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CHANGES IN THE FOREST GROWING STOCK OF THE TIMOK FOREST AREA FOLLOWING THE ICE STORM IN WINTER 2014/2015

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Abstract: *In the winter of 2014/2015, extremely cold air masses penetrated from the east and the Carpathians into a large part of eastern Serbia and formed extensive ice layers on infrastructure facilities and forest trees. Forest trees could not withstand large amounts of ice (up to several tons per tree), resulting in widespread ice breaks and ice throws. Extensive damage occurred in the Timok, Morava, Severni Kučaj, Rasina, and Južni Kučaj Forest Areas. In certain parts of the Timok Forest Area, the damage to forest ecosystems was catastrophic and required clear-cutting of large areas. This research focuses on the state-owned forests of the Timok Forest Area (natural forests and artificially established (stands) managed by "Srbijašume" State Enterprise from Belgrade. A comparative analysis of specific indicators of the current state of the forest growing stock in the Timok Forest Area was conducted (forest state by origin, preservation, mixture, tree species, stand classification, and socioecological categorisation). The analysis compared data collected on 31 December 2013 with data collected on 31 December 2021. The research aimed to determine whether there were significant changes in the state of forest growing stock in the Timok Forest Area in the study period.*

Keywords: Timok Forest Area, forest growing stock, natural disasters, ice break

PROMENA STANJA ŠUMSKOG FONDA U TIMOČKOM ŠUMSKOM PODRUČJU KAO POSLEDICA LEDOLOMA U ZIMU 2014/2015. GODINE

Sažetak: *Na prostoru većeg dela istočne Srbije u zimu 2014/2015. godine, došlo je do prodiranja izuzetno hladnih vazdušnih masa sa istoka i sa Karpata uslovljavajući pojavu velikih naslaga leda na objektima infrastrukture i stablima šumskog drveća. Velike količine leda (i po nekoliko tona po stablu) šumsko drveće nije moglo da izdrži, što je dovelo do ledoloma i ledoizvala na velikim površinama. Štete većih razmera desile su se na prostoru Timočkog, Moravskog, Severnokučajskog, Rasinskog i Južnokučajskog šumskog područja. U pojedinim delovima Timočkog ŠP došlo je do prave katastrofe po šumske ekosisteme te su morale biti izvršene čiste seče na velikim površinama. Predmet ovog istraživanja su obrasle površine Timočkog šumskog područja (prirodne šume i veštački podignute sastojine) u državnom vlasništvu kojima gazduje JP „Srbijašume"Beograd. Vršena je uporedna analiza*

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pojedinih pokazatelja stanja šumskog fonda Timočkog ŠP (stanje šuma po poreklu, očuvanosti, mešovitosti, vrstama drveća, sastojinskoj pripadnosti i cenoekološkoj pripadnosti). Uporedo su analizirani podaci svedeni na dan 31.12.2013. godine i podaci svedeni na dan 31.12.2021. godine. Cilj istraživanja je da se utvrdi da li je došlo do bitnih promena u stanju šumskog fonda na nivou Timočkog šumskog područja.

Ključne reči: Timočko šumsko područje, šumski fond, elementarne vremenske nepogode, ledolomi.

1. INTRODUCTION

Forest Area (FA) is an ecological and spatial geographic unit within which forest management is planned and functional sustainability ensured (Jović *et al*., 1991). Forest areas are established by Article 17 of the Law on Forests (*Official Gazette of the Republic of Serbia* No. 30/2010, 93/2012, and 89/2015), which defines that the forest area includes forests of all ownership forms and all purposes, excluding forests in national parks. The Timok Forest Area was formed in line with Article 21 of the Law on Forests (*Official Gazette of the Republic of Serbia* No. 46/91, 83/92, 54/93, 60/93, 67/93, 48/94, 54/96). The areas comprising the Timok Forest Area were defined by the *Forest and Forest Land Inventory,* which is an integral part of the Law.

Research presented in this paper was conducted within the Timok Forest Area, in forests managed by "Srbijašume" State Enterprise from Belgrade, "Timok Forests" Forest Estate from Boljevac. The Timok Forest Area mostly extends to the northeastern part of Serbia, specifically in the Timok Valley (*Ser. Timočka krajina*). This territory represents a geographically integral, closed area separated from adjacent regions by the mountain range extending from Gramada and Svrljig Mountains (*Ser. Svrljiške planine*) to Mt. Midžor in the south towards the Nišava Valley (*Ser. Ponišavlje*). To the north is the Danube River, to the east are the Balkan Mountains (*Ser. Stara planina*), and to the west is a series of high mountains from the eastern branches of Ozren to the Danube. The majority of the FA is covered by tributaries flowing into Svrljiški, Trgoviški, Beli, Crni, and Veliki Timok, which then flow into the Danube. Forests and forest land grow on mountain massifs such as Southern Kučaj, Čestobrodica, Rtanj, Malinik, Crni Vrh, Stara Planina, Tupižnica, Tresibaba, Miroč, Deli Jovan, and Northern Kučaj (Vasić, 2018).

The continental climate in the Timok Valley often gives rise to black ice, a common phenomenon in this region. In the winter of 2014/2015, a large portion of eastern Serbia was hit by extremely cold air masses from the east and the Carpathians, forming extensive ice layers on infrastructure facilities and forest trees (Pavlović *et al*., 2022). An ice catastrophe struck the entire area east of the Morava River, especially east of the Čestobrodica and Crni Vrh mountain passes. Practically, this area was "ice-ridden" for an extended period. Forest trees could not withstand large amounts of ice (up to several tons per tree), resulting in widespread ice breaks and ice throws *(*Marković *et al*., 2018).

In the Timok Forest Area, the "ice front" moved from the Bulgarian border westward and northwestward, affecting mountain masses from the northern branch of the Balkans Mountains (Zaglavak and Suvodol) over Tresibaba, Tupižnica, Slemen, Rtanj, Samanjac to Čestobrodica. Surrounding masses were also affected by the natural disaster, but the damage was less extensive. Significant damage was recorded on the mountain masses of the adjacent (southern) Morava Forest Area. This natural disaster struck natural forests of all structures and compositions in the belt between 600 and 900 meters above sea level.

Due to low temperatures, the rain froze on the ground and formed a thin coating of glaze ice. It also formed a thick sheath of ice on forest trees and shrubs that burdened entire trees, leading to the breakage of branches, tree tops, and lower (thick) portions of trees or causing ice throw of individual and grouped trees (Stojković, 2015).

According to the *"Action Plan for the Restoration of Damaged Forests in State and Private Ownership for 2015-2018"* developed by the "Srbijašume" State Enterprise, significant damage occurred in the Timok (Boljevac Forest Estate), Morava (Niš Forest Estate), Severni Kučaj (Kučevo Forest Estate), Rasina (Kruševac Forest Estate), and Južni Kučaj (Despotovac Forest Estate) Forest Areas (Baković *et al.*, 2015). According to the Action Plan, the damage was recorded on an area of 43,305.78 hectares, with 1,874,046 m^3 of dying and damaged trees. Clear-cutting was planned on 1,077.40 hectares, with a significant portion designated for vegetative and artificial regeneration.

Table 1. *Overview of Damaged Areas by Forest Areas*

Forest Area	State forests		Private forests		Total for restoration	
	ha	m^3	ha	m^3	ha	m^3
Timok	10,060.72	979,682	21,588.00	219,869	31,648.72	1,199,551.00
Morava	6,744.22	569,775	1,818.00	41,946	8,562.22	611,721.00
Northern Kučaj	1,612.60	7,868	460.00	3,850	2,072.60	11,718.00
Rasina	827.10	39,317	-	-	827.10	39,317.00
Southern Kučaj	175.14	11,339	20.00	400.00	195,14	11,739.00
Total	**19,419.78**	**1.607,981**	**23,886.00**	**266,065**	**23,886.00**	**1,874,046.00**

Source: *Action Plan for the Restoration of Damaged Forests in State and Private Ownership for 2015-2018, "Srbijašume" State Enterprise, Belgrade*

In the Timok Forest Area, the following Forest Management Units (FMUs) suffered the greatest damage: FMU Rtanj, FMU Tupižnica, FMU Šaška – Studena – Selačka Reka, FMU Zaglava I, FMU Tresibaba, FMU Vrška Čuka – Babajona – Treći Vrh, FMU Markov Kamen – Mečji Vrh, FMU Čestobrodica, FMU Dubašnica, FMU Zaglavak II, and FMU Stol.

According to Stojković (2015), the apocalyptic scene of ice breaks and ice throws was particularly striking in FMU Vrška Čuka – Babajona – Treći Vrh.

2. MATERIAL AND METHODS

According to the Extract from the Forest Growing Stock of the "Srbijašume" State Enterprise, as of 1 January 1 2017, the total area of forests and forest land in the Timok Forest Area was 214,623.42 hectares. A total of 89,190.42 hectares (38%) was in state ownership, while 132,433.00 hectares (62%) were privately-owned. Of the total area in state ownership, forests and forest land covered 79,030.38 hectares (96%), with the remaining cover and uses constituting 3,160.04 hectares (4%). Of the total stocked area in state ownership, 72,694.60 hectares are forests, while forest plantations (artificially established stands up to 20 years old) cover 579.96 hectares.

Of the total non-stocked area in state ownership, 5,755.82 hectares are suitable for afforestation (forest land), 1,713.36 hectares are barren land, 1,273.24 hectares are land for other purposes, and 173.44 hectares are occupied land.

The study examines only the forested areas of the Timok Forest Area, encompassing both natural forests and artificially established stands under state ownership managed by the "Srbijašume" State Enterprise, Belgrade. To achieve this, a comparative analysis of the forest growing stock in the Timok Forest Area considered key indicators such as origin, preservation state, mixture, tree species, stand classification, and socioecological classification.

Natural disasters inflicted substantial damage in some regions of the Timok Forest Area, leading to clear-cutting across more than 1200 hectares of forest stands. This research seeks to assess whether these events resulted in significant alterations to the state of the forest growing stock within the Timok Forest Area.

To analyze specific parameters of the forest growing stock in the Timok Forest Area, data from the database of the "Srbijašume" State Enterprise, Belgrade were employed, covering 11 forest management units (FMUs) under its management. The study aimed to assess the impact of ice storms on the state of the forest growing stock in the Timok Forest Area by comparing data collected on 31 December 2013 with data from 31 December 2021. It's important to note that during this period, the forest area expanded by 3,283.83 hectares, accompanied by a timber stock of 1,024,042.51 m³, posing a challenge for comparative analysis due to these changes. Additionally, alterations in forest stand classifications further complicate the evaluation. For instance, previously designated high forests have been reclassified as coppice forests, and a considerable portion of shrubland is now categorised as coppice forests or thickets. A more accurate depiction is obtained by investigating areas subjected to clear-cutting and examining forest management plans for the most severely affected FMUs.

3. RESULTS AND DISCUSSION

3.1. Stand State by Origin in the Timok Forest Area

One of the primary alterations in the forest growing stock of the Timok Forest Area relates to its origin. As of 31 December 2013 (Table 2), natural high stands constituted 31.8% of the forest growing stock in the Timok Forest Area, representing 56.5% of its volume and 47.0% of the volume increment. In terms of area, natural coppice stands of hardwoods were prevalent (32.2%), with a volume share of 36.2% and a contribution to volume increment of 38.7%. Artificially established coniferous stands covered 4.9% of the area, 6.8% of the volume, and 14.0% of the volume increment. Shrubland and thickets encompassed 31.1% of the area, while other forms (artificially established broadleaved stands) constituted approximately 0.1% of the forested area.

As of 31 December 2021 (Table 2), natural high stands constituted 30.9% of the forest growing stock in the Timok Forest Area, representing 55.8% of its volume and 46.1% of the volume increment. Natural coppice stands of hardwoods dominated in terms of area, accounting for 34.7%, with a volume share of 37.6% and a contribution to volume increment of 41.3%. Artificially established coniferous stands covered 4.1% of the area, 6.5% of the volume, and 12.3% of the volume increment. Shrubland and thickets encompassed 29.5% of the area, while other forms (artificially established hardwood and softwood stands) constituted approximately 0.7% of the forest stocked area.

The most notable observation is the substantial difference between the total area of the region and the total timber stock. The Timok Forest Area witnessed an expansion of 3,283.83 hectares in the intervening period, resulting in a total timber stock of 1,024,042.51 m³, attributed to the incorporation of areas previously under different ownership. Consequently, providing precise comments on the data derived from the 2013 and 2021 overviews presented in Table 2, concerning changes in the forest growing stock by origin, poses a challenge. A more accurate assessment of changes in the state of the forest growing stock can be derived from the relative share of individual stand forms.

Table 2. *State of Forests by Origin in the Timok Forest Area on 31 December 2013 and 31 December 2021*

Stand origin	Area		Volume		Volume increment	
	ha	%	m^3	%	m^3	%
Natural hardwood high stands 2013	22704.39	31.59	4499767.3	56.4	93374.4	46.9
Natural hardwood high stands 2021	22917.32	30.49	4973646.78	55.28	106127.70	45.59
Difference	212.93	-1.10	473879.50	-1.16	12753.29	-1.35
Natural softwood high stands 2013	0.00	0.00	0.00	0.00	0.00	0.00
Natural softwood high stands 2021	6.23	0.01	445.6	0.0	11.6	0.0
Difference	6.23	0.01	445.61	0.00	11.64	0.01
Natural hardwood coppice stands 2013	23120.57	32.17	2884329.5	36.2	77005.3	38.7
Natural hardwood coppice stands 2021	25953.25	34.53	3371537.1	37.5	95840.7	41.2
Difference	2832.68	2.36	487207.59	1.30	18835.44	2.46
Natural softwood coppice stands 2013	0.00	0.00	0.00	0.00	0.00	0.00
Natural softwood coppice stands 2021	175.90	0.23	4531.3	0.1	156.3	0.1
Difference	175.90	0.23	4531.31	0.05	156.27	0.07
Natural coniferous high stands 2013	95.42	0.13	7122.6	0.1	271.4	0.1
Natural coniferous high stands 2021	103.48	0.14	7122.6	0.1	271.4	0.1
Difference	8.06	0.00	0.00	-0.01	0.00	-0.02
Natural high stands of conifers and broadleaves 2013	0.00	0.00	0.00	0.00	0.00	0.00
Natural high stands of conifers and broadleaves 2021	187.66	0.25	34529.3	0.4	993.8	0.4
Difference	187.66	0.25	34529.31	0.38	993.81	0.43
Artificially established hardwood stands 2013	1.71	0.00	106.1	0.0	5.6	0.0
Artificially established hardwood stands 2021	527.44	0.70	19807.9	0.2	801.0	0.3
Difference	525.73	0.70	19701.78	0.22	795.36	0.34
Artificially established softwood stands 2013	33.73	0.05	543.5	0.0	22.6	0.0
Artificially established softwood stands 2021	7.29	0.01	319.6	0.0	8.3	0.0
Difference	-26.44	-0.04	-223.85	0.00	-14.30	-0.01
Artificially established coniferous stands 2013	3533.88	4.92	539370.9	6.8	27801.0	14.0
Artificially established coniferous stands 2021	3072.25	4.09	585190.0	6.5	28568.0	12.3
Difference	-461.63	-0.83	45819.06	-0.26	767.04	-1.70
Shrublands 2013	14096.72	19.61	41847.8	0.5	425.7	0.2
Shrublands 2021	10700.69	14.24	0.0	0.0	0.0	0.0
Difference	-3396.03	-5.38	-41847.80	-0.52	-425.71	-0.21
Thickets 2013	8292.37	11.54	0.0		0.0	
Thickets 2021	11511.11	15.31	0.0	0.0	0.0	0.0
Difference	3218.74	3.78	0.00	0.00	0.00	0.00
Total 2013	**71878.79**		**7973087.73**		**198905.96**	
Total 2021	**75162.62**		**8997130.23**		**232778.81**	
Difference	**3283.83**		**1024042.51**		**33872.85**	

Source: *Database of SE "Srbijašume" on 31 December 2013 and 31 December* 2021 *and authors' calculations.*

For a more comprehensive understanding of changes in the forest growing stock, the paper presents a summary of clear-cut stand areas by origin (Table 3). It's important to note that the extent of the area affected by the ice storm exceeds what is shown in this table. However, clear-cutting wasn't implemented on a significant portion of that area and, therefore, is not the focus of this study. Natural high stands of hardwoods saw an increase in area of approximately 200 hectares. Between 2015. and 2020., around 160 hectares of these stands underwent clear-cutting. However, nearly all clear-cut natural stands were left for vegetative regeneration, leading to a reduction in the initial forest growing stock of natural high stands of hardwoods. The expansion of the forested area contributed to the increase in the area of natural high stands of hardwoods in Table 2.

Following the ice storm, slightly over 800 hectares of natural coppice stands of hardwoods underwent clear-cutting. Their rise in the forest growing stock by a little over 2,800 hectares is, in part, the outcome of converting natural high stands of hardwoods affected by the natural disaster (approximately 160 hectares) into lower silvicultural forms through vegetative regeneration. The increase is also associated with the transformation of substantial areas covered by thickets into coppice forests and, undoubtedly, the expansion of the forested area.

The natural disaster had a profound impact on artificially established coniferous stands, leading to a reduction of approximately 460 hectares in their stock. Nearly half of this decrease (about 250 hectares) was a direct result of the ice storm and associated ice throws. Through biological reforestation efforts, some of these areas were replanted with hardwoods, contributing to the overall increase in the share of artificially established stands of hardwoods in the forest stock, while simultaneously decreasing the proportion of artificially established coniferous stands.

The substantial decrease in thickets (by 3,396.03 hectares) and the corresponding rise in shrubland (by 3,283.83 hectares) were not a direct result of the natural disaster. Instead, these changes were primarily due to the conversion of extensive areas covered by thickets into higher silvicultural forms, such as coppice stands, and permanent stages, namely shrubland.

Other alterations in the forest growing stock cannot be directly linked to the natural disaster but rather stem from the conversion of one stand type into another during the new forest inventory and the expansion of the forested area.

Table 3. *Structure by Origin of Ice-damaged Areas Subjected to Clear-Cutting in the Timok Forest Area from 2015 to 2020*

Origin	**Area(ha)**
High	161.31
Coppice	810.98
AES	248.74
Total	**1221.03**

3.1. Stand State by Origin in the Timok Forest Area

As of 31 December 2013, the preservation state of the forest stock in the Timok Forest Area was unsatisfactory. Well-preserved stands were the most dominant, constituting 42.5% of the area, 71.3% of the volume, and 75.4% of the volume increment. Thinned stands covered 19.5% of the area, accounting for 24.2% of the volume and 23.2% of the volume increment. In contrast, devastated stands, thickets, and shrublands collectively comprised 38.0% of the area, representing 4.6% of the total standing timber volume and 1.5% of the volume increment. The notable presence of devastated stands, thickets, and shrublands (38.0%) pointed to areas requiring extensive intervention and posing challenges. It's crucial to highlight that this area encompassed a significant proportion of shrubland, representing a permanent stage of vegetation, as opposed to thickets, which signify a degradation phase (Pavlović *et al*., 2022).

In the forest stock of the Timok Forest Estate, as of 31 December 2021, well-preserved stands accounted for 31.0% of the area, 52.6% of the volume, and 56.7% of the volumetric increment. There was a significant increase in the share of thinned stands, contributing to 32.5% of the area, 44.0% of the volume, and 40.7% of the volume increment. Devastated stands, thickets, and shrublands collectivelly made up 37% of the area, accounting for 3.5% of the total standing timber volume.

Table 4. *Forest Preservation State in the Timok Forest Area on 31 December 2013 and 31 December 2021*

Stand State	Area		Volume		Volume increment	
	ha	%	m³	%	m³	%
Well-preserved stands 2013	30563.72	42.5	5684412.8	71.3	150015.0	75.4
Well-preserved stands 2021	23263.93	31.0	4727991.7	52.5	131953.0	56.7
Difference	-7299.79	-11.5	-956421.1	-18.8	-18062.0	-18.7
Thinned stands 2013	14027.53	19.5	1925477.8	24.2	46008.6	23.2
Thinned stands 2021	24442.54	32.5	3959163.4	44.0	94819.0	40.7
Difference	10415.01	13.0	2033685.6	19.8	48810.4	17.5
Devastated stands 2013	4898.45	6.8	321349.4	4.1	2456.6	1.3
Devastated stands 2021	5244.35	7.0	309975.1	3.4	6006.8	2.6
Difference	345.9	0.2	-11374.3	-0.7	3550.2	1.3
Shrublands and thickets 2013	22389.09	31.2				
Shrublands and thickets 2021	22211.8	29.6				
Difference	-177.29	-1.6				
Total 2013	**71878.79**		**7931240.0**		**198480.2**	
Total 2021	**75162.62**		**8997130.2**		**232778.8**	
Difference	**3283.83**		**1065890.2**		**34298.6**	

Source: *Database of the "Srbijašume" State Enterprise as of 31 December 2013 and 31 December 2021 and authors' calculations*

The data in Table 4 indicates a significant decrease in the share of well-preserved stands by nearly 7,300 hectares (11.5%), while the share of thinned stands increased significantly by approximately 10,400 hectares (13%). Clear-cutting, resulting from the natural disaster, was conducted on an area of about 1,200 hectares (Table 3). These stands were reclassified as thinned in the new inventory. They should have been categorised as devastated stands because the damage from the natural disaster was total. However, they underwent artificial or natural regeneration, leading the planner to define them as thinned. It is important to note that a substantial part of the stands damaged by ice storm was not clear-cut, and some of these stands were classified as thinned stands. The increase in the area of thinned stands in the new inventory also resulted from converting shrublands into this silvicultural form, and to a lesser extent, from the expansion of the forested area by nearly 3,300 hectares. The increase in devastated stands in the forest growing stock was significantly smaller but still noteworthy (around 350 hectares).

The reduction in the share of shrublands during the study period by nearly 180 hectares resulted from converting certain areas covered by shrublands into higher silvicultural forms, specifically thinned stands.

The presence of thinned (insufficiently stocked) and devastated stand categories, shrublands, and thickets, on almost half of the total forested area, with all the associated negative effects (reduced ecological stability, underutilised site potential, diminished productivity compared to well-preserved stands, etc.), represents one of the fundamental, long-term challenges in managing our forests (Banković *et al*., 2009).

3.3. Stand State by Mixture in the Timok Forest Area

According to the state summary as of 31 December 2013, pure stands covered 36,630.30 hectares, which was 51% of the area. They accounted for 6,470,495.7 m^3 or 81.2% of volume and 157,431.1 m^3 or 79.2% of volume increment. Mixed stands covered 12,859.40 hectares (17.9%), accounting for 1,460,744.3 m^3 (18.3%) of volume and 41,049.1 m^3 (20.6%) of volume increment. The remaining area of 22,389.09 hectares (31.2%) comprised shrublands and thickets (Table 5).

According to the state summary as of 31 December 2021, pure stands covered 36,330.37 hectares, which was 48.3% of the area. They accounted for 6,944,750.1 m^3 or 77.2% of volume, and 173,597.9 m^3 or 74.6% of volume increment. Mixed stands covered 16,620.45 hectares (22.1%), with a volume of 2,052,380.2 m^3 (22.8%) and a volume increment of 59,181.2 m^3 (25.4%). The remaining area of 22,211.80 hectares (29.6%) comprised shrublands and thickets where the mixture, volume, and volume increment were not determined (Table 5).

Table 5. *Forest State by Mixture in the Timok Forest Area on 31 December 2013 and 31 December 2021*

Mixture	Area		Volume		Volume increment	
	ha	%	m^3	%	m^3	%
Pure stands 2013	36630.30	51.0	6470495.6	81.2	157431.1	79.1
Pure stands 2021	36330.37	48.3	6944750.1	77.2	173597.9	74.6
Difference	-299.93	-2.6	474254.4	-4.0	16166.8	-4.6
Mixed stands 2013	12859.40	17.9	1460744.3	18.3	41049.0	20.6
Mixed stands 2021	16620.45	22.1	2052380.2	22.8	59181.2	25.4
Difference	3761.05	4.2	591635.9	4.5	18132.2	4.8
Shrublands and thickets 2013	22389.09	31.1	41847.8	0.5	425.7	0.2
Shrublands and thickets 2021	22211.80	29.6				
Difference	-177.29	-1.6				
Total 2013.	**71878.79**		**7973087.7**		**198905.9**	
Total 2021.	**75162.62**		**8997130.2**		**232779.1**	
Difference	**3283.83**		**1024042.5**		**33873.3**	

Source: *Database of the "Srbijašume" State Enterprise as of 31 December 2013 and 31 December 2021 and authors' calculations*

The data presented in Table 5 indicates a decrease in the share of pure stands, accompanied by a notable increase in mixed stands. Besides the reasons mentioned earlier, such as the expansion of the forested area, this trend can be attributed to the greater vulnerability of pure stands, being a less stable stand type, which led to their replacement by artificially established coniferous stands in the form of monocultures. A significant portion of the areas that underwent clear-cutting were reforested with multiple tree species, resulting in the classification of these areas as artificially established mixed stands in the new forest inventory.

The areas covered by thickets and shrublands decreased due to the partial conversion of thickets into, most likely, mixed coppice stands.

The prevalence of pure stands, which are regarded as ecologically, functionally, and even productively inferior stand forms, poses a significant strategic challenge for the forests of Serbia (Banković *et al*., 2009). In contrast, mixed stands represent more stable forest ecosystems and demonstrate greater resilience to adverse abiotic and biotic influences, stressing the necessity to reduce the expansion of monocultures (Pavlović *et al*., 2022).

3.4. Stand State by Tree Species in the Timok Forest Area

The inventory of forests managed by the “Srbijašume” State Enterprise records a total of 75 tree species, comprising 59 broadleaved and 16 coniferous species. The number of tree species is of great importance from a biodiversity conservation perspective (Banković *et al*., 2009).

As indicated in Table 6, both before and after the natural disaster in the Timok Forest Area, broadleaved species maintained their dominance. They represented 93.4% of the volume and 86.2% of the increment. Among broadleaved species, beech was the most prominent, contributing to 72.3% of the total standing timber volume and 64.2% of the current volume increment. Other significant contributors to the standing timber volume among broadleaved species included sessile oak (9.0%), hornbeam (3.7%), Turkey oak (3.2%), Hungarian oak (2.6%), locust (0.5%), manna ash (0.4%), and sycamore (0.3%). Other hardwood species had minimal representation.

Coniferous stands accounted for only 6.6% in terms of volume and 13.8% in terms of increment. These were artificially established stands formed through afforestation of barren land and reclamation of devastated hardwood forests using spruce, pine, Douglas fir, and larch seedlings. The most significant coniferous species included Austrian pine with 4.6% volume and 10.2% volume increment, spruce with 1.3% volume and 2.1% volume increment, and Scots pine with 0.3% volume and 0.6% volume increment. Other coniferous species with notable contributions to volume included fir (0.3% volume, 0.5% volume increment), Douglas fir (0.1% volume, 0.2% volume increment), and Eastern white pine (0.1% volume, 0.3% volume increment).

The large number of tree species represents significant biodiversity and species richness, contributing to multiple environmental benefits (Pavlović *et al*., 2022). Particular attention should be devoted to species with the status of relict, endemic, rare, and endangered, according to the IUCN category – TBFRA 2000 (International Union for Conservation of Nature – Temperate and Boreal Forest Resource Assessment), as well as protected and strictly protected species, according to the Regulation on the Proclamation and Protection of Strictly Protected and Protected Wild Species of Plants, Animals, and Fungi (“Official Gazette of RS“ no.

5/10, 47/2011, 32/2016, and 98/2016). Therefore, special consideration should be given to species such as Turkish hazel, Balkan maple, various forest fruit trees such as walnut, service tree, wild service tree, etc., and shrub species such as those from the *Daphne* genus, as well as numerous herbaceous species such as *Ramond*a, etc. (Pavlović *et al*., 2022).

Table 6. *Forest State by Tree Species in the Timok Forest Estate as of 31 December 2013*

Tree species	Volume		Volume increment	
	m³	%	m³	%
Beech	5761269.0	72.3	127661.8	64.2
Sessile oak	721555.8	9.0	16243.9	8.2
Hornbeam	292060.7	3.7	7608.6	3.8
Turkey oak	257581.8	3.2	6852.0	3.4
Hungarian oak	205728.0	2.6	6693.8	3.4
Locust	37517.2	0.5	1768.8	0.9
Flowering ash	28750.3	0.4	891.5	0.4
Sycamore	25551.4	0.3	690.1	0.3
Field maple	20796.4	0.3	633.1	0.3
Turkish hazel	20215.6	0.3	490.8	0.2
OHS	17511.3	0.2	469.1	0.2
Oriental hornbeam	11859.0	0.1	297.6	0.1
Norway maple	9767.9	0.1	259.1	0.1
Common ash	9619.1	0.1	235.8	0.1
Large-leaved lime	7144.7	0.1	246.4	0.1
European aspen	4371.9	0.1	164.0	0.1
Cherry	3684.0	0.0	11.6	0.0
Silver lime	3580.5	0.0	102.6	0.1
OSS	1659.5	0.0	31.9	0.0
Wych elm	1537.1	0.0	43.8	0.0
Wild service tree	1023.8	0.0	0.0	0.0
Downy oak	950.2	0.0	0.7	0.0
Broadleaves	**7443735.1**	**93.4**	**171397.2**	**86.2**
Austrian pine	363435.0	4.6	20371.9	10.2
Norway spruce	105127.3	1.3	4140.0	2.1
Scots pine	24424.1	0.3	1286.2	0.6
Fir	22579.3	0.3	916.4	0.5
Douglas fir	6865.5	0.1	290.0	0.2
Eastern white pine	6585.8	0.1	502.7	0.3
Larch	325.0	0.0	0.0	0.0
Yew	6.7	0.0	0.0	1.0
Conifers	**529348.7**	**6.6**	**27507.2**	**13.8**
Total	**7973083.8**	**100.0**	**198904.4**	**100.0**

Source: *Database of the "Srbijašume" State Enterprise as of 31 December 2013 and authors' calculations*

The state of the forest growing stock by tree species in the Timok Forest Area after the natural disaster was almost unchanged. Namely, the most significant broadleaved and coniferous species, as well as their share in terms of volume and volume increment, did not undergo significant alterations.

3.5. Stand State by Stand Classification in the Timok Forest Area

According to the state assessment from 2013, beech forests dominated the forest growing stock of the Timok Forest Estate, covering 44.2% of the total forested area. Beech was followed by thickets and shrublands, occupying an area of 22,132.74 hectares, or 30.8% of the forested area (Table 7). The next in rank were sessile oak forests with 8.7%, hornbeam forests with 3.7%, Hungarian oak forests with 3.3%, Turkey oak forests with 3.0%, pine forests with 2.7%, forests of locust, aspen, and birch with 1.4%, spruce forests with 1.3%, followed by maple and ash forests, lime forests, and poplar forests with a minimal share in the total forested area. The prevalence of beech forests was even more evident when considering their contribution to the total volume (73.6%) and volume increment (65.6%). They were followed by sessile oak forests with a share in volume of 9.5% and in volume increment of 8.8%, pine forests with 5.0% in volume and 11.0% in increment, hornbeam forests with a volume share of 3.1% and an increment share of 3.5%, Hungarian oak forests with a volume share of 2.9% and an increment share of 3.7%, Turkey oak forests with a volume share of 2.8% and an increment share of 3.1%, spruce forests with 1.3% in volume and 2.1% in increment. Forests of other broadleaves and conifers had a negligible share in volume and volume increment (Table 7).

According to the state summary from 2021, beech forests continued to prevail, covering 43.2% of the forested area. Thickets and shrublands followed, occupying an area of 22,211.80 hectares, or 29.6% of the forested area. Significant contributions were also made by sessile oak forests with 8.5%, hornbeam forests with 4.2%, Turkey oak forests with 4.1%, Hungarian oak forests with 3.4%, pine forests with 2.5%, forests of locust, aspen, and birch with 1.6%, spruce forests with 1.1%, forests of other conifers with 0.7%, and ash and maple forests with 0.6%. Other categories had a negligible share in the total forested area. When considering the share in the total volume and volume increment, beech forests were also prevalent (contributing 71.9% in volume and 64.0% in volume increment). Sessile oak forests followed with a volume share of 9.5% and an increment share of 9.3%, pine forests with 4.6% in volume and 9.4% in increment, hornbeam forests with a volume share of 4.1% and an increment share of 4.3%, Turkey oak forests with 3.6% share in volume and 4.3% share in increment, Hungarian oak forests with a volume share of 3.0% and an increment share of 3.8%, spruce forests with 1.5% share in volume and 2.2% share in increment, and forests of other conifers with 0.5% in volume and 0.8% in increment. Forests of other broadleaves and conifers had a negligible share in volume and volume increment (Table 7).

By expanding the forested area by 3,283.83 hectares, the timber stock in high, coppice and artificially established stands without thickets and shrublands increased by 1,060,058 m^3. Even in stands where the area decreased, the timber stock increased. The area covered by shrublands and thickets slightly increased, not so much due to the addition of a small area, but primarily because a large part of them were converted into coppice stands, as mentioned earlier. The expansion of the area had the most significant impact on the increase in Turkey oak forests, followed by beech and hornbeam forests. Ice breaks and ice throws caused the most significant damage in artificially established stands of spruce, Austrian pine, and Scots pine. This led to the reduction of the area covered by these species. These areas were often artificially regenerated using broadleaved species, and these biological activities contributed to the expansion of their stands, primarily beech and sessile oak, and the reduction of areas covered by stands of the mentioned coniferous species.

Table 7. *Forest State by Stand Type in Timok Forest Area as of 31 December 2013*

Stand unit	Area		Volume		Volume increment	
	ha	%	m³	%	m³	%
Beech forests 2013	31747.20	44.2	5869464.2	73.6	130390.4	65.6
Beech forests 2021	32491.25	43.2	6464732.7	71.9	148914.3	64.0
Difference	744.05	-1.0	595268.5	-1.7	18523.9	-1.6
Sessile oak forests 2013	6238.53	8.7	759462.6	9.5	17527.1	8.8
Sessile oak forests 2021	6356.14	8.5	850859.5	9.5	21721.5	9.3
Difference	117.61	-0.2	91396.9	0.0	4194.4	0.5
Hornbeam forests 2013	2651.26	3.7	250190.6	3.1	7019.9	3.5
Hornbeam forests 2021	3151.68	4.2	364265.0	4.1	9958.5	4.3
Difference	500.42	0.5	114074.4	1.0	2938.6	0.8
Hungarian oak forests 2013	2345.79	3.3	230211.4	2.9	7396.3	3.7
Hungarian oak forests 2021	2516.29	3.4	269063.5	3.0	8823.1	3.8
Difference	170.50	0.1	38852.1	0.1	1426.8	0.1
Turkey oak forests 2013	2155.05	3.0	223612.4	2.8	6160.7	3.1
Turkey oak forests 2021	3044.90	4.1	320578.2	3.6	9928.9	4.3
Difference	889.85	1.1	96965.8	0.8	3768.2	1.2
Pine forests 2013	1918.81	2.7	396889.4	5.0	21923.1	11.0
Pine forests 2021	1868.82	2.5	408958.8	4.6	21848.1	9.4
Difference	-49.99	-0.2	12069.4	-0.4	-75.0	-1.6
Locust, aspen and birch forests 2013	1024.27	1.4	37090.8	0.5	1748.0	0.9
Locust, aspen and birch forests 2021	1209.01	1.6	38451.3	0.4	1894.6	0.8
Difference	184.74	0.2	1360.5	-0.1	146.6	-0.1
Spruce forests 2013	945.50	1.3	105181.8	1.3	4073.6	2.1
Spruce forests 2021	797.41	1.1	138045.7	1.5	5044.8	2.2
Difference	-148.09	-0.2	32863.9	0.2	971.2	0.1
Ash and maple forests 2013	203.82	0.3	9959.5	0.1	321.1	0.2
Ash and maple forests 2021	479.82	0.6	37337.3	0.4	1094.3	0.5
Difference	276.00	0.3	27377.8	0.3	773.2	0.3
Forest of other broadleaves 2013	196.95	0.3	2523.3	0.1	38.6	0.0
Forest of other broadleaves 2021	244.52	0.3	16359.3	0.2	353.1	0.2
Difference	47.57	0.0	13836.0	0.1	314.5	0.2
Forests of other conifers 2013	165.60	0.2	15642.3	0.2	774.4	0.4
Forests of other conifers 2021	517.66	0.7	44777.9	0.5	1931.7	0.8
Difference	352.06	0.5	29135.6	0.3	1157.3	0.4
Fir forests 2013	99.39	0.1	33238.7	0.4	1109.7	0.6
Fir forests 2021	183.82	0.2	33453.8	0.4	969.7	0.4
Difference	84.43	0.1	215.1	0.0	-140.0	-0.2
Lime forests 2013	32.53	0.1	2906.1	0.1	94.7	0.1
Lime forests 2021	38.17	0.1	6670.4	0.1	181.2	0.1
Difference	5.64	0.0	3764.3	0.0	86.5	0.0
Poplar forests 2013	20.42	0.1	569.7	0.0	15.1	0.0
Poplar forests 2021	27.48	0.0	2391.5	0.0	83.2	0.1
Difference	7.06	-0.1	1821.8	0.0	68.1	0.1
Willow forests 2013	0.93	0.0	129.5	0.0	1.4	0.0
Willow forests 2021	23.85	0.0	1185.6	0.0	31.8	0.0
Difference	22.92	0.0	1056.1	0.0	30.4	0.0
Total (excluding thickets and shrublands) 2013	**49746.05**	**69.2**	**7937072.2**	**100.0**	**198594.0**	**100.0**
Total (excluding thickets and shrublands) 2021	**52950.82**	**70.5**	**8997130.2**	**100.0**	**232778.8**	**100.0**
Difference	**3204,77**	**1,3**	**1060058,0**	**0,0**	**34184,8**	**0,0**
Total (thickets and shrublands) 2013	**22132,74**	**30,8**				
Total (thickets and shrublands) 2021	**22211,80**	**29,6**				
Difference	**79,06**	**-1,2**				

Source: *Database of the "Srbijašume" State Enterprise as of 31 December 2013 and 31 December 2021 and authors' calculations.*

3.6. Forest State by Socioecological Classification in the Timok Forest Area

Socioecological classification is defined by site and phytosociological classification, serving as an ecological characteristic of forests that does not significantly change between two management periods. However, it is not a fixed category; rather, such changes, require a much longer time period. Changes in socioecological units can result from long-term and gradual climate changes. In this context, we are addressing weather extremes occurring in specific years, which, as such, cannot individually have a significant impact on the site and potential vegetation. They can only temporarily “disturb” the ecosystem balance. If the site is not significantly altered, the ecosystem returns to balance through vegetation succession. As this process is not short, the task of forest managers is to accelerate it through artificial regeneration, bypassing some stages in succession and quickly creating the climax stages and oroclimax-conditioned forest communities (Pavlović *et al*., 2022). Artificial regeneration of clearcut areas was carried out several times, both with species compatible with the site and with species that were not suitable for the potential vegetation. On the other hand, pioneer tree species and vegetative regeneration from stumps and shoots more commonly occurred. This spontaneous vegetation represented different stages in the succession of vegetation on clearcut surfaces.

As presented in Table 8, the most prevalent forest type in the forest growing stock was the mountain beech forest (*Fagetum moesiacae montanum*) on various brown soils (33.89%). It was followed by the submontane beech forest (*Fagetum moesiacae submontanum*) on acidic brown and other soils (17.27%), the Oriental hornbeam forest (*Carpionion orientalis moesiacum*) on rendzinas and various eroded soils (11.96%), the sessile oak and hornbeam forest (*Querco-carpinetum moesiacum*) on brown and leached brown soils (11.47%), and the sessile oak forest (*Quercetum montnaum*) on brown soils (10.96%). Other socioecological units covered less than 10% of the area.

Table 8. *Forest State by Socioecological Classification in the Timok Forest Area as of 31 December 2021*

Socioecological unit	Površina	
	ha	%
Mountain beech forest (*Fagetum moesiacae montanum*) on various brown soils	24357.37	33.89
Submontane beech forest (*Fagetum moesiacae submontanum*) on acidic brown and other soils	12412.45	17.27
Oriental hornbeam forest (*Carpionion orientalis moesiacum*) on black soil and various eroded soils	8594.22	11.96
Sessile oak and hornbeam forest (*Querco - carpinetum moesiacum*) on brown and brown leached soils	8245.77	11.47
Sessile oak forest (*Quercetum montnaum*) on brown soils	7876.97	10.96
Typical forest of Hungarian oak and Turkey oak (*Quercetum frainetto-cerris typicum*) on brown leached soils	4356.91	6.06
Forest of Oriental hornbeam with oaks (*Carpino orientalis-Polyquercetum*) on pararendzinas and shallow eutric cambisol over loess	2966.22	4.13
Sessile oak and Turkey oak forest (*Quercetum petraeae-cerris*) on soils over loess. silicate rocks and limestone	875.25	1.22
Turkey oak forest (*Quercetum cerris*) on A-C to A1-A3-B1-C soil series	544.55	0.76
Forest of Hungarian oak and Turkey oak with Oriental hornbeam (*Quercetum frainetto-cerris carpinetosum orientalis*) on dystric brown and eutric brown soils	391.29	0.54
Forest of Hungarian oak and Turkey oak with hornbeam (*Quercetum frainetto-cerris carpinetosum betuli*) on brown and leached soils and diluvium	345.47	0.48
Forest of beech. hornbeam. and noble broadleaves (*Aceri - Carpini - Fagetum moesiace montanum*) on humus-silicate and more or less skeletal brown soils	317.26	0.44
Spruce forest (*Piceion excelsae serbicum*) on distric humus-silicate brown soils and black soils over limestone	248.40	0.35
Forest of Hungarian oak and Turkey oak with sessile oak (*Quercetum frainetto-cerris petraetosum*) on various brown and humus-silicate soils	69.13	0.10
Forest of different oaks with manna ash (*Orno-Polyquercetum*) on various shallow soils	58.71	0.08
Forest of beech and fir (*Abieti-Fagetum serpentinicum*) on peridotites. serpentinised peridotites. and serpentinites	49.09	0.07
Forest of Hungarian oak and Turkey oak with pedunculate oak (*Quercetum frainetto-cerris quercetosum roboris*) on eutric cambisol and leached to pseudogley soils	40.24	0.06
Forest of sessile oak. hornbeam and Turkey oak (*Carpino - Quercetum petraeae - cerris*) on soils over loess and acidic silicate rocks	35.15	0.05
Forest of beech and sessile oak (*Querco-Fagetum*) on various brown and leached brown soils	32.86	0.05
Forest of white and black poplar Šuma bele i crne topole (*Populetum albo-nigrae*) on a mosaic of different alluvial soils	29.73	0.04
Forest of Turkey oak and large-leaved downy oak (*Quercetum cerris-virgilianae*) on poorly developed soils over loess. marl. and limestones	11.55	0.02
Forest of different oaks and hornbeam (*Carpino- Polyquecetum*) on soils formed over loess	8.40	0.01
Hungarian oak forest (*Quercetum frainetto*) on leached and leached acidic brown soils	6.46	0.01
Forest of white poplar (*Populetum albae*) on dry recent alluvial deposits. initial phases. and other dry variants of alluvial pararendzinas (semigley soils)	3.82	0.01
Forest of white willow (*Salicion albae*) on moist recent alluvial deposits and gleysols	0.93	0.00
Black alder swamp forest (*Alnetum glutinosae*) on alpha/beta to beta-gleysol and humogley	0.59	0.00
Total	**71878.79**	**100.00**

Source: *Database of the "Srbijašume" State Enterprise as of 31 December 2021 and authors' calculations*

5. CONCLUSION

The natural disaster manifested as ice breaks, snow breaks, ice throws, and snow throws during the winter of 2014/2015, had adverse effects on the forest growing stock and the state of forests in some parts of the Timok Forest Area.

The damage varied in intensity, with approximately 1200 hectares experiencing such extensive damage that clear-cutting became necessary. Artificially established stands were nearly completely destroyed, while natural stands struck by this icy catastrophe suffered significant harm.

Accurately assessing changes in the forest estate after the natural disaster proves challenging when relying solely on a comparison of conditions before and after the event. This difficulty arises from the expansion of the Timok Forest Area by 3283.83 hectares, encompassing a total growing stock of 1.024.042.51 m³, through the incorporation of areas previously managed by other owners. Additionally, certain stands underwent alterations in their stand structure during new forest inventories. To comprehend changes in the forest growing stock, an examination of areas requiring clear-cutting as a necessary measure, alongside biological and silvicultural operations within management units, was employed. It should be noted that clear-cutting was not performed over a large area within less damaged stands. Some of these stands changed the category they belonged to from preserved to thinned and devastated stands in the new forest inventory.

The most significant changes in the forest growing stock were related to the origin and preservation state of stands. Besides the increase in the forest area by over 3200 ha, a large part of high forests were converted to coppice forests, a lower silvicultural form, as they were left to regenerate vegetatively. Consequently, the area under coppice forests, mainly of hardwoods, increased. Conversely, artificially established conifer stands suffered extensively, with some areas being afforested with hardwoods. This led to the increase in the share of artificially established stands of hardwoods in the forest growing stock, but not enough compared to the increase in hardwood coppice forests. The reduction in the share of artificially established conifer stands was beneficial in terms of forest stability against potential future weather disasters. All stands that were clear-cut and artificially or naturally (vegetatively) regenerated were defined as thinned in the new inventory, even though they were essentially devastated. The limited success of artificial regeneration makes these areas (former artificially established conifer stands) prone to natural regeneration through vegetation succession. Pure stands, particularly conifer monocultures, displayed increased vulnerability to the natural disaster, contributing to changes in the forest growing stock concerning stand mixture.

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CHANGES IN THE FOREST GROWING STOCK OF THE TIMOK FOREST AREA FOLLOWING THE ICE STORM IN WINTER 2014/2015

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Summary

During the winter of 2014/2015, ice rain inflicted substantial damage to forest trees in eastern Serbia. This study focuses on the state-owned forest areas within the Timok Forest Area, encompassing both natural forests and artificially established stands under the management of the "Srbijašume" State Enterprise. The natural disaster, characterised by icebreaks and ice throws, caused severe devastation in some parts of the Timok Forest Area, prompting extensive clear-cutting measures on approximately 1200 hectares of forest stands. The primary objective of this research was to determine whether notable changes occurred in the state of the forest growing stock at the area level. The artificially established stands affected by the natural disaster faced near-total destruction. Concerning natural forests, all stand types and structures situated between 600 and 900 meters above sea level were affected by this ice calamity. It moved from the northern part of the Balkan Mountains along the border with Bulgaria, in a west-northwest direction until reaching Čestobrodica. Every natural stand in its way incurred damage. Over the study period, there was a significant decrease in the share of high stands of hardwoods, while the proportion of coppice stands of hardwoods experienced an increase. Concurrently the share of artificially established conifer stands, particularly monocultures, decreased, leading to a rise in artificially established mixed stands of hardwoods. Additionally, the proportion of preserved stands decreased, whereas thinned and devastated stands witnessed an increase. In some areas, artificial regeneration was not entirely successful. Natural regeneration initiated in these regions, marked by the colonisation of pioneer species at various stages of vegetation succession.

PROMENA STANJA ŠUMSKOG FONDA U TIMOČKOM ŠUMSKOM PODRUČJU KAO POSLEDICA LEDOLOMA U ZIMU 2014/2015. GODINE

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Rezime

Na području istočne Srbije u zimu 2014/2015. godine, ledena kiša je pričinila velike štete na šumskom drveću. Predmet ovog istraživanja su obrasle površine Timočkog ŠP (prirodne šume i veštački podignute sastojine) u državnom vlasništvu kojima gazduje JP „Srbijašume“ Beograd. Elementarna vremenska nepogoda je u pojedinim delovima Timočkog ŠP pričinila ogromne štete u vidu ledoloma i ledoizvala, te su morale biti izvršene čiste seče na velikim površinama (oko 1200 ha šumskih sastojina). Cilj istraživanja je da se utvrdi da li je došlo do bitnih promena u stanju šumskog fonda na nivou područja. Veštački podignute sastojine, zahvaćene vremenskom nepogodom stradale su gotovo u celosti, a od prirodnih šuma zahvaćeni su svi sastojinski i strukturni oblici u pojasu između 600 i 900 m nadmorske visine. Ledena stihija se kretala pravcem od severnog dela Stare planine od granice sa Bugarskom u smeru zapad-severozapad, do Čestobrodice. Stradale se sve prirodne sastojine koje su se našle na udaru. U analiziranom periodu, naročito se smanjilo učešće visokih šuma tvrdih lišćara, a povećalo ućešće izdanačkih sastojina tvrdih lišćara. Takođe se smanjilo učešće veštački podignutih sastojina četinara (monokultura), na račun povećanja

veštački podignutih mešovitih sastojina tvrdih lišćara. Takođe se realno smanjilo učešće očuvanih, a povećalo učešće razređenih i devastiranih sastojina. Na pojedinim mestima, veštačko obnavljanje nije u potpunosti uspelo. Na ovim površinama je takođe započelo prirodno obnavljanje, naseljavanjem pionirskih vrsta u različitim fazama sukcesija vegetacije.