction or fragmentation of their natural habitats. Measures and activities aimed at biodiversity protection at species and ecosystem level (national and global interest) include the following:

- biodiversity monitoring and valorisation of the state in diversity centres,
- detection of endemic, relict, rare and endangered species and species of international importance, aiming at their more effective protection;
- study of natural populations, particularly from the aspect of conservation biology;
- proposal for appropriate measures of protection aiming at preservation of biodiversity in diversity hotspots, where natural diversity is endangered (in situ and ex situ conservation).

Selection of Species for Afforestation

Only autochthonous tree and shrub species should be used in afforestation and establishment of non-forest greenery. Allochthonous broadleaved and coniferous species may be used solely for the establishment of intensive plantations. It is necessary to prevent the spread i.e. to take measures for the suppression of invasive tree and shrub species which disturb natural forest and other ecosystems (*Acer negundo*, *Ailanthus glandulosa*, *Amorpha fruticosa*, *Celtis occidentalis* etc.). Furthermore, allergenic tree species should not be planted in the vicinity of residential areas. The use of cultivars and clones should be prevented in natural and partially-modified natural habitats.

In the selection of afforestation tree species, a broad range of species has been made for each habitat. Principal, accessory and shrubby tree species have been defined – edifying species of potential communities on a given area. Forest fruit tree planting also contributes to the revitalisation of forest ecosystems.

Serbia has 122 fruit species, classified into 23 families and 38 genera in its natural, primarily forest ecosystems. The territory of Serbia is assumed to be a PRIMARY GENE CENTRE of most fruit tree species grown today, which is indicated by their large presence in natural, mostly forest ecosystems.

The Strategy takes a habitat as the basic unit of afforestation together with all the changes that will occur in future as a result of the changes in climate factors. Its aim is to eliminate the causes of destruction and extinction of certain species and their habitats:

- destruction of entire natural habitats which are then replaced by secondary or artificial habitats, unfavourable for the survival of native species of primary ecosystems;
- fragmentation of natural ecosystems;
- partial disturbances that change the structure and functions of an ecosystem;
- excessive exploitation of species;
- direct or indirect pollution of water, air, and soil;
- introduction of allochthonous plant and animal species, which changes the composition of autochthonous fauna, flora and ecosystems;

Seed Sources and Production of Seedlings for Afforestation

According to data from the Register of Seed Sources (Ministry of Agriculture and Environmental Protection, The Republic of Serbia), there are 310 seed sources in Serbia, occupying the area of 2,954 ha, which accounts for 0.095% of the total forest area. There are 95 registered conifer seed stands. The largest number of seed stands belongs to Norway spruce (*Picea abies*) - 24, followed by fir (*Abies alba*) - 23, Austrian pine (*Pinus nigra*) - 12, Scots pine (*Pinus silvestris*) – 11 and Serbian spruce (*Picea omorika*) - 6. Among broadleaves, the most numerous are the seed stands of species appreciated for high wood mass yield (pedunculate oak, sessile oak, beech, etc.); there is also a significant number of allochthonous species whose seedlings are used for afforestation (Douglas-fir, eastern white pine, cedar, etc.) or for the production of ornamental planting stock (cypress, thuja, sequoia, etc).

The structure of the species represented in the seed stands doesn't correspond to habitat changes caused by climate change; therefore, it is necessary to:

- Determine the adaptability of species and genotypes in given climate conditions, the limits of their mobility, and the development of climate-based seed characteristics in the zones that will change over time (Parker et al. 2000, Ratknić 1999). Provenances should be tested on the boundaries of their ecological range of distribution, with a proper understanding of relevant physiological processes (Tyree 2003).
- Grow specific genotypes with higher resistance to pests and a greater tolerance to climate extremes (Wang et al. 1995).
- Grow forest fruit trees. Certain forest fruit species will disappear from forest ecosystems due to changes in climate conditions. As they represent the basis for normal ecosystem functioning, genotypes that are resistant to changes should be found (Ratknić 2005).

The Register of Forest Fruit Seed Sources accounts for only a small part of the entire resource of autochthonous Serbian dendroflora. The Strategy envisages amending the Register by adding populations of autochthonous tree and shrub species with low value in use, as they also contribute to the stability and biodiversity of forest communities and ecosystems. Therefore, these species should be used intensively in the reconstruction of potential vegetation. The Strategy does not rely only on the resources of state-owned forests, as in some parts of Serbia resources of privately-owned forests are more diverse and abundant in terms of flora.

Nursery production in Serbia is characterised by fragmentation of production areas, weak links between producers of planting stock and potential users, frequent lack of morphological and physiological characteristics of seedlings necessary for specific habitats and a small share of broadleaved species. Production of tree and shrub planting stock based on the use of seed of recognised provenances and cultivars considerably improves afforestation success, adaptability and productivity of forest plantations.

Afforestation Technology Improvement

If we want to halt degradation and reduce degraded land surface area, we must apply afforestation technology that guarantees success with low investment

(Ratknic 2004). However, such terrains have highly variable orographic and pedological characteristics that differ even at short distances. Therefore, seedling properties, planting techniques, planting schemes and the number of plants per unit of surface area must be planned for each individual locality.

The most important criteria in the selection of seedling production technology are the following: seed genetic quality, nursery conditions and the type of habitats for afforestation. The study of environmental characteristics of barrens that are planned for afforestation represents the basis for the selection of the most suitable seed source, adequate seedling production technology, terrain preparation for planting, planting scheme preparation, planting, and selection of tending and protection measures that suit the established plantations.

In afforestation, particularly of eroded terrains, radical changes of potential ecosystems and their main edifying species should not be made. Natural progressive succession should be encouraged as much as possible. It can be achieved by introducing suitable, primarily broadleaved species.

Action Plan

Potential Afforestation Areas

The Strategy uses the suitability classification based on the following structure of the FAO land suitability classification (FAO 1976):

- Suitability orders reflect kinds of suitability;
- Suitability classes reflect degrees of suitability within orders;
- Suitability subclasses reflect kinds of limitation;
- Suitability units reflect minor differences within subclasses.

For decision-making on optimum land use, the following data are necessary:

- Agriculture: soil quality classes I-V, surface area use (cultures);
- Landscapes: national beauty landscapes, landscapes of regional significance;
- Nature protection: nature reserves, natural monuments, memorial natural monuments, surrounding area of immovable cultural monuments, forest parks, natural history collections;

- Recreational activity/tourism: tourist routes, viewpoints;
- Drainage basins: river basins, spring areas, major rivers and courses, reservoirs and reservoir areas, canals;
- Infrastructure: urban areas, roads;
- Forestry: existing forests (by form, type, mixture and function);
- Socio-economic information: population trends;
- Administrative areas: municipalities, cadastral municipalities, forest management areas, management units.

Principles of Afforestation Area Selection

The Action Plan designates municipalities in which the process of afforestation must be initiated. They are: Novi Pazar, Sjenica, Tutin, Raška, Vranje, Bujanovac, Preševo, Trgovište, Bosilegrad, Surdulica, Vladičin Han and Belgrade.

Table 1. Potential afforestation areas and their dynamics

Municipality	Year										Total (ha)
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	
Novi Pazar	100	100	200	200	200	200	200	200	200	200	1800
Sjenica	500	700	700	800	800	1000	1000	1000	1000	1000	8500
Tutin	100	100	200	200	200	200	200	200	200	200	1800
Raška	100	100	200	200	200	200	200	200	200	200	1800
Surdulica	300	300	300	350	350	400	400	400	400	400	3600
Vladičin Han	20	30	30	30	50	50	50	50	50	50	410
Vranje	50	50	50	50	50	50	50	50	50	50	500
Bujanovac	50	50	100	100	150	150	150	150	150	150	1200
Preševo	50	50	50	50	50	50	50	50	50	50	500
Trgovište	100	100	100	100	100	150	150	150	150	150	1250
Bosilegrad	200	200	200	250	250	300	300	300	300	300	2600
Belgrade	200	300	400	400	500	500	500	500	500	500	4300
TOTAL	1770	2080	2530	2730	2900	3250	3250	3250	3250	3250	28620

Source: Ratknic, M. et al, 2015

A detailed terrain analysis was performed in order to select the most suitable areas for afforestation. Particular attention was paid to non-productive pastures, areas of low-fertility soil unsuitable for agriculture and erosion-affected areas (soil fertility classes V, VI and VII). Non-productive rocky grounds were not taken into consideration, as their revitalisation would require large investments with entirely uncertain outcomes (Ratknic and Šmit 1999). In order to preserve biodiversity of natural habitats, we didn't include all the areas of the above-mentioned soil categories. Some were left to natural succession of vegetation. The Strategy envisages afforestation of 28,620 ha over the 2015-2024 period (Table 1).

Erosion and Torrential Floods in Serbia

Erosion is a form of soil degradation which can be caused by water or wind. The consequences may include loss of topsoil, terrain deformation, formation of dunes, beams and the like. Erosion is a natural process. Although it occurred long before the mankind, human activities have accelerated erosion processes in many places. Thus, naturally occurring erosion is often determined through the concept of soil loss tolerance, which refers to soil erosion that allows a high degree of cost-effective and sustainable crop production (Wischmeier, Smith, 1979) On the other hand, the erosion caused by human activities is often termed anthropogenic erosion. Erosion can lead to a significant reduction in fertility, and even the loss of soil, especially in the countries with uncontrolled deforestation.

The areas affected by medium, slight and very slight erosion must be considered as areas of potential danger since their erosion processes can easily be intensified. Generally, the occurrence and the intensity of erosion in Serbia increase from the north to the south and from the west to the east, reaching its peak in eastern and southeastern Serbia

Over the 1950-2014 period, torrential floods took over 80 lives and caused losses of several billion Euros. The frequency of torrential flooding, its intensity and distribution pose a constant threat which can have consequences in ecological, economic and social spheres (Ristic, R., 2014).

In July 1999, torrential floods in the basins of the main tributaries of the Great Morava took 8 lives and damaged tens of thousands of residential

buildings and a few hundred commercial properties. The greatest damage was done in Smederevska Palanka, Velika Plana, Jagodina, Batočina, Kragujevac, Aranđelovac, Rekovac, Kruševac, Kraljevo and Mladenovac. The watercourses in the Lepenica basin caused soil erosion and polluted the water sources. (Milanovic, A., 2007). The floods also hit the rivers: Lugomir (one third of Jagodina was flooded) Resava (in Svilajnac), Ravanica (in Cuprija), Crnica (in Paracin) and Jovanovačka reka (in Cicevac).

In the period from April 10th to April 17th 2006, the Danube water levels through Serbia exceeded historical maximums. The river Sava also exceeded the 1981 maximum reaching 738 cm. Floods were registered in Apatin, Sombor, Bogojevo, Zrenjanin, Beočin, Senta, Titel, Sečanj, Žabalj, Novi Sad, Bačka Palanka, Indjija, Belgrade, Zemun, Grocka, Smederevo, Veliko Gradište, Golubac, Kladovo, Negotin, etc. The floods affected a total of 213 settlements and about 1,000 people were evacuated (mostly in the municipality of Grocka). In the area of Belgrade, the Danube flooded Zemun, Novi Beograd and Veliko selo and the river Sava flooded the areas of the quay in New Belgrade, Sajam, Nebojša tower at Kalemegdan, Čukarica and Ostružnica. Flooding was also registered in the Mlava and Jadar basins (downstream from Loznica in the village of Gornji Jadar). It further caused the occurrence of landslides. A total of 3069 landslides were registered in Serbia and they directly threatened 966 settlements. They mostly occurred in the basins of the Morava and Kolubara rivers, and partly in the river basins of the Sava tributaries in Mačva district. Landslides damaged 2,300 housing units, 639 roads and 17 bridges in central Serbia.

On May 15th 2010, Trgovište was hit by devastating torrential flooding of the river Pčinja. Two people were killed...

A series of floods and torrents of catastrophic proportions hit the country in 2014. In the period from May 14th to May 17th, the territory of the Republic of Serbia received great amounts of rainfall, which first caused torrential floods of all tributaries of the Drina and Kolubara Rivers, and then of the Great Morava, Mlava and Pek. The floods hit Krupanj, Loznica, Ljubovija, Mali Zvornik, Valjevo, Ub and Obrenovac. Obrenovac had the most devastating floods. In September 2014, floods in eastern Serbia destroyed Tekija, Podvrška, Velika Kamenica, Grabovica, Rečica, Bor and Majdanpek (Stefanovic et al., 2014).

„The devastating effects of torrential floods of May 2014 could have been substantially lower if preventive measure had been taken in the last twenty years. This refers to the concept of integrated management of torrential basins, which includes the design and construction of the following measures: technical (dams, thresholds, regulations, micro-reservoirs, retention basins, embankments), biotechnical (rehabilitation of gullies, slope protection), biological (afforestation, amelioration of degraded forests, meadows and pastures, orchard establishment on terraces) and administrative (management rules, land use and its protection in affected catchments). Furthermore, the existing systems of protection against torrents and erosion (riverbed cleaning of sediment, vegetation and debris, repairs of damaged structures) were not maintained, which significantly reduced their effectiveness” (Ristic, R., 2014).

An Example of Successful Torrential Flood Risk Management –

Case Study of Grdelička Klisura and Vranjska Kotlina

The mid 20th century was the period in which the area of Grdelička klisura and Vranjska kotlina had the lowest percentage of forest cover in its history. If we take into account that other forests were also highly degraded, this was clearly the period of the highest deforestation and degradation of forest ecosystems. After World War II, especially in the period of agrarian reform from 1950 to 1960, the ecological balance was disturbed again, resulting in new intensifying erosion processes. Since the sixties, there has been an increase in forest cover caused by a number of factors: the fight against erosion, reforestation, planned forest management, forest tending and protection, migration from mountainous areas, etc (Kostadinov, S. et al., 1996).


In 1956, 31% of the total surface area of Grdelička klisura and Vranjska kotlina was covered by forests (Table 2). In 2012, it had 48.65% of the total area covered by forests. From the phytosociological aspect, it is dominated by indigenous forests of Hungarian oak and Turkey oak. Besides the dominant oak species, ash, hornbeam, Turkish hazel, etc occur in mixtures. There are visible erosion processes in the forests, especially on southern aspects and on steeper slopes. Around settlements, they are often threatened by excessive logging.

Table 2. Structure of land use before performing ECW

Grdelička klisura and Vranjska kotlina	Area ha	Share %
Forests	53864.83	31.1
Arable land	51419.21	29.7
Pastures	38474.88	22.2
Meadows	12131.11	7.0
Fruit orchards	1777.82	1.0
Vineyards	2231.92	1.3
Rocky ground, gullies	13360.84	7.7
Total	173260.61	100.0

Source: General plan of afforestation, amelioration and cultivation of forest areas of Grdelička klisura and Vranjska kotlina (1957)

Table 3. Structure of land use in 2012

	Grdelička klisura		Vranjska kotlina	
	Surface area ha	Share %	Surface area ha	Share %
Productive areas				
Forests	23526.18	99.43	58456.61	96.41
Degraded forests	134.36	0.57	2177.52	3.59
Forests	23660.5	54.97	60634.13	46.56
Meadows and pastures	10772.61	100.00	23828.97	85.75
Degraded pastures	-		1358.08	4.89
Alpine meadows and pastures	-		2601.88	9.36
Meadows and pastures	10772.6	25.03	27788.93	21.34
Arable land	2727.59	6.34	28069.24	21.55
Vineyards	68.26	0.16	1121.67	0.86
Fruit orchards	127.75	0.30	2001.01	1.54
House yards and gardens	1296.97	3.01	5669.73	4.35
Total	4220.57	89.80	125284.71	96.20
Non-productive areas				
Settlements (construction zone)	698.37	1.62	3052.93	2.34
Gullies	-	0.00	52.99	0.04
Rocky ground	23.79	0.06	208.31	0.17
Gravel	81.96	0.19	45.68	0.04
Road networks and waterways	3586.16	8.33	1572.00	1.21
Total	4390.28	10.20	4931.91	3.80
Total	43044.00	100.00	130216.62	100.00

Source: Braunovic, 2013

Biological and biotechnical works conducted in Grdelička klisura in the period from 1947 to 1977 covered 2251.7 ha (1041.2 ha were forested, 1210.5 ha were covered by grass). In the same period, Vranjska kotlina had 4409.7 ha forested and 3258.3 ha covered by grass (Jelic, B., 1978). The works were carried out in the areas which were under excessive and severe erosion, especially on the slopes of the upper and middle parts of the torrential catchments.

The data on land use for 2012, obtained from the map of land use made by dividing the area into homogeneous plots (7100 plots were determined), showed that 54.97% of Grdelička klisura was forested (Braunovic, Ratknic, 2012). Vranjska kotlina had slightly lower percentage of forested area that amounted to 46.56% (Table 3). Therefore, the Strategy envisaged greater intensity of afforestation in the area of Surdulica, Vranje and Bujanovac (Table 1).

Table 4. Intensity of erosion in 1953 and 2012

Category of destructiveness	The intensity of erosion processes	Mean value of The coefficient of erosion Z_{sr}	Share in the total area			
			1953		2012	
			(km ²)	%	(km ²)	%
I	Excessive	1.25	492.63	28.44	2.34	0.14
II	Severe	0.85	544.93	31.45	13.08	0.75
III	Moderate	0.55	441.99	25.51	129.26	7.46
IV	Slight	0.30	32.47	1.87	783.25	45.21
V	Very slight	0.10	220.58	12.73	715.60	41.30
Ukupno			1732,60	100.00	1643.51	94.86
The value of the coefficient of erosion in the study area			$Z_{sr} = 0,78$		$Z_{sr} = 0.24$	

Source: The map of erosion in Grdelička klisura and Vranjska kotlina, 1953; Braunovic, S., 2013

The data on the erosion before the mass erosion control works were conducted in the area of Grdelička klisura and Vranjska kotlina are shown in Table 4.

Excessive erosion affected 28.44% of the total surface area. There were numerous gullies and landslides, and in some places layers of soil were stripped away exposing the parent rock. Processes of severe erosion (with gullies of up to 50 cm deep and a lot of fine and coarse skeletal material on the surface, landslides on deforested areas) affected 544.93 km² (31.45%).



Figure 1. Brnjarska river, 1953 year

Source: Foto album Grdelička klisura, 1956



Figure 2. Predejan river, 2013 year

Source: Fotograf by Braunovic Sonja

The map of erosion (Braunovic, 2013) provides data on spatial distribution and intensity of erosion processes (Table 4). Severe erosion affected 0.75% of the total surface area. It affected Grdelička klisura between the villages of Dankovci and Repište, near the villages of Garinje and Kalimance. It was also recorded in Vranjska kotlina around the villages of Klašnjice, Sobina, Balinovac, north of Vranje, Soderce, Bunuševca, Milivojce, Beli Breg, Dubnica, from the village of Gornji Vrtoškoš and Lopardince to Veliki Trnovac and between the villages Viševce, Motina, Curkovic and Nastavce. Excessive erosion processes affected smaller areas of Vranjska kotlina.

The mean coefficient of erosion was $Z_{\text{mean}} = 0.78$ (severe erosion) in 1953, and it was $Z_{\text{mean}} = 0.24$ (slight erosion) in 2012. Excessive erosion processes in 1953 affected 28.44% of the area, and only 0.14% in 2012. Erosion processes of moderate intensity affected 25.51% in 1953, and this percentage decreased to 7.46% in 2012. These results prove that the effects of the conducted erosion control works contributed to the reduction in the intensity of erosion and suggest that the works should be continued.

According to data of the Republic Bureau of Statistics from 2013, the most intense erosion in Serbia is right at the periphery of Vranjska kotlina, in the valley of the river Pčinja, in Grdelička klisura, in the Vlasina basin and in the valley of the river Lim, in the upper stream of Ibar and in the hilly area of Šumadija.

Despite these facts and findings, key documents that would make the basis for prevention have not been developed. These documents include: the National Strategy for soil erosion control and protection against torrential flooding; Maps of erosion in Serbia; Register of torrential flows in Serbia; Register of conducted works; Maps of flood zones, etc. Such documents were last made in the seventies, so they cannot be considered relevant today.

Conclusions

Apart from providing the principles necessary for the identification of the areas for afforestation and contributing to the preservation of habitats and biodiversity, the expert system developed within the framework of the Strategy enables timely preparation for afforestation and initiation of operational works - the production of seedlings of recognized provenances that suit habitats and their characteristics, along with the selection of the optimal method of seedling production and afforestation technologies. Application of GIS will provide new information obtained by combining databases at different levels. Spatial models will be used to predict direct and indirect consequences before making a final decision on the land use.

The adoption of the aforementioned principles of afforestation area designation, the use of appropriate techniques and technologies of biological and biotechnical works in catchments and the proper selection of species will contribute to the continuation of the 'battle' against erosion, torrential flows, landslides, mudslides and ecological disasters.

Application of a new strategy, based on the ecosystem preservation and sustainable development, will contribute not only to the greater success of the established cultures and plantations, but also to the improvement of other forest functions. The implementation of the Afforestation Strategy of Serbia is expected to significantly reduce the risk of torrential floods in the affected areas.

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