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Natural regeneration of post-fire forest areas in Stara Zagora Regional Forest Directorate, Bulgaria

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Thematic field: Forest disturbances and management challenges

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Abstract

The rapid and persistent climate change in recent years has amplified the occurrence and spread of various extreme weather events, causing significant socio-economic, ecological, and cultural damages. Forest fires have become constant threat to human life and major challenge to the resilience of forest ecosystems and their ability to recover after severe disturbances. The focus is on the topic of forest vegetation regeneration as first stage of recovery and adaptation. The study, conducted as part of the FIRE-RES project, focuses on the area affected by one of the most severe wildfires near the village of Dabovo (2007), within the jurisdiction of the Regional Forest Directorate Stara Zagora. Due to its characteristics, the area faces constant threat of extreme fires. The objective of the study is to conduct a scientifically grounded assessment of forest resilience and post-fire recovery capacity. To assess regeneration processes, we established methodology for evaluating regeneration and development of understorey vegetation in forest areas affected by fires. Three areas with different exposures, i.e., different types of habitats, were selected within the burned area, where three transects were laid, covering all altitudes within the fire zone. The inventory in the survey plots was carried out by tree species, origin, coverage, and height. The results demonstrate significant relationships between post-fire regeneration dynamics and the structural and ecological condition of the landscape following the disturbance. The real assessment of regeneration after major disturbances allows precise determination of appropriate forestry measures and the creation of a landscape resilient to various challenges. Fifteen years after the Dabovo fire, natural regeneration remains spatially uneven and incomplete, with pioneer species dominating the sun-exposed slopes, emphasising the need for targeted actions to provide ecosystem recovery.

Key words: adaptation, forest fires, recovery, resilient landscapes.

Introduction

In recent years, there has been a growing frequency of sudden natural disasters that disrupt – and in some cases entirely devastate – the normal course of development in natural ecosystems. Among the primary drivers of these extreme events is the ongoing climate change, specifically rising average temperatures, prolonged droughts, intense precipitation events, and unseasonal cold spells. The significance of such disturbances for forest stands is often substantial and is largely determined by the scale of disruption and the pre-existing condition of forests. Nevertheless, climate change is not the sole factor contributing to the increased vulnerability of natural ecosystems. The intensification of land use – manifested in the expansion of infrastructure and urban areas, the conversion of vegetation for agricultural and pastoral activities, as well as increased human presence in natural sites for tourism, recreation, and sport – has created conditions favourable to the ignition and spread of wildfires, particularly during the warmer and drier months (UNDRR 2017). Anthropogenic climate change is inducing large-scale transformations in forest ecosystems, both directly through changes in temperature and precipitation patterns, and indirectly by altering the natural disturbance regimes (Anderson-Teixeira et al. 2013, McDowell et al. 2020). Frequent and severe wildfires have long-term impacts on forest development patterns and biodiversity (Adámek et al. 2016). Globally, there has been a marked increase in both the number of wildfires and the extent of the damage they cause. According to the European Forest Fire Information System (EFFIS 2025), a total of 8,448 forest fires were recorded across Europe in 2024, affecting an area of 1,684,273 ha. In Bulgaria alone, 133 fires were registered during the same year, burning a total of 44,745 ha. Increasing attention is being paid by both scientists and practitioners to the issue of limiting the adverse effects of forest fires, particularly in regions, such as those found in South-east European geographic latitudes. Several key focus areas have emerged, including: preventive measures, rapid fire detection, improved strategies for combating ongoing wildfires, and technologies for post-fire recovery and ecosystem adaptation.

Fires exert a destructive impact on forest ecosystems, acting as local ecological catastrophes. In addition to destroying tree stands, wildfires cause degradation across all components of the forest ecosystem – vegetation cover, soil and associated microorganisms, as well as animal communities (Tashev et al. 2003). The ecological consequences of forest fires vary depending on the season, the quantity, condition and distribution of combustible materials, climatic conditions, fire intensity and duration, terrain slope, aspect and elevation, vegetation type, soil properties, and many other factors (Bogdanov 2010). Following such a dynamic disturbance as fire, ecosystem recovery tends to be slow and often incomplete, mainly due to the severity of degradation. Consequently, the affected ecosystems frequently lose their capacity to provide essential ecosystem services – ecological, social, and economic. In particular, disturbances that are both extensive and severe can impair forest recovery processes (i.e., the restoration of forest structure, composition, and function), which are core components of ecosystem resilience (Nikinmaa et al. 2020). Such disruptions may result in successional shifts toward altered forest types or even non-forest ecosystems (Donato et al. 2016, Martínez-Vilalta and

Lloret 2016, Young et al. 2019, Coop et al. 2020). Therefore, the study of post-fire succession, and particularly the regenerative processes of forest vegetation, is of critical importance for ensuring the resilience of natural ecosystems at the landscape level. The main objective of this study is precisely to assess the forest's recovery capacity and the influence of certain determining factors. Although such studies are inherently regional, they often reveal universal ecological patterns (Tashev et al. 2003). Forest regeneration is often hindered by a combination of limited seed availability and the environmental consequences of large-scale, severe disturbances. In particular, drought conditions accompanied by elevated temperatures may significantly obstruct the successful establishment and growth of tree regeneration following fire events (Harvey et al. 2016, Hansen et al. 2018, Davis et al. 2019). The initial reorganisation phase following disturbance is widely recognised as a crucial window for determining future forest dynamics (Seidl and Turner 2022). Forest recovery is strongly constrained by the scale of disturbance. In the case of large burnt areas, it is essential to consider whether viable seed sources remain from surviving trees or adjacent territories, and to what extent the fire has impacted soil properties (Bogdanov 2023).

Wildfires lead to the destruction of vegetation and the degradation of soil, with coniferous forests being most severely affected – especially plantations of Austrian black pine (*Pinus nigra* J.F.Arnold) in the lower altitudinal zones of Bulgaria (Tashev et al. 2003, Bogdanov 2022). Coniferous plantations established outside the natural range of the respective tree species require adapted management and strategies to minimise the negative effects caused by their low resistance to various biotic and abiotic factors. Their location in the lower vegetation belt is a significant predisposition for the occurrence and spread of forest fires and various calamities (Popov et al. 2016, 2018).

The primary objective of the study is to provide a scientifically substantiated assessment of the capacity of forest ecosystems to regenerate and recover following wildfire disturbances. This involves evaluating the effectiveness and dynamics of natural regeneration processes, identifying key ecological factors influencing recovery, and determining adaptive forest management strategies aimed at enhancing post-fire resilience.

Materials and Methods

The study was conducted in an area affected by a wildfire in 2007 near the village of Dabovo. This area is located in south-central Bulgaria, within the Kazanlak Valley, between the northern slopes of the Sarnena Sredna Gora and the Balkan Mountains (Stara Planina). The area falls within the jurisdiction of the Mazalat State Game Enterprise, managed by the Regional Forest Directorate (RFD) of Stara Zagora (Fig. 1).

The climatic characteristics of the region predispose it to various natural disturbances that can compromise the condition of forest ecosystems and the ecological functions they provide. Average annual temperatures range between 12 and 14 °C, with annual precipitation around 500–600 mm, and prolonged hot and dry periods during summer. The wildfire was recorded on 25 July 2007 and was extinguished five days later. The reported cause of ignition was a short circuit along a railway line, in an area predominantly covered with grasses and shrubs. The

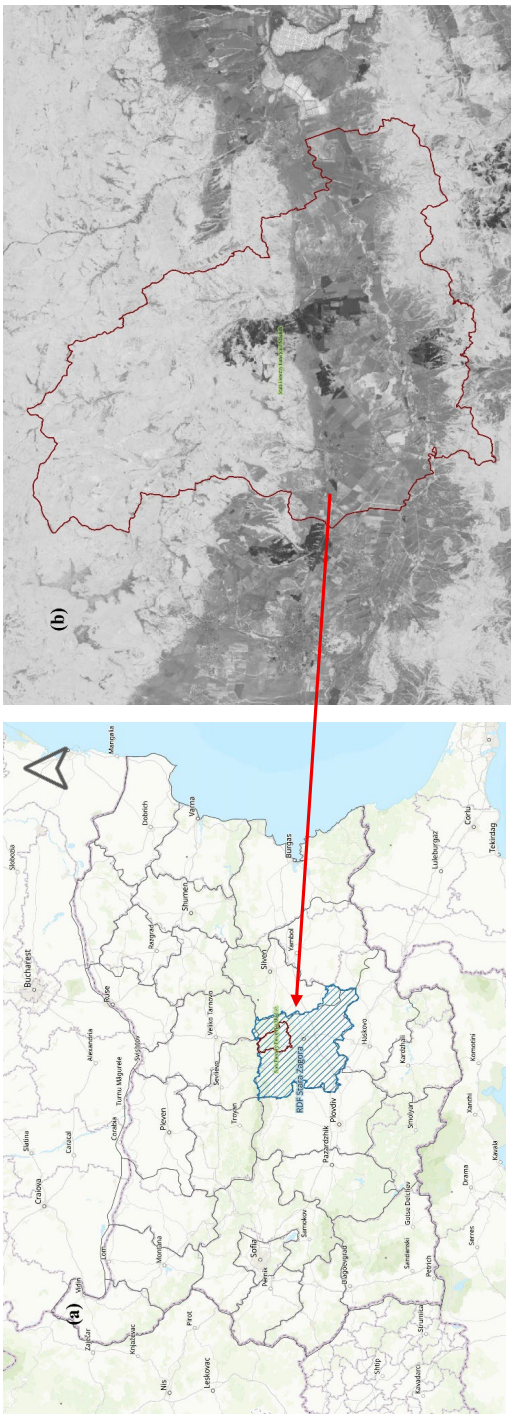


Fig. 1. Location of the studied region: (a) The territorial scope of the Stara Zagora Regional Forestry Directorate is shaded in blue, and the Mazalat State Hunting Enterprise is shown in green. (b) The area affected by the wildfire near the village of Dabovo is outlined in black, illustrating its proportion relative to the total territory of the hunting estate.

fire spread rapidly, resulted in the destruction of 1,370.4 ha of forested land, coniferous Austrian black pine plantations and oak forest stands.

The regeneration assessment was conducted in accordance with the officially adopted Methodology for the Evaluation of Natural Regeneration and Development of Understorey in Forest Areas (EFA 2025). According to this methodology, three linear transects were predetermined, covering three aspects – north-east (NE), south-east (SE), and east (E). Sample plots were established at approximately 20 m intervals, with minor deviations in some locations due to terrain features. The transects measured 307 m, 302 m, and 186 m for the first, second, and third transects, respectively. Along each transect, a total of 40 circular sample plots were established. Each sample plot consisted of two concentric circles with a common centre but different radii: the smaller with a radius of 1.30 m and the larger with a radius of 2.80 m.

The regeneration within the two concentric circles was categorised by tree species, origin, height, and degree of suppression. In the smaller circle, regeneration with a height of up to 1.30 m was recorded, while in the larger circle, individuals exceeding 1.31 m were documented. Only healthy and vigorous regeneration was counted.

The final assessment of regeneration took into account the measured elevation, aspect, and slope – factors which, although indirect, exert a significant influence on the processes involved in the formation of new plant communities.

Regeneration was classified into five categories: very good, good, satisfactory, unsatisfactory, and poor according to Table 1.

Table 1. Regeneration assessment classes concerning the number of seedlings, shoots, and canopy cover.

Level of regeneration	Seedlings, pc·ha^{-1}			Total shoots, pc·ha^{-1}	Canopy cover, %
	Total	Shade-tolerant	Heliophilous		
Very good	20,000	23,000	10,500	16,800	81–100
Good	10,000–20,000	15,000–23,000	6,800–10,500	10,900–16,800	61–80
Satisfactory	5,000–10,000	8,000–15,000	3,500–6,800	5,900–10,900	41–60
Unsatisfactory	3,000–5,000	4,500–8,000	2,000–3,500	3,400–5,900	21–40
Poor	3,000	4,500	2,000	3,400	0–20

Note. Column 2 ('Total') is used for assessment in plots where regeneration includes both shade-tolerant and light-demanding tree species. Columns 3 ('Shade-tolerant') and 4 ('Heliophilous') are applied when regeneration consists exclusively of shade-tolerant or exclusively of light-demanding species, respectively.

Results

The assessment of the regeneration processes was carried out 15 years after the disturbance. In the first transect, which is located on a north-eastern aspect, 15 sample plots were established. Regeneration was found to be poor or completely absent in 40 % of the plots. According to the scale provided in the applied regeneration assessment methodology, 53 % of the plots demonstrated good or very good regeneration. The natural regeneration was dominated primarily by pioneer species such as European hornbeam (*Carpinus betulus* L.), oriental hornbeam (*Carpinus orientalis* Mill.), and European hop-hornbeam (*Ostrya carpinifolia* Scop.). Common beech (*Fagus sylvatica* L.) also played a significant role in the regeneration process. The results are summarised in Table 2 and illustrated in Figure 2.

Table 2. Assessment of natural regeneration in the first transect.

Sample plot	Seedling regeneration			Total shoots, pc·ha^{-1}	Canopy cover, %	Regeneration estimation	Slope, °	Elevation, m a.s.l.
	Shade-tolerant	Heliophilous	Total, shade-tolerant + heliophilous					
1	24,498	1,884	26,382	9,422	81–100	Very good	27	869
2	3,769	22,613	26,382	13,191	81–100	Very good	31	841
3	1,884	3,769	5,653	16,960	81–100	Very good	32	817
4	0	0	0	0	0–20	Poor	17	793
5	0	5,653	5,653	0	41–60	Satisfactory	30	772
6	22,613	9,422	32,036	13,191	81–100	Very good	22	750
7	0	1,884	1,884	0	0–20	Poor	24	730
8	0	1,884	1,884	0	0–20	Poor	24	715
9	0	1,884	1,884	0	0–20	Poor	24	682

Sample plot	Seedling regeneration			Total shoots, pc·ha^{-1}	Canopy cover, %	Regeneration estimation	Slope, °	Elevation, m a.s.l.
	Shade-tolerant	Helio-philous	Total, shade-tolerant + heliophilous					
10	1,884	0	1,884	9,422	61–80	Good	16	671
11	3,769	0	3,769	13,191	61–80	Good	38	654
12	39,573	15,076	54,649	0	81–100	Very good	32	628
13	0	0	0	0	0–20	Poor	34	600
14	11,307	0	11,307	0	61–80	Good	26	551
15	0	0	0	0	0–20	Poor	25	487

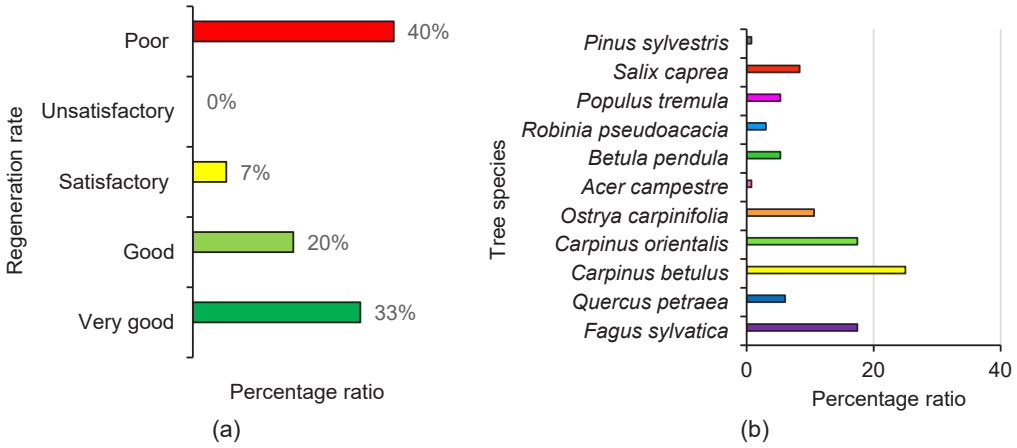


Fig. 2. Natural regeneration in the first transect: (a) assessment according to the applied methodology; (b) regeneration by tree species.

In the sample plots of the second transect, regeneration was more successful, with 87 % of the plots classified as having good or very good regeneration. No plots with absent regeneration were recorded, while only 7 % showed poor regeneration. The most commonly occurring tree species were manna ash (*Fraxinus ornus* L.), oriental hornbeam, sessile oak (*Quercus petraea* Matt.), and Austrian black pine.

The results are presented in Table 3 and Figure 3.

Table 3. Assessment of natural regeneration in the second transect.

Sample plot	Seedling regeneration			Total shoots, pc·ha^{-1}	Canopy cover, %	Regeneration estimation	Slope, °	Elevation, m a.s.l.
	Shade-tolerant	Helio-philous	Total, shade-tolerant + heliophilous					
1	0	16,960	16,960	0	61–80	Good	26	657
2	0	11,307	11,307	7,538	61–80	Good	26	649
3	0	1884	1,884	0	0–20	Poor	24	638
4	0	11,307	11,307	18,844	81–100	Very good	21	620
5	11,307	18,844	30,151	0	81–100	Very good	24	594
6	30,151	3769	33,920	0	81–100	Very good	26	532

Sample plot	Seedling regeneration			Total shoots, pc·ha^{-1}	Canopy cover, %	Regeneration estimation	Slope, °	Elevation, m a.s.l.
	Shade-tolerant	Helio-philous	Total, shade-tolerant + heliophilous					
7	0	41,458	41,458	0	81–100	Very good	26	567
8	0	3,769	3,769	5,653	41–60	Satisfactory	38	534
9	0	13,191	13,191	24,498	81–100	Very good	32	514
10	0	13,191	13,191	0	61–80	Good	26	502
11	0	45,227	45,227	0	81–100	Very good	30	482
12	0	47,111	47,111	24,498	81–100	Very good	26	464
13	32,036	30,151	62,187	0	81–100	Very good	22	446
14	0	39,573	39,573	0	81–100	Very good	30	424
15	13,191	35,804	48,996	0	81–100	Very good	29	389

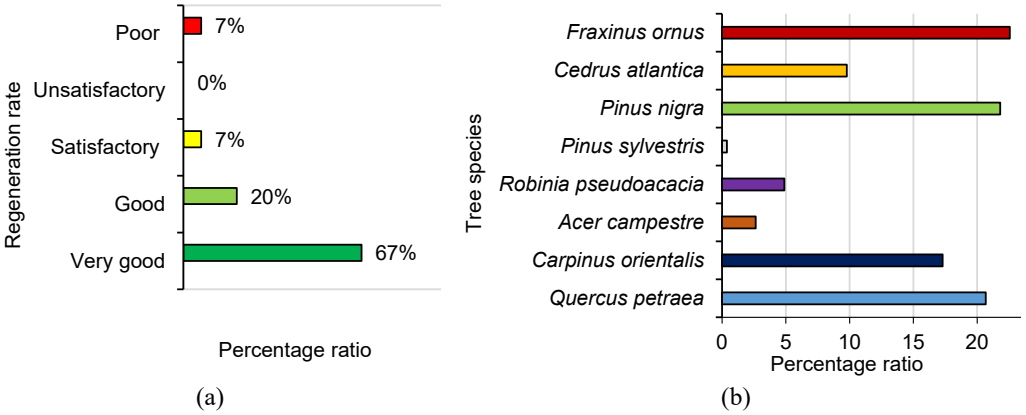


Fig. 3. Natural regeneration in the first transect: (a) assessment according to the applied methodology. (b) regeneration by tree species.

The results from the third transect indicated that 90 % of the sample plots exhibited good or very good regeneration, while 10 % showed poor regeneration. The main present tree species were manna ash, oriental hornbeam, European hornbeam, and sessile oak.

The results from the third transect are presented in Table 4 and Figure 4.

Table 4. Assessment of natural regeneration in the third transect.

Sample plot	Seedling regeneration			Total shoots, pc·ha^{-1}	Canopy cover, %	Regeneration estimation	Slope, °	Elevation, m a.s.l.
	Shade-tolerant	Helio-philous	Total, shade-tolerant + heliophilous					
1	0	3,769	3,769	28,267	81–100	Very good	22	839
2	3,769	1,884	5,653	18,844	81–100	Very good	24	821
3	28,267	3,769	32,036	11,307	81–100	Very good	22	795
4	0	16,960	16,960	0	61–80	Good	8	772
5	0	1,884	1,884	0	0–20	Poor	10	734
6	15,076	22,613	37,689	0	81–100	Very good	30	672

Sample plot	Seedling regeneration			Total shoots, pc·ha^{-1}	Canopy cover, %	Regeneration estimation	Slope, °	Elevation, m a.s.l.
	Shade-tolerant	Helio-philous	Total, shade-tolerant + heliophilous					
7	11,307	26,382	37,689	0	81–100	Very good	30	593
8	30,151	16,960	47,111	0	81–100	Very good	31	533
9	52,764	39,573	92,338	0	81–100	Very good	32	489
10	0	20,729	20,729	13,191	81–100	Very good	6	455

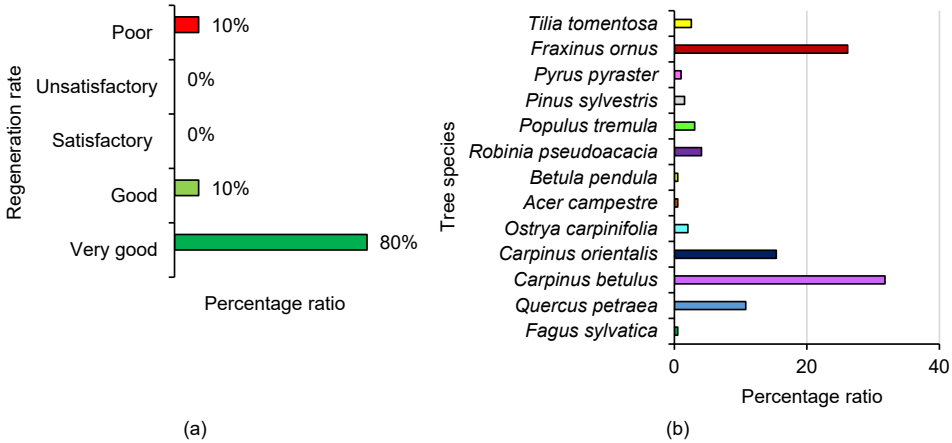


Fig. 4. Natural regeneration in the first transect: (a) assessment according to the applied methodology. (b) regeneration by tree species.

When selecting the transect routes, the aim was to cover different slope aspects. In this way, the available variety of site conditions was included, allowing for a relatively objective overall assessment of regeneration across the burned area. The elevation difference within the fire-damaged territory exceeds 400 m a.s.l. (ranging from 389 to 869 m a.s.l.). No clear correlation was identified between altitude and the degree of regeneration (Fig. 5).

In the sample plots with a northern aspect

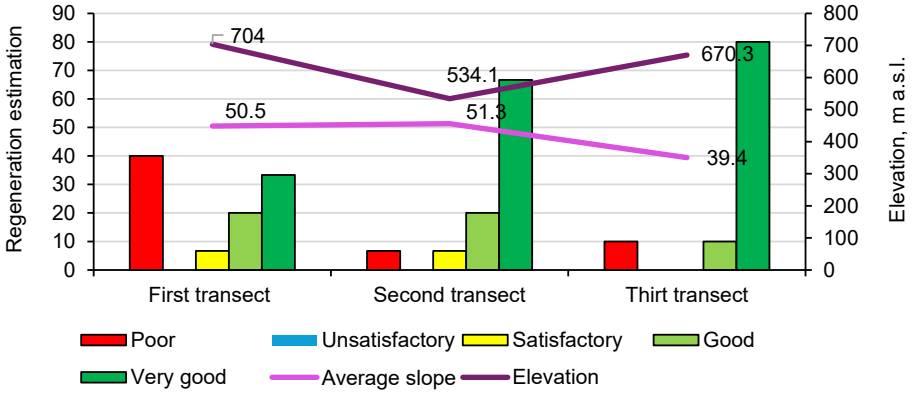


Fig. 5. Total post-disturbance regeneration by average slope and average elevation.

(first transect), higher presence of common beech, a representative of shade-tolerant species, was observed compared with the other two transects (Fig. 6).

The tree vegetation is predominantly represented by light-demanding pioneer species, generally considered to be of lower silvicultural value (Fig. 7).

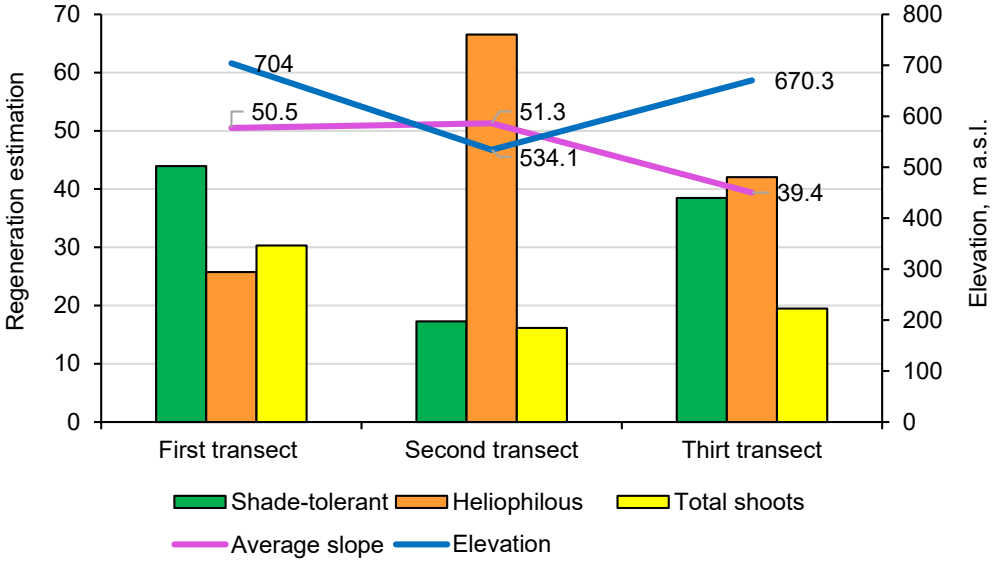


Fig. 6. Total post-disturbance regeneration undergrowth type, average slope, and average elevation.

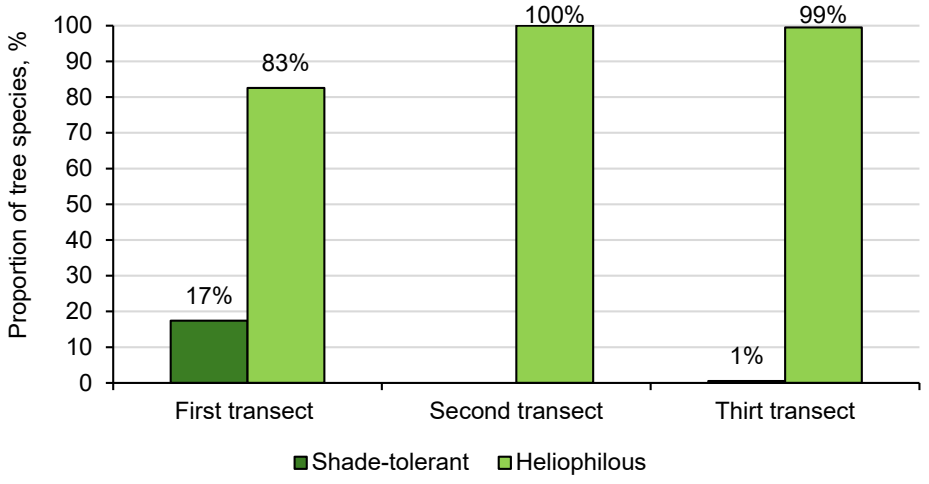


Fig. 7. Proportion of shade-tolerant and light-demanding species by aspect in the three transects.

Discussion

Extreme forest fires increasingly threaten the resilience of forest ecosystems and their capacity to maintain ecological, social, and economic services (EASAC 2025). A key determinant of resilience is natural regeneration. However, following high-severity disturbances, this process is often limited due to altered soil properties, absence of seed sources, and unfavourable climatic conditions, such as rising temperatures and prolonged droughts (Kostov 2024). On steep slopes, the risk of further degradation is particularly high, necessitating anti-erosion measures (Petkova and Tashev 2003, Tashev and Ivanova 2020).

The 2017 wildfire near Kresna illustrates that post-fire recovery in large and complex terrains cannot rely solely on natural processes. In such cases, afforestation has proved essential for controlling erosion and initiating ecosystem restoration (GeoPolymorphic Cloud 2017).

The findings from Dabovo, 15 years after the fire, confirm that natural regeneration is spatially uneven and relatively slow. Compared with earlier regeneration data for common beech in the same forest vegetation zone (Nedelin 1988), recovery appears delayed, with substantial areas still lacking young stands. Although regeneration is more successful on southern and south-eastern slopes, large portions of the burned landscape remain poorly regenerated or entirely devoid of trees.

Similar patterns have been reported in other parts of southern Europe. A study in central Spain found that post-fire Mediterranean shrublands have limited natural recovery potential, particularly where soils are degraded; species from the Genisteae tribe dominate the successional process and stabilise the site (Ugarte et al. 2021). Furthermore, research from southern Spain demonstrates that high fire recurrence and intensity strongly affect vegetation structure and diversity, often resulting in shrub-dominated rather than forested landscapes (Ortega et al. 2025).

The dominance of pioneer, light-demanding species in Dabovo aligns with typical post-disturbance successional trajectories (Cerioni et al. 2024). Although these species provide valuable ecological functions, their prevalence indicates slow compositional recovery. Shade-tolerant species, such as common beech, are largely confined to cooler, north-facing slopes, highlighting the decisive role of site conditions in shaping regeneration pathways. This pattern reflects a typical successional sequence, where pioneer species first establish structural dominance, gradually facilitating the establishment of more shade-tolerant and longer-lived species. Although some species have lower economic value, they play a critical ecological role in soil stabilisation, biodiversity support, and the provision of habitats for fauna.

Overall, the results suggest that in severely affected areas, particularly on steep and eroded slopes, natural regeneration should be complemented by artificial interventions. Targeted reforestation with local, resilient species, combined with timely silvicultural treatments, can enhance ecosystem resilience and reduce the risk of future high-severity fires (Popov et al. 2016, 2018).

Conclusions

Fifteen years after the Dabovo fire, natural regeneration is spatially uneven, with southern and south-eastern slopes showing the best recovery, whereas north-east-

ern aspects remain poorly regenerated.

Regeneration is dominated by light-demanding pioneer species, while shade-tolerant species are restricted to cooler, north-facing slopes.

Recovery remains slow and incomplete, with substantial areas still lacking regeneration, indicating risk of long-term degradation.

Artificial regeneration should be prioritised on steep, eroded slopes and sun-exposed sites with high fire risk, using local, resilient species.

Long-term monitoring is essential to guide forest management and provide the ecological and functional restoration of post-fire landscapes.

Acknowledgments

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References

Adámek M, Hadincová V, Wild J. 2016. Long-term effect of wildfires on temperate *Pinus sylvestris* forests: vegetation dynamics and ecosystem resilience. Forest Ecology and Management 380: 285–295. https://doi.org/10.1016/j.foreco.2016.08.051

Anderson-Teixeira K.J., Miller A.D., Mohan J.E., Hudiburg T.W., Duval B.D., Deluca E.H. 2013. Altered dynamics of forest recovery under a changing climate. Global Change Biology 19(7): 2001–2021. https://doi.org/10.1111/gcb.12194

Bogdanov S. 2010. Soil Characteristics Changes in Soils of Class Luvisols influenced by Forest Fires. PhD thesis. University of Forestry, Sofia. 128 p. (in Bulgarian).

Bogdanov S. 2022. Forest-growing Properties of Soils in Natural Black Pine (*Pinus nigra* Arn.) Forests in the Western Rhodopes. University of Forestry Publishing House, Sofia, Bulgaria: 8–15. (in Bulgarian). https://www.researchgate.net/publication/365024967_LESORASTITELNI_SVOJSTVA_NA_POCVI_V_ESTESTVENI_GORI_OT_CEREN_BOR_Pinus_nigra_Arn_V_ZAPADNI_RODOPI_Sofia_2022#fullTextFileContent

Bogdanov S. 2023. Changes in the Characteristics of Luvisols Soils under the Influence of Forest Fires. Avangard Prima, Sofia. 217 p. (in Bulgarian). https://bpos.bg/api/FilesStorage?key=3c4f9d90-12ea-4df6-a271-da4e59815970&-fileName=%D0%9A%D0%BD%D0%B8%D0%B3%D0%B0%20%D0%B4%D0%B8%D1%81%D0%B5%D1%80%D1%82%D0%B0%D1%86%D0%B8%D1%8F.pdf&dbId=1

Cerioni M., Brabec M., Bače R., Bāders E., Bončina A., Brůna J., Čečko E., Cordonnier T., de Koning J.H.C., Diaci J., Dobrowolska D., Dountchev A., Engelhart J., Fidej G., Fuhr M., Garbarino M., Jansons Ā., Keren S., Kitenberga M., Nagel T.A. 2024. Recovery and resilience of European temperateforests after large and severe disturbances. Global Change Biology 30(2), e17159. https://doi.org/10.1111/gcb.17159

Coop J.D., Parks S.A., Stevens-Rumann C.S., Crausbay S.D., Higuera P.E., Hurteau M.D., Tepley A., Whitman E., Assal T., Collins B.M., Davis K.T., Dobrowski S.F., Donald A., Fornwalt P.J., Fule P.Z., Harvey B.J., Kane V.R., Littlefield C.E., Margolis E.Q., North M., Parisien M.-A., Prichard S., Rodman K.C. 2020. Wildfire-driven forest conversion in western North American landscapes. BioScience 70(8): 659–673. https://research.fs.usda.gov/treesearch/60427

Davis K.T., Dobrowski S.Z., Higuera P.E.,

Holden Z.A., Veblen T.T., Rother M.T., Parks S.A., Sala A., Maneta M.P. 2019. Wildfires and climate change push low-elevation forests across a critical climate threshold for tree regeneration. Proceedings of the National Academy of Sciences of the USA 116(13): 6193–6198. https://pmc.ncbi.nlm.nih.gov/articles/PMC6442553/?utm_source=chatgpt.com

Donato D., Harvey B.J., Turner M.G. 2016. Regeneration of montane forests 24 years after the 1988 Yellowstone fires: A fire-catalyzed shift in lower treelines? Ecosphere 7(8), e01410. https://doi.org/10.1002/ecs2.1410

EASAC (European Academies' Science Advisory Council) 2025. Changing Wildfires: Policy Options for a Fire-literate and Fire-adapted Europe. https://easac.eu/publications/details/changing-wildfires

EFA (Executive Forests Agency) 2025. Methodology for assessing the regeneration and development of understorey vegetation in forest areas. 12 p. (in Bulgarian). https://www.bulprofor.org/pdocs/doc_916.pdf

EFFIS (European Forest Fire Information System) 2025. https://forest-fire.emergency.copernicus.eu/ (Accessed 20 July 2025).

GeoPolymorphic Cloud 2017. Satellite Map of Bulgaria Using Sentinel-2 Imagery. Produced 5 December 2017. (in Bulgarian). Available at: https://geopolymorphic-cloud.org/case-study/

Hansen W.D., Braziunas K., Rammer W., Seidl R., Turner M.G. 2018. It takes a few to tango: changing climate and fire regimes can cause regeneration failure of two subalpine conifers. Ecology 99(4): 769–999. https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/ecy.2181

Harvey B.J., Donato D.C., Turner M.G. 2016. Drivers and trends in landscape patterns of stand-replacing fire in forests of the US Northern Rocky Mountains (1984–2010). Landscape Ecology 31: 2367–2383. https://doi.org/10.1007/s10980-016-0408-4

Kostov P. 2024. Forest regeneration after extreme wildfires: challenges and management. Forest Ecology Review 18(1): 45–58. https://doi.org/10.1234/forecorev.2024.0018

Martínez-Vilalta J., Lloret F. 2016. Drought-induced vegetation shifts in terrestrial ecosystems: The key role of regeneration dynamics. Global and Planetary Change 144: 94–108. https://doi.org/10.1016/j.gloplacha.2016.07.009

McDowell N.G., Allen C.D., Anderson-Teixeira K., Aukema B.H., Bond-Lamberyt B., Chini L., Clark J.S., Dietze M., Grossiord C., Hanbury-Brown A., Hurtt G.C., Jackson R.B., Johnson D.L., Kueppers L., Lichstein J.W., Ogle K., Poulter B., Pugh T.A.M., Seidl R., Turner M.G., Uriarte M., Walker A.P., Xu C. 2020. Pervasive shifts in forest dynamics in a changing world. Science 368(6494), eaaz9463. https://doi.org/10.1126/science.aaz9463

Nedelin B. 1988. Beech regeneration in forest ecosystems. Sofia University Press. 210 p. (in Bulgarian).

Nikinmaa L., Linder M., Cantarello E., Jump A.S., Seidl R., Winkel G., Muys B. 2020. Reviewing the use of resilience concepts in forest sciences. Current Forestry Reports 6(6): 61–80. https://doi.org/10.1007/s40725-020-00110-x

Ortega, M., Lora A., Yocom L., Zumaquero R., Molina J. 2025. Effects of fire recurrence and severity on Mediterranean vegetation dynamics: Implications for structure and composition in southern Spain. Science of the Total Environment 961, 178392. 12 p. https://www.sciencedirect.com/science/article/pii/S0048969725000269?utm_source=chatgpt.com

Petkova K., Tashev A. 2003. Restoration of Fire Damaged Woods in Bulgaria. Journal of Balkan Ecology 6(2): 136–138. (in Bulgarian).

Popov G., Kostov G., Markov I., Dodev Y., Georgieva D. 2018. Coniferous plantations in Bulgaria created outside of their natural habitat. Avangard Prima. 121 p. (in Bulgarian). https://www.researchgate.net/publication/340939865_Coniferous_plantations_in_Bulgaria_created_outside_

of_their_natural_habitat_Iglolistnite_kulturi_v_Blgaria_szdadeni_izvn_estestvenia_im_areal

Popov G., Kostov G., Markov I., Georgieva D., Borisov M., Dodev Y. 2016. Transformation of coniferous plantations created on low altitude sites. National Conference on Perspectives and Guidelines for the Management of Artificially Established Coniferous Forests: 42–58 (in Bulgarian). https://www.researchgate.net/publication/340949800_Transformation_of_coniferous_plantations_created_on_low_altitude_sites_Transformacia_na_iglolistnite_kulturi_szdadeni_v_dolnata_lesorastitelna_zona

Seidl R., Turner M.G. 2022. Post-disturbance reorganization of forest ecosystems in a changing world. Proceedings of the National Academy of Sciences of the United States of America 119(28), e2202190119. https://doi.org/10.1073/pnas.2202190119

Tashev D., Ivanova P. 2020. Influence of topography and exposure on natural regeneration after forest fires in Bulgaria. Forest Ecology and Management 463, 118056. https://doi.org/10.1016/j.foreco.2020.118056

Tashev A., Petkova K. 2003. Floristic Composition and Phytocoenotic Structure of Natural Austrian Pine Community after Forest Fire in Bulgaria. Journal of Balkan Ecology 6(2): 173–180. https://www.researchgate.net/publication/305636459_Tashev_A_K_Petkova_2003_Floristic_Composition_and_Phytocoenotic_Structure_of_Natural_Austrian_Pine_Community_after_Forest_Fire_in_Bulgaria_Journal_of_Balkan_Ecology_Vol_6_No_2_173_-_180

Tashev A., Petkova K., Ovcharov D., Nustorova M. 2003. Impact of Fires on Forest Ecosystems and Methods for Their Restoration. In: Rosnev B. (Ed.), International Scientific Conference '75 Years of the Forest Research Institute – BAS', vol. 1: 298–304.

Ugarte R., Garcia M., Sánchez-Mata D. 2021. Evaluating the post-fire natural regeneration of Mediterranean-type scrublands in Central Spain. Mediterranean Botany 42, e67331. 11 p. doi: 10.5209/mbot.67331

UNDRR (United Nations Office for Disaster Risk Reduction) 2017. Fires in Europe fuelled by urbanisation and climate change. https://www.undrr.org/news/fires-europe-fuelled-urbanisation-and-climate-change?utm_source=chatgpt.com

Young D.J.N., Meyer M., Estes B., Gross S., Wuenschel A., Restaino C., Safford H.D. 2019. Forest recovery following extreme drought in California, USA: natural patterns and effects of pre-drought management. Ecological Applications 30(1), e02002. https://doi.org/10.1002/eap.2002