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NATURAL REGENERATION OF BEECH FORESTS IN SERBIA

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Abstract: *Natural regeneration of beech forests has been studied in eleven high beech stands in Serbia. The stands are very heterogeneous and predominantly uneven-aged in terms of structure, owing to which group-shelterwood felling was recommended as a means of regeneration. The regeneration process is unmethodical, while the number and quality of young growth are unsatisfactory. The optimum canopy closure for a successful beech regeneration is from 0.6 to 0.7. If canopy closure is higher, a spontaneously occurred young growth will die out, while in case it is lower than the optimum value, weed infestation occurs.*

Key terms: Beech, uneven-aged stands, regeneration

PRIRODNA REGENERACIJA BUKOVIH ŠUMA U SRBIJI

Izvod: *Prirodna regeneracija bukovih šuma je istraživana u jedanaest visokih sastojina bukve na području Srbije. Sastojine su vrlo heterogene i po strukturi pretežno raznodobne, te se u njima preporučuje grupimično-oplodna seča, kao način obnavljanja. Proces podmlađivanja je neplanski, a brojnost i kvalitet podmlatka nezadovoljavajući. Optimalan sklop za uspešno podmlađivanje bukve je od 0,6-0,7. Ukoliko je sklop veći, spontavno pojavljen podmladak izumire, a ukoliko je ispod optimalnih vrednosti dolazi do zakorovljavanja.*

Ključne reči: Bukva, raznodobne sastojine, podmlađivanje.

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1. INTRODUCTION

According to the National Forest Inventory of the Republic of Serbia (Banković et al 2009), beech forests are the most represented and cover 660,400 ha, or 29.3% of the total forest area, 67.4% out of which is state owned. Moreover, beech dominates in terms of volume, and accounts for 40.5% of the total wood volume, and 30.6% of the volume increment.

High beech forests, which are the subject of this study, account for 53.1% of the total beech forest area. The average number of trees is 530 per hectare, the average volume is 269 m^3/ha, while the volume increment amounts to 5.0 m^3/ha. Pure stands account for 86.3% of the total beech forest area, with the average volume of 239 m^3/ha and volume increment of 4.5 m^3/ha.

As a result of the previous method of high beech forest management, the studied stands are predominantly heterogeneous and uneven-aged. Based on previous studies of beech, it has been observed that a process of natural regeneration of stands does not take place continuously and in a planned manner.

According to common practice, the term *young growth* refers to plants below the taxation threshold (5cm), when it concerns uneven-aged, that is, selection stands. The same principle is applied in even-aged stands, although the data cannot have the same character in young and middle-aged stands. The term *seedling* refers to plants of the up to 0.1m height.

The task and aim of this study of number and quality of *young growth* in high beech forests are of exceptional importance, as the obtained results provide insight into a natural regeneration of stands development process, which represents an important indicator of sustainable management.

2. OBJECT OF STUDY

The object of study consists of eleven high pure uneven-aged beech stands, selected in six forest areas: Severni Kučaj, Jablanica, Podrinje-Kolubara, Donji Ibar, Golija and Rasina.

In the Severni Kučaj forest area, three beech stands were selected. In the 'Majdan Kučajna' Management Unit, the stand 33a was selected, while in the 'Crni Vrh' Management Unit, stands 42a and 42b were selected.

In the Jablanica forest area, two beech stands were selected. In the 'Kačer-Zeleničje' Management Unit, the stand 31a was selected, while in the 'Kukavica 1' Management Unit the stand 46a was selected.

In the Rasina forest area, one beech stand was selected. In the 'Lomnička reka' Management Unit, the stand 116a was selected.

In the Donji Ibar forest area, one beech stand was selected. In the 'Željin' Management Unit, the stand 44a was selected.

In the Golija forest area, two beech stands were selected. In the 'Javor-Koravčina' Management Unit, stands 8a and 8b were selected.

In the Podrinje-Kolubara forest area, two beech stands were selected. In the 'Istočna Boranja' Management Unit, the stand 122a was selected, while in the 'Zapadna Boranja' Management Unit, the stand 27a was selected.

3. WORK METHOD

Data on *seedling* and *young growth* were collected concurrently with other extensive data on site and stand, on trial plots in form of circle and of different radii (Koprivica, M. et.al. 2005). A network of trial plots, at the distance of 100 x 100 m, was distributed in stands. In every trial circle, following the marking of its centre, the data on *seedling* and *young growth* numbers were collected first, which was followed by an evaluation of *young growth* quality and manner of occurrence. Three concentric circles, of radii 1.0, 1.5 and 12.62m, were placed.

In the 1.0 m radius circle, the number of *young growth* plants, of the up to 1.3 m height, was recorded according to tree species and the total number. Two categories of *young growth* were selected:

- *young growth* of the up to 0.5 m height (early *young growth*) and
- *young growth* of the height between 0.5 and 1.3 m (late *young growth*).

In the 1.5 m radius circle, the number of *young growth* plants, of the breast diameter from 0 to 5 cm (*young forest*), was recorded according to tree species and the total number. The occurrence of *seedling* was also recorded in this circle, but only in terms: '*seedling* exists' and '*seedling* does not exist'. If *seedling* occurred, it was recorded only according to tree species, while the number of plants was not determined. For the existence of *seedling* to be confirmed, it was sufficient to record at least one plant.

In the 12.62m radius circle, the *young growth* quality and manner of occurrence were recorded. The quality of *young growth* was defined by evaluation of *young growth* suppression and damage. The evaluation of *young growth* suppression and damage includes all previously mentioned categories (with respect to height and diameter) considered together, but according to tree species. Three categories of *young growth* suppression and damage were distinguished:

- *young growth* suppressed
- *young growth* slightly suppressed
- *young growth* severely suppressed

- *young growth* undamaged
- *young growth* slightly damaged
- *young growth* severely damaged

The *young growth* suppression was established based on a plant general appearance.

Damage to *young growth* (caused by livestock, wild game and all other causes) was established according to tree species. The *young growth* was slightly damaged in case when less than 1/5 of plants were damaged, and severely damaged when the number of damaged plants was higher than 1/5 of the total number of *young growth* plants.

In the 12.62 m radius circle, a manner of occurrence of *young growth* was also recorded. In that respect, it was recorded whether *young growth* occurred in form of uniformly distributed individual plants, or in groups, or in both forms together. These data were gathered collectively for all categories of young growth. The data were recorded in both uneven-aged and even-aged stands.

When counting *young growth* plants, that is, young trees, the same procedure was applied as when recording adult trees.

In the 12.62 m radius circle, orographic factors were also recorded: altitude, terrain inclination and exposure, along with all collected data on trees above the taxation threshold, necessary for determining stand factors (canopy closure, quality, number of trees, basal area, volume, volume increment, etc.)

For classification of *young growth* according to development phases, the East European nomenclature was used (Tkačenko, M.K. 1952; Bunuševac, T. 1950; Dakov, M., Vlasev, V. 1972). For the purpose of gaining insight into stand conditions, data on geological substratum, soil type and ground vegetation were collected.

4. STUDY RESULTS AND DISCUSSION

4.1 Pedological conditions

Beech is a species of broad ecological amplitude, which, in Serbia, creates a large number of plant communities, spreading from a sub-montane to a sub-alpine belt. In addition to a broad climatic amplitude, this species occurs in different geological substrata and in different soil development stages. In Serbia, beech forests occur on ten soil types (Knežević, M. 2003).

In nine localities, in which the study was conducted, seven soil types were identified.

In the Severni Kučaj forest area, in the stand 33a, the geological substratum consists of limestone (with clearly distinct elements of karst relief), along with red and quartz sandstone. On the limestone with steep inclinations, shallow typical black soils were formed next to colluvial soils, in areas with mild inclinations. In flat limestone terrains, luvisols were formed. In the part of stand in which red and quartz sandstones are represented, acid brown soils are present. In the stands 42a and 42b pedological conditions are uniform. The soil type is district ranker, which in the lower part of the profile attained brown colour. In all three studied stands, pedological conditions for occurrence of *young growth* are favourable.

In the Jablanica forest area, in the stand 31a, pedological conditions are different, which is a result of a distinctly corrugated character of the terrain, various micro-exposures and inclinations. The geological substratum consists of decomposing gneiss, while the most represented type of soil is acid brown – typical. On milder inclinations, in lower parts of stand, acid brown soil is affected by a loess process. In the under ridge part of the stand, below a dense blueberry canopy, brown podzolic soil was recorded. A high acidity indicates an increased presence of distinctly acidophilus species, which characterise a strong to extreme acidity of soil solution, such as: *Luzula luzuloides, Leucobrium glaucum, Pteridium aquilinum, Vaccinium myrtillus* and *Hieracium pilosella.* The limiting factors for occurrence and survival of *young growth* in this stand are: high inclination, erosion processes, and soil wash off. In the stand 46a, brown acid soil, (district cambisol), was recorded on gneiss of shaley structure. Owing to a high content of sand, soils are water-permeable and well-aerated, which are good preconditions for occurrence and survival of young growth.

In the Rasina forest area, in the stand 116a, brown acid soil was recorded. Physical and chemical properties of this soil are favourable for a natural regeneration process.

In the Donji Ibar forest area, in the stand 44a, acid brown soil, of relatively uniform physical and chemical properties, was recorded. Soil physical and chemical properties in this stand are also favourable for a natural regeneration process.

In the Golija forest area, in the stands 8a and 8b, acid brown soil alone was recorded in all trial plots. In most part of the studied stand, the soil is well water-permeable and aerated. A high acidity of stand is characterised by an increased presence of the following acidophilus species: *Oxalis acetosella, Veronica officinalis, Vaccinium murtillus, Luzula nemorosa, Pteridium aquilinum* and moss of genus *Hepaticae*. These stands are generally of poor quality, which results in a less successful natural regeneration. An additional limiting factor is presence of blueberry in form of large facies, which physically hamper natural regeneration.

In the Podrinje-Kolubara forest area, in the stand 122a, acid brown soil - typical was recorded. In the stand 27a, acid brown soil dominates. In addition to this type of soil, pseudogley frequently occurs, and, less frequently, luvisol. In both studied stands, in pedological terms, conditions for natural regeneration are favourable.

4.2 The impact of stand characteristics on occurrence and quality of *young growth*

Natural regeneration of even-aged beech stands is most commonly performed by means of shelterwood felling. A standard shelterwood felling on large areas has been applied in case when stand conditions are homogenous. The analysis of *young growth* occurrence and quality is contingent upon a structural and silvicultural form of stand. Generally, *young growth* is not analysed in young even-aged stands, owing to the fact that, even when it exists, it most commonly represents a result of unskilled forest management. In these stands, regeneration is not a priority silvicultural goal.

This study is concerned with uneven-aged beech stands. Stand conditions are largely heterogeneous, owing to which combined methods, employed on smaller areas and graded according to time, space and intensity, represent more suitable means of regeneration. Under the above-mentioned stand conditions, such methods are proposed by Dobrev, D. et. al. (1974), Dakov, M., Vlasev, V. (1979), Krstić, M. (1982), Stojanović, Lj., Krstić, M. (2000. 2003). Group-shelterwood felling in different variants, along with a free technique of silviculture (Mlinšek, D. 1968), were most frequently proposed as combined regeneration methods.

4.2.1 The analysis of taxation elements

According to structure, nearly all stands are group uneven-aged. The exceptions are stands 42a and 8a, which are, as a result of a solely low thinning, currently even-aged in terms of structure. In all stands natural regeneration occurs spontaneously. *Young growth* predominantly occurs in small groups, in areas where conditions for its occurrence were fulfilled as a result of applied silvicultural measures. In areas where canopy closure is more open, that is, creates a gap, weed infestation and absence of *young growth* occurred. The summary of basic taxation elements for studied stands is presented in Table 1.

Table 1. *Basic taxation elements of studied beech stands*

Management Unit	Stand	Quality	Dg	H_L	Type of tree	N (pcs)	G (m^2/ha)	V (m^3/ha)	Iv (m^3/ha)
Majdan-Kučajna	33a	II	39, 4	31, 0	beech	258.3	32.01	504.54	8.14
					other	15.7	1.41	17.95	0.46
					total	273.9	33.42	522.49	8.60
Crni vrh	42a	III	35, 4	24, 5	beech	321.1	31.68	379.61	6.61
Crni vrh	42б	III/IV	36, 1	21, 7	beech	304.0	31.39	332.41	4.93
					other	4.0	0.14	0.81	0.03
					total	308.0	31.53	333.22	4.96
Kačer-Zeleničje	31a	II	30, 2	28, 0	beech	294.4	21.41	289.86	6.28
					other	6.9	0.12	0.98	0.08
					total	301.3	21.53	290.84	6.36
Kukavica I	46a	II/III	31. 5	27, 5	beech	281.4	22.89	314.04	9.94
					other	17.1	0.32	1.96	0.13
					total	298.6	23.21	316.00	10.07
Lomnička reka	116a	II/III	30, 0	26, 7	beech	248.5	20.34	273.02	7.16
					other	65.5	1.86	16.83	0.87
					total	313.9	22.20	289.85	8.03
Željin	44a	I/II	36, 7	32, 1	beech	292.2	31.01	501.81	9.22
					other	1.7	0.03	0.22	0.01
					total	293.9	31.04	502.03	9.23
Javor-Koravčina	8a	II/III	33, 3	25, 9	beech	352.5	30.78	385.15	8.92
Javor-Koravčina	8б	II/III	27, 9	24, 6	beech	482.0	29.45	360.90	6.70
Istočna Boranja	122a	I/II	41, 6	33, 7	beech	213.8	29.03	503.58	10.49
Zapadna Boranja	27a	II	33, 7	30, 2	beech	259.0	23.10	353.76	8.03

Number of trees per hectare is uniform in all stands. As a result of recently performed felling, there is a slightly lower number of trees in Istočna and Zapadna Boranja, while there is a slightly higher number of trees in the stand 8b on account of non-performed shelterwood felling. In addition to the above-mentioned stand characteristics, number of trees is contingent upon a stand quality and, in consequence, the best quality stands have the lowest number of trees.

Basal area and volume, as direct indicators of productivity, are also contingent upon the stand quality. The highest values of these taxation elements are attained in the best quality stands, while they decrease as the quality deteriorates. However, the average volume values in studied stands are higher than the average and optimum values for Serbia, amounting to 207.2 m^3/ha (Tomanić, L. 1993) and 250.0 m^3/ha (Milin, Ž. et al 1994) respectively in high beech forests in Serbia.

Furthermore, a current volume increment, as an indicator of stand productivity, is directly contingent upon the stand quality. The stand of best quality (122a) has a current volume increment of over 10 m^3/ha, whereas a stand of worst quality (42b) has a current volume increment of 4.96 m^3/ha. The average value of current volume increment in high beech forests in Serbia amounts to 4.6 m^3/ha

(Tomanić, L. 1993), whereas the optimum volume increment amounts to 6.0 m³/ha (Milin, Ž. et.al. 1994).

4.2.2 The impact of canopy closure on natural regeneration

In the studied beech stands, regeneration largely occurred spontaneously, in form of groups in areas where canopy closure was more open. For initiation of the process of natural regeneration in beech stands, canopy closure should be reduced to 0.6 – 0.7 (Stojanović, Lj., Krstić M. 2000). As can be seen in Table 2, there are very few such areas, which indicates that a planned regeneration has not been initiated. In all studied stands, there are most trial plots with the largest canopy closure, and the fewest trial plots with the smallest canopy closure. The exceptions are stands 31a and 8a, where the average canopy closure is optimum, although a high representation of areas with the canopy closure over 0.7 has also been recorded in these stands. In areas where canopy closure is more open, the presence of *Rubus sp., Vaccinium myrtillus* and *Pteridium aquilinum,* which hamper natural regeneration of beech, is increased.

By bringing canopy closure to the optimum level (0.6-0.7), a more rapid transformation of organic matter and improvement of general soil characteristics take place, while reducing the canopy closure below this threshold can lead to increased presence of species *Vaccinium myrtillus* and *Pteridium aquilinum*, which hamper natural regeneration.

In the areas in which canopy closure is 0.6-0.7, *young growth* occurred in most cases and its tending will depend on stand characteristics. In the stands 33a, 44a and 8b, there were no exemplary areas with canopy closure optimum for regeneration, while the average canopy closure in these stands is over 0.9. A large canopy closure and lack of canopy closure areas optimum for regeneration in stands 33a and 8b can account for a large decrease in number of plants, from *seedling* and early *young growth* phases to a late *young growth* phase. More specifically, a large number of plants die out within a short period in a negative selection phase, due to a lack of light. In the stand 33a, favourable pedological conditions, primarily in terms of receiving and retaining accessible water, cannot enable survival of plants in long-term, due to a closed canopy closure and lack of lights.

Table 2. *Distribution of beech stand areas according to a canopy closure degree*

Management Unit	Stand	Land coverage degree (%)									
		1-20	21-30	31–40	41–50	51–60	61–70	71–80	81–90	91–100	Average
Majdan-Kučajna	33a	-	-	4.35	-	-	-	8.70	21.73	65.22	90.43
Crni vrh	42a	-	-	-	-	5.55	11.11	11.11	22.23	50.0	86.78
Crni vrh	42б	-	-	-	-	10.0	10.0	20.0	10.0	50.0	83.9
Kačer-Zeleničje	31a	3.12	-	3.12	21.88	3.12	12.50	15.63	25.00	15.63	69.38
Kukavica I	46a		3.57	-	3.57	-	3.57	10.71	10.71	87.86	87.14
Lomnička reka	116a	-	-	-	6.06	-	9.09	18.18	36.36	30.30	83.1
Željin	44a	-	-	-	-	-	-	8.70	17.39	73.91	93.7
Javor-Koravčina	8a	-	6.25	-	6.25	6.25	12.50	25.0	37.5	6.25	74.38

Javor-Koravčina	8б	-	-	-	-	-	-	10.0	40.0	40.0	91.2
Istočna Boranja	122a	-	-	-	-	6.90	10.34	6.90	31.03	44.83	85.55
Zapadna Boranja	27a	-	-	-	-	-	15.0	10.0	30.0	45.0	85.35

In the stand 44a, canopy closure is large, while regeneration and weed infestation are low. A favourable capacity for receiving and retaining accessible water in this stand enabled germination of *seedling* and its preservation until the early *young growth* phase; however, lack of light was a limiting factor causing a drastic drop in its number in the late *young growth* phase. Although the average canopy closure in the stand 8a is optimum, the total canopy closure area below 0.6 accounts for 20% of the stand, which increased a share of areas strongly infested by weed, which could not be regenerated. A large number of plants in the *seedling* and early *young growth* phase were recorded. In such cases, the increased weed infestation affected the reduction of *seedling*. More specifically, a previously uneven-aged stand was transformed, by means of a radically low thinning, into a structurally even-aged stand, which led to a higher opening of land and its weed-infestation.

The stand 31a has an average canopy closure optimum for regeneration, but approximately 30% of the area has canopy closure below 60%, which led to occurrence of more than 20% of area with an increased weed-infestation and low number of *seedling*. Unfavourable pedological conditions probably also had an impact on number of *seedling* in this stand.

All other stands have had a large share of areas with canopy closure over 0.7 for a long period, which resulted in a low number of *seedling* during all *seedling* development phases. In the stands of poorer production capacity and quality, in certain groups it was necessary to perform shelterwood felling, that is, tending of spontaneously occurred *young growth*. In some groups with a sufficient number of trees of good productivity and quality, tending of quality trees ought to be continued, regardless of occurrence of *young growth*. In groups where canopy closure is interrupted, it is necessary to start natural regeneration by means of group-shelterwood felling. In stands in which *young growth* reached the 0.5-0.6m height, and canopy closure is interrupted, *young growth* ought to be released from a large shade and canopy closure reduced to 0.2-0.4 by a subsequent felling (Stojanović, Lj., Krstić, M. 2000).

A large presence of areas with terraced canopy closure indicates uneven-aged stands. The exceptions are two structurally even-aged stands (8a and 42a), in which areas with horizontal canopy closure prevail.

4.2.3 Weed infestation impact

Weed infestation of stands is directly related to their canopy closure. It has been already observed that natural regeneration of stands cannot take place unless the canopy cover is reduced to 0.6-0.7. Further reduction of a canopy closure degree usually leads to soil weed infestation. Depending on forest site conditions, weed infestation can occur if natural regeneration was not successful, due to a lack of seed yield or other reasons. With deterioration of a site quality, stand productivity and quality, weed infestations increases, which hampers natural regeneration. In most stands, weed infestation is moderate (Table 3), while its increase is influenced by a felling performed in the previous period (8a).

Table 3. *Distribution of beech stand areas according to a weed infestation degree*

Management Unit	Stand	A weed infestation degree (%)					
		1-20	21-40	41–60	61–80	81–1000	Favourab le
Majdan-Kučajna	33a	17.39	8.70	8.70	8.70	8.70	47.83
Crni vrh	42a	-	27.78	22.22	16.67	33.33	-
Crni vrh	42б	-	-	10.00	10.00	80.00	-
Kačer-Zeleničje	31a	12.50	21.88	21.88	12.50	6.25	25.00
Kukavica I	46a	75.00	10.71	-	7.14	7.14	-
Lomnička reka	116a	30.30	15.15	15.15	15.15	21.21	3.03
Željin	44a	56.52	17.39	13.04	8.70	4.35	-
Javor-Koravčina	8a	12.50	12.50	6.25	25.00	31.25	12.50
Javor-Koravčina	8б	40.00	40.00	-	-	20.00	-
Istočna Boranja	122a	17.24	20.69	10.34	27.59	24.14	-
Zapadna Boranja	27a	65.00	15.00	-	-	-	20,00

The stand most affected by weed infestation is 4b. If a set silviculture goal is regeneration, that is, rejuvenation, in some cases auxiliary measures ought to be taken for removal of weed.

Among woody species hampering regeneration, the most represented is *Sambucus nigra*. Other woody species such as *Fraxinus ornus*, *Corylus avellana*, *Cornus mas*, *Sambucus racemosa*, *Lonicera sp*. and *Rosa sp.* are far less represented. The most important among semi-shrubs is *Vaccinium myrtillus*, which crates whole facies on strongly acid soils, which completely prevent natural regeneration of beech. Among herbaceous species, the most important are species of genus Rubus. *Pteridium aquilinum,* which can threaten natural regeneration on acid soils, occurs slightly less frequently. Other species from the shrub storey and ground flora do not have a significant impact on natural regeneration of studied beech stands.

4.2.4 Young growth number and manner of occurrence

According to studies by Dobrev, D. et al (1974), for a stand natural regeneration to be successful, a number of *young growth* plants in the earliest phase should amount to 10-15 pieces per m^2, that is, 100-150 thousand per hectare. This refers to *young growth* of the 11-50 cm height. When *young growth* is over 50 cm high, a final or subsequent felling is performed. As can be seen in Table 4, in studied stands there are no sufficient numbers of *young growth* of any category. In some stands (32a, 42a, 8a and 8b), a slightly higher number of plants in the early *young growth* phase (11-50 cm) was recorded. However, a significant reduction of late *young growth* (51-130cm) and early *young forest* plants (of a 0-5 cm breast height diameter) was recorded in all stands. The analysis of canopy closure impact on a *young growth* number indicates that canopy closure in these stands is far larger than the optimum for a successful regeneration process. It is clear that canopy closure performed the key role in a die out of large number of plants in negative selection, from the early *young growth* phase to the late *young growth* and early *young forest* phase. Furthermore, a regression analysis confirmed that a number of *young growth* in the early *young forest* phase is most affected by canopy closure of parent stand. Soils in these stands are of good water-air properties, which particularly refers to stand 33a, which has the largest number of plants in the early *young growth* phase (11-50 cm).

In other stands (42б, 31a, 46a, 116a, 44a, 122a and 27a), number of *young growth* in all development phases is far below the minimum necessary for the process of regular natural regeneration. However, since the *young growth* in stands is most frequently distributed in groups, in some groups there is a sufficient number of *young growth* for stand regeneration by shelterwood felling. In stands 33a and 8b, due to uneven-aged character of trees in the entire area, *young growth* most frequently occurs individually. The priority silvicultural goal in such cases is removal of predominant and overage trees. Following the removal of these trees, it is probable that a new *young growth* core will be created with a group occurrence of *young growth*.

Table 4. *Number of young growth in beech stands according to given categories*

Management Unit	Stand	Tree type	Number of *young growth* plants (per hectare)			
			Height 11–50 cm	Height 51–130 cm	Diameter 0–5 cm	Total
Majdan-Kučajna	33a	Beech	28.524	831	62	29.417
		Other	1.107	-	-	1.107
		Total	29.631	831	62	30.524
Crni vrh	42a	Beech	18.754	14.685	4.797	38.236
		Other	-	10	31	41
		Total	18.754	14.695	4.828	38.277
Crni vrh	42б	Beech	2.866	2.548	-	5.414
Kačer-Zeleničje	31a	Beech	6.170	896	4.777	11.843
Kukavica I	46a	Beech	682	341	758	1.781
		Other	683	341	202	1.226
		Total	1.365	682	960	3.007
Lomnička reka	116a	Beech	2.316	483	2.574	5.373
		Other	1.448	-	472	1.920
		Total	3.764	483	3.046	7.293
Željin	44a	Beech	4.154	415	738	5.307
Javor-Koravčina	8a	Beech	26.473	398	885	27.756
Javor-Koravčina	8б	Beech	9.236	-	425	9.661
Istočna Boranja	122a	Beech	3.075	110	1.367	4.552
Zapadna Boranja	27a	Beech	2.548	2.229	1.274	6.051

It should be noted that the data on numbers of *young growth* given in Table 4 represent the average value for the entire stand area. However, stand conditions are heterogeneous and suitable for group-shelterwood regeneration methods, therefore, the number of *young growth* is more important in certain groups in which regeneration is set as a silvicultural goal. The occurrence of *seedling* and development of *young growth* also depends on site conditions. Among others, climatic factors, which are largely determined by the altitude, are of significant importance. With the increase of altitude, a climate humidity increases, duration of vegetation period decreases, winters are colder and longer, which affects seed germination and *seedling* development. Additionally, less favourable climatic conditions affect the frequency of fruit bearing, quantity of seed and its germination ability. For that reason, in addition to stand condition, high altitude can be one of the reasons that number of *young growth* per hectare is among the lowest in stand 42b. General macro-climatic conditions can be modified by a form, size and direction of initial regeneration core felling, by which more favourable micro-climatic conditions for occurrence and survival of *young growth* are created (Krstić, M., Stojanović, Lj. 2003).

4.2.5 Young growth quality

Young growth was evaluated based on a level of plant suppression and damage. The best quality *young growth* was recorded in stands 33a, 31a, 42a. The next in terms of quality are the stands 27a, 122a, 46a and 42b, while the *young growth* of poorest quality is found in stands 44a, 116a, 8a, 8b. It has been observed that suppression of *young growth* is most frequently represented in stands with overlarge canopy closure, as well as in stands that had such a canopy closure prior to last felling. Physical and chemical properties of soil did not have a significant impact on quality of *young growth*. Similarly to *young growth* suppression, the largest representation of trial plots with damaged *young growth* is in stands 116a, 8b, 8a, 44a and 27a.

All other stands have a relatively low percentage of damaged *youth growth*. The damage to *youth growth* is largely caused by felling and extracting of trees, and, to a less extent, by wild game, livestock and antibiotic factors.

4.2.6 Presence of seedling

Seedling is most represented in stands 33a, 8b and 8a. Owing to a large area crown spreading, the highest number of *seedling* occurs in stands with the largest canopy closure. However, when the opening of canopy closure and its reducing to the optimum size did not take place, this *young growth* most frequently deteriorates, which can be seen from the analysis of *young growth* numbers. *Young growth* in these stands remains until the end of early *young growth* development phase, after which a die out of plants occurs, due to lack of light. Physical and chemical properties of soil did not have a significant impact on occurrence of *young growth*.

5. CONCLUSION

By studying natural regeneration of high beech stands in Central Serbia, the following conclusions can be drawn:

- All studied stands are heterogeneous and uneven-aged, for which reason in most cases it is necessary to perform regeneration by means of group-shelterwood felling.
- Natural regeneration of stands depends mostly on site and stand factors. A site produces an impact as a complex of correlated factors, while micro-climatic conditions are changed following the performance of various shelterwood

felling measures. Among stand conditions, canopy closure, which regulates the amount of light influx, has the strongest impact on occurrence and preservation of *young growth*. In stands with the largest canopy closure, owing to a large area crown spreading, a relatively high quantity of seed and, consequently, a high quantity of *seedling* is obtained, which survives until the end of early *young growth* phase, after which it abruptly dies out through negative selection, as a result of lack of light.

- A regeneration level of all studied stands is low in the entire area, but in certain groups, as a result of heterogeneous structure, it is sufficient for performance of group-shelterwood felling, if, based on site and stand conditions, regeneration is set as a silvicultural goal in these groups.
- In certain parts of stands in which canopy closure is more open, a strong weed infestation occurred. In order to transform these areas into *young growth* cores, it is also necessary to apply auxiliary measures to aid natural regeneration, primarily removal of weed and, in extreme climatic conditions, to introduce 1-2 subsequent felling.
- The previous method of high beech forest management in Serbia led to their strong heterogeneousness and uneven-aged character. A system of selection and, after that, group management, has been applied for a long period. Since 1990's, a system of moderate stand management has been introduced, which has not produced significant results. In practice, quality trees were frequently cut off, which led to a decrease of capacity of stands for production and regular natural regeneration. The process of their natural regeneration does not take place in a planned manner and continuity. A number of plants per hectare of all categories of *young growth* is insufficient, while its quality is unsatisfactory. That is in collision with the principles of sustainable forest management. Therefore, this aspect of the analysis of condition of high beech forests also points out to a need for re-examination of current systems of beech forest management in Serbia.

REFERENCES

Banкović, S., Medarević, M., Pantić, D., Petrović, N. (2009): Nacionalna inventura šuma Republiкe Srbije: šumsкi fond Republiкe Srbije. Ministarstvo poljoprivrede, šumarstva i vodoprivrede Republiкe Srbije, Uprava za šume, Beograd.

Bunuševac, T. (1950): Tehniкa obnove i gajenja šuma, Beograd.

Daкov, M., Vlasev, V. (1972): Obšo lesovodstvo, Zemizdat, Sofiя.

Dobrev, D., Damяnov, A., Turlaкov, P., Arsov, A., Bogdanov B. (1974): Narčniк po stopanisuvane na gorite, Zemizdat, Sofiя.

Кnežević, M. (2003): Zemljišta u buкovim šumama Srbije, Šumarstvo 1-2, Beograd (97-105).

Koprivica, M., Miletić, Z., Tabaković-Tošić, M. (2005): Metodika prikupljanja i obrade taksacionih podataka za proučavanje kvaliteta i sortimentne strukture visokih sastojina bukve u Srbiji, Rukopis. Institut za šumarstvo, Beograd.

Krstić, M., (1982): Istraživanje režima svetlosti i uticaja na pojavu podmlatka u različitim ekološkim jedinicama bukovo-jelovih šuma na Goču, Magistarski rad, Šumarski fakultet Univerziteta u Beogradu, Beograd.

Krstić, M., Stojanović, Lj. (2003): Melioracija degradiranih bukovih šuma u cilju unapređenja stanja, Šumarstvo 1-2, Beograd (39-58).

Milin Ž. (1988): Grupimično gazdovanje - teorijske osnove, osobine i primena, posebno izdanje Šumarskog fakulteta, Beograd.

Mlinšek, D.(1968): Slobodna tehnika gajenja šuma na osnovu nege, Jugoslovenski poljoprivredno-šumarski centar, Beograd.

Stojanović, Lj., Krstić, M. (2000): Gajenje šuma III, Šumarski fakultet Univerziteta u Beogradu.

Stojanović, Lj., Krstić, M. (2003): Osnovni problemi gajenja bukovih šuma, Šumarstvo 1-2, Beograd (25-37).

Tkačenko, M.K. (1952): Obščee lesovodstvo, Moskva.

Tomanić, L., (1993): Stanje šumskog fonda najzastupljenijih vrsta drveća u Srbiji, Šumarstvo 3-5, Beograd.