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FOREST REVIEW

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INTERNATIONAL SCIENTIFIC JOURNAL

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PREFACE

Dear Colleagues and respected Readers,

It is our pleasure, after the online publication of the first issue, to announce the online publication of the second issue of 47th volume of the Forest Review!

We have doubled the efforts and start to publish two issues a year. We are convinced that you will find very interesting articles, due to the diverse research work in it.

The next 2017 is a jubilee year. UKiM Faculty of Forestry in Skopje celebrates 70 years of its establishment, but more on this in our next volume. Until then, enjoy in our "second born" in 2016!

Special thanks to all authors and members of the Forest Review, as well as to all peer – reviewers for the participation in this volume and issue.

On behalf of the Editorial Board,

Б. Симовски

Asst. Prof. Bojan Simovski PhD, Editor-in-Chief

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IMPACT OF FLOODING ON WOOD ASSORTMENT PRODUCTION

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ABSTRACT: This paper presents the results of a study of the impact of flooding on the total revenues generated by the production of wood assortments in poplar plantations. The research was carried out in two sample plots in the PE "Vojvodinašume". The impact of flooding on the qualitative structure of assortments is estimated on the basis of the curvature of the lower part of the stem. The method applied in this paper is the method of quality factor isolation [1]. The results of this research show that flooding has an impact on the curvature of the most valuable, lower, part of the stem, i.e. on the total value of produced assortments. The analysis of the loss of wood mass cut after a flooding was performed in the area of the Special Nature Reserve "Gornje Podunavlje" in the FA "Apatin" and the "Apatinski rit" FMU. The analysis was conducted in the period from 2009 to 2013. The data for the analysis were obtained from the commission reports. After the flooding, the annual loss of wood accounted for 0.03 to 1.90% of the total amount of felled wood in the area of FA "Apatin". In value terms, this percentage is even lower, considering the large share of firewood. The share of classical and multi-purpose wood for heating and cellulose accounts for 85.59% of the total losses. In order to minimize losses in unprotected areas, works in compartments and sections at the lowest elevations need to be carried out during the dry season of the year, i.e. during the period with the lowest probability of flooding.
Key words: flooding, poplar, structure of assortments, wood losses, dynamics of works

1 INTRODUCTION

Considering the existing knowledge on the hydrological role of forests and forest land and their extremely important water management role, the following question arises: How to use the forest and forest land during and after a flooding event, while maintaining and implementing all planned works in forestry? Flood waters of large rivers have an impact on all planned works in forestry primarily through:

- the dynamics of flooding (flood height),
- the duration of the flooding and
- the time of year when the flooding occurred.

Forests exposed to the impact of flooding can be found in the forelands of rivers. This area is characterized by a pronounced micro relief. It is intersected with ponds, micro-depressions and canals. Throughout the year, it is flooded, sometimes on several occasions, which considerably hampers the operating conditions in forestry.

Works in forestry take place throughout the year, including a certain volume and dynamics. The impact of flooding on forestry operations cannot be completely avoided. However, by taking appropriate measures, the consequences of flooding can be significantly mitigated. Forest professionals working in these conditions constantly monitor the water level of the nearby rivers, in order to adapt their activities (felling and production of wood assortments, skidding, etc.) to the potential dangers of flooding in the areas where these works are implemented.

The flooding of a riverbed stops the works of felling and wood assortment production. It happens that a part of produced wood assortments remains in the felling site, mainly due non-compliance of felling and assortment production with skidding. The presence of water in the felling site makes skidding impossible until the road subgrade dries.

After the withdrawal of water into the riverbed, there are losses of timber that remains in the felling site after the flooding. These losses vary in different felling sites, depending on the site conditions and the structure of materials.

The losses are considerably higher if no appropriate technical measures are taken to prevent the removal of cut timber by the stream of flood water. The frequency of flooding during plant growth affects the external characteristics of the stem, and most of all, the curvature of the lower (most valuable) part of a standing tree.

In addition to negatively influencing the quality of produced wood assortments and the share of utilization in mechanical wood processing, this feature of a tree causes a change in certain properties of wood. Studies of this problem indicate that a curvature can affect the development of compression and tension wood, fibre deviation and knot size [3], [9].

During tensile shrinking of the wood, deformations occur on the products of mechanical wood processing, while it also causes cracking of the most valuable part of the stem during felling [2]. The problem of tension wood has been investigated by several authors [8], [4], [6], [5].

Deviation from the straight form affects the share of round wood utilization in the process of further wood processing, which is significantly decreased. It also reduces the total value of the stem and in particular of its lower most valuable part, where this characteristic is the most pronounced [3].

According to [7], the use of cut and peeled assortments is significantly reduced with an increase in the degree of curvature.

The greatest impact of flooding on this characteristic of the stem occurs in the first years of development. The effect of curvature in the plantation exposed to flooding is 2.4 times higher than the impact of curvature in a flood-protected plantation [2].

In addition to the losses in the assortment structure and losses incurred by the removal of wood assortments during flood water withdrawal, there is a disruption in the dynamics of the execution of planned works.

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The aim of this paper is to study the impact of flooding on the production effects, with a special emphasis on the qualitative structure of assortments and the loss of wood assortments after the flooding of a felling site. One more aim is to analyse the impact of flooding on the dynamics of execution of works in forestry.

On the basis of recent knowledge and with the aim of ranking the quality factor, the initial assumption was that the curvature of the lower part of the stem is more pronounced in terrains exposed to flooding, which affects the qualitative structure of wood assortments.

2 MATERIALS AND METHODS

2.1 Research area

The research was carried out in the area of the PE Vojvodinašume, in the FE " Sombor", the FMU "Apatinski rit", the FE "Pančevo", and the FMU "Gornje Potamišje".

The forest management unit "Apatinski rit" is located in the northwestern part of Bačka, on the left bank of the Danube River.

It extends from 1409 km in the north to 1367 km in the south. The villages of Bogojevo, Svilojevo and Sonta are in the east and southeast, while it is also located east of the town of Apatin.

The total area of state forests in the northern Bačka forest area is 23,438.00 ha. In this area 73% are surfaces under forests and 27% non-wooded forest land. Within this forest area there are ten management units, four of which are located along the Danube River, where conditions for the growing of poplar and willow are highly favorable. The total wood volume is 2 495 012.0 m^3 and 147 $m^3 \cdot ha^{-1}$. Poplar and willow account for 48% of the total wood volume.

The forest management unit "Apatinski Rit" is located in a flood-prone zone on an area of 3 652.67 ha.

The eastern boundary of this management unit goes along the embankment and separates the flood-prone area from the protected part. The terrain inside this management unit is intersected with canals, ponds, depressions, etc. The altitude ranges from 82 to 86 m. During the high water level, the Danube River pours out of its riverbed and floods this flood-prone area, which among other things had an impact on the formation of certain plant communities. The average annual rainfall is 583,3 mm, and during vegetation it amounts to 333,4 mm (Special forest management plan for the FMU "Apatinski rit").

The forest management unit (FMU) "Gornje Potamišje" represents a homogeneous whole, with a width ranging from several hundred meters to 2.5 km. It is located in the area between the floodgates in Opovo and Tomaševec. The natural border consists of loess terraces, and the Tamiš and Karašac Rivers in other parts.

The forests of this area are characterized by a highly developed micro relief, which has a decisive influence on the flooding regime and the groundwater regime. Inundations intersect extreme depressions and remains of abandoned parts of the riverbed, where water is retained throughout the year. The climate of this area is typical for the wider area of Vojvodina, as part of a large closed basin. The secondary maximum of precipitation occurs at the end of autumn and most often in December. The season with the highest precipitation is summer with an average 1/3 of annual precipitation. The lowest precipitation is recorded in autumn and winter. During the vegetation period, the amount of precipitation accounts for 56% of the total annual precipitation (Special forest management plan for the FMU "Gornje Potamišje").

A sample plot was established in the area of this FMU, in a poplar *Populus × euramericana* 'I-214' plantation which is exposed to the impact of flooding. The planned rotation is 25 years, and the planting spacing is 6 × 6 m, i.e. 278 seedlings per hectare. The control sample plot was established in the FMU "Donje Podunavlje" located in the south Banat area, in the territory of the municipalities of Pančevo and Kovin. It extends along the Danube River, in the form of a 55 km-long belt. Most of the areas are occupied by the largest Danube River islands, and a small part of the FMU is located in a protected area. The central part and the area close to terraces are located in a protected zone of the alluvial plane. A control sample plot, which was not exposed to the impact of flooding was established in that part of the management unit.

2.2 Method

Felling was conducted in the sample plots in order to measure the elements needed for theoretical cutting. The choice of stems for the analysis was carried out using the principle of random sampling. The data of measurements performed were entered into the recording list created for the purpose of this research. All the elements necessary for the qualitative division of the stem, as well as other details that can be significant in the analysis of the results (noted as a phenomenon) were recorded.

The order of recording corresponded with the basic principles of qualitative division of a tree. The health state of a tree was determined at the forefront of the stem (canker, etc.), and, after that, two cross-sections (*mm*) were measured. These are the elements that need to be recorded at the forefront of the thicker trunk end and at cross sections, after the trunk has been cut through, and can be expressed either numerically or descriptively.

The diameters were cross-measured at every two meters starting from the thicker end of the stem, primarily for the purpose of ovality calculation.

The curvatures of the stem were measured before it was cut through and that included all curvature elements, regardless of the curvature being left, right, concave or convex (in relation to the axis of felled trees). The elements of the measurement were the lengths of the curvature arch arrow and arch tendon. The shorter knot axis was measured with a ruler with an accuracy of one millimeter, as required by the SRPS standards.

Data processing was performed according to the methodology that enables dealing with similar research problems in previous investigations [1].

The value of assortment classes is expressed by the value ratio of classes. The value ratio was derived from the price lists of the Public Enterprise "Srbijašume" for assortments produced according to the national (SRPS) standards. The price of 1m^3 of class II logs was taken for the coefficient 1 value.

In addition to the data directly measured in the field, data on the level of water in the area where the sample plots were established were also used. The analysis of losses of harvested timber was conducted in the area of the special nature reserve "Gornje Podunavlje" in the FA "Apatin" and the FMU "Apatinski rit". The analysis covered the annual periods from 2009 to 2013. The data on the quantities lost during flooding events were obtained on the basis of commission reports. The analysis included both quantitative and qualitative losses of timber in the felling site.

In addition, the data necessary for the assessment of the impact of flooding on the dynamics of the execution of works were taken over from the records of the FA "Apatin".

3 RESEARCH RESULTS

3.1 Impact of flooding on the quality structure of asssortments

In these studies, the initial assumption was that flooding will influence the qualitative structure of assortments in poplar plantations. The impact of flooding is reflected in the higher curvature of the lower, most valuable, part of the stem and it depends on the frequency of flooding and the height of the flood water mirror in the first years of plantation development (fifth to tenth year). During the withdrawal of water into the riverbed, seedlings bend down in relation to the vertical position.

During cold winter months, deposits of ice are formed on the water mirror, which leads to the bending of seedlings.

In the following period of the year, the plant reaches out for light, returning to a vertical position. As a consequence, curvature appears at the lower, most valuable, part of the tree.

During the planning period (25 years), there was no flooding for only one year in the observed sample plot. The terrain was on average flooded three times annually, i.e. at least once a year, and at most six times during one year (Table I). The water mirror level measured from the level of the ground reached a maximum of 2.37 in the first years of plantation development, or an average of about 1 m in height. It should be noted that in the first yeas after plantation establishment, flooding was common in winter, when temperatures are low and snow cover appears, which additionally burdens the plants causing curvature.

Table I: Flooding and its duration

Year	Period		Height
77.	F M A-M	15-28. II. 1-26. III. 18 IV.-6. VI.	1,07 1,03 1,07
78.	M M-J J	3.III.-17.III. 7.V.-8.VI. 5.VII.-14. VIII.	0,67 0,73 0,61
79.	J J-M	6.I.-12.I. 29.I.-2.III.	0,64 0,97
80.	F M-J J-A	8.II.-18.II. 10.V.-24.VI. 29.VII.-13.VII	0,43 0,81 1,24
81.	F-A M-J J-A N-J	26.II.-18.IV. 10.V.-4.VII. 27.VII.-10.VIII. 17.XI.-26.I.	2,37 0,63 0,19 1,19
82.	F M-J	4.II.-8.II. 1.III.-4.IV.	0,51 1,19
83.	M-A	30.III.-11.IV.	1,21
84.	F A-M	3.IV.-25.V.	0,41 1,17
	S-O		0,46
85.	M A M J-J	11.III.-17.III. 1.IV.-29.IV. 10.V.-30V. 27.VI.-7.VII.	0,35 0,43 0,37
86.	M-M	30.IV.-10.V.	0,70
87.	F-M A-J	19.II.-28.II. 3.IV.-28.VI.	0,43 1,61
88.	M-M	20.III.-10.V.	1,63
89.	M-A M J S	29.III.-6.IV. 11.V.-29.V. 10.VI.-16.VII. 2.IX.-8.IX.	0,71 0,61 0,36 1,01
90.	-	-	-
91.	M-J A	17.V.-4.VI. 6.VIII.-18.VIII	0,43 0,51
92.	M-A	28.III.-15.IV.	0,69
93.	M-M	30.III.-5.V.	0,83
94.	J A-M	1.I.-14.I 16.IV.-10.V.	0,21 0,79
95.	A-M M-J	30.IV.-10.V. 19.V.-11.VII.	0,41 0,61
96.	J F-M A M-J S-O N-J	1.I.-20.I. 25.II.-3.III. 4.IV.-27.IV. 27.V.-4.VI. 22.IX.-7.X. 30.XI.-19.I.	1,11 0,33 0,47 0,71 0,35 1,15
97.	F A-M J-A O	20.II.-27.II. 22.IV.-30.V. 28.VII.-18.VIII. 20.X.-24.X.	0,29 1,25 0,87 0,21
98.	J A-M J N	1.I.-22.I. 25.IV.-16.V. 23.VI.-27.VI. 8.XI.-30.XI.	0,49 0,65 0,13 0,73
99.	J F-J J-A D-J	18.I.-21.I. 25.II.-13.IV. 26.VI.-6.VIII. 20.XI.-15.I.	0,11 1,63 0,46 1,27
00.	F-M	5.II.-22.V.	1,25
01.	M-A A-M J-J S-O	22.III.-7.III. 26.IV.-15.X. 24.VI.-11.VII. 22.IX.-8.X.	0,87 0,99 0,65 0,47
02.	A	16.-19.VIII.	0,57
03.	J M	8.I.-16.I. 6.V.-30.V.	0,49 0,89
04.	F F-M N-D D	12.-15. II. 28.II.-8.V. 30.IX.-1.XII. 8.XII.-12.XII.	0,25 1,19 0,17 0,35

The number of stems for analysis in the sample plot and the control plot is adequate (Table II).

The total value of assortments produced from trees of certain dimensions is in direct correlation with the diameter at breast height of a tree. With an increase in the diameter at breast height of a tree, the total value of produced assortments is significantly increased (Table III).

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Table II: The number of required and implemented measurements

Diameter classes		Areas	
		Sample plot	Control plot
27,5 cm	R	18	22
	I	21	23
32,5 cm	R	33	38
	I	41	38
37,5 cm	R	26	38
	I	40	42
42,5 cm	R	24	29
	I	45	40
47,5cm	R	32	27
	I	42	27
52,5 cm	R	29	10
	I	36	12
TOTAL	R	162	168
	I	225	182

R-required, I-implemented

The Reomer-Orphal's distribution was used to determine the strength of the correlation.

The correlation between the value of assortment structure and stem diamater in this plantation is represented by a power function.

$$\ln Y = b \ln X - \ln(a) \qquad (1)$$

The variables are fully correlated. The statistical elements of regression equations are shown in Table III.

Table III: Statistical elements of adopted functions$V_{SS} = f(D_{1,3})$

Areas	**Sample plot**	**Control plot**
a	-8,25	-10,47
b	2,39	2,94
t_a	-46,66	-44,42
t_b	50,44	44,91
R	0,959	0,959
R^2	91,94	92,06
S_x	0,138	0,204

V_{SS}-Total value of produced assortments
$D_{1,3}$-Diameter at breast height

An increase in the value of a tree with the growth of the stem diameter is created due to the production of more valuable assortments: logs for peeled veneer, logs for cut veneer and class I logs for processing.

There are no significant statistical differences between the total value of the assortments produced in the sample plot and the control plot (F-1.27, p-0.265). The average value in the sample plot is 1.63, and in the control plot 1.92. However, even though this difference is not significant, it has also been recorded in this case, and it amounts to 0.29.

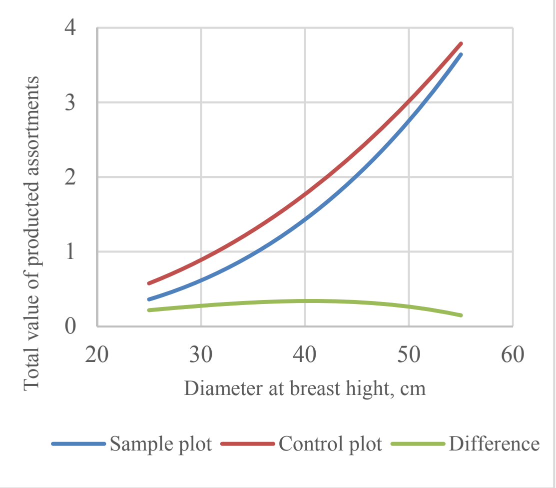

Figure 2: Total value of produced assortments

3.2 Impact of flooding on the losses of timber

Logging and wood assortment production in poplar plantations are implemented throughout the year. The intensity of works in forest utilization is the highest in the summer period (July-November), when the conditions for work in flood-prone terrains are optimal. In the spring period, the dynamics of works execution is affected by the sensitivity of poplar to cracking at the lower, most valuable, part of the stem during felling. The reason is high moisture content in the sapwood and heartwood of the poplar species. In comparison to other broadleaved species, moisture content in the central part is higher than in the peripheral part. Therefore, the intensity of works on felling and wood assortment production is lower in the spring period.

This period of the year is characterized by frequent rainfalls that can cause flooding. There is a particularly pronounced rise of water levels in rivers due to the melting of snow in Central Europe. The appearance of underground surface waters causes an increase in water levels, in some cases exceeding the levels of regular flood defence, as well as the emergency flood protection levels. The limit of regular defence is declared when the water level at the hydrological station Apatin reaches 600 cm, and the limit of the emergency defence when the water level is 750 cm at the same hydrological station.

The zero elevation is 78.84 m altitude, and the level of water levels is added to it. When the water level is 430 cm in the Apatin hydrological station, it is necessary to stop works in the FMU "Apatinski rit", as the roads become impassable.

Water flows out of the riverbed, pours over the canals and ponds flooding the terrain. In the lowest depressions, the flood water remains for a long time, even after the withdrawal into the riverbed. In unfavorable climate conditions (rapid snow melting in the Alps with freezing in the middle and lower Danube streams) winter floods can occur in January and February.

During these floods, it is possible to access the forest only by boats, and it is not an uncommon way to perform skidding. (Figure 3)

Figure 3: Transport of wood by water

Figure 4: Combined transport

In protected areas of forest management units, the water level in ponds and depressions, i.e. the groundwater regime, depends on the water level in the unprotected part.

The characteristics of the water level and flow-average water level for the long-term period are the following:

- Two high-water waves, i.e. two maximums and two minimums occur during one year.
- The main maximum in this part occurs in mid-June, and the secondary maximum in mid-April.
- The main minimum occurs in autumn, as a result of summer droughts in the basins of the main tributaries.
- From September to the end of February, as a rule, there are no maximum water levels. However, high water levels occur in October, November and December.
- The high variation of the water level in the Danube River Basin is the consequence of the diversity of climate conditions in the precipitation region of the Danube and its tributaries.
- The construction and operation of the HPP "Djerdap" significantly changed the regime of the Danube River compared to the natural conditions.

In the case that wood assortments remain in a felling site located in the FMU "Apatinski rit" the connecting of logs with steel reinforcement is performed, and after the withdrawal of water, the works are continued. The data on the incurred damage can be obtained after the completion of skidding.

The timber assortments that remain in the felling sites after the flooding float on the surface of the water (Figure 5). At the moment of withdrawal of water into the riverbed, the water stream carries a part of the timber towards the riverbed. Without previously taken measures to prevent the free movement of logs and stack wood, losses are incurred, since one part of the timber is carried away to the riverbed, which is the Danube riverbed in this case.

Figure 5: Timber in water after felling

Figure 6: Technical roundwood at the Danube riverbank

The quantity of timber assortments lost in this way is analyzed in the area of the FA"Apatin, the FMU"Apatinski rit". The data are systematized and shown in Table IV. The systematization of data was performed for the 2009-2013 period by the type of assortment.

The total quantity of wood harvested in the five-year period in the FA "Apatin" is 165498.73 m^3, or 33099.75 m^3 per year. The total losses of wood created during the flooding amount to 1249.6 m^3, or an average of 245 m^3 per year.

The losses of wood incurred during the investigated period of timber amount to 2294942.4 dinars. The share of wood losses in the total amount of felled wood in the area of the FA "Apatin" is from 0.03 to 1.90%. In value terms, this percentage is lower, since the share of firewood is considerable. The share of classical and meter wood for heating and cellulose accounts for 85.59% of the total losses.

In the case of a deficiency, a commission for the assessment of damages is formed. Another possibility is to suspend all works and form a commission for an extraordinary inventory, which would determine the factual situation in that case.

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Table IV: Type and quantity of wood assortments which appears as loss after the floods from 2009 to 2013.

Type of assortment	F	L	I class	II class	VTO	Firewood I class	Total
Tree species	m^3						
Euromerican poplar	11,74	33,3	49,22	60,92	41,75	905,36	1102,29
Willow	0	0	4,65	6,5	0	34,16	45,31
White poplar	0	0	3,2	5,35	0	0,69	9,24
American ash	0	0	0,97	0	0	5,52	6,49
Elm	0	0	0	0	0	13,12	13,12
Other soft leaves	0	0	0	0	0	45,85	45,85
Other hard leaves	0	0	0	0	0	27,27	27,27

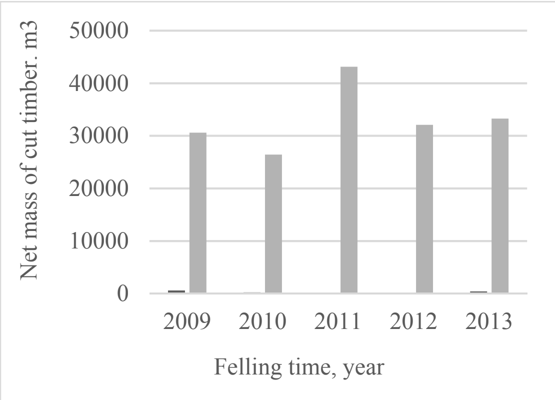

Figure 7: Total amount of felled timber and losses created after flooding in the 2009-2013 period

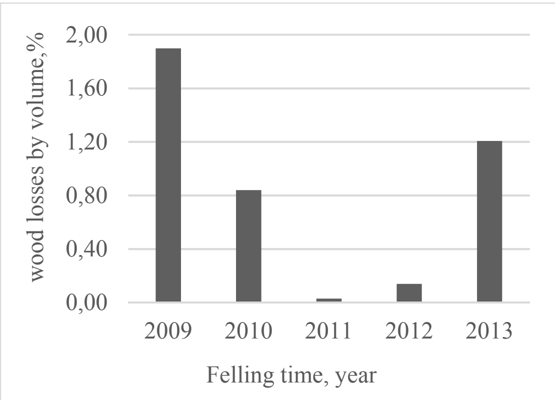

Figure 8: Share of losses in the total amount of produced assortments

After a detailed review, the commission makes a report, which requires several days of work and engagement of a number of persons, as well as the use of machinery, which is deficient and expensive. In addition, there are costs of re-stacking of scattered pulp wood and determination of its amount. The current Forest law does not clearly regulate matters related to the collection of wood material from the river or from the coast after a flood event.

This wood material ends up in the possession of organized groups dealing with its collection and sale. It is generally very difficult to prove the origin of that material, since there are no specific visible marks on it.

3.3 Impact of flooding on the dynamics of works execution

The value of a forest is estimated on the basis of several indicators, and one of them is the value of produced wood. It varies depending on the quality of produced assortments and their prices. The curvature of the logs is correlated with the diameter, length and diameter decrease, and it significantly influences the value of the logs and assortments produced in further mechanical processing (Tuner and Tombleson, 1999).

The planning of works on forest utilization is a demanding and complex activity. It is necessary to align the activity plan with activities that are limited regarding the available technical capacities, weather, market trends and organizational abilities at various levels of an enterprise. The consequences that appear after poor planning are multiple and primarily related to the non-execution of planned activities in the observed period, which in turn affects the financial results of a company's operations. That problem is not only the concern of a timber raw material producer, but a general problem of the supply chain in the raw materials market. This chain includes wood processing capacities, energy plants, pulp and paper production plants, plants for the production of final wood products, the needs of citizens for wood, etc. The need for raw materials is in a large number of cases related to the fulfillment of contracted obligations of employers in the national and international markets. A failure to fulfill contractual obligations may lead to the termination of contracts and other undesirable events.

Clear cutting in the area of the FA "Apatin" is carried out on an area of 120 ha with an average felling volume of about 350 m^3 per ha. The largest part of the total area planned for cutting is mostly exposed to the impact of flooding. The planning of works in unprotected areas is performed so that the logging and production of wood assortments in compartments and sections at the lowest elevations are planned for the dry season of the year, i.e. in the period with the lowest probability of flooding.

In the FA "Apatinski rit", the problems in the execution of works in forest utilization appear at the Danube water level of +260 m. At that water level, the water is 20 cm above the the road level at the crossings over the Srebrenica canal, which stops works in the largest part of the area of fish ponds of Kanlija pesak and Duboki jendek.

When it comes to the area of the Harčaš fish pond, at a water level of +300 m, the access of machinery (forwarders and tractor teams) is not possible. At a water level of +420 m, all four stone paths in the FMU "Apatinski rit" are exposed to the impact of flooding at their lowest parts.

This situation suggests that the works of logging and assortment production in the unprotected part of the FMU

“Apatinski rit" during flooding should be planned to be organized in the FMU "Protected forests", thereby reducing the impact of floods on the dynamics of planned works.

The number of effective days of work on the operations of forest utilization is on average 170 per year.

4 DISCUSSION OF RESEARCH RESULTS

Based on the results of these studies, it appears that floods occurring in the forelands of large rivers have a continuous impact throughout the entire process of wood assortment production. The impact of curvature on the assortment structure is significant, because it occurs on the lower, most valuable, part of the tree, and in co-occurrence with various other factors (wind, light), the impact of this characteristic is even higher and generally manifested as multiple curvature. This feature of a tree cannot be completely avoided, although it can be reduced by certain measures. The suggested measures are increasing the quality of planting, straightening of the seedlings after floods, etc.

The quantity of assortments occurring as a loss cannot be ignored even though these are not large quantities. They are mostly small-size assortments from the stack wood category. The amount of loss can be significantly reduced if adequate measures are taken. These could be either planned performance dynamics or technical measures. An example of such a measure is to connect the assortments in the felling site during the flooding.

The assortments which remain in the felling site must be connected with the steel reinforcement before the arrival of flood water along the periphery of the felling site in order to reduce the losses resulting from the withdrawal of the water into the riverbed. In this way, an obstacle is formed from the edge trees, which prevents timber assortments from being taken away by the water stream. These trees are cut at the end of the harvest.

This operation is performed by a team of two workers with a boat and a tool for installing the steel reinforcement. It is important to know the direction of the water withdrawal, in order to position the reinforcement on the right side.

These protection measures have proved to be effective in practice, although it is not possible to preserve all stack wood in this way.

After the withdrawal of the water, the assortments in the felling site are concentrated in the lower part along the direction of the water withdrawal.

5 CONCLUSIONS

The following conclusions were reached on the basis of the conducted research:

- The total value of assortments produced from trees of certain dimensions is in direct correlation with the diameter at breast height of a tree.
- There are no significant statistical differences between the total value of produced assortments in plantations that are exposed to the impact of flooding and the plantations located in the area protected from floods. The impact of curvature in the plantations exposed to floods is more than twice as high as the impact of curvature in the plantations protected from floods.
- Wood losses after the occurrence of a flood event can be significantly reduced if the logs are previously connected with steel reinforcement.
- The share of wood losses in the total quantity of felled wood in the area of FA "Apatin" is from 0.03 to 1.90%.
- The share of classical and multi-purpose wood for firewood and cellulose accounts for 85.59% of the total losses.
- The works in unprotected areas and departments and sections at the lowest elevations should be planned for the dry season of the year, i.e. at the time with the lowest flooding potential.

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Original scientific article

SOIL EROSION RATES IN TWO SUCCESSIVE RESERVOIR CATCHMENTS: SPILJE AND GLOBOCICA RESERVOIR, MACEDONIA

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ABSTRACT: The catchments of the reservoirs Spilje and Globocica are positioned in the western part of Macedonia. This part is known for the more than average rainfall (800-900 mm/annually) for the country and large portion of the catchment is consisted of forests and natural grasslands. In the past, this region had been a huge economic centre. As a part of the process of migration, many of the mountainous regions of Macedonia have been practically deserted. This had a huge effect on the environment and it largely diminished the human impact. The catchment of the reservoir Globocica is beginning from the outflow of the river Drim from the Ohrid Lake. The main water source for this reservoir is the river Drim and some minor tributaries. The catchment of the Spilje reservoir is beginning from the Globocica dam, continuing the flow of the Drim River and also form north the second main tributary is Radika River. The two catchments were mapped for erosion according to the Erosion Potential Method (EPM) by Gavrilovic. The two erosion maps created for the two reservoir catchments show very different results. The catchment of the reservoir Globocica is one of the most preserved catchments from soil erosion point of view with average erosion coefficient (Z) of 0.29, specific annual production of erosive sediment is 394 $m^3km^{-2}yr^{-1}$., and the specific annual transport of erosive sediment is $247 m^3km^{-2}yr^{-1}$. On the other hand the catchment of the reservoir Spilje is one of the most erosive areas in the country, with average erosion coefficient (z) of 0.44, specific annual production of erosive sediment is *776* m^3/km^2/ann., and the specific annual transport of erosive sediment is *541* m^3/km^2/ann.
Keywords: Soil erosion, erosion rate, EPM, reservoir sedimentation

1 INTRODUCTION

Erosion phenomena and processes in the catchment areas and torrential activity in riverbeds cause endangerment and destruction of hydropower and irrigation facilities and systems, settlements, roads, water supply facilities, industrial facilities and large areas of productive lands (Trendafilov et al, 2014).

Reservoirs are designed to operate for a limited amount of time, but often their lifespans are reduced by sedimentation. Despite the designed life, reservoirs realistically have a project life defined as the period during which the reservoir can reliably serve the purposes it was originally constructed for. Reaching of the project life, the failure to meet designed needs occurs typically before half of the storage volume of the reservoir is reduced from sedimentation. The storage capacity, or reservoir yield, is expressed"as a function of available storage volume in the conservation pool" (Nikitina, 2011).

Reservoir sedimentation is a serious consequence of soil erosion with large environmental and economic implications. On the other hand, reservoir sedimentation also provides valuable information on erosion problems and sediment transport within a drainage basin. A reservoir can be considered as a large scale experiment, as the outlet of a giant erosion plot (Verstraeten and Poesen, 2000).

The main purpose of sedimentation surveys in reservoirs is to "determine the volume and weight of sediment accumulated between surveys, or during the recorded period of storage" (Hall, 2010). The information provided by a survey of this type can be used to approximate sediment yields, assess sediment damages, and predict reservoir storage life expectancies. Siltation of the reservoir and other factors continue to create water quantity and quality problems that affect the many uses of the reservoirs in general like providing potable water, flood control, recreation, irrigation, production of electricity, etc. Solving this problem is an enormous challenge that requires gathering crucial information about the state of the reservoir. Bathymetric mapping and reservoir assessment are becoming particularly important. These data are vital in creating and analysing protective sedimentation measures in watersheds.

During the last fifty years in the country there were built 23 dams and large reservoirs and around 120 small reservoirs in order to ensure sustainable use of existing hydrological potential, managing the water and sediment regime and providing water for various purposes. Existing reservoirs have great contribution in improving and regulating the water regime and sediment, but still the country is very far from a state of full regulation and control of the hydrological potential.

As a consequence of the erosion phenomena and processes in watersheds and torrential activity in the riverbeds, the annual mean sedimentation in the existing reservoirs in the country, without the reservoirs "Lisice", "Kozjak" and "Zletovica" is approximately $3{,}5x10^6 m^3$ erosive sediment (Trendafilov A., 2004). Filling up the reservoirs with erosive sediment is natural process but also is an anthropogenic process, and depending on the erosion potential in the watershed it limits the lifespan of the reservoir to a greater or lesser extent.

1.1 Monitoring of the filling up of the reservoir with erosive sediment

Given the great importance of reservoirs for the overall development of RM, after their construction, they were constantly monitored for sedimentation.

The main purpose of measuring the volume of deposited sediment in the reservoir is establishing the relationship between the erosion in the watershed and filling the reservoirs with sediment. Based on data for specific transport of sediment (m^3/km^2/year, m^3/ha/year, t/ha/year) and the structure of the erosion processes in the watershed, erosion measures and works are planned in order to reduce the erosion rate in the catchment and to prolong the lifespan of the reservoir (Trendafilov A., 2001).

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Based on previous findings, knowledge and experiences derived from the implementation of the EPM (Erosion Potential Method) of S. Gavrilovic it is deemed the most adequate for the country. The model was used for calculation of the average annual production and measured data for deposed sediment in all the reservoirs in the country, and abroad (Mincev, 2015a, b; Spalevic V. et al., 2015

Hydropower facilities and systems, primarily reservoirs are of great importance not only for the power system, but also for the viability, sustainability and improvement of the environment. The longevity, sustainability, profitability of each hydropower system, including hydropower systems Globocica, Spilje Mavrovo, Tikves, Matka, Kozjak, Sv. Petka and others managed by the electrical company ELEM, depends not only on technical and technological level of the plant and sustainability and improving and upgrading of the equipment and facilities of the power plant, but primarily from the water regime and erosion potential / intensity in the watershed and the regime of sedimentation in the reservoir. This means that the disposition of the safest and most modern hydropower plant also does not mean lifelong, affordable and profitable hydropower system, especially if the accumulation is filled up with sediment at a rapid pace.

1.2 Reservoir sediment regime

In the world scientific literature, there are several methods for determining the erosive sediment regime which are primarily based on measured and analytically based values (Trendafilov A. et al., 2002; Blinkov&Kostadinov, 2010). The use of appropriate methodology is conditioned by the existing data about erosive sediment regime.

Various methods for erosion risk assessment are used by various countries in Europe. Generally, three types of approaches exist to identify areas at risk (Eckelmann et al., 2006): qualitative approach, quantitative approach, and model approach. All these methods vary in their characteristics and applicability. All already developed methods and approaches are improved in the recent period through use of GIS enabled technologies. The most spread erosion type in the East and Southeast Europe as well as in whole continent is water erosion (Blinkov & Kostadinov, 2010).

The difficulty in applying the physically-based erosion models to natural landscapes lies in the fact that sediment yield predictions are still widely based on very simple empirical models developed by multiple regression methods between morpho-climate parameters and limited measurements of sediment yield and/or sediment fluxes (Jansen and Painter, 1974; Ciccacci et al., 1980; Mulder and Syvitski, 1996; Poesen et al., 2003, Lazzari et al, 2015).

Reservoir sedimentation is a consequence of soil erosion with large environmental and economic implications. On the other hand, reservoir sedimentation also provides valuable information on erosion process and sediment transport within a drainage basin.

The aim of this paper was to determine the erosion potential of the catchment of the reservoir Spilje and Globochica and to determine the rate of the sediment transport and deposition in the reservoir in order to assess the lifespan of the reservoirs and its sustainability.

2 MATERIALS AND METHODS

2.1 Study area

The catchment areas of the reservoirs “Spilje” and “Globocica” are located in the western part of the Republic Macedonia, with an area of 3,941 km^2 and 301 km^2, respectively excluding the Ohrid Lake catchment.

The catchment area of the Spilje reservoir is constituted of two mayor catchment areas. The northern catchment is represented by the one of the most beautiful rivers in R. Macedonia: Radika River and the southern extends the catchment area of the river Crn Drim. Reservoir "Spilje-Dragozel" stretches east and south of the town of Debar, in its immediate and wider environment, an area of 13.20 km^2.The dam “Spilje” is located on the Crn Drim River, 3.5 km south of the town Debar, about 300m upstream of the Macedonian-Albanian border. The total storage of the reservoir is projected on 540x10^{6}m^3.

The main water source of the Globocica reservoir is the Drim River. The total storage of the reservoir is projected on 58x10^{6}m^3

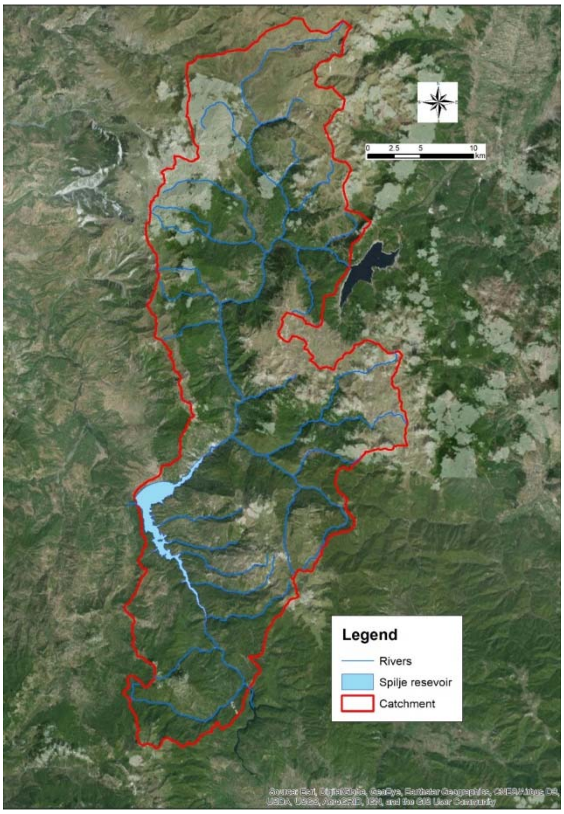

Figure 1: Catchment of the reservoir Spilje

2.2 Environmental conditions

The climate parameters, primarily air temperature, precipitation, wind, insolation, relative humidity and other parameters have a direct or indirect impact on the erosion potential.

Climatic characteristics of the catchment area of the reservoirs are strongly influenced by geographical location, orographic, biogeographic and hydrological conditions of the region. The lowest parts of the basins are affected by the sub-Mediterranean climate, hilly and upland areas are affected by moderate continental and mountainous climate and highland areas are affected by typical mountain climate. The average annual air temperature for the station Struga is 10.7°C and for Ohrid 11.1°C.

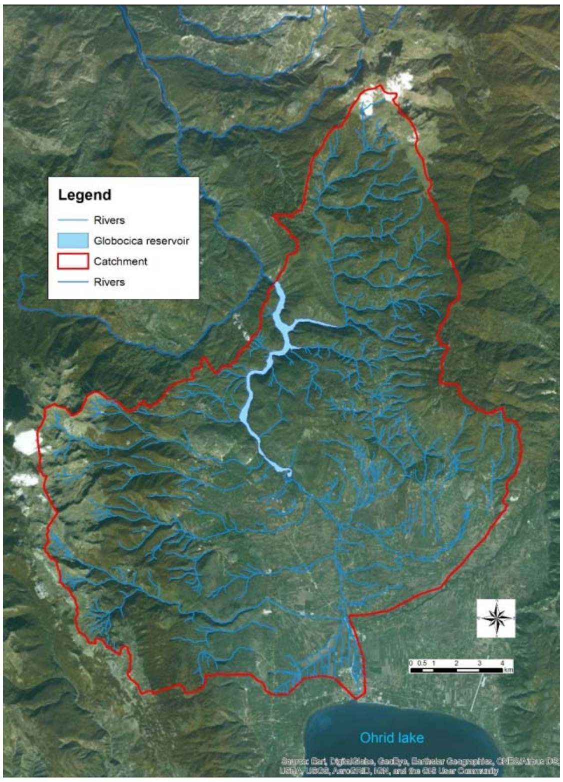

Figure 2: Catchment of the reservoir Globocica

The average annual temperature ranges between 6.9°C for Lazaropole to 7.0°C in Mavrovi Anovi for the period 1971-2000, respectively 4.9°C Popova Shapka to 7.3°C Lazaropole for the period 1981-2010. The pluviometric regime for the catchment of Crn Drim is based on the data for the stations Struga and Ohrid. The average annual rainfall sum is 788,5 mm for Struga, and 698,3mm for Ohrid. The most rainy months are: November, December and January and the driest months are: July and August. *(Source: Spatial plan for the Ohrid-Prespa region 2005-2020, Agency for spatial planning, Skopje, 2007).*

Within the analyzed period (1971-2000), the meteorological stations Mavrovi Anovi and Lazaropole the average annual rainfall amounts are ranging from 931.8 mm in Mavrovi Anovi to 1025.7 mm in Lazaropole.

For the period 1981-2010, the average annual precipitation sum for the analyzed stations Lazaropole and Popova Shapka, are ranging from 898.3 mm for Popova Shapka to 1057.1 mm for Lazaropole. On the higher mountain areas, the annual precipitation sum ranges from 700 to 900 mm and on the highest mountain tops, the annual precipitation sum reaches up to 1250 mm. (Source: Study for a revalorization of the protected area Mavrovo, 2011).

The catchment area of the reservoir "Spilje" has heterogeneous geological structure (Source: Engineering geological and basic geological map of the Republic of Macedonia, Geological Institute, Skopje, 1977). In the catchment area of the reservoir is dominated by the following geological formations: complex phyllites, metasand stones and conglomerates 24%, complex sandstones, clay, argiloshists and limestone 14% and 13% of limestone with chert, clay and massive limestones. The soils are formed and are evolving under the influence of the climate, geological substrate, living organisms and solar energy. As a result the soil forming factors in the catchment can be found the following soil types: brown forest soils (eutric and distric cambisols) 30%, rankers 28%; calcocambisols 12% and lithosols 10%.

The catchment area of the reservoir Globocica has similar geological and soil structure with some differences. Plate dolomite with chert, shale limestone and conglomerate 32%, alluvium 14%, sandstone, shale limestone and conglomerate 12%, marl clay, sands and gravel 11%, phyllite schists 8%, etc. The dominant soils are calcomelanosol 22%, brown forest soils (eutric and distric cambisols) 21%, complex of calcomelanosols, calcocambisols and dolomite 14% and molic fluvisols 11%.

From vegetation aspect can be concluded that the majority of the mountain ranges are covered with forest and grasslands. In the hilly and mountainous region, with the exception of the vicinity of the villages, it is dominated by forest vegetation, primarily of oak forests and beech or beech-fir forests and in the catchment of Adžina Reka, spruce forests. The upper limit of the forest is dominated by alpine and subalpine meadows, rocky and massive rock formations. In terms of erosion, the existing vegetation basically provides relatively good protection of the land from erosion. The worst situation is in the vicinity of the inhabited areas, where the land use is significantly affected by human.

From hidrographic-hydrological aspect, the catchment area of the river Crn Drim has developed hydrographic network and well balanced water regime, primarily due to the large hydro potential of the springs in "St.Naum". The mountain Jablanica is characterized by moderately to highly develop hydrographic network, which strongly influences the run-off and transport of the erosive sediment in the reservoirs "Globochica" and "Spilje". The catchment area of the river Radika has developed hydrographic network with streams characterized with pronounced mountain, subalpine and alpine features, with variable water regime and abundance of springs and surface water.

2.3 Erosion processes and phenomena

As a result of the great ecological diversity, characteristics and specifics of the erosion factors, especially climate, geology and soil, orography and vegetation in the catchment area of the reservoir "Spilje" it is dominated by phenomena and processes of water erosion from pluvial, fluvial and karstic type. The special characteristics of the Radika catchment is that in the subalpine and alpine zone of the mountain range Korab, are also present phenomena and processes of glacial and glacio-fluvial type.

Within the catchment area there are present almost all forms and types of water erosion. In the catchment of Radika there is the biggest landslide in RM in the vicinity of villages Rostushe, Bitushe and Vele Brdo. In mountain massifs built carbonates significant places have phenomena and processes of karst erosion: sipars, depressions, hollows, potholes, caves and other forms and types of karst erosion.

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Fluvial erosion is present in the catchment of Radika River, primarily along the river and along the tributaries: Crn Kamen, Adžina Reka, Nistovska-Ribnichka Reka, Zhirovnichka Reka, as well as direct tributaries of the reservoir: Papradnichka Reka, Breshtanska Reka, Kodzhadzhishka Reka, Dolgashka Reka, Trebishka Reka, Piskupshtinska Reka and other alpine and mountain streams. This type of erosion takes place in riverbeds, and is caused by kinetic-erosive power of the discharge and is the source of large quantities of erosive sediment.

Figure 3: Phenomena and processes of erosion in the catchment of the reservoir Spilje

Figure 4: Phenomena and processes of sedimentation of in the catchment of the reservoir Spilje

Phenomena and processes of deposition-sedimentation is a natural phenomenon which occurs as a result of the relationship between erosive potential of the catchment and the kinetic-transport capacity of the streams. Basically, their extent, characteristics, intensity primarily depend on the state of the erosion in the catchment and hydrographic, hydrological and hydraulic characteristics of the catchment and the watercourses. The process of sedimentation starts in the highest parts of the basin and stream bed, where the largest fractions are deposited, while the smallest factions are deposited in the final recipient or in the case of this study, in the reservoir. In mountainous, and even more in the alpine, subalpine - alpine sections of the streams, the conditions and for retaining sediment are minimal, practically non-existent.

Almost the entire sediment of some streams is transported through the hydrographic network to the final recipient: Radika, Crn Drim and direct tributaries of the reservoir and are deposited in the lowest section of the rivers (Boškov Most and village Dolno Kosovrasti) and Debar Lake and Globocica Lake. On the other hand, the rivers Breshtanska, Trebishka and the most dominant of all others is Dolgashka River bring large quantities of erosive sediment material, mostly minor fractions: dust, clay, sand, gravel and are directly transported and deposited in the reservoir.

2.4 Erosion Potential Method (EPM)

At the moment, there are several methods used for estimating erosion on site and on catchment level. Blinkov and Kostadinov (2010) in their paper stress the good and bad sides of several models for estimation of erosion: EUROSEM, USLE, PESERA, KINEROS, WEP, WEPP and EPM. Several of these methods are able to model erosion from different point of view. Only few deal with transport and deposition of the sediment: EUROSEM, WEPP and EPM.

EPM was chosen to be used in the study because it has the unique trait that was developed in the Balkan region, south Serbia which is very similar in climatic conditions with Macedonia, secondly the ability to predict sediment transport and deposition was developed with calibration of deposited sediment in the existing reservoirs and also the data produced about the erosion potential in Macedonia was developed with the EPM, so the results would be comparable and the methodology would be transferable (Mincev, 2015b; Blinkov&Kostadinov, 2010).

There are several papers explaining the EPM model (see Mincev and Blinkov, 2007) and only shortly will be explained what kind of data was used in the process.

3 RESULTS AND DISCUSSION

3.1 Spilje

In the catchment of the reservoir "Spilje" the dominant type of erosion is IV erosion category on area of 45,674.76 ha, respectively (43.4 %) of the total area of the catchment. The second is III erosion category with an area of 23,027.05 ha, respectively (21.9%) of the total area. The third category by area is the V erosion category, represented with area of 17,547.07 ha, respectively (16.7%) of the total catchment area.

It is concerning that extremely strong phenomena and processes of erosion are present in large areas compared to the total area of the catchment Spilje. The strongest or the most extreme phenomena and processes of erosion (I category) represented an area of 8894.94 ha, respectively (8.4%) of the total area of the catchment, and the phenomena and processes of II category of erosion is prevalent on the area of 8653.58 ha, respectively (8.2%) of the total catchment area. The two strongest categories of erosion (I and II category) cover 16.6% of the total catchment area, which is a high percentage. If these two categories are combined with the III category of erosion, then the total percentage will be 38.5%. So it can be concluded that more than 1/3 of the catchment should be subject to erosion mitigation and remediation measures. These categories are most common in the catchment areas of rivers Breshtanska Reka, Kodzhadzhishka Reka, Dolgashka Reka and Trebishka Reka.

The immediate catchment of the reservoir has the strongest erosion processes together with the highest specific production of erosive material (m^3/km^2/year) and specific transport of erosive sediment (m^3/km^2/year).

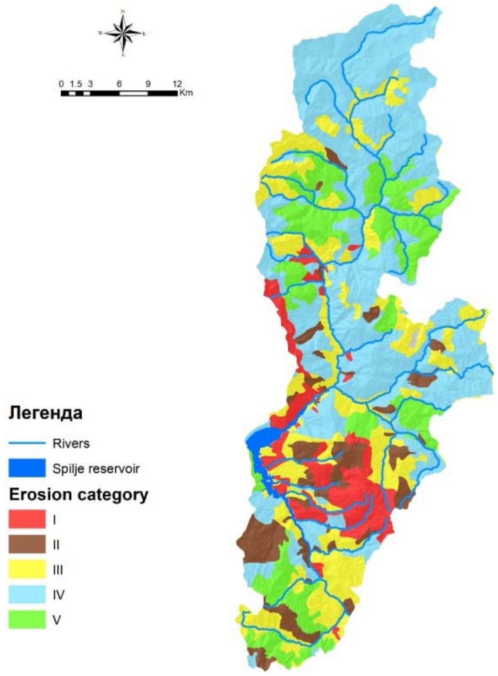

Figure 5: Structure of the erosion by categories in the catchment of Spilje

The largest total mean annual production of erosive material (W) has the catchment Radika 394.041 m^3/year and total mean annual transport of sediment (G) is 275.318 m^3/year. The second is the immediate catchment with total mean annual production 347.352 m^3/year and total mean annual transport of sediment 312.473 m^3/year in particular: Dolgashka, Kodzhadzhichka, Breshtanska, Papradnichka and other major and smaller streams and torrential series which are formed and run in depressive relief forms of Stogovo Mountain. With the lowest mean annual production (100.405 m^3/year) and mean annual transfer of sediment (78.094 m^3/year) is the catchment area of the river Crn Drim.

When the separate streams are observed then the largest total annual production of erosive material of 67.087 m^3/year and the highest total mean transport of sediment of 66.415 m^3/year is Breshtanska Reka (catchment area of 24,76 km^2). Second in line is Dolgashka Reka with a total annual production of erosive material of 53.784 m^3/year) and total mean transport of sediment of 52.248 m^3/year with a catchment area of 20,07 km^2.

The intensity - potential erosion in the catchment areas of the rivers is easily determined by the specific mean annual production of erosive material and specific mean annual transport of sediment.

The largest value for the specific mean annual production of erosive material is Kodzhadzhichka Reka with 3.996 m^3/km^2/year and mean specific transport of erosive sediment of 3.547 m^3/km^2/year. Followed by: Breshtanska Reka with a specific mean annual production of erosive material of 2.709 m^3/km^2/year and mean specific transport of erosive sediment of 2.682 m^3/km^2/year, then Dolgashka Reka with specific mean annual production of erosive material of 2.679 m^3/km^2/year and mean specific transport of erosive sediment of 2.603 m^3/km^2/year, Papradnichka Reka with a specific mean annual production of erosive material of 2.183 m^3/km^2/year and mean specific transport of erosive sediment of 2.039 m^3/km^2/year.

3.2 Globocica

In the catchment of the reservoir "Globocica" the dominant type of erosion is IV erosion category on area of 12,586.1 ha, respectively (41.7 %) of the total area of the catchment. The second is V erosion category with an area of 10,285.7 ha, respectively (34.1%) of the total area. The third category by area is the III erosion category, represented with area of 6,687 ha, respectively (22.2%) of the total catchment area. The first two categories are only 1.2% of the total area.

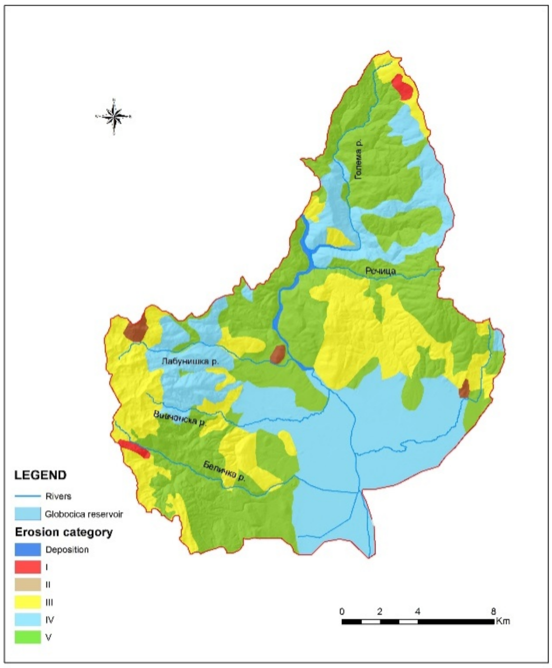

Figure 6: Structure of the erosion by categories in the catchment of Globocica

When comparing the total amount of produced and transported sediment the immediate catchment of the reservoir and the catchment of the Drim River have similar values. The produced sediment is higher of the catchment of the Drim River, 54% vs. 46% of the area. On the other hand the total transported sediment to the reservoir is slightly higher in the immediate catchment, 53% vs. 47%.

Separately, the highest transporters of sediment per unit area is coming from the catchment of Labunishka Reka 479 m^3/km^2/year. Also, other rivers with high transport values are Rechica and Golema Reka, 300 and 278 m^3/km^2/year, respectively.

4 CONCLUSIONS

According to the current situation in certain parts of the basin, primarily due to unfavourable environmental conditions, it cannot be expected that without the support of the human, nature will be able to establish the expected balance, primarily in the immediate catchment area of the reservoir Spilje, where the intensity of erosion is extremely large.

In catchment area affected by mildly strong, strong and extremely strong phenomena and processes of erosion, inevitably it is required planning and undertaking appropriate erosion mitigation activities. All these activities should be aimed at reducing the severity of erosion, reduction of the erosive material production and transport. The results of the mitigation activities are aimed at reducing the dynamics of sedimentation in the reservoir, extending the life of the reservoir and a sustainable, cost-effective planning and utilization of the hydropower potential of the available water from the catchment of the reservoir Spilje.

On the other hand, the catchment of the reservoir Globocica has much milder erosion processes. It can be concluded that the situation is much better. This is mainly due to lower or in some cases non-existent human impact.

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TIMBER PRODUCTION IN POPLAR PLANTATIONS WITH DIFFERENT PLANT SPACING

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ABSTRACT: The paper presents the results of a study of the impact of plant spacing of different poplar clones on the revenues generated per unit area. The research was carried out in six sample plots in the period from 2007 to 2016. The research object are clones *Populus×euramericana* 'I-214', *Populus×euramericana* 'M1' and *Populus deltoides* PE 19/66. On the basis of the results of this research, it can be concluded that larger plant spacing causes an increase in revenues at the same age of a plantation, with a small difference in production costs. The type of clone has a significant impact on the potential qualitative structure of the assortments, as shown by the results of the analyses of increment of clones PE 19/66 and I-214 at the same age. Until the fifth year of age, a higher diameter increment was found for clone PE 19/66, and from the fifth year of age for clone I-214. In addition, hexagonal plant spacing produced a higher diameter increment compared to tetragonal plant spacing.
Key words: poplar, plant spacing, assortment structure, revenues and costs

1 INTRODUCTION

Poplar is the most common tree species in the forests managed by the PE "Vojvodinašume". The establishment of poplar plantations began after World War I, but plantations on large areas were established after World War II. During the 1960s, clone I-214 (*Populus×euramericana* (Dode) Guinier) was introduced into production, because it showed high production potentials and resistance to pathogens. Similar to the clones previously used for the establishment of plantations, the sensitivity of this clone to the pathogens of cortical tissue (*Dothichiza populea* Sacc. et Br.) and leaf (*Melampsora* sp. and *Marssonina brunnea* Ell. et Ev.) increased over time, as well as to the mass epiphytotics of the pathogen *populea* Sacc. et Br. on large surfaces, which culminated in 1977-78.

The problem was solved by introducing new poplar clones, primarily the clones of American black poplar (*Populus deltoides* Bartr. ex Marsh.) into production, as they showed resistance to the pathogens of bark and leaf, as well as significant advantages in terms of production in comparison with clone I-214 in the first half of rotation [11].

Nevertheless, clone I-214 is still very much present in the territory of Vojvodina. Poplar cultivation as a specific and intensive way of production of wood assortments is gaining importance worldwide and in this country due to the high value of poplar wood in use. Poplar wood is used for different purposes [4], [15], [2], [21]. [12] investigated the impact of age on the properties of wood for three clones of Euramerican poplar, including clone 'I -214', and concluded that age significantly affects them.

Since poplar is characterized by rapid growth and a short production cycle, it is increasingly used worldwide as a raw material for energy use. Research related to the testing of the energy value of poplar wood shows that its use for this purpose is justified [20], [3], [9].

Factors with an impact on the yield of wood mass per unit area are numerous, and among them need to be mentioned the type of clone, plant spacing, soil type, hydrological conditions, tending measures, etc. [22], [8], [19], [10], [5], [6]. These factors influence the length of production cycle, i.e. the efficiency of production.

Na optimalnim zemljištima, uz obezbeđenje svih potrebnih tehnoloških mera, klon I-214 nakon 31. godine starosti stabla pokazuju visok proizvodni potencijal što predstavlja i reperni osnov za postizanje visokih proizvodnih efekata u zasadima topola [1].

On optimal soils and when all necessary technological measures are provided, clone I-214 shows a high production potential after the 31st year, which also serves as a benchmark for the achievement of high production effects in poplar plantations [1].

The aim of this paper is to determine whether plant spacing has an impact on the production potential of poplar clones PE 19/66, I-214 and M1, as well as to determine the age at which profit can be expected.

2 RESEARCH OBJECT

The research was carried out in six sample plots (SPs) in the period from 2007 to 2016. In the area of PE "Vojvodinašume" in the FA "Banat", the FMU "Donje Podunavlje" compartment 54 section a and sections b (Figure 1).

Figure 1: Position of the sample plots in the FMU „Donje Podunavlje" compartment 54 section a and 54 section b

The sample plots were established in the plantations of *Populus × euramericana* 'I-214', *Populus × euramericana* 'M1' and *Populus deltoides* PE 19/66. The plant spacing is tetragonal, and the distance is 5 × 5 m and hexagonal, with distances of 6 × 6 and 6.5 × 6.5 m. The number of trees per hectare varied depending on the plant spacing and distance of planting.

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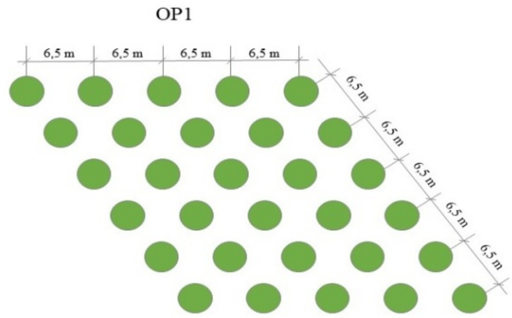
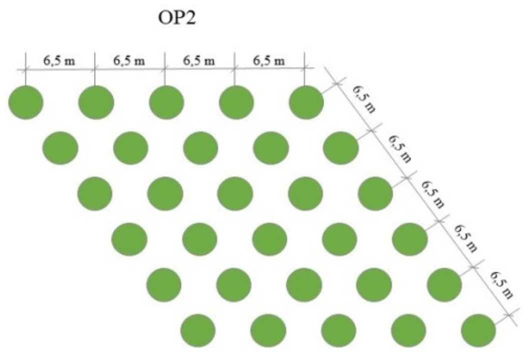
Table I shows the characteristics of plantations in which the sample plots were established.

Table I: The characteristics of plantations in which the sample plots (SP) were established

Sample plot	Type of clone	Period of measurements	Plant spacing	Spacing between the lines (m)	Number of stems per hectare	Planting depth
SP 1	I-214	1-10	hexagonal	6×6	320	shallow
SP 2	PE 19/66	1-10	hexagonal	6×6	320	shallow
SP 3	I-214	1-10	hexagonal	6,5×6,5	272	shallow
SP 4	PE 19/66	1-10	hexagonal	6,5×6,5	272	shallow
SP 5	I-214	3-13	tetragonal	5×5	400	shallow
SP 6	M1	3-13	tetragonal	5×5	400	shallow





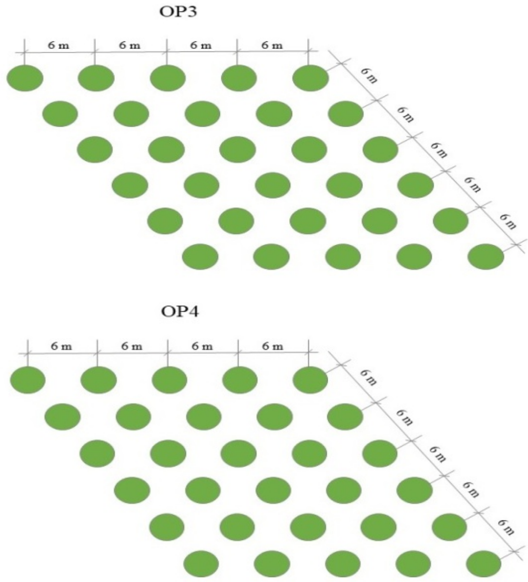


Figure 2: Scheme of the experiment with hexagonal plant spacing (SP1, SP2, SP3 and SP4)

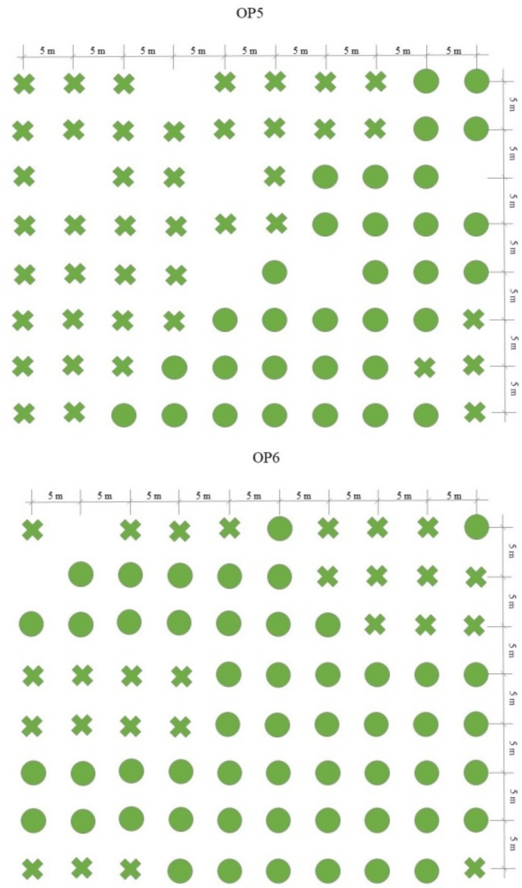


Figure 3: Scheme of the experiment with tetragonal plant spacing (SP5 and SP6)

O – denotes the place taken by the stem in the plantation, X – denotes the place where the planted tree died or was felled in the meantime.

Figures 4 and 5 show hexagonal plant spacing in the sample plots.

Figure 4: Hexagonal distribution of stems 6×6 m of clone PE 19/66 in SP3

Figure 5: Hexagonal distribution of stems 6×6 m of clone I-214 in SP1

The same type of forest can be found in all sample plots: the forests of ash and pedunculate oak (*Fraxineto-Quercetum*) on marsh black soils. The depth of planting in hexagonal plantations is shallow, and it is deep in the ones with tetragonal spacing. All experiments were located in the area protected from floods in the FMU "Donje Podunavlje".

At hexagonal plant spacing (6 × 6 m) for clones I-214 and PE 19/66 the size of the sample plot was 0.094 ha, and at the plant spacing of 6.5 × 6.5 m it was 0.110 ha. In the case of tetragonal plant spacing (5 × 5 m) of clone I-214, the sample plot area was 0.27 ha, and of clone M1 it was 0.23 ha.

3 METHOD

In all sample plots, perimeters of the stems were measured at breast height every year. Wood volume was calculated on the basis of the diameter and height degree. The estimation of the share of technical and stack wood in the total volume was based on the experience gained in similar plantations, where wood volume had already been cut. The shares of certain quality classes in the total volume of technical roundwood were obtained on the basis of provisional assortment tables. The values of timber assortments were obtained on the basis of provisional norms and pricelists of wood assortments of the PE "Vojvodinšume". The costs of establishment and tending of the plantation were calculated. In addition, these costs included the costs of logging, skidding and the tax for felled timber.

Common statistical and mathematical methods were used in this paper.

4 RESEARCH RESULTS

Figure 6 shows wood volume per hectare and Figure 7 the mean diameter of a tree at the age of ten years in the plantations of different clones by sample plots.

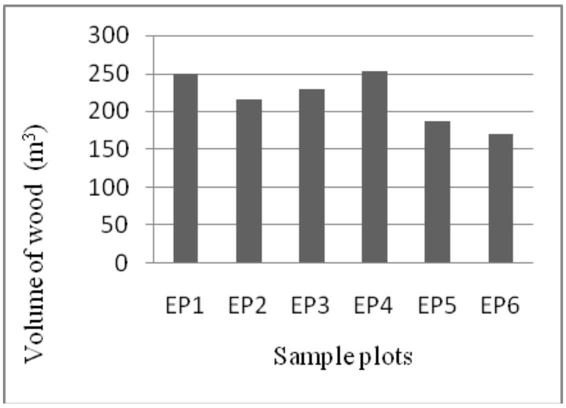


Figure 6: Wood volume in plantations of different clones

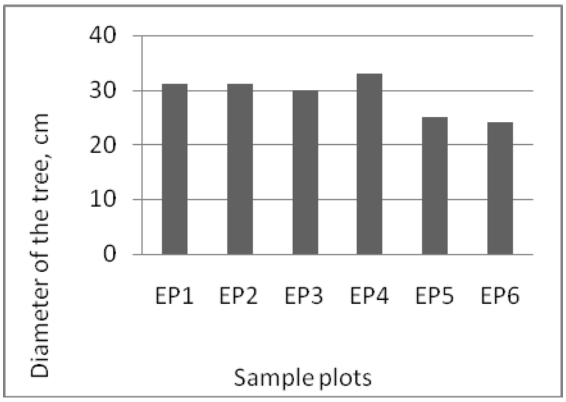


Figure 7: Mean diameter in plantations of different clones

The highest wood volume and consequently the largest mean diameter of a tree were obtained in the plantation of clone PE 19/66 (SP4), and the lowest volume was found in the case of clone M1 plantation (SP6).

Figure 8 shows the diameter increment per hectare at the age of ten years in sample plots 1, 2, 3 and 4.

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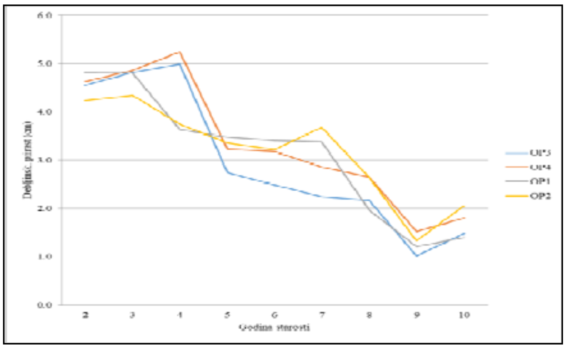

Figure 8: Diameter increment at hexagonal plant spacing

The highest diameter increment at the age of ten years was recorded for clone PE 19/66 with a 6.5 × 6.5 m plant spacing (SP2). In the period from the eight to the tenth year of age, a higher diameter increment was achieved in the plantations of clones with a larger plant spacing.

The technological assortment structure is shown in Figure 9, and the assortment structure in Figure 10.

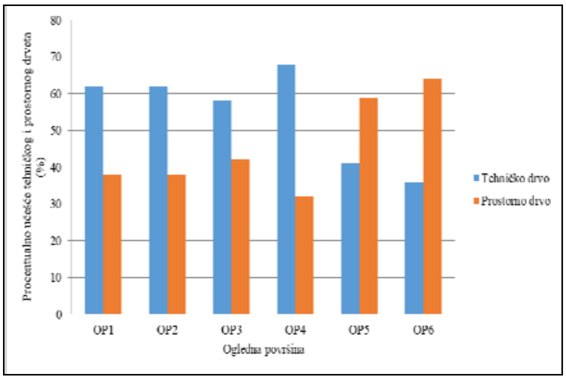

Figure 9: Technological structure of assortments

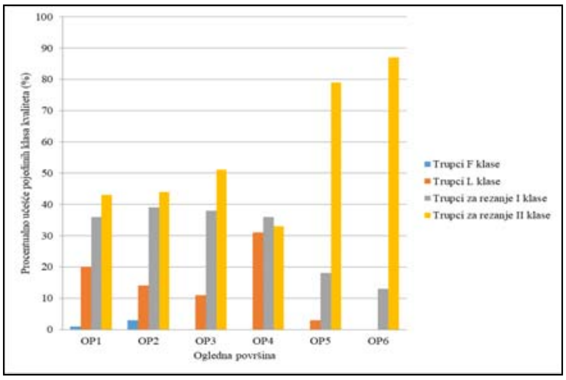

Figure 10: Assortment structure of technical roundwood

The best technological and assortment structure was achieved in the plantation of clone PE 19/66 (SP4), and the worst one in the plantation of clone M1 (SP6).

Potential assortment structure is the volume share of the assortments of wood of certain classes in the total volume of technical roundwood.

The largest share of F and L class assortments was recorded in SP1 and SP2, where plant spacing was 6.5 × 6.5 m.

Figure 11 and 12 show direct costs of production of unit products and potential revenues that would be achieved at the plantation age of ten years.

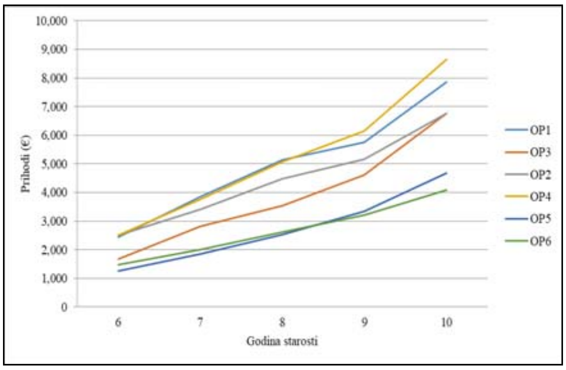

Figure 11: Dependence of profits on plantation age

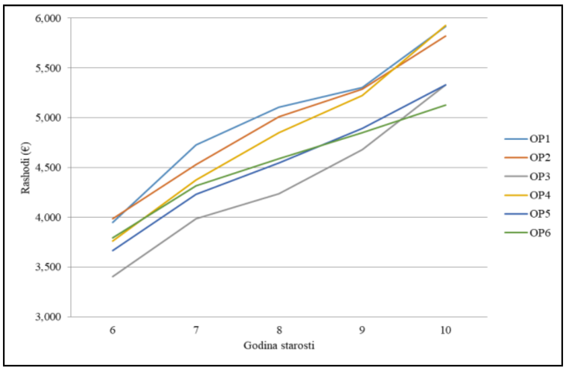

Figure 12: Dependence of expenditures on plantation age

The highest costs and at the same time revenues at the tenth year of age were achieved in the plantation of clone PE 19/66 (SP4), and the lowest values were found in the plantation of clone M1 (SP6).

The profit per hectare was calculated on the basis of the difference between revenues and costs (Figure 13).

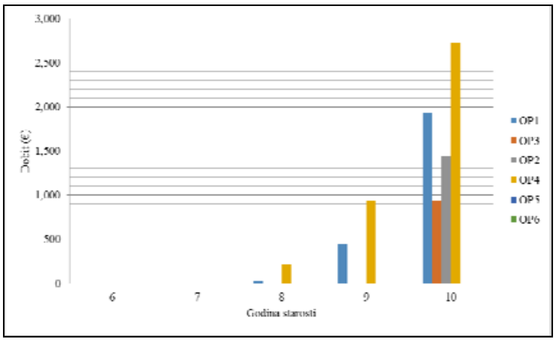

Figure 12: Correlation between the age of the plantation and revenues

At the age of eight and nine years, profits are generated in the plantation of clone I-214 (SP1) and in the plantation of clone PE19/66 (SP4). At the age of ten, profits have still not appeared in the plantations of clones with a 5 × 5 m plant spacing.

4 DISCUSSION OF RESEARCH RESULTS

In these studies the largest mean diameter and the largest volume per hectare were found in SP4 out of six sample plots, i.e. in the plantation of clone PE 19/66 with a 6 × 6 m plant spacing, while the smallest diameter and volume were recorded in SP6, where planting was performed with clone M1 using a 5 × 5 m plant spacing. This was expected, given that according to previous studies, new clones on better quality soil produce significantly higher wood mass per hectare at the same plant spacing, while the hybrid clone M1 is used more due to its resistance to disease, especially on poor soils.

The largest share of technical roundwood was found in SP4, while the lowest share was recorded in SP6. In terms of assortment structure, the best structure was achieved in SP2, and after that in SP1, where plant spacing was 6.5 × 6.5 m. Clone I-214 in SP1 is expected to reach the value of wood assortments of clone PE 19/66 in the coming years. The reason for this is higher diameter increment of clone I-214 in the period from the fifth to the tenth year of age. This is a potential assortment structure based only on dimensions, assuming that other characteristics of the stem are within tolerable limits (Nikolić, 1988, 1993, Danilović 2000).

From the seventh to tenth year of age the diameter increment is higher in the plantation with a 6,5 × 6,5 m, plant spacing, which will produce a higher value of wood assortments in the coming years, and thus higher profits compared to the plantation with a 6 × 6 m spacing.

The highest revenues were recorded in SP4, while the lowest revenues were found in SP6. The reason for this is direct connection between the diameter of a tree and potential structure of the assortments, i.e. minimum dimensions as a limiting factor in the production of more valuable assortments. The impact of this factor on the value structure of assortments amounts to 2.68% (Danilović, 2011).

Profit is achieved in the case of hexagonal plant spacing (6 × 6 m) in the plantation of clone PE 19/66 (SP4) from the age of eight to ten years, and at a 6,5 × 6,5 m spacing profit appears at the age of ten years (SP2). In the case of 6.5 × 6.5 m plant spacing of clone I-214, like in SP4, the profit appears already at the age of eight years.

In the case of 6,5 × 6,5 m plant spacing, profit was expected to be achieved earlier, due to the larger area for the development of trees. However, this did not happen, probably due to poorer rooting of the seedlings in the first years of plantation development.

In the case of tetragonal plant spacing (5 × 5 m) profit was not generated at the tenth year of age of the plantations of clones I-214 and M1. According to research data, profit will appear earlier in the I-214 clone plantation compared to the clone M1 plantation. The reason is that clone M1 on average has a higher diameter increment by 4 mm until the fifth year of age and therefore also a higher value of wood assortments, and clone I-214 from the fifth to the tenth year.

Generally, based on the results of this research, a higher value of wood assortments at the age of ten years was found at larger plant spacing compared to smaller plant spacing. At larger spacing per unit area, there is a smaller number of trees, which provides greater space per tree. Consequently, a better assortment structure can be achieved, thereby increasing the value of wood assortments.

5 CONCLUSIONS

The following conclusions can be reached on the basis of the above research:

- In the *Populus × euramericana* 'I-214' poplar plantation with a 6 × 6 m hexagonal plant spacing profit is achieved at the age of ten years, and in the case of 6.5 × 6.5 m plant spacing it appears at the age of eight years.
- In the poplar plantations of *Populus deltoides* 'PE 19/66' at a 6 × 6 m hexagonal plant spacing, profit appears at the age of eight years, and in the case of 6.5 × 6.5 m plant spacing at the tenth year.
- So far, no profit has been observed in the case of tetragonal 5 × 5 m plant spacing at the age of ten years for both clone I-214 and clone M1.
- At the same plantation age the value of wood assortments is higher at a larger plant spacing observed over a period of ten years.
- Since these are some of the first results of the research related to determining and comparing the profits in plantations of different clones, these studies need to be continued so that they can serve as the basis for selecting the suitable clone from the economic point of view.

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TESTING THE APPLICABILITY OF THE MATHEMATICAL MODEL FOR FOREST OPENNESS

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ABSTRACT: In order to establish the applicability of the mathematical model for determining the theoretical optimal density of the forest roads in Republic of Macedonia, a testing of the model in practice has been conducted. Mathematically, the theoretical optimal density is acquired as a sum of the optimal density of forest roads and the density of the receptors. Additionally, models for the optimal density of forest roads have been graphically designed in the software ARC MAP. The existing network of forest roads, as well as the area which is theoretically opened, have been taken as a basis for these graphic models. Additionally, the necessity for building new forest roads in order to create the complete network of forest roads in the area has been determined. At that, the new roads have been designed on the basis of the optimal distance of the forest roads acquired according to the mathematical model for optimization of the density of truck roads. Seven forest economic units at the area of the Forestry Plackovica in Radovis have been tested, and at the results that were obtained from the design of the optimal network and the theoretical optimal density of the forest roads, average relative absolute variation of 14% has been determined. The results that were obtained confirm the application of the mathematical model which was set for the optimal density of forest roads in Republic of Macedonia, drawing a conclusion that certain deviations from the mathematical solution are possible.

Key words: forest openness, optimal density, theoretical density, receptors, mathematical model, relative absolute variation

1 INTRODUCTION

The building of the forest road network in Republic of Macedonia is in an advanced phase in most of the economic forests. Therefore, when finding a solution for the optimal density of forest roads it is necessary that the existing road network is included.

In the past, in Republic of Macedonia, there have been mistakes in relation to the development of the forest road network, because according to the Law it is allowed the planning of the roads to be connected strictly with the designing of the special plans for forest management. Thus, in many situations the lack of professional solutions when designing forest roads is evident. The road network has been developed, and is still being developed, without a precise mathematical model for forest openness, and without appropriate design documentation, i.e. without creating general plans for forest openness.

For the needs of this research, seven forest economic units in the Public Company “Macedonian Forests”, Forestry Plackovica – Radovis, have been covered. These forests have: different openness, different form of cultivation, different models of management, and so on.

At all these forest economic units the existing roads, as well as the area that is opened by these roads in relation to the mathematical model for optimization have been considered. In that way the real area which has been opened with the forest roads is obtained.

For the non-opened area there is a design of a road network according to the mathematical model for theoretical optimal density in order to create the complete road network. In the end one gets results about the current density of the forest road network, i.e. the final necessary density of the road network for each of the forest economic units that have been tested.

In the future, in Republic of Macedonia, it would be best that before designing the special plan for forest management, one to design a general plan for forest opening on the basis of the real situation of the forest transport and the appropriate mathematical model for forest openness, for every forest economic unit.

2 METHOD OF WORK

In order to establish the applicability of the mathematical model for theoretical optimal density, an appropriate testing has been conducted in the department of the Public Enterprise “Macedonian Forests”, Forestry Plackovica in Radovis, for the forest economic units: Smrdesnik, Radoviska River – Oraovicka River, Konecka Mountain, Goten, Sirava River, Smiljanska River – Left River, Plackovica and Lomija River.

In this paper, the research was made in three different ways of skidding: skidding with animals (horses), skidding with adapted tractor Ford 5600 and skidding with cable railway (type KOLER). This is old machinery which often suffers from breakdowns. The research was conducted on Plackovica and Kozuf mountains Republic of Macedonia. The gradient of the terrain varied from 30 to 45 %, and the dominant wood type is beech, with assortment wood structure: 60% firewood and 40% technological tree or logs. In this research the skidding with the animals and the tractor was mostly done in fall, only a small part was done in increase, whereas with the cable railway the total skidding was done in increase.

With the research we have come to the conclusion that in all the researched cuttings the assortment technology has been applied. This means that after the cutting the wood is trimmed on the very spot by the tree-stump. The assortments are made after the trimming. In all the researched cases two types of assortments have been produced: fire or spatial wood, and technological tree or logs. At the production, not much attention has been given to adjusting the cutting to the technology of skidding, i.e. the type of the skidding method.

The theoretical model for forest openness is presented in Figure 1; at that this model for forest openness is in the form of irregular chess field, typical for mountain terrains which are usual in the Republic of Macedonia.

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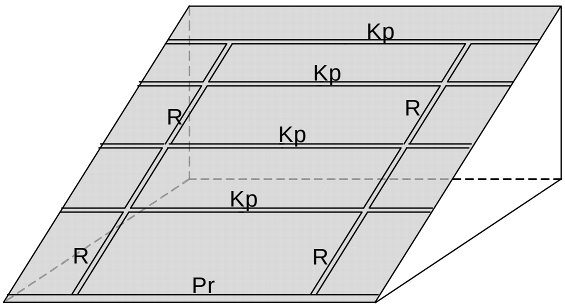

Kp – Truck road   R- Receptor   Pr – Public road

Figure 1: Graphic display of the theoretical model for forest openness in mountain conditions

Truck roads are roads built in the forest, which are used for transport (export) of wood assortments. These roads thoroughly open the area so that the skidding of all the wood assortments can be made from the place of cutting to the truck road. In mountain conditions these roads are usually built horizontally or under a mild longitudinal gradient on a slope, and that is why they are also called storey truck roads.

Receptors are truck roads which are primarily used for the transport of wood assortments to the final consumer. They are positioned in such a way so that they redirect the movement from the truck roads towards them. In certain situations a partial skidding of wood assortments can be made on the receptors, but their role is not primarily for that purpose. These roads are used for a longer period of time during the year.

The approach to a solution for the optimal network of forest roads could be very different, but in practice it has been proven that the best solution is reached if one starts from the economic moment, i.e. minimal costs for transport are requested, and at that the network of forest roads must fulfill all the necessary conditions for normal forests' management on the basis of ecological principles.

In solving this problem it has been noted that there is different relation between the optimal density of truck roads and the optimal density of receptors. That is why two analyses are conducted, with which the optimal density of truck roads is separately calculated, i.e. with a separate mathematical procedure the optimal density of the receptors is determined.

Mathematically, the theoretical optimal density (Gkptheo) is acquired as a sum of the optimal density of forest roads and the optimal density of the receptors.

$$Gkp_{real} = Gkp + GR \qquad (1)$$

Gkp - density of truck roads
GR - density of receptors

2.1 Optimization of the road network

The methodology described in Z. Trajanov [5] has been used in the production of this scientific paper. The optimal density of road network is calculated by differential calculations, i.e. the first deduction from the total costs for transport.

The equation (1) is used for calculating the optimal density of road network for wood transport.

$$\frac{DT_{sum}}{DG_{kp}} = 0 \qquad (2)$$

Total costs for tractor skidding - *Tsum,* are calculated with the equation (2).

$$T_{sum} = T_t + T_{kp} + T_{dp} \qquad (3)$$

Tt – costs for tractor skidding
Tkp – costs for truck roads
Tdp – costs for tractor roads

This formula is the basis for calculating the optimal density of road network. Similar methodology has also been used in other researches from this area, in the Republic of Macedonia, researches of R. Akimovski [2]. The reason why this methodology is being used, as well as the introduction of changes, is because of the new mathematical software which can solve complicated problems. Therefore, in contrast to the past situations when many parameters have been neglected in order to get simpler formulae for calculation, the new software solutions do not put limits to the number of unknown parameters and the combining of various mathematical operations. The new software also provides us with flexibility, i.e. easy calculations for each situation separately, all in order to get more accurate results. This paper will analyze the solutions obtained for a specific situation in the practice of skidding of wood assortments with tractors, in the mountain Plackovica in the Republic of Macedonia.

The optimal density of forest roads does not offer a complete solution for the density of forest roads in real circumstances where there is a necessity for joining the storey roads, as well as real losses in the aspect of errors in the design of the existing road network, the relief of the terrain and so on.

The solution is improved with completing the model and using the density of receptors in the final calculations for theoretical optimal density of forest roads.

The density of receptors is calculated with a differential calculation, estimating the first deduction according to the equation:

$$\frac{DTR_{sum}}{DGR} = 0 \qquad (4)$$

TR_{sum} -Total costs for receptors

This methodology is thoroughly elaborated on by Z. Trajanov [6].

In order to establish the applicability of the theoretical mathematical model in real conditions of a forest openness it is necessary all the roads to be designed completely, i.e. a general plan for forest opening to be made. When designing the new roads in the aspect of forest openness, the most useful tool for the designer is the optimal distance of forest roads in the area.

The optimal distance of roads Rкp is calculated according to the formula:

$$Rkp = \frac{1ha}{Gkp} \qquad (5)$$

Gkp–Optimal density of truck roads

With this tool the designer can come to a decision whether to design a certain road or roads, i.e. whether there is economic justifiability from the designing of new roads.

Whenever one talks about a solution for theoretical optimal density of the road network, one must make a distinction between two procedures for establishing the solution:

- A mathematical procedure for determining the theoretical optimal density
- A designed optimal density which is acquired with a direct designing of the road network on the basis of previously determined mathematical principles

In order to see the applicability of the mathematical model for theoretical optimal density in the department of the Public Company “Macedonian Forests”, Forestry “Plackovica” in Radovis, electronic maps for all the forest economic units have been designed in GIS, on which the existing roads have been displayed. By using the mathematical model, i.e. previously defined buffers in relation to: the means of skidding, technology of work, relief, wood allowable as a potential for use and so on, the open area is being defined. This method is elaborated on by Pentek T. [8] and Danilovic M. [9]. In the non-opened areas, new roads have been designed in order to open the total area in the forest economic unit.

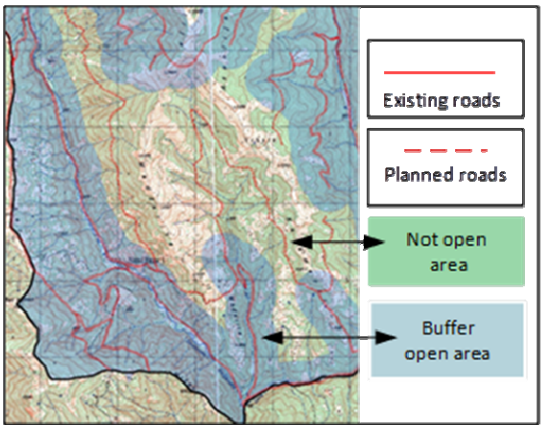

Figure 2: Graphic display of the existing and the planned road network

In Figure 2, there is a segment of the electronic map for the forest economic unit Smiljanska River. The open part of the area segmented with buffers is displayed in the image, marked with blue color. The remaining part is not open and that is where new roads are being designed.

The area which was opened with the newly planned roads is also tested with buffers, in order to determine the total open area. At that, it was insisted on the total open area to be over 90%.

3 RESULTS - TESTING OF THE THEORETICAL OPTIMAL DENSITY OF FOREST ROADS

According to the research, a connection between the density of the road network and the volume of wood that would be used when managing the forests can be established. The data for the optimal density of the road network according to the wood coverage is given in Figure 3.

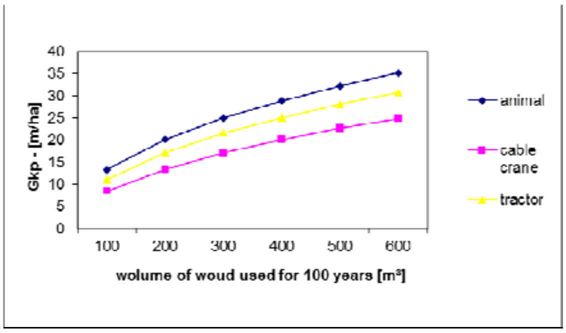

Figure 3: Relation of the optimal road network density to the amount of the volume of wood used for 100 years

From the Figure 3 one can see that with the increase of the volume of used wood, the density of the optimal road network also increases.

The results for optimal density of forest roads with horse skidding are presented in the scientific paper of Z. Trajanov [5] and [7].

One can also come to a conclusion that there is an obvious distinction of the optimal density of forest roads in relation to the different means of skidding. In the further estimations the tractor will be taken as a referential means of skidding, for which average values for the optimal density of forest roads are acquired. The tractor is also the most commonly used mechanical means of skidding in the Republic of Macedonia.

In table I, data about the areas of the forest economic units, as well as data about the possible usage of wood allowable in the period of a hundred years are presented. Additionally, data about the condition of the density of forest roads, the mathematical projection of the optimal density and the density of receptors determined according to the mathematical model are elaborated on.

The sum of these mathematical densities gives the relative optimal density of the forest roads. At the forest economic units with a lower potential of use of the wood allowable, a lower density of forest roads will be designed. The lowest theoretical optimal density is planned for the FEU Smrdesnik, with density of 14,89 m/ha. The highest theoretical optimal density of forest roads is planned for the FEU Plackovica – Lomija River, with density of 34,95 m/ha.

The implementation of the optimal density of forest roads, as well as the optimal density of the receptors, determined by models, in practice is followed by certain deviations which depend on many factors. Such factors are: the natural circumstances of the terrain, the condition of the forest, the condition of the bare parts in the forest, the models for the forest management, the technology of transport of wood assortments, the way of cultivation of the outer forest borders, the condition of the urban areas in the forest, and so on. All these factors oscillate in various areas of forest openness and additionally make the problem complicated for solving.

In the real circumstances, a factor which mostly influences the implementation of the theoretical optimal network of forest roads is the existing road network. All the errors which occur from the unplanned development of the road network are somehow implemented in the solution.

Table I: The condition of the forest openness and the theoretical optimal density of the road network according to forest economic units

Forest economic unit	Area	Used wood allowable	Density of forest roads			
			Condition until 2016	Optimal	receptors	Theoretical optimal
name	[ha]	[m³/100 years]	[m/ha]	[m/ha]	[m/ha]	[m/ha]
Smrdesnik	5,470.00	111,00	7,90	11,86	3,02	14,89
Radoviska River - O.R.	8,600.67	139,00	11,80	13,67	3,37	17,04
Konecka Mountain	3,381.93	157,00	21,70	14,82	3,59	18,42
Goten	6,228.00	160,00	8,58	15,00	3,63	18,63
Sirava River	4,921.68	138,00	7,97	19,02	4,43	23,45
Smiljanska River - L.R.	4,612.40	362,00	19,13	23,83	5,46	29,29
Plackovica – Lomija River	2,387.30	513,00	29,49	28,45	6,50	34,95
Sum/Average	35601,98	225,71	15,22	18,09	4,29	22,25

The existing roads can make higher or lower density of the forest roads in relation to the optimal density. The final effect would be worse financial results, i.e. leaving the level of minimal transport costs.

A checkpoint on the mathematical model for theoretical optimal density could be conducted with the model for graphic designing of the total road network. The complete designing of the forest roads will be made on the basis of the already existing road network, with the help of the mathematical models for optimization and testing of the total solution.

Table II presents the values about the condition of the open and non-open area with forest roads, i.e. a display of the theoretical openness of the forest. In the table there are also values about the length of the existing roads, as well as values about the length of the newly planned roads and the density of those roads.

Table II: The open and non-open area by FEU, existing and planned road network with estimated density of the forest roads

Forest economic unit	Total area	Open area	Non-open area	Relative openness	Existing roads	Density of the open area	Planned roads	Density of the non-open area
	ha	ha	ha	%	m	m/ha	m	m/ha
Smrdesnik	5470,00	2657,59	2812,41	49	43213	16,26	36430	13,0
Radoviska R - O.R.	8600,67	4625,45	3975,22	54	101488	21,94	41484	10,4
Konecka Mountain	3381,93	3128,49	253,44	93	73388	23,46	0	0,0
Goten	6228,00	3286,71	2941,29	53	53436	16,26	43027	14,6
Sirava River	4921,68	2352,45	2569,23	48	39226	16,67	51988	20,2
Smiljanska R - L.R.	4612,40	3901,00	711,40	85	88235	22,62	17993	25,3
Plackovica -Lomija	2387,30	2210,00	177,30	93	74401	33,67	6183	34,9
Sum/Average	35601,9	22161,6	13593,1	62	473388	21,36	197106	14,7

The theoretical openness of the forests is within the range of 48 % (not enough openness) up to 93 % (excellent openness). The average real openness is 62 % which means low openness. The problem of the real forest openness is thoroughly elaborated on by T. Pentek [1].

In table III, the values about the projected optimal density of the forest roads, for all the forest economic units in Radovis, are presented.

With mathematical analysis, a correlation between the two trends has been established (theoretical openness in relation to the projected openness of the forest) of 0.89, which points to a high level of dependence, i.e. a confirmation about the applicability of the offered solution. The relative variations are within the range of -15% to 27%. The relative absolute variation has been estimated about each of the forest economic units, at which deviations within the range of 1 to 27% have been obtained.

Table III: Variations between the real and the projected optimal density of forest roads by forest economic units

Forest economic unit	Projected optimal density Gkp (m/ha)	Theoretical optimal density Gkp (m/ha)	Variation Gkp	Absolute variation	Relative variation	Relative absolute variation
Smrdesnik	14,56	14,89	0,33	0,33	2%	2%
Radoviska R - O.R.	16,62	17,04	0,41	0,41	2%	2%
Konecka Mountain	21,70	18,42	-3,28	3,28	-15%	15%
Goten	15,49	18,63	3,14	3,14	20%	20%
Sirava River	18,53	23,45	4,92	4,92	27%	27%
Smiljanska River - L.R.	23,03	29,29	6,26	6,26	27%	27%
Plackovica-Lomija River	33,76	34,95	1,19	1,19	4%	4%
Average	20,53	22,25	1,85	2,79	10%	14%

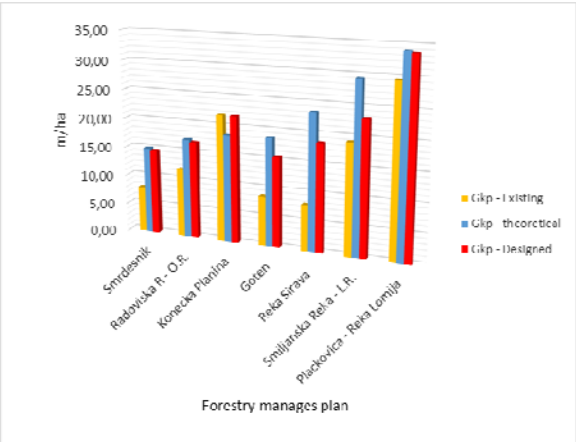

Figure 3: A comparison among the density of the road network, the theoretical optimal density and the projected optimal density of forest roads, by forest economic units.

A display of the condition of the density of forest roads, the mathematically obtained theoretical optimal density and the graphic-analytical projected optimal density for all the forest economic units in the Public Company “Macedonian Forests”, Forestry “Plackovica” in Radovis, are presented in Figure 3.

4 DISCUSSION

The theoretical optimal density is acquired as a sum of the optimal density and the density of receptors. The theoretical optimal density is a mathematical quantity towards which one should strive when opening the forests. The results that were obtained confirm the application of the mathematical model which was set for the optimal density of forest roads in Republic of Macedonia, drawing a conclusion that certain deviations from the mathematical solution are possible. With mathematical analysis, a correlation between the two trends has been established (theoretical openness in relation to the projected openness of the forest) of 0.89, which points to a high level of dependence, i.e. a confirmation about the applicability of the offered solution. The relative variations are within the range of -15% to 27%. The relative absolute variation are within the range of 1 to 27% have been obtained.

5 CONCLUSIONS

- Mathematically, from the optimal density we get the Rkp – the optimal distance between two storey truck roads, which is the most useful tool for designing forest roads.
- The current density of the forest truck roads in the Forestry “Plackovica” is within the range of 7.97 m/ha to 29.49 m/ha. In average these forests are open with 15.22 m/ha.
- The existing roads can generate higher or lower density of forest roads in relation to the optimal density. The final effect is worse financial results, i.e. leaving the level of minimal transport costs.
- The theoretical optimal density of the forest truck roads in the Forestry “Plackovica” should be within the range of 14.89 m/ha to 34.95 m/ha. In average these forests should be open with 22.38 m/ha.
- The usable value of the theoretical optimal density has been tested by making the planned optimal density of forest roads, with the help of the buffer method with previously determined mathematical parameters.
- With mathematical analysis, a correlation between the two trends has been established (theoretical openness in relation to the projected openness of the forest) of 0,87% which points to a high level of dependence, i.e. a confirmation about the applicability of the offered solution. The average relative absolute variation is 14%.
- The relative optimal network is an accounting quantity; it can be lower or higher in relation to the existing road network. Thus, the relative variations are within the range of -15% to 27%.

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- In the future, this methodology should be tested on more samples in relation to more parameters, and in that way more precise conclusions could be drawn about its applicability in the forest practice in the Republic of Macedonia.

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[12] Forest management plan for the forest spatial unit "Konecka Mountain", Skopje 2010
[13] Forest management plan for the forest spatial unit "Goten", Skopje 2006
[14] Forest management plan for the forest spatial unit "Sirava River", Skopje 2011
[15] Forest management plan for the forest spatial unit "Plackovica - Lomija River", Skopje 2009
[16] Forest management plan for the forest spatial unit "Smiljanska River – Leva Reka", Skopje 2015

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THE EURASIAN DRY GRASSLAND GROUP (EDGG) 13th EURASIAN GRASSLAND CONFERENCE REPORT: MANAGEMENT AND CONSERVATION OF SEMI-NATURAL GRASSLANDS- FROM THEORY TO PRACTICE
(20-24 September 2016, Sighişoara, Romania)

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In this report made is review of what is the Eurasian Dry Grassland Group (EDGG) and since when exists? Listed are the main activities of the EDGG. Given is review of so far realized 13 conferences, with special emphasis on the last realized 13th Eurasian Grassland Conference "Management and conservation of semi-natural grasslands: from theory to practice", held on 20-24 September 2016 in Sighişoara, Romania.

INTRODUCTION

The Eurasian Dry Grassland Group (EDGG, formerly known as European Dry Grassland Group) is an official working group of the International Association for Vegetation Science (IAVS) and was founded in 2008. The EDGG is a network of currently 1141 members from 64 countries (26 July 2016), interested in Palaearctic natural and semi-natural grasslands from any point of view, including fauna, flora, vegetation, ecology biodiversity, conservation, land use and management.

The main activities of the EDGG are:

1) The facilitation of international communication between researchers, site managers, policy and decision-makers;
2) Coordination of scientific and policy-related actions in grassland research, conservation and restoration in the whole Palaearctic;
3) Promotion of the development of databases for grassland classification, best-practice in conservation and restoration;
4) Organisation of annual events, such as the Eurasian Grassland Conferences (EGCs) and Field Workshops (formerly known as EDGG Research Expeditions); and
5) Dissemination of research results in Special Features of peer-reviewed international journals such as Agriculture, Ecosystems & Environment , Biodiversity and Conservation (Habel et al. 2013, Török et al. 2016), Applied Vegetation Science, Plant Biosystems, Tuexenia and Hacquetia.

The EDGG has undergone a number of fundamental changes during 2015. First of all, whilst they are still the EDGG, "EDGG" now stands for 'Eurasian Dry Grassland Group', in place of the previous 'European Dry Grassland Group'. This reflects a broadening in their geographical scope that has been evident for a considerable time, with active contributions from North Africa, the Near East and Central Asia. The grassland biome extends eastwards far beyond the borders of Europe, and their interest and activities certainly do not end at the European border. The scope of the EDGG has also been modified to cover all Palaearctic natural and seminatural grasslands, without the previous restrictions to dry grasslands and to Europe. This change reflected in the sub-title they have added to the name of the organization, "Eurasian Dry Grassland Group – Grassland Research and Conservation".

CONFERENCES

So far have been realized 13 conferences:

- 2004: 1st European Dry Grassland Meeting: Dry grasslands as biodiversity hotspots (Lüneburg, Germany)
- 2005: 2nd European Dry Grassland Meeting: Observation scales in dry grasslands (Münster, Germany)
- 2007: 4th European Dry Grassland Meeting: Restoration and spontaneous establishment of dry and semi-dry grasslands at traditional and urban-industrial sites (Freising-Weihenstephan, Germany)
- 2008: 5th European Dry Grassland Meeting: Dry grasslands in a changing environment (Kiel, Germany)
- 2009: 6th European Dry Grassland Meeting: Dry grasslands – species interaction and distribution (Halle (Saale), Germany)
- 2010: 7th European Dry Grassland Meeting Succession, restoration and management of dry grasslands (Smolenice, Slovak Republic)
- 2011: 8th European Dry Grassland Meeting Dry grassland of Europe: biodiversity, classification, conservation and management (Uman', Ukraine)
- 2012: 9th European Dry Grassland Meeting Dry Grasslands of Europe: Grazing and Ecosystem Services (Prespa, Greece)
- 2013: 10th European Dry Grassland Meeting When theory meets practice: Conservation and restoration of grasslands was held in Poland 24-31 May, Zamosc
- 2014: 11th European Dry Grassland Meeting "Steppes and Semi-natural dry grasslands: ecology, transformation and restoration" was held in Russia, Tula, 5-15 June
- 2015: 12th European Dry Grassland Meeting "Population biology and community ecology of dry grasslands and dry grassland species" was held in Germany, Mainz, 23-26 May
- 2016: 13th Eurasian Grassland Conference "Management and conservation of semi-natural grasslands: from theory to practice" 20-24 September 2016 in Sighişoara, Romania

Until now, we have taken participation at three conferences of EDGG:

Ćušterevska. R., Matevski V., Kostadinovski. M., Čarni. A., 2010, Main characteristics and spreading of the plant community ass. *Erysimo-Trifolietum* Micevski 1977 in the Republic of Macedonia, 7th European Dry Grassland Meeting in Smolenice (Slovakia)

Vassilev, K., Aćić, S., Ćušterevska, R., Pedashenko, H., Todorova, S., Apostolova, I., Bergmeier, E., Boch, S., Čarni, A., Ganeva, A., Kostadinovski, M., Matevski, V., Pirini, C., Sopotlieva, D., Stefanović Dajić, Z., Stoyanov, J., Tsiripidis, I., Dengler, J. 2012. What do we know about diversity of dry grasslands on Central Balkan Peninsula?, 11th European Dry Grassland Meeting in Prespa, Book of Abstracts, 79-80. Prespa (Greece).

Ćušterevska. R., Matevski V., Kostadinovski. M., Čarni. A., 2016, Grassland vegetation on the national park Galičica (SW Macedonia), 13th Eurasian Grassland Conference "Management and conservation of semi-natural grasslands: from theory to practice" 20-24 September 2016 in Sighişoara, Romania

2.1.2016: 13th Eurasian Grassland Conference "Management and conservation of semi-natural grasslands: from theory to practice" 20-24 September 2016 in Sighişoara, Romania

The main aims at the 13th annual meeting of the EDGG (formerly known as European Dry Grassland Meetings, EDGM), were to promote exchange and collaboration between those interested in all aspects of grassland research and conservation across Eurasia. The conference intended to bring together latest research, and to link this to practical management and policy contributing to the sustainability of semi-natural grasslands. For the first time, three optional pre-conference workshops were realized:

- Scientific writing for peer-reviewed international journals
- Reflecting ecology in policy
- Establishing and maintaining national grassland databases and using their data for broad-scale vegetation classification and other research

At this conference took part 85 participants.

Conference location

Romania contains five biogeographical regions – Continental, Pannonian, Alpine, Pontic and Steppic – and as such supports a wealth of grassland species.

The region of Transylvania within the arc of the Carpathians is known for its low intensity agriculture and species-rich semi-natural grasslands.

The town of Sighişoara is renowned as a UNESCO World Heritage site, but it is also at the edge of the Sighişoara- Târnava Mare Natura 2000 area. This Site of Community Interest contains large areas of the priority habitat types 6210* Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) with important orchid sites, and 6240* Sub-pannonic steppic grasslands.

Field excursion

The mid-Conference field excursion was visit a selection of sites in the Târnava Mare landscape, with an emphasis on the pastures and positive and negative aspects of sheep-grazing on hills near Viscri were have been demonstrated aspects of pastoral farming and practical management of pastures and adjacent hay-meadows. Plants were still be in flower, notably long-flowering species such as *Prunella* spp. and *Scabiosa ochroleuca*, lilac sheets of *Colchicum autumnale* in mesic grassland, and *Aster amellus*, *Carlina acaulis* and *Gentianopsis ciliata* in drier grassland. We have chance to visit few fortified churches and we join in a traditional village meal at the end of the excursion.

Figure 1: Traditional Roman house (photo R. Ćušterevska, 19.09.2016)

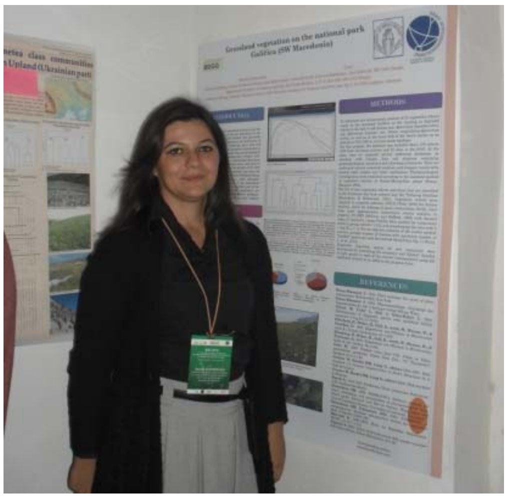

Figure 2: Poster presentation - R. Ćušterevska

Figure 3: Driving with drawn wagons

Figure 4: Traditional village dinner

Figure 5: Oral presentation, conference room in Sighişoara

Figure 6: Field excursion in Apold

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The **title** of the article should be informative and concise. It must be followed by the author(s) name(s) – listing the principal author first, organisation, complete address, telephone, fax and e-mail address.

No logos may appear in the title.

The **abstract** preceding the body of your article should give a brief account of the most relevant aspects of your article, in 200/250 words. Please avoid using symbols, graphics and text formatting (bold, italic, underline) in this part of the document.

Next, in order of importance, select three to six of the most relevant **keywords** and include them in your article. The keywords should be separated with commas.

The **body** of the text must be in **two columns**. Number each heading using decimal numbering. Follow the layout specifications in section 3 below.

3 LAYOUT SPECIFICATIONS

The layout of your article should have exactly the same format as this master document.

Before you start working on your article, if you use Adobe Acrobat, select the printer option "Acrobat Distiller" (version 5.0) or Adobe pdf (version 6.0), in order to avoid accidental misplacement of layout elements afterwards when converting the Word file into PDF format.

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Font type: **Times New Roman**. Font size: **9pt**. Line spacing: **single**. Text alignment: **justified left and right**. Captions should have the same font and size as the typeface used for the text. Make sure that illustrations are clear and easy to read. Please do not use any other font than Times New Roman.

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Page size must be **A4** (210 mm x 297 mm).
Margins: top: 32 mm; bottom: 19 mm; left and right: 25 mm.

The **body of the text must be in two equal columns** of 73.6 mm each. All written parts and images must fit **inside** these margins (for further details see subsection 4.1 about figures and subsection 4.2 about tables).

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Begin at the top of the first page with the **title** of the article in bold capital letters and centered.

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Leave one blank line before each section and one blank line before the heading of each sub-section. Headings and sub-headings should be numbered (e.g. 3, 3.1, 3.2). Separate the numbers from the text of the heading with two spaces.

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All illustrations must be numbered progressively in bold decimals (e.g. **Figure 1**:) and have a reference in the text (e.g. Fig. 1). Captions should be as clear as possible, to allow comprehension of the illustration without reference to the text.

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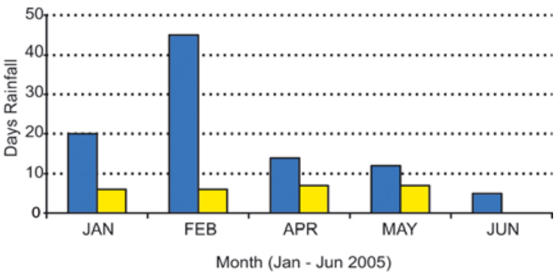

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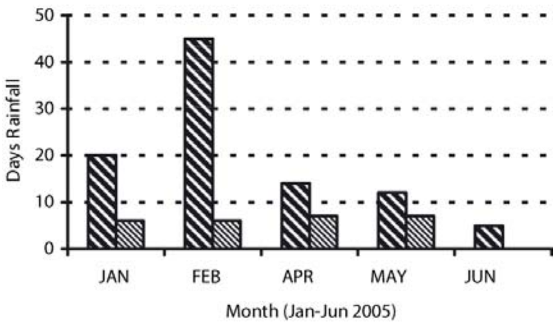

Figure 1: Clear line drawings are essential

4.2 Tables

Tabular presentation of data is an easy way to condense many items. Tables must be numbered in bold Roman numerals (e.g. **Table I**), and have a reference in the text. Captions should be as clear as possible, for an easy comprehension of the tables.

Table I: Overview of biomass resources available

Biomass Sources	Quantity	Moisture	Residue
Sewage Sludge	1.86	1.73	1.40
Septage	0.32	0.28	0.16
Fruit Pulp	3.78	3.89	4.02

4.3 References and notes

References and notes must not appear as footnotes in the pages, but should be listed together at the end of the text, in the dedicated sections.

When referring to them in the text, please type the corresponding reference number in brackets. Use round brackets for the notes (1) and square brackets for the references [1].

To make them easier to find, indent your notes and references from the second line, as in the examples (see sections 5 and 6).

4.4 Acknowledgements

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6 REFERENCES

[1] This section should have the progressive number before the title, exactly as for the previous ones.
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[3] G. Campolmi, Proceedings of the 3rd World Biomass Conference – Biomass for Energy, Industry and Climate Protection, III Vol. (2005), pag. 981.
[4] D. Reed, Evaluation of Biomass Resources in the southern regions in Nigeria, (2007), pag. 124.
[5] O. Vecchi, Biofuel Production in central Italy, (2008), pag. 45.

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Please **do not use any Password / Security when making the Pdf file.** As the header and page numbers will be added by us, we need to ensure that you pdf file is not password protected.

9 ACKNOWLEDGEMENTS

- We thank you for successfully following these instructions. This will make the Reviewers easier to read and avoid queues at the Technical Editors!
- The Authors are grateful to the students-members of DREN - Forestry Students’ Association for their helpful cooperation.
- …….

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