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THE USE OF FORESTS IN THE RIVER ZAGRŽA BASIN FOR THE CONSERVATION OF ITS HYDROLOGICAL AND WATER PROTECTIVE FUNCTION

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Abstract: The data on forests shown in this paper which are general useful functions determine the main way of managing, because these forests are marked as water protective and especially significant for the water supply of the Vrnjačka Banja area from 1985. These are forests of beech and beech mixed with fir of the highest quality located in the river Zagrža basin on mountain Goč and they represent more than 85 % of the basin and provide the hydrological and water protective functions at the highest level. For that reason, they have a special protective status. In the river Zagrža basin, there is the management unit "Selište" of particular importance and the accumulation Selište was built there with about 380 000 m³ volume and its primary task is water supply of the Vrnjačka Banja area during critical months without water. The aim of this scientific paper is to emphasize the need of increasing and protecting the water potential using adequate ways of forest vegetation management, which means overall basin organization. The final result should be related to the optimal use of natural sources in that area.

Key words: protective forests, beech, fir, hydrological forest function, water quality, the use of woody and non-woody sources

INTRODUCTION

Because of its deficiency, from the strategic point of view water has become one of the most important sources. The problem of low water quantity is very serious, especially because of global warming which causes increased water use. Besides the emphasized needs for water that are caused by climate factors, there is a pronounced problem of water contamination, not only of water on the ground, but also of underground water. Forests have the most important role to cycle water in natural conditions, because it is the most stable ecosystem due to its complexity and spatial distribution. The hydrological function of forest

ecosystem is one of the crucial ones together with the water protective and anti-erosion function and its importance has become greater in the 21-st century, because of the lack of needed quantity of high quality water. General useful forest functions have a big social importance in developed countries. The impact of vegetation on the water running regime and ground water quality is very significant for useful water yield from forest ecosystems that dominate in hilly and mountainous conditions in Serbia. Determining of the water potential of these areas is the subject of numerous researches, so, for example, in the river Zagrža

basin, there is a domination of eco-biological conditions of the forest type *Abieto-Fagetum* with its all sub-associations. Beech and beech-fir forests are plant communities with the greatest impact on the connection between rainfall and water running from the basin.



Figure 1. Beech and fir forests in the river Zagrže basin, management unit “Goč-Selište” (photo by Lazarević, 2012.)

The purpose of the research is to explain the way of forest management in the river Zagrža basin in order to conserve its, above all, hydrological and water protective function with the application of an adequate system of management and complete basin organization. The final result of it is optimal use of natural resources in the whole.

OBJECT AND METHOD OF RESEARCH

The area covered by this research includes the zone that belongs to the River Zagrža basin and its tributaries the Mala and Velika Rivers that are located south of Vrnjačka Banja on mountain Goč. The basin surface of this river is located inside the area of the management unit „Goč-Selište“ which is close to the River Rasina basin, whose tributary from the left side is the Zagrža River. It is formed on the slopes of mountain Goč from the Velika and Mala Rivers, whose basin areas are 2.42 km², and 1.18 km², respectively. This basin is close to the border with the Gvozdačka, Sokolje and Novoselska Rivers (Figure

2). The river Zagrže basin has a long form with the greatest height of 1387 meters and with the lowest one of about 950 meters, Figure 2. The

area of the river basin is 4,34km², and it is covered with beech-fir forest of very high quality in current climate conditions with an average value of rainfall of about 800-900 mm, and in such ground conditions, as well.

The forest complex on this part of mountain Goč is with a high level of opening, because of its density of primary roads network that is over 41 km/103ha, while the density of the secondary roads network is about 26 km/103ha, and this fact has its positive and negative effects to the hydrological and productive forest functions. The accumulation „Selište“ is formed at the mouth of the Velika and Mala rivers, with a relatively low volume of 380x103m³ that serves for the water supply of the Vrnjačka Banja area.

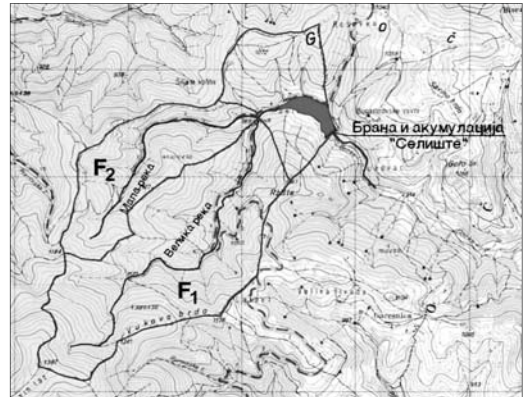


Figure 2. The river Zagrža basin with its tributaries the Velika and Mala Rivers (photo by Mihailovic M., 2007)

The methods that are used for defining water sources condition of the Zagrža river basin, and ecological parameters of the basin, the way of forest management and their influence between each other include:

- the method of analytical evaluation of the basic environmental conditions: orography, geological base, soil conditions, hydrological conditions, condition and distribution of the vegetation
- the method of descriptive analysis of the collected data about the way of forest management impact on water sources condition in the Gočka river basin



Figure 3. Accumulation “Seliste” on mountain Goc, (photo by Lazarević, 2012.)

RESULTS

On the basis of the available date of the analyses of the geological base, climate, vegetation, running of water, and the way of forest management in the Zagřža river basin, the following can be concluded:

Hydrological features of the river Zagřža basin

On the basis of the available date, this basin has big water quantities with a very high quality. Long-term measurements of RHMZ (1959.-1995.), and Hidroprojekt (1995) and Mihalović M., (2007),

as well, conclude that from the area of the basin of about 4.34 km² about 100 l/s runs.

The overall water quantity that runs during a year is about $W=3180 \times 10^3 \text{ m}^3$, and during dry season, the minimum volume of running water is $W=1103 \times 10^3 \text{ m}^3/\text{god}$, which means that water running from this basin is $Q_{\text{min}}=35,0 \text{ l/s}$. During the wet season, the maximum volume of running water is much bigger and it is $W=5992 \times 10^3 \text{ m}^3/\text{god}$, which means that the maximum water running is about $Q_{\text{max}}=190,0 \text{ l/s}$.

Minimum running values are recorded during August-September period, and maximum is recorded in the period March-May. The basin orography is characterized by deep and long slopes of rivers and streams. They are provided by water from numerous resources whose possibilities depend on the geological base and the structure of snow, as well.

The data shown about water running from the basin of Zagřža introduce the consequence of relation between ground, climate and vegetation. Important climate factors, besides temperature, include quantity, distribution and structure of rainfall. Monthly rainfall sums measured at the referent station Stanišinci (1983.-2011.) are between minimum values in January to maximum values during June and July (diagram 1). There is also an important share of snow which from hydrological point of view represents the most suitable form of precipitation. On the basis of the data, the annual rainfall is between 800 and 900 mm.

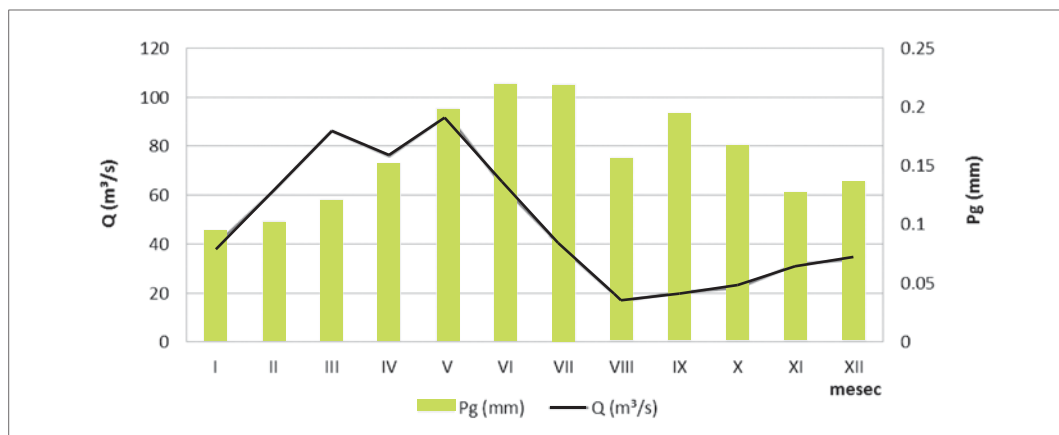


Diagram 1. Medium monthly water discharge (the Gocka river) and medium monthly rainfall

Vegetation cover in the river Zagrža basin

Forests of the basin area of the river Zagrža introduce very important space of green background of Vrnjacka Banja, which enables a very significant protection for Vrnjacka Banja that mostly depends on it. Forests in this area regulate water regime, decrease erosion and enrich complex down the water with oxygen, clean water. At the same time, these forests use carbon-dioxide and decrease general air toxicity. On the basis of the data and due to bad consequences as a result of unreasonable management of these forests during and after the Second World War, they are marked as everlasting protective forests.

On the basis of a detailed typological research in the management units "Željina" and "Goč-Gvozdac" (table 1), there are the following forest types in this region: *Abieti - fagetum pauperum*, *Fagetum moesiacaе montanum typicum*, *Abieti - fagetum drymetosum*, *Abieti - fagetum typicum* and *Fagetum moesiacaе subalpinum typicum*.

Mixed beech-fir forests form special climate-regional belt is over the belt of mountain beech forests. They are mainly located in high mountains in Serbia. As a powerful climate-regional belt, beech-fir forests are developed on mountain Goc in different orographic, soil and climate conditions. Beech and fir are the most important species, because they form the most suitable hydrological conditions (Hewlett J.D. et al., 1969).

There are mainly high beech-fir forests of uneven ages and high beech forests of uneven ages, as well. On the basis of a special planning document, for that management unit, there is 50.3 % of clean beech stand of the whole tree area. Mixed stands, mainly consisting of beech and fir participate with 49.7 %.

The whole tree area of the river basin is dominated by high stands (natural and artificial stands) that cover about 90.5 % of the whole area. Artificial stands cover 6.6 % and coppice forests about 2.9 %.

Forest management and its influence on useful water yield

Essential hydrological role of forests includes keeping of big water quantity on the forest ground

and its gradual running through deep soil layers. On the area surface there are formed resources. Depending on soil characteristics, about 5000 m³/ha could be kept (Velasevic et al., 2002). It should also be emphasized that forest ecosystem influences running, keeping and rainfall filtrating which depend a lot on the management way, development of plants and tree species.

Forest influence on useful water yield in the basin of the river Zagrža

Maximum yield of useful waters could be expected just in well-formed forest associations where stable ecosystem exists and has a great hydrological and protective function. Cuttings over optimal level changes micro-climate and soil features of habitat, and as a consequence, stand architecture is damaged. As a result, hard insolation has a harmful influence on opened trees and on soil, as well. Opening of stand architecture and degradation of primary stand structure cause soil drying and development of weeds, and, as a result, it endangers the hydrological and water-protective forest function. This is related to a decrease of resources capacity (Letic et al., 2012). For example, there is illustration of the problem that exists in Vrnjacka Banja – decreased capacity of mineral water resources occurred after unreasonable cuttings during and after the Second World War (Lazarevic I., 2012).

During last several decades, there have been numerous attempts for improving current forest state with applying of appropriate measures in the basin of river Zagrza, but not only there, but also on mountain Goc on the whole. Choosing of adequate measures (rotation period, dimensions of cutting maturity) causes creating of uneven-aged stands with an expressed mixture (Krstic, M., 2006). All the mentioned measures in these forests are undertaken in order to provide enough organic substances as a key factor for the filtration of atmospheric waters, which go deeper into the ground, then they are filtrated and provide enough nutrients for resources (Djekovic, V., 2007).

There is an attempt at providing the whole stand architecture, and suitable water and air soil regime which provide not only hydrological, but also anti-erosion forest function. Its productive

Table 1. Ecological forest structures on mountain Goc (special base for management of the management unit "Seliste" forests, 2010)

Num.	Forest type	Soil type	Structure	Department	Height above the sea (meters)	Exposition	Inclination (grades)	Architecture	Area km ²				
1	Abieti- fagetum pauperum (beech and fir forests)	Deep till very deep braon acid soils on shales and metamorphic rocks	High uneven-aged forest	13a	980-1050	NW	10	0.8-0.9	0.20				
				19a	1030-1170	E	15	0.8-0.9	0.28				
2	Fagetum moesiacaе montanum typicum (mountain beech forest)	Deep dystric (occasionally eutric) brown soils	High uneven-aged forest	13b	1050-1080	N	0.5	0.8-0.9	0.06				
				14b	1090-1140	N	0.5	0.8-0.9	0.05				
				15a	1100-1180	N	10	0.6	0.15				
				16a	1150-1250	N	15	0.6	0.10				
				14a	1000-1100	N	15	0.8-0.9	0.20				
3	Abieti-fagetum drymetosum (beech and fir forest mixed with Festuca spp.)	Humus-silicate shallow soils on shales and metamorphic rocks	High uneven-aged forests	15b	1040-1100	N	15	0.7	0.19				
				20a	1040-1180	N	15	0.7	0.31				
				21a	980-1120	SE	15	0.8-0.9	0.25				
				24b	1050-1140	SE	20	1.0	0.14				
				25b	1010-1070	S	20	0.7	0.21				
				26a	970-1070	SE	15	0.7	0.23				
				16b	1130-1240	N	15	0.7	0.09				
4	Abieti- fagetum typicum- (typical beech and fir forests)	Medium deep acid brown soils on granodiorits and quartzdiorits	High uneven-aged forest	17b	1200-1270	NE	25	0.7	0.12				
				22a	970-1120	E	20	0.7	0.25				
				23a	110-1240	SE	15	0.8-0.9	0.31				
				18b	1130-1200	E	20	0.7	0.13				
				24a	1050-1240	E	15	0.6	0.25				
				25a	1050-1140	SE	15	0.7	0.11				
				26b	980-1030	SE	10	0.8-0.9	0.24				
				5	Fagetum moesiacaе subalpinum typicum (subalpine beech forests)	Rendzinas and variations of humus-silicate acid braon soils	High uneven-aged forest	16c	1210-1300	N	20	0.6	0.03
								18a	1200-1350	E	20	0.7	0.14

Table 2. Changes of woody mass supplies in high and coppice forests of mountain Goc (by Lazarević I., (2011.))

Year	Woody mass supplies in high forests (m ³ / ha)	Woody mass supplies in coppice forests (m ³ /ha)
1966	264,6	114,0
1988	335,6	146,0
1998	358,8	158,8
2008	382,0	168,4

features are not neglected. Data from the planning documents on management from 1966, 1988, 1998, and 2008 confirm that.

There are increased values of woody mass supplies shown in table 2 in high coppice forests of the river Zagrza basin in the period 1966-2008. Applying of adequate measures had a great influence on the changing of supply values. These results show an increased hydrological and protective function of these forests.

Forest influence on erosion processes in the basin of river Zagrza

Apart from river banks, basins are the biggest base of sediments and they need adequate protective measures. Sediment production from basins could be decreased to a minimum with soil protection and keeping of the protective vegetative cover. Forest cover is the most important,

because its root mass provides stability of soil substances.

As there is a big part of basin river Zagrza area with good structure, there is no significant danger from greater sediment quantity. The whole area is completely covered with forest next to the accumulation „Seliste”. There is a small danger from the movement of some sediments quantity next to the accumulation. In order to solve that problem, there is a plan for establishing an adequate system for filtrating (V.P.Srbijavode, 2006). Its main purpose is cleaning of surface waters that are going to the accumulation. There are many microorganisms in those filtrating belts and they feed on organic material that is running together with water. They filtrate water throw its organisms and it goes to deeper layers, and after that follows mineralization of organic substances and increase of soil productivity, which influences soil structure changes (Djekovic, V., 2007).

Table 3. View of measurements of water fuzziness in the river Zagrza basin (by Lazarevic, 2012)

Red. number	March			June		
	Date of sampling	Weather conditions	Fuzziness NTU*	Date of sampling	Weather conditions	Fuzziness NTU*
1	08.3.2010.	without rainfall	399	01.6.2010.	rain	1085
2	16.3.2010.	without rainfall	446	02.6.2010.	moderate rain	32
3	17.3.2010.	without rainfall	82	03.6.2010.	moderate rain	4,7
4	18.3.2010.	without rainfall	190	06.6.2010.	without rainfall	13
5	22.3.2010.	without rainfall	15,4	07.6.2010.	without rainfall	11,5
6	23.3.2010.	without rainfall	594	08.6.2010.	without rainfall	13,0
7	24.3.2010.	without rainfall	604	09.6.2010.	without rainfall	14,0
8	25.3.2010.	without rainfall	26	11.6.2010.	without rainfall	0,9
9	29.3.2010.	without rainfall	2	14.6.2010.	without rainfall	3,9
10	30.3.2010.	without rainfall	750	16.6.2010.	without rainfall	12,8
11				20.6.2010.	moderate rain	14,0
12				23.6.2010.	moderate rain	4,1
13				28.6.2010.	rain	192
14				30.6.2010.	without rainfall	28

*NTU (Nephelometric turbidity units)

It should be emphasized there is a developed net of forest roads in the river basin that enables, before all, transport of woody assortments. There are shown water fuzziness changes in table 3 of the Gocka River depending on wood assortments transport in the river basin and on rainfall quantity, as well. Clear increasing of fuzziness of the river Zagrza is clear during March, in the period without rainfall, when planned cuttings were performed. On the other hand, there are lower values of water fuzziness during June, apart from rainy days that caused the increase.

Forest influence on water quality in the river Zagrza basin

Forest ecosystems are important factors for water quality increasing, especially in terms of separation from sediments and improving its quality for sanitary purposes (Macan, G., 1985). However, grade to which forest ecosystem will play this role depends above all on forest management.

On the basis of the main purpose of water from the river basin of the Zagrza – to satisfy water needs in the region of Vrnjacka Banja – taking of water samples is performed regularly on the accumulation Seliste profile, in order to permanent control of water quality. These analyses include the following indicators: physical and chemical features, heavy metals, dangerous and harmful materials, rests of different insecticides, and on the basis of long-term analysis, from these results it could be concluded that both physical-chemical and micro-biological features of the river Zagrza water are so good that this water could be marked as the first category of surface waters (Lazarevic, I., 2011).

There is often discussion on the conflict of interest between productive and water protective function of these forests, and in order to solve these

miss-understandings, Lazarevic I., (2012) mentioned researches of Tomanic, L. (1994) and Stamenkovic, V. (1994) that are related to *Pseudotsuga menziesii* and *Pinus nigra* cultures in this area.

The table shows data on assortments used in forestry and about a small part that remains in the forest (leaves, cortex, small branches) and its ratio is 64.1:35.9 % for *Pseudotsuga menziesii* and 66.3:33.7 % for *Pinus nigra*. Trees are the poorest in nutrient content (N,P,K,Ca,Mg), and its elimination from a forest does not cause its deficit, because its concentration in part of mass that remains is much greater and has a priceless role in the formation and protection of soil and water accumulation.

DISCUSSION

Absence of any measures and application of non-adequate measures, as well, could cause forest damaging and endanger its functions: hydrological, protective, productive, etc. An incomplete understanding of the dynamic processes of forest ecosystems development results in a great deal of criticism. This is another fact that explains the connection between planned forest management and its protective function.

The current state of forests in the river Zagrza basin is a bit more suitable than the average forest state in Serbia on the whole. Adequate measures could enable achievement of the state of complete functionality:

- The basic question about water-protective forests is related to its grade of opening. That is, as mentioned above, a very important condition for a successful achievement of planned forest measures, but it is at the same time the endangering factor, too, because of the expressed water-pro-

Table 4. Woody mass structure of forest cultures of douglas fir and black pine (by Tomanic, L., 1994; Stamenkovic, V., 1994 citation by Lazarevic I., 2012)

Experimental plot	Species	Age (years)	Volume of big wood (m ³ /ha)	UDM (m ³ /ha)	% of big wood UDM
1	<i>Pseudotsuga menziesii</i>	30	245	382	64,1
2	<i>Pinus nigra</i>	32	230	347	66,3

tective function of these forests. A possible solution would be finding an appropriate balance between these functions by building roads which means as few roads as possible down the slopes and throw steep paths and build enough roads along reefs in order to reduce sediments and pollution in the water

- in order to achieve the water-protective function of these forests, it is needed to achieve melioration of coppice degraded forests. It could be performed by conversion and restitution measures. If we keep in mind the fact that 49.1 % stands of this basin are diluted stands, it is necessary, where habitat conditions enable that, correction of these stands state. The principle of applying domestic species should be used in the future by choosing adequate species for afforestation. Apart from that, vacancies inside diluted stands should be compensated by species with a shallow root system (it is proved that these species provide better water circulation). It is also important to form appropriate floors from the undergrowth level to the level consisting of dominant trees. These measures enable presence and keeping of water in the stand, which is closely related to the enrichment of underground and surface waters.
- The improvement of forest state in this area has to be related to adequate management of that forests, not only in even-aged stands, but also in uneven-aged stands. About 50.3 % of these forests are clean stands and they are, from the biological point of view, not so stable. At the same time, with management measures application, it has to be increased mixture with the conversion of clean into mixed stands and it could be achieved by providing a greater share of noble hardwoods.
- because of the special importance of forests in the river basin of Zagrza, permanent monitoring of all important parameters related to the healthy condition of plants should be conducted, especially in the case of high beech stands.

Having in mind that the river Zagrza basin belongs to a mountain from the orographic point of view, which means increased endangering from occasional floods, especially in fall and spring, it is necessary to undertake adequate protective measures. The base of these measures is inside the Law on forests and it is related to forests of special purposes (Sl.gl.br.30, 2010, 93/12). Apart from this, the field of waters is part of other five laws: the Law on water, the Law on planning of space and settlements, the Law on communal activities, the Law on environmental protection and the Law on the use of water resources and water supply. These measures have a certain order: resources have priority, they are followed by the basin from which accumulation provides water and in the end comes protection of the accumulation. Protective measures include many bio-technical activities and they should satisfy some criteria, to be as simple as possible, and cheap and ecologically acceptable at the same time (Lujic R, 1973).

The best water protection from sediments contamination is achieved by establishing protective belts of trees, under-growth and grasses. A higher level of cutting along the river causes water erosion, so management of protective forests like in uneven-aged forests is the best option. In basins like the analyzed one, there are special measures that are everlasting.

CONCLUSIONS

On the basis of the analyzed facts, the following can be concluded:

- basin of the river Zagrza is mainly covered with forest vegetation with a forest cover of about 85 %. There is a significant part of diluted stands in this area (49.1 %) and it makes the whole situation not so suitable in terms of hydro-potential. As mentioned above, it is needed to meliorate these stands and improve their regulating features. Non-covered forest ground, that includes about 14.9 % of the river basin, should be transferred to forest ground as soon as possible
- apart from big forest communities next to the river Zagrza basin, there are also ba-

sis for erosion processes that are concentrated in non-forest cover on steep paths, then on roads and river net as well. These places should be improved by applying adequate management measures: afforestation, buffer zones, etc) and by forming bio-technical objects in order to prevent coming of big sediments quantity into the space of accumulation. Besides that, this space with the purpose of water supply is very sensitive to organic remains and fallen leaves, so from that point of view, it should also be protected

- for achieving its primary function (hydrological and water protective), forests of this basin should be converted to an optimal state and after that it should be maintained forever by the application of adequate management measures. Some important questions should be solved – the principle of management and reproduction, conversion, the way of cutting, the length of youth category, etc. The length of rotation period, diameter of cutting maturity and balanced volume are factors that should also be considered. From the functional point of view, it introduces provision and maintenance of high productivity and vitality of the forest.

The main way for achieving optimal stand state in the basin of the river Zagrza is the application of management like in uneven-aged forests. With the application of this way of management, it is possible to achieve many forests functions:

- permanent maintenance of stand architecture that enables creation and regulation of suitable micro-climate conditions, and maintenance of high productivity level of soils, as well
- possibility of maintaining the optimal state in terms of forest cover, structure and mixture with regulation of youth categories of desirable species, permanent selection and maintenance of desirable stand structure
- this way of management enables the creation of the most suitable conditions for the regeneration of beech and fir as the most dominant species that are hydrologically the most important, as well.

Just with a reasonable management of this area it is possible to achieve the optimal use of its hydrological, water protective and productive functions, which means the achievement of balance between forest management and water management.

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