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The impact of forest fires on ecosystem

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Abstract. Fires cause significant changes to forest structure, disrupt ecological connections, and affect recovery processes. This study aimed to assess the extent of damage to tree stands and compare the resistance of coniferous and deciduous species to fire. The impact of these phenomena on various tree species and the functioning of forest ecosystems in northeastern Ukraine, which experienced large-scale fires between 2022 and 2024, was analysed. The analysis included an

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examination of damage to the bark, trunk, root system, and tree crowns, as well as an assessment of natural succession processes. Coniferous species, such as *Pinus sylvestris* L., were found to be the most vulnerable: approximately 60% of trees were either completely destroyed or severely damaged, and 70% of root systems lost their ability to recover. The crowns were destroyed in 80% of cases, leading to a reduction in tree stand density. In contrast, deciduous species such as oak and maple demonstrated greater fire resistance, with only 20-30% of trees sustaining severe damage, most of which successfully regenerated through regrowth. Mosses and lichens, which play a crucial role in soil stabilisation, were among the most affected, with their populations declining by more than 40%. This disruption in natural succession processes negatively impacted forest regeneration. Fires also increased forest fragmentation, underscoring the importance of creating ecological corridors and enhancing connectivity between forested areas to facilitate natural recovery. It is recommended to develop adaptive forest management strategies that consider the increasing frequency of fires, driven by both natural factors (such as climate change) and anthropogenic influences. The spread of fires caused by military activities is particularly relevant to the northeastern region of Ukraine. Determining tactical and strategic approaches for managing such areas requires consideration not only of the specific dynamics and patterns governing forest ecosystems but also of security-related factors. Military actions act as an additional powerful force driving environmental transformation and pollution. Addressing these challenges should form an integral part of programme documents concerning the post-war restoration of Ukraine's natural complexes

Keywords: biodiversity; ecological fragmentation; succession processes; natural regeneration; remote sensing; adaptive forest management

Introduction

Fires are among the most powerful environmental factors, exerting a diverse impact on ecosystems and posing one of the most serious threats to forested areas in Ukraine. This risk is particularly pronounced in the context of global climate change, which has led to an increase in the frequency of droughts and the duration of hot periods. In particular, fires disrupt the integrity of forest landscapes and their ecological connections (Jones *et al.*, 2021; Slattery & Fenner, 2021). Additionally, fires exacerbate the degradation of forest ecosystems by destroying root systems and tree crowns, as highlighted in the studies of F. Niccoli *et al.* (2023). However, the extent and nature of both the direct and indirect impacts of fires are also determined by the intrinsic properties of forest ecosystems, including the species composition

of different vegetation layers, particularly the living aboveground cover, which plays a crucial role in soil stabilisation and moisture retention (Hu *et al.*, 2020; Thielen *et al.*, 2021; Kakeh *et al.*, 2021). M. García-Carmona *et al.* (2021) demonstrate that mosses and lichens, which are significantly affected by fires, recover very slowly, and their loss is often accompanied by increased soil degradation. The changes induced by fires also influence succession dynamics and natural forest regeneration (Vanderhoof *et al.*, 2020; Hishe *et al.*, 2021).

Since the onset of the large-scale invasion by the Russian Federation, fires have affected vast areas of Ukraine, including extensive forested regions. According to the State Emergency Service of Ukraine, artillery and rocket attacks have triggered numerous forest fires,

complicated firefighting efforts and causing large-scale environmental damage (Over the past 24 hours..., 2024). Under these conditions, fires have not only become more frequent but also significantly more hazardous, as military operations have impeded rescue services' access to affected areas and reduced their ability to respond effectively (Sumy region..., 2024).

Due to its border location with the aggressor country, fires have become widespread across northeastern Ukraine. Existing literature already documents fires in the Desniansko-Starohutskyi National Nature Park (NNP), which covers an area of 16,215.1 hectares, including 7,231.5 hectares of forested land, primarily represented by the Starohutskyi forest massif. The vascular plant flora of the Desniansko-Starohutskyi NNP comprises 880 species, making it the most floristically diverse among the national parks and reserves of Polissya. Within its territory, 35 plant species are listed in the Red Book of Ukraine, alongside 49 regionally rare species. The park's fauna also exhibits a high degree of biodiversity and significant ecological value. A substantial number of vertebrate species recorded in the Desniansko-Starohutskyi NNP are included in both national and international Red Lists and conservation agreements. Specifically, the protected species include: Red Book of Ukraine – 39 species; Red List of the International Union for Conservation of Nature (IUCN) – 34 species; European Red List – 11 species; Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973) – 39 species; Convention on the Conservation of Migratory Species of Wild Animals (1979) – 55 species; Convention on the Conservation of European Wildlife and Natural Habitats (Appendix II, 1979) – 170 species (Periodic review for..., 2020).

Among the fires caused by the aggressor country, the largest occurred in May 2023 (Shaforost *et al.*, 2024). It raged for more than a

week, with no possibility of extinguishment due to the danger posed by its proximity to the Russian Federation's border. As a result of this fire, 32 forest blocks within the Desniansko-Starohutskyi National Nature Park were affected. This represents one-fifth of the land covered with forest vegetation and one-third of the recreational zone. The area of forest phytocenoses damaged by the fire primarily consisted of *Pinus sylvestris* L. stands over 60 years old, growing in conditions of fresh pine-oak (B2DS) and moist pine-oak (B3DS) forests. The herbaceous and shrub layer, including *Vaccinium myrtillus* L. and *Vaccinium vitis-idaea* L., also suffered damage. Populations of plant species representing rare phytodiversity, particularly those protected at the national or regional levels, were significantly affected. These include *Huperzia selago* (L.) Bernh. ex Schrank et Mart., *Lycopodium annotinum* L., *Carex brunnescens* (Pers.) Poir., *Salix starkeana* Willd., *Dactylorhiza fuchsii* (Druce) Soó, *Epipactis helleborine* (L.) Crantz, *Platanthera bifolia* (L.) Rich., *Dactylorhiza incarnata* (L.) Soó, and *Salix myrsinifolia* Salisb. (Andrienko, 2006). The fauna of the national nature park was also significantly impacted.

The issue of fire spread and its impact on the natural complexes of northeastern Ukraine, against the backdrop of the large-scale invasion, was also addressed in the project Assessing the Environmental Consequences of War for Communities. This study focused on the Khotyn and Velykopysariv communities in the Sumy region, both of which are located near the state border with the Russian Federation. According to the project's findings, which included satellite monitoring using archival data from the NASA FIRMS service (covering the period from 24 February 2022 to 15 August 2023), fires were recorded over an area of 196.13 hectares in the Khotyn community and 210.36 hectares in Velykopysariv. Additionally, a fire covering 9.5 hectares was detected in the forest massif

of the Hetman National Nature Park within the Velykopyrsariv territorial community (Assessing the environmental..., 2023).

These findings indicate that, at present, the impact of fires on Ukraine's environment is increasing significantly, particularly in regions where natural complexes have been affected by the war. Consequently, further research is required on how forest ecosystems respond to pyrogenic factors. Such studies should not only contribute to understanding the ecological relationships characteristic of modern forest ecosystems but also form a scientific basis for developing strategic and tactical approaches to the post-war restoration of Ukraine's natural complexes.

Thus, the aim of this study was to examine the impact of pyrogenic factors on the dominant forest-forming species and forest phytocenoses of northeastern Ukraine, with a focus on identifying priority measures for mitigating the consequences of fires and reducing their negative impact.

Materials and Methods

To assess the impact of forest fires on biodiversity and ecosystem functioning, a comprehensive study was conducted in northeastern Ukraine, specifically within the Sumy region and the adjacent areas of the Chernihiv and Poltava regions, covering the period from 2022 to 2024. The analysis of fire effects on forest stand structure began with an examination of the responses of coniferous and deciduous trees to fire. The primary focus of the study was on key tree species, including Scots pine (*Pinus sylvestris* L.), common oak (*Quercus robur* L.), and sycamore maple (*Acer platanoides* L.). An inventory of trees was conducted to estimate the number of surviving and dead specimens. During field studies, damage to the bark, trunk, root system, and tree crowns was recorded. Additionally, changes in the species composition

of forest stands before and after fires were analysed, particularly in relation to the ratio of fire-resistant to vulnerable species.

To identify the key characteristics of forest recovery processes, multiple areas with varying post-fire periods were surveyed. Changes in biodiversity and vegetation structure occurring during different stages of succession were assessed. The research was supported by the use of GIS technology, specialised online resources, and computer software, including Digitals 5.0 (Fire information for..., 2025).

Results

Analysis of statistical data from the relevant department of the Sumy Regional State Administration revealed that between April and October 2024, fires affected a total area of 339.92 hectares within the Northern Forest Office of the State Enterprise (SE) Forests of Ukraine. The majority of these fires were recorded in the Svesky forestry, where they covered an area of 242.08 hectares (Fig. 1). Additionally, fires were reported in the Okhtyrsky, Sumy, Lebedynsky, Krasnopilsky, and Shostka forestry districts. Between 19 September and 1 November 2024, within the Sumy Regional Municipal Agroforestry Enterprise Sumyoblagerolis, fires were registered over a total area of 314.85 hectares. The largest number of these occurred in SE Seredino-Budsky Agroforestry (240.2 hectares), followed by SE Nikolaevsky Agroforestry (40.7 hectares), SE Yampilsky Agroforestry (12.4 hectares), and SE Shostky Agroforestry (9.4 hectares).

An analysis of the response of forest ecosystems and their components to the effects of pyrogenic factors revealed that coniferous species, particularly *Pinus sylvestris*, were more vulnerable due to their high resin content. This characteristic facilitates rapid ignition and the spread of fire (Table 1). The study found that approximately 60% of pine forests in the

affected areas were either destroyed or critically damaged. In contrast, deciduous species

exhibited greater resistance to fire, with tree mortality rates reduced to 20-30%.

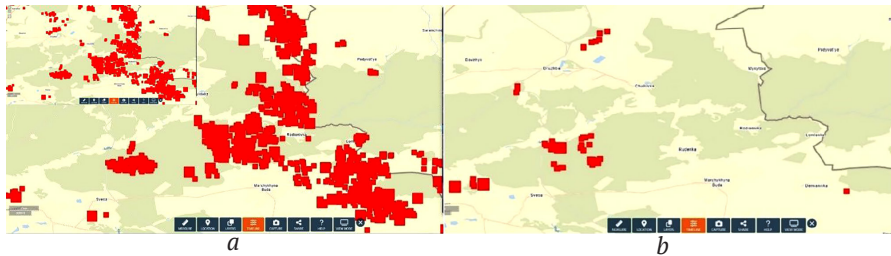


Figure 1. Spread of fires in the territory of the Svesky Forestry Department and adjacent territories

Note: a) data for September 2024; b) for October 2024

Source: created by the authors

Table 1. Comparison of damage to forest-forming species after fires

| Parameter | <i>Pinus sylvestris</i> | <i>Quercus robur, Acer platanoides</i> |
|--------------------------|--|--|
| Percentage of dead trees | 60% of the total number of trees | 20-30% of the total number of trees |
| Cortical damage | 65% of trees with damage to more than 50% of the bark area | 37% of oaks, 42% of maples with bark damage |
| Trunk damage | 70% of trees with significant trunk damage | 35% of oaks, 20% of maples with trunk damage |
| Crown damage | 80% of trees with crown damage | 43% of oaks and maples had crown damage |

Source: created by the authors

Pine trees exhibited the greatest degree of bark damage, with 65% of individuals suffering damage to more than 50% of their bark, ultimately leading to their gradual decline. In contrast, deciduous trees were less affected, with only 37% of oaks and 42% of maples experiencing significant bark damage.

Conifers also showed higher levels of trunk damage, recorded in 70% of affected trees. By comparison, damage to the trunks of oak and maple trees was considerably lower, with only 35% of oaks and 20% of maples exhibiting such negative effects. The root systems of trees were also severely impacted by fire. In pine forests, 70% of trees suffered root damage at depths of up to 30 cm, significantly limiting their ability to recover. Deciduous species, particularly oak and maple, demonstrated greater resilience to

root damage, with only 30% of oaks and 20% of maples sustaining significant harm, allowing for faster post-fire regeneration.

The tree crown is a critical component for growth, and its damage can substantially reduce a tree’s ability to regenerate. Among pines, 80% of trees experienced crown damage, leading either to their death or a significant reduction in growth rate. In contrast, only 43% of oak and maple trees exhibited crown damage, highlighting their greater resistance to fire. Thus, the analysis of fire impact on forest-forming species indicates that coniferous species, such as pine, are significantly more vulnerable to thermal stress. Deciduous species, such as oak and maple, exhibited markedly higher resistance, which can be attributed to their thicker bark, stronger trunk structure, and more

developed root systems. These findings suggest that effective forest ecosystem management in areas with heightened fire risk should incorporate recovery strategies that account for species-specific characteristics.

Within the study region, an analysis of fire impact on different age groups of trees was also

conducted. The greatest losses were observed among young stands, as immature trees lacked sufficient resistance to high temperatures. In the forests surveyed, more than 80% of young trees under the age of 10 perished following the fire, with young pines being particularly vulnerable (Table 2).

Table 2. Changes in age and spatial structure after fires

| Indicator | Young trees (up to 10 years old) | Middle-aged trees (10-30 years old) | Old trees (over 30 years old) |
|---------------------------------|---|-------------------------------------|-------------------------------|
| Percentage of dead trees | 80% (especially among pines and maples) | 50% | 40% (mainly among conifers) |
| Trees saved after fire | 20% | 50% | 60% (mostly oaks and maples) |
| Loss of diversity of age groups | High | Moderate | Low |
| Increasing forest fragmentation | 35% of the total forest area | 20% | 15% |

Source: created by the authors

Older oaks and maples demonstrated greater resilience, with approximately 40% of individuals sustaining only minimal damage. Among trees older than 30 years, deciduous species exhibited a higher survival rate compared to conifers. This can be attributed to the thick bark of mature oaks, which provides protection for internal tissues against thermal effects, as well as their more developed root systems. The decline in age group diversity following fires was evident, as young trees – typically crucial for forest regeneration – were almost entirely eliminated in the affected areas.

The analysis revealed that fires have the capacity to alter the species composition of the woody layer in forest ecosystems, leading to a higher representation of fire-resistant species while reducing the proportion of vulnerable plants. Fires also had a significant impact on the grass-moss layer, primarily due to direct destruction, which exceeded 40% in some areas (Fig. 2). Additionally, in certain locations – particularly on slopes – the disappearance of the living topsoil led to an acceleration of soil erosion

processes. These transformations, characterised by a reduction in species diversity and a simplification of ecosystem structure, ultimately result in a diminished capacity of the forest to withstand adverse external factors.



Figure 2. Fire and its consequences in one of the deciduous forest areas

Source: created by the authors

The restoration of forests following fires is a critical issue. In general, this process is complex and multi-stage, often spanning several decades and influenced by numerous factors,

including forest type, fire intensity, climatic conditions, and soil quality. Within the studied region, significant differences were observed in the speed and nature of recovery between coniferous and deciduous forests. However, the following stages of restoration were typically well-defined: initial restoration (1-3 years); development of pioneer species (3-7 years); formation of a young stand (7-15 years); ecosystem stabilisation (over 15 years).

Coniferous forests, particularly pine stands, exhibited a slower rate of recovery, whereas deciduous forests regenerated more

rapidly. Within the first three years following a fire, active regeneration was observed in 60% of the affected areas in deciduous forests (Table 3). In contrast, coniferous forests showed significantly slower recovery, with only 30% of the affected area demonstrating signs of regeneration during the same period. Additionally, the recovery of pine forests was further hindered by the widespread occurrence of species replacement processes and the increased prevalence of pests and diseases, which further complicated and slowed down their restoration (Fig. 3).

Table 3. Comparison of natural regeneration rates of coniferous and deciduous forests

| Parameter | Coniferous forests | Deciduous forests |
|---|--------------------|-------------------|
| Starting the recovery | In 2-4 years | In 1-2 years |
| Area recovered in 3 years | 30% | 60% |
| Average time for formation of a young stand | 8-10 years | 5-7 years |
| Area recovered in 10 years | 50-60% | 80% |

Source: created by the authors



Figure 3. The current state of a pine forest area that in 2008 became a hotbed of grass fire spread and subsequent intensification of the impact of the top bark beetle

Source: created by the authors

Natural forest recovery following fires typically takes between 10 and 20 years, depending on forest type. However, repeated fires or adverse environmental conditions can significantly extend this period, necessitating the development of long-term strategies to enhance ecosystem resilience. In designing these strategies, it is essential to consider that fires contribute to increased fragmentation of forested areas.

Forest fragmentation is a particularly pressing issue in northeastern Ukraine, as demonstrated by research conducted even before the large-scale invasion of the Russian Federation in the Novgorod-Siverskyi Polissya region. In accordance with the principles of island biogeography, the perimeter-to-area ratio (P/A) and its reciprocal (A/P) were used as key indicators in analysing fragmentation levels. These criteria complement each other: P/A primarily characterises territorial structures (in this study, forested areas) in terms of their

linear dimensions and provides insight into the ecological permeability of their boundaries. A/P focuses on the size of forest patches and reflects their ecological optimality. A higher A/P value suggests increased ecological stability, as it indicates a greater distance between the core and the peripheral (external) edges of the area. A high level of ecological stability is associated with areas where A/P exceeds $1 \text{ km}^2/\text{km}$ and P/A remains below $1 \text{ km}/\text{km}^2$.

The research findings indicate that even within one of the most forested regions of Ukraine – Novgorod-Siverskyi Polissya, where forest cover was approximately 20% at the time of the study – the A/P values for forest massifs predominantly ranged from 0.1 to $0.4 \text{ km}^2/\text{km}$, while P/A values varied between 3 and $8 \text{ km}/\text{km}^2$. The highest recorded A/P values reached 0.7-0.8 km^2/km , while the lowest P/A values ranged between 1.2 and $1.4 \text{ km}/\text{km}^2$. However, some forest massifs exhibited significantly higher levels of fragmentation, with A/P values dropping as low as 0.02-0.03 km^2/km and P/A increasing to 39.9-55.2 km/km^2 . These findings objectively demonstrate a high degree of forest fragmentation, a high ecological permeability of forest boundaries, and a low level of protection for interior areas from both natural and anthropogenic disturbances. In the context of increased fire activity, further reductions in A/P values and increases in P/A values (typically within a 10-30% range) have been recorded across forest areas. This trend indicates an increasing degree of forest fragmentation, heightened permeability of forest phytocenosis boundaries, and a more pronounced clearing effect.

One of the ecological consequences of increased forest fragmentation – even in the absence of fires – is a significantly heightened likelihood of invasive species colonising forest phytocenoses. These species are often not typical of undisturbed natural ecosystems and

can alter the structure and stability of local flora populations. Due to the high permeability of forest boundaries and the widespread manifestation of the clearing effect, conditions emerge that facilitate processes such as synanthropisation, adventitisation, and therophytisation – all of which are indicators of geosystem disturbance. The ecological transformations resulting from high forest fragmentation have the potential to disrupt the entire system of ecological-coenotic interactions within the ecosystem. This can negatively impact populations of forest-forming species, alter cohort structures in younger tree generations, and hinder natural regeneration processes – including in areas previously affected by fires.

Discussion

The study confirmed that fires cause significantly greater losses among coniferous species compared to deciduous species, with *Pinus sylvestris* being the most vulnerable. The results indicated that 70% of pine root systems were severely damaged, and tree crowns were destroyed in 80% of cases. These findings align with those of S. Sydorenko *et al.* (2021), who noted that pines are among the most fire-prone tree species due to their high flammability. Similar conclusions were drawn by A.C. Scheper *et al.* (2021), who emphasised the need for active intervention in the restoration of coniferous forests, as natural regeneration processes alone are insufficient under conditions of frequent wildfires.

In contrast, deciduous species such as oak and maple demonstrated significantly greater fire resistance. In this study, only 20-30% of deciduous trees suffered critical damage, a finding consistent with S.-P. Zeng *et al.* (2020), who highlighted that the morphological characteristics of deciduous trees contribute to their increased fire resilience. The results obtained suggest the importance of promoting mixed

stands, where coniferous and deciduous species coexist to enhance overall ecosystem resilience. This is supported by the research of T. Ramidantsoa *et al.* (2023), who found that mixed forests are more capable of withstanding fires and recovering more rapidly due to a combination of diverse regeneration strategies.

The study also analysed the impact of fires on different layers and components of the forest phytocenosis. It was observed that fires cause significant changes at the level of the living aboveground cover, often leading to its destruction. One of the key consequences of this is the acceleration of erosion processes and the deterioration of conditions for tree growth. These findings align with the conclusions of S. Meilleur *et al.* (2022) and A. Siwach *et al.* (2021), who noted that the recovery of mosses can take more than five years and plays a crucial role in soil stabilisation and moisture conservation. Similarly, Z.H. Aliyev & F.F. Suleymanova (2022), along with Y. Fu *et al.* (2022), highlighted that soil degradation resulting from fires often serves as a limiting factor in the restoration of grass cover in forest ecosystems.

Fires significantly influence forest regeneration processes by regulating the quantitative and qualitative composition of litter and living aboveground cover, as well as by facilitating substrate mineralisation (Skydan *et al.*, 2021). In particular, regarding *Pinus sylvestris*, it has been established that the impact of fire on natural regeneration can be both positive and negative, depending on the type of fire (crown or surface) and its intensity. At present, climate change is further contributing to the occurrence and spread of fires (Bayegizova *et al.*, 2024). Rising temperatures and decreasing precipitation not only increase fire risks but also complicate regeneration processes. These challenges necessitate the development of adaptive approaches to forest resource management, as emphasised by J. Leciña-Díaz *et al.* (2021) and M. Sample *et al.* (2022).

One of the most serious consequences of forest fires is the increased fragmentation of forest areas, exacerbating an already significant issue, as research has shown that fragmentation is a concern even in regions with relatively high forest cover. The link between fires and increased fragmentation is further supported by the study of D. Armenteras *et al.* (2021), who investigated forest ecosystems and found that frequent fires contribute to the fragmentation of forested landscapes. The resulting loss of connectivity between forest patches slows natural succession processes, as plant seeds and pollinators struggle to disperse effectively across isolated areas.

Additionally, R. Halbac-Cotoara-Zamfir *et al.* (2022) highlighted that in highly fragmented environments, the risks of soil degradation and the spread of invasive species increase, as such species can rapidly colonise burnt areas. Their study also found that isolated forest patches, lacking connections to larger forested areas, exhibit limited natural recovery potential. These findings underscore the urgent need for active management strategies to reduce fragmentation and establish ecological corridors to enhance ecosystem connectivity.

Research by J. Hilty *et al.* (2020), and T. Zhai & L. Huang (2022) has demonstrated that creating ecological corridors between fragmented forest areas significantly improves ecosystem recovery by facilitating species migration and providing access to essential resources. These corridors also mitigate the risk of genetic isolation, a common consequence when species populations become confined to small forest patches. The preservation of ecological corridors is therefore a key component of modern landscape management strategies, particularly in light of climate change and the increasing frequency of wildfires (Matkivskiy & Taras, 2024). Furthermore, L. Li *et al.* (2021) suggested that an important area for future

research is the impact of distance between fragmented forest patches on biodiversity recovery rates and overall forest viability.

Thus, reducing forest fragmentation and creating ecological corridors are essential priorities in modern forest management. Restoring connectivity between forested areas facilitates faster natural regeneration, reduces biodiversity loss, and enhances ecosystem resilience to future fires (Lozinska *et al.*, 2024; Tykhonova *et al.*, 2024). Developing networks of ecological corridors that link isolated areas is crucial for ensuring the long-term stability and functionality of ecosystems.

The findings of this study open several promising avenues for further research aimed at improving forest management and enhancing ecosystem resilience to wildfires. One key area of focus is the optimisation of mixed forest stand composition. It was found that combining coniferous and deciduous species helps reduce ecosystem vulnerability to fires and supports more sustainable post-fire recovery. The study by D.A. MacLean & K.L. Clark (2021) confirms that mixed forests are more resistant to external stressors, as deciduous species inhibit the spread of fire, while conifers contribute to the long-term stability of forest ecosystems. These findings suggest that continued research is needed to identify optimal species combinations adapted to local climatic conditions.

Another important research direction is the restoration of not only the tree stand but also other components of the forest ecosystem, particularly mosses and lichens (Biyashev *et al.*, 2024). The results of M.A. Bowker *et al.* (2023) indicate that the recovery of mosses and lichens is a long-term process, often taking several years. This highlights the need to develop new approaches to accelerate the regeneration of these vital ecosystem components.

Overall, the findings confirm that fires have a profound impact on forest ecosystems,

particularly on coniferous forests. The increasing frequency of wildfires due to climate change necessitates adaptive management strategies that focus on reducing forest fragmentation, restoring all components of forest phytocenoses, and strengthening ecosystem resilience. In the context of ongoing climate change, an urgent priority is the improvement of fire prediction models and the assessment of their impact on forest stands, ensuring more effective mitigation and response strategies.

Conclusions

The study found that forest fires had a significant impact on forest ecosystems in north-eastern Ukraine between 2022 and 2024. The key findings indicate that coniferous species were particularly vulnerable to fire, primarily due to their high resin content and structural characteristics. In contrast, deciduous species, particularly *Quercus robur* and *Acer platanoides*, exhibited higher fire resistance. This resilience can be attributed to their thicker bark and/or ability to regenerate quickly. Although local damage was observed in these species, their resistance helped maintain a certain level of ecological balance after fires. It was also determined that the lower layers of the forest suffered significant damage, including direct destruction, which in turn increased the risk of soil erosion. Furthermore, forest fragmentation in the studied regions has intensified, exacerbating ecological disruptions.

In light of these findings, it is crucial to implement active restoration measures, including promoting natural regeneration, afforestation, and the creation of ecological corridors. These actions will help mitigate the effects of fragmentation and restore ecological connectivity between isolated areas.

Looking ahead, it is also recommended to develop adaptive forest management strategies that account for the increasing frequency of

fires, both due to natural factors (such as climate change) and anthropogenic influences. In the northeastern part of Ukraine, the spread of fires caused by military actions presents a particularly pressing challenge, characterised by unique complexities and a higher degree of environmental impact. Effectively managing such territories requires considering not only the ecological dynamics and functional patterns of forest ecosystems but also security-related factors. Military activity represents a powerful driver of environmental transformation, contributing to severe soil degradation and contamination with pollutants associated with

explosives and their combustion by-products. Addressing these challenges should be integrated into policy frameworks and programme documents focused on post-war restoration efforts for Ukraine's natural complexes.

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Conflict of Interest

None.

References

- [1] Aliyev, Z.H., & Suleymanova, F.F. (2022). Impact of irrigation erosion on the agrochemical properties of mountain-brown soils and the productivity of cereals and legumes. *B.R. Nahata Smriti Sansthan Agricultural Extension Journal*, 6(3), 95-100. doi: [10.22377/aextj.v6i3.325](https://doi.org/10.22377/aextj.v6i3.325).
- [2] Andrienko, T.I. (2006). *Phytodiversity of the Ukrainian Polissia and its conservation*. Kyiv: Phytosociocentre.
- [3] Armenteras, D., Dávalos, L. M., Barreto, J.S., Miranda, A., Hernández-Moreno, A., Zamorano-Elgueta, C., González-Delgado, T.M., Meza-Elizalde, M.C., & Retana, J. (2021). Fire-induced loss of the world's most biodiverse forests in Latin America. *Science Advances*, 7(33), article number eabd3357. doi: [10.1126/sciadv.abd3357](https://doi.org/10.1126/sciadv.abd3357).
- [4] Assessing the environmental impacts of war on communities. (2023). Retrieved from <https://necu.org.ua/proyekty/wedua/#1706288573537-32dd777f-38a0>.
- [5] Bayegizova, A., Abdikerimova, G., Kaliyeva, S., Shaikhanova, A., Shangytbayeva, G., Sugurova, L., Sugur, Z., & Saimanova, Z. (2024). Fire detection using deep learning methods. *International Journal of Electrical and Computer Engineering*, 14(1), 547-555. doi: [10.11591/ijece.v14i1.pp547-555](https://doi.org/10.11591/ijece.v14i1.pp547-555).
- [6] Biyashev, B., Drobitko, A., Markova, N., Bondar, A., & Pismenniy, O. (2024). Chemical analysis of the state of Ukrainian soils in the combat zone. *International Journal of Environmental Studies*, 81(1), 199-207. doi: [10.1080/00207233.2023.2271754](https://doi.org/10.1080/00207233.2023.2271754).
- [7] Bowker, M.A., Doherty, K.D., Grover, H.S., Antoninka, A.J., Durham, R.A., & Ramsey, P. (2023). Moss establishment in restoration: The role of moss production method and short-term benefits of abscisic acid. *Land Degradation and Development*, 34(14), 4320-4327. doi: [10.1002/ldr.4779](https://doi.org/10.1002/ldr.4779).
- [8] Convention on International Trade in Endangered Species of Wild Fauna and Flora. (1973, March). Retrieved from <https://cites.org/sites/default/files/eng/disc/CITES-Convention-EN.pdf>.
- [9] Convention on the Conservation of European Wild Fauna and Flora and Natural Habitats. (1979, September). Retrieved from https://zakon.rada.gov.ua/laws/show/995_032#Text.

- [10] Convention on the Conservation of Migratory Species of Wild Animals. (1979, November). Retrieved from https://www.cms.int/sites/default/files/instrument/CMS-text.en_.PDF.
- [11] Fire information for resource management system. (2025). Retrieved from <https://firms.modaps.eosdis.nasa.gov/map/#d:today;@55.5,25.4,3.3z>.
- [12] Fu, Y., Wang, D., Sun, W., & Guo, M. (2022). Impacts of grass planting density and components on overland flow hydraulics and soil loss. *Land Degradation and Development*, 34(1), 234-249. doi: [10.1002/ldr.4456](https://doi.org/10.1002/ldr.4456).
- [13] García-Carmona, M., Arcenegui, V., García-Orenes, F., & Mataix-Solera, J. (2021). Effects of early post-fire moss biocrusts on soil abiotic and biotic properties in a Mediterranean forest. doi: [10.5194/EGUSPHERE-EGU21-10050](https://doi.org/10.5194/EGUSPHERE-EGU21-10050).
- [14] Halbac-Cotoara-Zamfir, R., Polinesi, G., Chelli, F., Salvati, L., Bianchini, L., Marucci, A., & Colantoni, A. (2022). Found in complexity, lost in fragmentation: Putting soil degradation in a landscape ecology perspective. *International Journal of Environmental Research and Public Health*, 19(5), article number 2710. doi: [10.3390/ijerph19052710](https://doi.org/10.3390/ijerph19052710).
- [15] Hilty, J., et al. (2020). *Guidelines for conserving connectivity through ecological networks and corridors*. Gland: International Union for Conservation of Nature.
- [16] Hishe, H., Giday, K., Fremout, T., Negussie, A., Aerts, R., & Muys, B. (2021). Environmental and anthropogenic factors affecting natural regeneration of degraded dry Afromontane forest. *Restoration Ecology*, 29(6), article number e13471. doi: [10.1111/rec.13471](https://doi.org/10.1111/rec.13471).
- [17] Hu, M., Liu, Y., Wang, T., Hao, Y., Li, Z., & Wan, S. (2020). Fire alters soil properties and vegetation in a Coniferous-Broadleaf mixed forest in central China. *Forests*, 11(2), article number 164. doi: [10.3390/f11020164](https://doi.org/10.3390/f11020164).
- [18] Jones, G.M., Keyser, A.R., Westerling, A.L., Baldwin, W.J., Keane, J.J., Sawyer, S.C., Clare, J.D., Gutiérrez, R., & Peery, M.Z. (2021). Forest restoration limits megafires and supports species conservation under climate change. *Frontiers in Ecology and the Environment*, 20(4), 210-216. doi: [10.1002/fee.2450](https://doi.org/10.1002/fee.2450).
- [19] Kakeh, J., Gorji, M., Mohammadi, M.H., Asadi, H., Khormali, F., Sohrabi, M., & Eldridge, D. J. (2021). Biocrust islands enhance infiltration, and reduce runoff and sediment yield on a heavily salinized dryland soil. *Geoderma*, 404, article number 115329. doi: [10.1016/j.geoderma.2021.115329](https://doi.org/10.1016/j.geoderma.2021.115329).
- [20] Lecina-Diaz, J., Martínez-Vilalta, J., Alvarez, A., Vayreda, J., & Retana, J. (2021). Assessing the risk of losing forest ecosystem services due to wildfires. *Ecosystems*, 24, 1687-1701. doi: [10.1007/s10021-021-00611-1](https://doi.org/10.1007/s10021-021-00611-1).
- [21] Li, L., Gou, M., Wang, N., La, L., & Liu, C. (2021). Do ecological restoration programs reduce forest fragmentation? Case study of the Three Gorges Reservoir Area, China. *Ecological Engineering*, 172, article number 106410. doi: [10.1016/j.ecoleng.2021.106410](https://doi.org/10.1016/j.ecoleng.2021.106410).
- [22] Lozinska, T., Zadorozhnyy, A., & Mamchur, V. (2024). Strategies and methods for reducing the risk of forest fires and the spread of pests. *Scientific Reports of the National University of Life and Environmental Sciences of Ukraine*, 20(1). doi: [10.31548/dopovidi.1\(107\).2024.021](https://doi.org/10.31548/dopovidi.1(107).2024.021).
- [23] MacLean, D.A., & Clark, K.L. (2021). Mixedwood management positively affects forest health during insect infestations in eastern North America. *Canadian Journal of Forest Research*, 51(7), 910-920. doi: [10.1139/cjfr-2020-0462](https://doi.org/10.1139/cjfr-2020-0462).

- [24] Matkivskiy, M., & Taras, T. (2024). Pollution of the atmosphere, soil and water resources as a result of the Russian-Ukrainian war. *Ecological Safety and Balanced Use of Resources*, 15(1), 87-99. doi: [10.69628/esbur/1.2024.87](https://doi.org/10.69628/esbur/1.2024.87).
- [25] Meilleur, S., Gu  n  -Nanchen, M., Hugron, S., Fenton, N.J., & Rochefort, L. (2022). Towards the regeneration of brown mosses for fen restoration. *Bryologist*, 125(1), 23-35. doi: [10.1639/0007-2745-125.1.023](https://doi.org/10.1639/0007-2745-125.1.023).
- [26] Niccoli, F., Altieri, S., Kabala, J. P., & Battipaglia, G. (2023). Fire affects tree growth, water use efficiency and carbon sequestration ecosystem service of *Pinus nigra* arnold: A combined satellite and ground-based study in central Italy. *Forests*, 14(10), article number 2033. doi: [10.3390/f14102033](https://doi.org/10.3390/f14102033).
- [27] Over the past 24 hours, more than 33 fires covering an area of 76 hectares have been extinguished in Ukraine, and another 24 are in the process of being extinguished. (2024). Retrieved from <https://mepr.gov.ua/za-mynulu-dobu-v-ukrayini-pogasyly-ponad-33-pozhezhi-ploshheyu-76-gektariv-shhe-24-znahodyatsya-v-stani-likvidatsiyi>.
- [28] Periodic review for Desnianskyi Biosphere Reserve. (2020). Retrieved from <http://www.nppds.inf.ua>.
- [29] Ramiadantsoa, T., Ratajczak, Z., & Turner, M.G. (2023). Regeneration strategies and forest resilience to changing fire regimes: Insights from a Goldilocks model. *Ecology*, 104(6), article number e4041. doi: [10.1002/ecy.4041](https://doi.org/10.1002/ecy.4041).
- [30] Sample, M., Thode, A. E., Peterson, C., Gallagher, M.R., Flatley, W., Friggens, M., Evans, A., Loehman, R., Hedwall, S., Brandt, L., Janowiak, M., & Swanston, C. (2022). Adaptation strategies and approaches for managing fire in a changing climate. *Climate*, 10(4), article number 58. doi: [10.3390/cli10040058](https://doi.org/10.3390/cli10040058).
- [31] Scheper, A.C., Verweij, P.A., & van Kuijk, M. (2021). Post-fire forest restoration in the humid tropics: A synthesis of available strategies and knowledge gaps for effective restoration. *Science of the Total Environment*, 771, article number 144647. doi: [10.1016/j.scitotenv.2020.144647](https://doi.org/10.1016/j.scitotenv.2020.144647).
- [32] Shaforost, Yu., Pogrebniak, O., Lut, O., Litvin, V., & Shevchenko, O. (2024). Chemical military-technogenic load on the soils of military training grounds. *Plant and Soil Science*, 15(2), 67-79. doi: [10.31548/plant2.2024.67](https://doi.org/10.31548/plant2.2024.67).
- [33] Siwach, A., Kaushal, S., & Baishya, R. (2021). Effect of Mosses on physical and chemical properties of soil in temperate forests of Garhwal Himalayas. *Journal of Tropical Ecology*, 37(3), 126-135. doi: [10.1017/s0266467421000249](https://doi.org/10.1017/s0266467421000249).
- [34] Skydan, O.V., Fedoniuk, T.P., Pyvovar, P.V., Dankevych, V.Ye., & Dankevych, Y.M. (2021). Landscape fire safety management: the experience of Ukraine and the EU. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, 6(450), 125-132. doi: [10.32014/2021.2518-170X.128](https://doi.org/10.32014/2021.2518-170X.128).
- [35] Slattery, Z., & Fenner, R. (2021). Spatial analysis of the drivers, characteristics, and effects of forest fragmentation. *Sustainability*, 13(6), article number 3246. doi: [10.3390/su13063246](https://doi.org/10.3390/su13063246).
- [36] Sumy region: During the day, rescuers extinguished fires that broke out in the residential sector due to enemy shelling 4 times. (2024). Retrieved from <https://sm.dsns.gov.ua/news/nadzvicaini-podiyi-sumska-oblast-uprodovz-dobi-riatuvalniki-4-razi-likvidovuvali-pozezi-ia-ki-vinikli-v-zitlovomu-sektori-cerez-vorozi-obstrili>.

- [37] Sydorenko, S., Voron, V., Koval, I., Sydorenko, S., Rumiantsev, M., & Hurzhii, R. (2021). Postfire tree mortality and fire resistance patterns in pine forests of Ukraine. *Central European Forestry Journal*, 67(1), 21-29. doi: [10.2478/forj-2020-0029](https://doi.org/10.2478/forj-2020-0029).
- [38] Thielen, S.M., Gall, C., Ebner, M., Nebel, M., Scholten, T., & Seitz, S. (2021). Water's path from moss to soil: A multi-methodological study on water absorption and evaporation of soil-moss combinations. *Journal of Hydrology and Hydromechanics*, 69(4), 421-435. doi: [10.2478/johh-2021-0021](https://doi.org/10.2478/johh-2021-0021).
- [39] Tykhonova, O., Marukha, T., Rybalko, P., Butenko, S., & Horbas, S. (2024). Ecological typology of woody vegetation of the Starohut forest massif as a component of the restoration of disturbed ecotopes. *Scientific Horizons*, 27(10), 124-135. doi: [10.48077/scihor10.2024.124](https://doi.org/10.48077/scihor10.2024.124).
- [40] Vanderhoof, M.K., Hawbaker, T.J., Ku, A., Merriam, K., Berryman, E., & Cattau, M. (2020). Tracking rates of postfire conifer regeneration vs. deciduous vegetation recovery across the western United States. *Ecological Applications*, 31(2), article number e02237. doi: [10.1002/eap.2237](https://doi.org/10.1002/eap.2237).
- [41] Zeng, S.-P., Liu, F.-L., Zhao, M.-F., Ai, Y., & Chen, X.-W. (2020). Age- and organ-related variances in fire resistance traits of typical tree species in subtropical China. *Journal of Applied Ecology*, 31(4), 1063-1072. doi: [10.13287/j.1001-9332.202004.008](https://doi.org/10.13287/j.1001-9332.202004.008).
- [42] Zhai, T., & Huang, L. (2022). Linking MSPA and circuit theory to identify the spatial range of ecological networks and its priority areas for conservation and restoration in urban agglomeration. *Frontiers in Ecology and Evolution*, 10, article number 828979. doi: [10.3389/fevo.2022.828979](https://doi.org/10.3389/fevo.2022.828979).

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Анотація. Пожежі спричиняють суттєві зміни в структурі лісів, порушують екологічні зв'язки та впливають на процеси відновлення. Метою дослідження було оцінити ступінь пошкоджень деревних насаджень та порівняти стійкість хвойних та листяних порід до пожеж. Проаналізовано вплив цих явищ на різні типи деревних порід та функціонування лісових екосистем у межах північно-східної України, яка у 2022-2024 роках зазнала масштабних пожеж. Аналіз охоплював вивчення ушкоджень кори, стовбура, кореневої системи та верхівок дерев, а також оцінку природних сукцесійних процесів. Хвойні породи, такі як *Pinus sylvestris* L., виявилися найбільш уразливими: близько 60 % дерев були повністю знищені або серйозно пошкоджені, а 70 % кореневих систем втратили здатність до відновлення. Верхівки були знищені у 80 % випадків, що призвело до зменшення щільності деревостанів. Натомість листяні породи, такі як дуб і клен, продемонстрували вищу стійкість до пожеж, зокрема лише 20-30 % цих дерев зазнали серйозних ушкоджень, і більшість із них успішно відновилися завдяки порословому відновленню. Важливу роль у стабілізації ґрунтів відіграють мохи та лишайники, які постраждали найбільше – їхня кількість скоротилася більше ніж на 40 %. Це порушило природні сукцесійні процеси та вплинуло на відновлення лісів. Пожежі також збільшили фрагментацію лісових масивів. Це підкреслює загальну важливість створення

екологічних коридорів та покращення зв'язності між лісовими масивами для полегшення природного відновлення. Рекомендовано також розробляти адаптивні стратегії управління лісами з урахуванням підвищення частоти пожеж, як наслідку протікання природних процесів (змін клімату тощо), так і антропогенних. Показано, що для північно-східної частини України особливо актуальним є питання поширення пожеж, обумовлених впливом воєнних дій. Визначення тактичних та стратегічних підходів щодо управління такими територіями вимагає врахування не лише особливостей та закономірностей функціонування власне лісових екосистем, а й аспектів безпекової ситуації та того, що воєнні впливи виступають додатковим потужним чинником трансформації та забруднення довкілля. Окреслення підходів до розв'язання зазначеного питання має стати частиною програмних документів, пов'язаних із повоєнним відновлення природних комплексів України

Ключові слова: біорізноманіття; екологічна фрагментація; сукцесійні процеси; дистанційне зондування; стабілізація ґрунтів; адаптивне управління лісами