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Impact of climate change on forest ecosystems in Western Polissia

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Abstract. Climate change is affecting forest ecosystems, leading to changes in the distribution of tree species, ecological relationships, and the functioning of forest plant communities. The study aimed to analyse the impact of climate change on forest ecosystems in the Western Polissia of Ukraine. To achieve this goal, in 2005-2023, the State Enterprise "Gorodetske" Research Farm studied the current state of the forest ecosystem, analysed the impact of climate change on it, and conducted detailed forest pathology reconnaissance surveys of the stands. Biodiversity indices were also determined, and the rate of degradation and death of forests was analysed using field data and satellite images. The study determined that climate change in the Western Polissia Region has a significant impact on forest ecosystems, causing changes in forest composition, the spread of diseases and pests, and a decrease in natural biodiversity. The study established that to ensure their sustainable functioning and conservation, it is necessary to take specific measures, including early diagnosis of the state of forests, adaptation to climate change, prevention of forest fires, and use of forest resources based on the principles of sustainable forestry. Implementation of such strategies can contribute to the preservation of ecological diversity and sustainable development in the region for years to come. The results obtained are of great importance for environmental management and conservation of natural resources in the Western Polissia Region, as they provide an opportunity to identify specific strategies and measures for the adaptation of forest ecosystems to climate change and other environmental challenges

Keywords: forest stand; phytopathogens; natural communities; degradation; biodiversity

Introduction

Climate change affects forest ecosystems through fluctuations in temperature and precipitation and can significantly affect the distribution of tree species in forests. Some species may be losing their natural habitat due to changing climatic conditions, while others may be expanding their range beyond their traditional range. This can lead to changes in biodiversity and ecosystem functioning. In addition, climate change can affect the production and distribution of nutrients in the forest, as rising temperatures and changes in precipitation patterns can alter the availability of water to trees and other plants, affecting their growth and development. B.D. Appiagyei *et al.* (2022) noted that the ability of plants to adapt to new climatic conditions depends on their genetic diversity and plasticity, i.e., the ability to change their physiological processes in response to environmental changes. Plants with high genetic diversity have a greater potential for adaptation, as diversity allows them to use a wide range of adaptive strategies. However, the speed and scale of climate change may exceed the ability of many plant species to adapt.

Q. Lyu *et al.* (2021) and M. Mpanda *et al.* (2021) noted that climate change can significantly affect the age structure of the forest. As temperatures rise, some tree species may grow faster, which can lead to changes in the overall structure of forest ecosystems. C. Homer *et al.* (2020) argue that it can also increase competition between different species for available resources such as light, water, and nutrients. These changes can have a significant impact on ecosystem processes and forest biodiversity. Rising temperatures can create conditions for faster growth of young trees, potentially

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changing the age structure of the forest and making it younger. Changes in age structure may have further implications for the sustainability of forest ecosystems. Young trees often require more resources to grow rapidly, which can lead to the depletion of available nutrients and water, especially in a changing climate. Climate change may change the distribution of pathogens that damage forest ecosystems. G.C. Hurtt *et al.* (2020) emphasise that this can lead to the spread of new pests and diseases or changes in the intensity of their impact. Rising temperatures can create favourable conditions for the reproduction of some pests that were not previously typical of a particular area. Climate change in forest ecosystems is leading to significant environmental changes, reducing biodiversity, and altering the dynamics of animal populations. According to L.J.R. Nunes *et al.* (2021), the decline in forest area and degradation of forest quality due to drought and rising temperatures are leading to a decline in populations of animals such as birds, mammals, insects, and others. It also affects predators that depend on these animals as food sources. Such a chain reaction can have far-reaching consequences for the ecosystem, disrupting the natural interconnections and balance between species.

Climate change is one of the world's biggest challenges and affects the forest ecosystem. Climate has a significant impact on species distribution, growth rates, and forest structure. Warming directly affects the rate of plant photosynthesis and indirectly increases the risk of phytopathogen infection (Nigatu Gebeyehu & Hailu Hirpo, 2019). The impact of climate change on the forest ecosystems of the Western Polissia Region of Ukraine is an important topic of research in ecology and natural history. The region is in the western part of Ukraine and is known for its unique biodiversity and vast forests. Any changes in climate, such as rising temperatures, changes in precipitation patterns, and the intensity of natural disasters, can have a serious impact on forest ecosystems (Kimeichuk & Kaidyk, 2022). Following V. Lavnyy *et al.* (2022), climate change requires sustainable management of forest resources to ensure their sustainability and restoration. Therefore, studying the impact of climate change on forest ecosystems in Western Polissia, Ukraine, is relevant for ensuring effective management and conservation of natural biodiversity.

Thus, climate change has a complex and multifaceted impact on forest ecosystems, which should be studied in detail and addressed when developing forest management strategies, which is the relevance of the study. Research gaps are noted in that there is a lack of precision in predicting the specific effects of these changes on different species of trees, vegetation, and animals in different ecosystems. The study aimed to address and reveal the impact of climate change on forest ecosystems in the Western Polissia Region of Ukraine. To achieve the stated goal, the following tasks were set: to conduct a detailed analysis of existing data on climate change in the Western Polissia Region; to research which tree species are typical for the region; to identify which pests and diseases are becoming more common or threatening forests due to climate change; and to develop adaptation and forest management strategies to ensure the sustainability and conservation of ecosystems in Western Polissia. These tasks will describe the impact of climate change on forest ecosystems in Western Polissia and develop appropriate management strategies to ensure their resilience and conservation.

Materials and Methods

During 2005-2023, the study of the impact of climate change on forest ecosystems in the territory of Horodets Village Council of Volodymyrets District of Rivne Region was carried out. These studies were conducted at the State Enterprise "Gorodetske" Research Farm ("Gorodetske"), which is part of the Institute of Agriculture of Western Polissia of the National Academy of Agrarian Sciences of Ukraine and is subordinated to the Ministry for Development of Economy, Trade and Agriculture of Ukraine (Fig. 1).

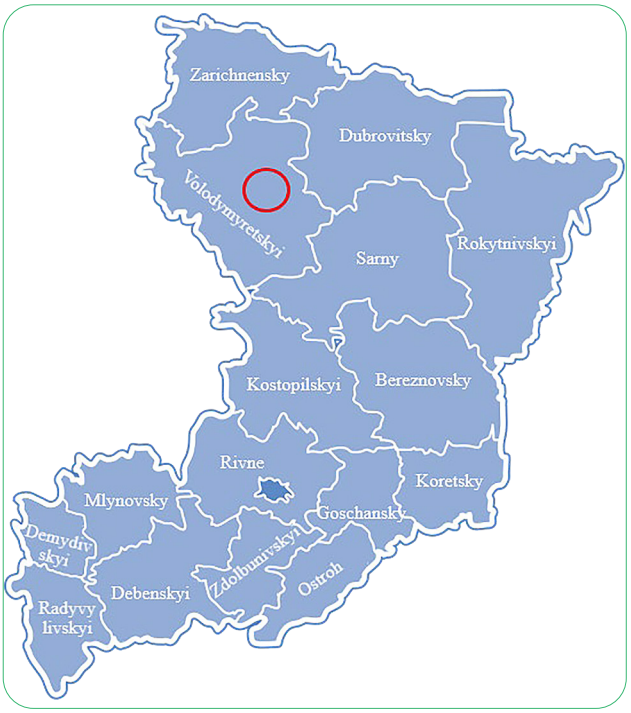

Figure 1. Territorial location of the study area
Source: compiled by the author

The study area covers 106.3 ha and is in the Ukrainian Polissia – Western Polissia Forestry District. Most of the forest plantations in this region grow in fresh subsoil conditions. The research was informed by official materials, statistics, and publications of the Ministry of Environmental Protection and Natural Resources of Ukraine (National environmental policy, n.d.), the State Agency of Forest Resources of Ukraine (General characteristics…, n.d.), and the State Statistics Service of Ukraine (Sales of forest products…, 2024). Rivne Meteorological Station (n.d.) data were used to analyse climate change, which provided a detailed analysis of changes in average annual temperature,

precipitation, temperature fluctuations, and anomalous climate parameters over the period 1979-2023. Historical data from archival documents, literature, and forest management reports were studied to determine the distribution of tree species and the spread of diseases and pests, and compared with the current state (State Audit Service of Ukraine, 2020; Environmental passport of Rivne Region, 2021).

To obtain data on the current state of the forest ecosystem and the impact of climate change on it, detailed forest pathological reconnaissance surveys of stands for pests and diseases were carried out by laying out trial temporary areas. During these inspections, the plants are examined, assessing their appearance, shape, growth, and leaf colour. Any signs of damage, such as holes in the leaves, changes in the colour or texture of the bark, insect damage or nests, as well as spots, fungal fruiting bodies, or other signs of disease infestation, were inspected. Modern environmental research often involves the collection and analysis of large amounts of data (e.g., biodiversity monitoring data, climate data, satellite imagery). To simplify calculations, efficient processing and analysis of such a large amount of data, it is advisable to use programming methods. Therefore, the study used formulas to determine biodiversity indices, which were then processed by a script written in the R programming language. Simpson's index is an indicator of species diversity that considers the number of species (E) and the relative abundance of each species (p) (Somerfield *et al.*, 2008). It is calculated as:

$$E = 1 / (\Sigma\, p^2), \quad (1)$$

where Σp – the total proportion of individuals in the community belonging to a particular species. The Shannon index is an indicator of species diversity that considers the number of species (S) and the relative abundance of each species (p):

$$S = -\Sigma\, p \times \log 2\,(p), \quad (2)$$

where p – is the proportion of individuals in the community belonging to a particular species. The Brillouin index is an indicator of species diversity that takes into account the number of species (H), the total number of individuals (N), and the number of individuals of each species (n):

$$H = ln\,(N!) - \Sigma\,(S \times ln\,(n_i) / N), \quad (3)$$

where N – is the total number of species; n_i – is the number of individuals of each species; S – is the number of species. The study addressed the species structure of the forest fund of Rivne Region, which is part of the Western Polissia zone, with a total area of forest plots of 374,993.5 ha. The analysis of the rates of degradation and death in forest areas was carried out by collecting and processing field research data, which included direct observation, recording, and identification of plants by route. Satellite imagery and aerial photography were also used to identify degraded areas and analyse the factors causing degradation, such as deforestation, fire, pathogens or anthropogenic factors. The obtained research results were processed for their reliability using the multivariate analysis of variance MANOVA method. Microsoft Excel and Statistica 10 software were used for this purpose.

Results

The climate indicators in the Western Polissia Region in 2000-2023 are characterised by an increase in the average annual air temperature by 2°C. The highest temperature increases are observed during the cold season, which reduces the likelihood of prolonged and severe cold weather, although short-term cold snaps are still possible. During the cold season, fog, frost, snowfall, ice, and strong gale-force winds are common, with a probability of 80-95%. The warm season is characterised by extreme heat, increased fire danger, as well as intense rain, thunderstorms, hail, and squalls. These phenomena are local in nature but manifest themselves with a certain regularity and intensity.

Since the beginning of 2000, the climatic conditions in Western Polissia have undergone significant changes as a result of global warming, which is observed in all parts of the world. Winters have become milder, and rain instead of snow in December has become a common occurrence. Since the end of 2010, spring droughts and windstorms have become more frequent, negatively impacting agriculture and forest ecosystems. Summer cold snaps are often accompanied by strong winds, heavy rains and hail, which leads to significant losses. Climate change is affecting all aspects of life in the region. Warmer winters lead to a decrease in snow cover, which is important for the water balance and prevention of spring floods. Long, hot periods in the summer increase the risk of forest fires and reduce the possibility of active photosynthetic activity. Therefore, it is necessary to adapt technologies, water management and urban planning to minimise the negative impacts and ensure sustainable development in the region.

The data show that the linear trend of climate change is increasing, which indicates that the temperature trend is positive and that the Western Polissia Region is becoming warmer due to climate change. Moreover, one can observe a complete absence of blue colour bands, which are characteristic of colder years in the chart since 2000, while there is a clear trend of red bands, which are characteristic of warmer and hotter years (Fig. 2). The amount of precipitation has been decreasing over the years, so conditions in the Western Polissia Region are becoming drier over time. In addition, drier years are becoming more and more common, with brown stripes instead of rainy ones on the chart, creating a moisture deficit for forest ecosystems (Fig. 3). The temperature anomaly for each month since 1979 indicates how much warmer or colder it was than the 30-year average air temperature between 1980 and 2010. Red months indicate warmer values, and blue months indicate colder values than the average. According to the data obtained, it is possible to state that the number of warm months has been increasing over the years, which indicates global warming

associated with climate change (Fig. 4). The bottom part of the figure shows the precipitation anomaly for each month since 1979; the anomaly indicates whether the month had more precipitation than the average for the 30 years of climate observations from 1980-2010. Green months show an excess of precipitation, and brown months show a deficit compared to the norm. Thus, over the years, the trend of periods of precipitation deficit has been observed.

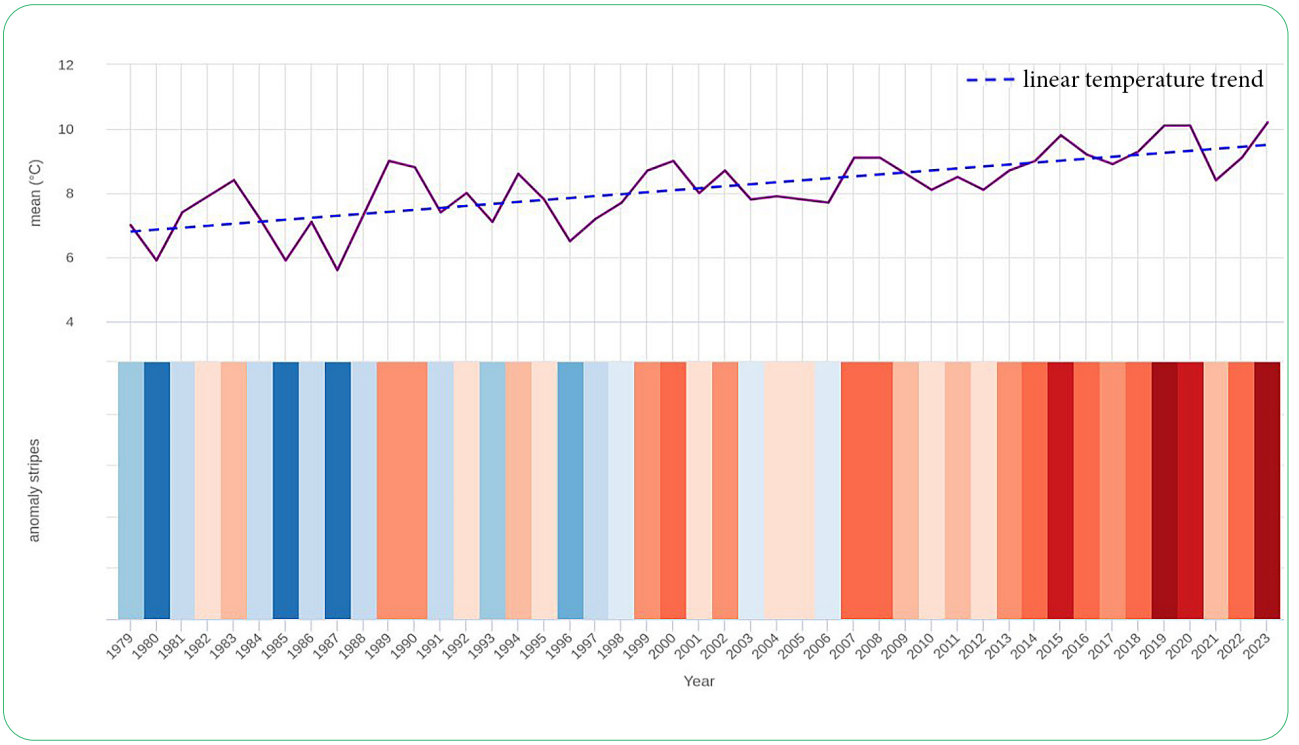

Figure 2. Annual temperature change at the Rivne Meteorological Station, 1979-2023

Source: compiled by the author based on Rivne Meteorological Station (n.d.)

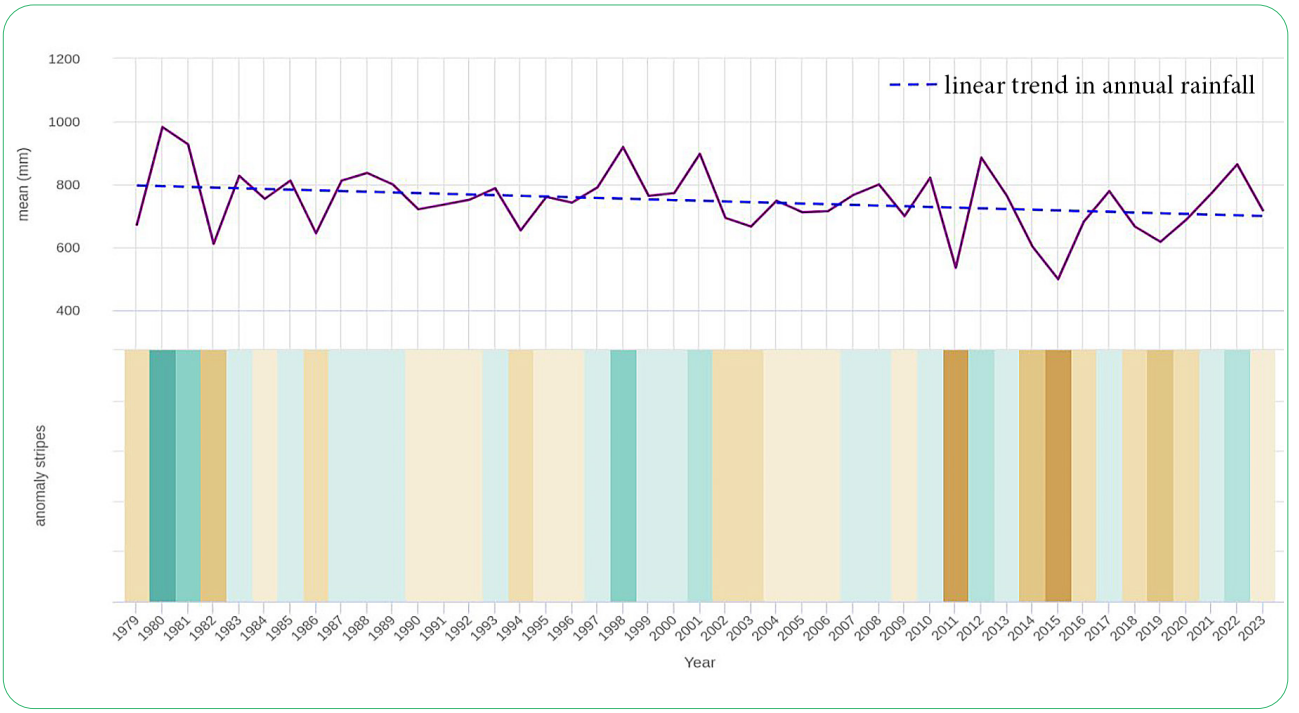

Figure 3. Dynamics of annual precipitation at the Rivne Meteorological Station, 1979-2023

Source: compiled by the author based on Rivne Meteorological Station (n.d.)

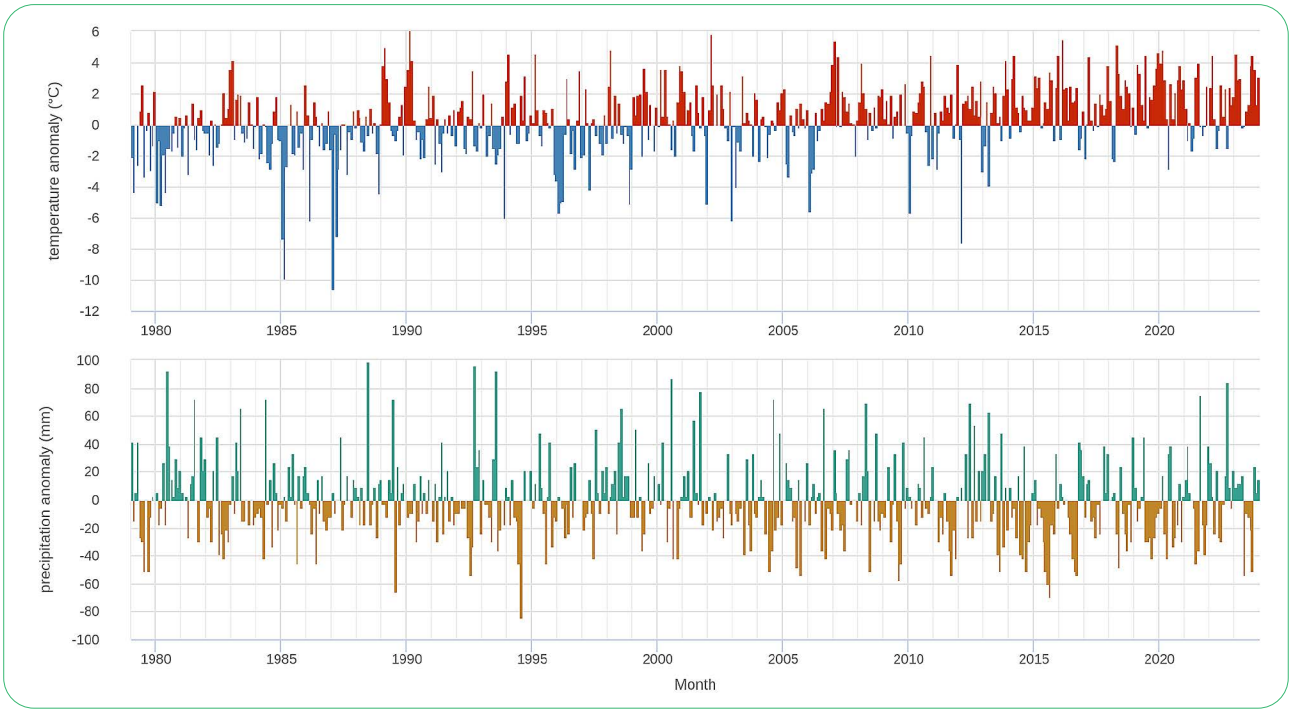

Figure 4. Deviations from the norm of average monthly air temperature and monthly precipitation at the Rivne Meteorological Station, 1979-2023

Source: compiled by the author based on Rivne Meteorological Station (n.d.)

The study established that over the past decade in Western Polissia in the example of the Rivne Region, there have been changes in the species composition of forests, which has led to a decrease in the number of valuable and productive tree species (both coniferous and hardwood) and an increase in derivative stands and less valuable forest plantations. This increase was due to the expansion of low-bonus hardwood and softwood plantations, which indicates negative changes in the quality of plantations. Such changes are considered negative due to reduced forest productivity, lower resistance to pests and diseases, and soil degradation (Lavnyy *et al.*, 2022). According to the structure of forests by species groups, conifers predominate common pine, which occupies 65% of the total forest area (374,993.5 ha) (Fig. 5).

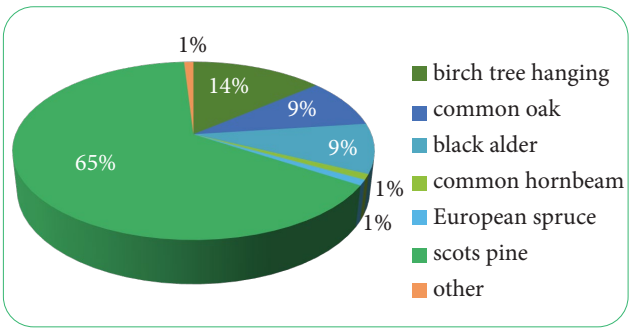

Figure 5. Species structure of the forest fund of Rivne Region

Source: compiled by the author

Other dominant forest species include hanging birch, common oak and black alder, which cover large areas: 81,658.8 ha, 52,110.9 ha and 53,892.2 ha respectively (9% each). Other species account for 3%, of which European spruce and hornbeam account for 1% each. According to the study, rising temperatures have led to the spread of diseases in forest ecosystems, in particular rust, fusarium, and pine blight. In recent years, the dry climate has contributed to the spread of root sponge, which is the most damaging to pine plantations and leads to their depletion. In addition, climate change has affected the spread of pests in forest ecosystems, such as: bark beetle, blue pine bark beetle, ribbed ragworm, goldeneye, large pine beetle, moustachioed beetle, silkworm, beetle and pine pole beetle (Fig. 6). Moreover, climate change may affect forest biodiversity. Some plant and animal species may lose their natural habitats due to changes in the growing season or soil moisture. This can lead to a disturbance of the ecological balance in forest ecosystems. The study revealed a negative trend in biodiversity loss. A script made with the R programming language was used to calculate biodiversity indices for the study plots (Table 1). In general, a downward trend can be noted for all three indices during the period under review. This may indicate a decrease in plant diversity at the "Gorodetske". The Shannon and Simpson indices, which address both the number and diversity of species, appeared to be more sensitive to changes than the Brillouin index, which takes into account only the number of species. Thus, the decline in the Shannon and Simpson index reflects not only a decrease in

the number of species but also a loss of diversity. Changes in biodiversity can be caused by various factors, such as climate change, changes in land management, habitat destruction, and the loss of plant habitats. To determine in detail the causes of changes in forest ecosystems, the rates of degradation and death of forests were analysed (Fig. 7-8).

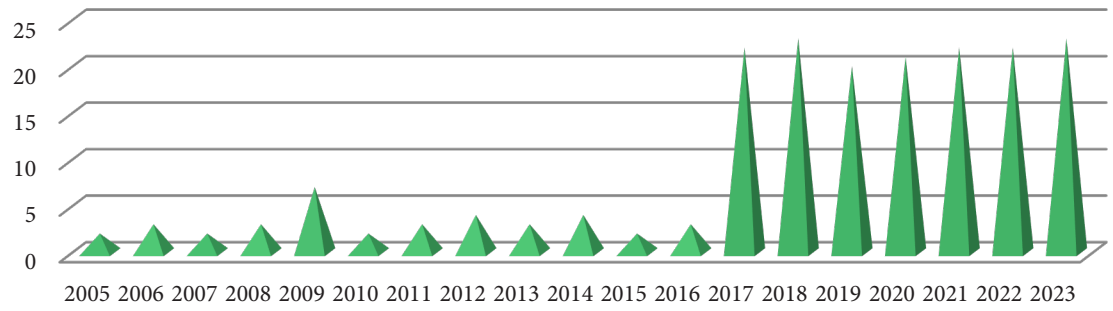

Figure 6. The presence of forest pests and diseases in the "Gorodetske", 2005-2023

Source: compiled by the author

Table 1. Plant biodiversity index at the "Gorodetske", 2005-2023, plot average

Year	Brillouin index	Shannon index	Simpson index
2005	4.5	2.8	0.65
2006	4.3	2.7	0.63
2007	4.2	2.6	0.61
2008	4.1	2.5	0.59
2009	4	2.4	0.57
2010	3.9	2.3	0.55
2011	3.8	2.2	0.53
2012	3.7	2.1	0.51
2013	3.6	2	0.49
2014	3.5	1.9	0.47
2015	3.4	1.8	0.45
2016	3.3	1.7	0.43
2017	3.2	1.6	0.41
2018	3.1	1.5	0.39
2019	3	1.4	0.37
2020	2.9	1.3	0.35
2021	2.9	1.2	0.34
2022	2.8	1.2	0.33
2023	2.7	1.1	0.31

Source: compiled by the author

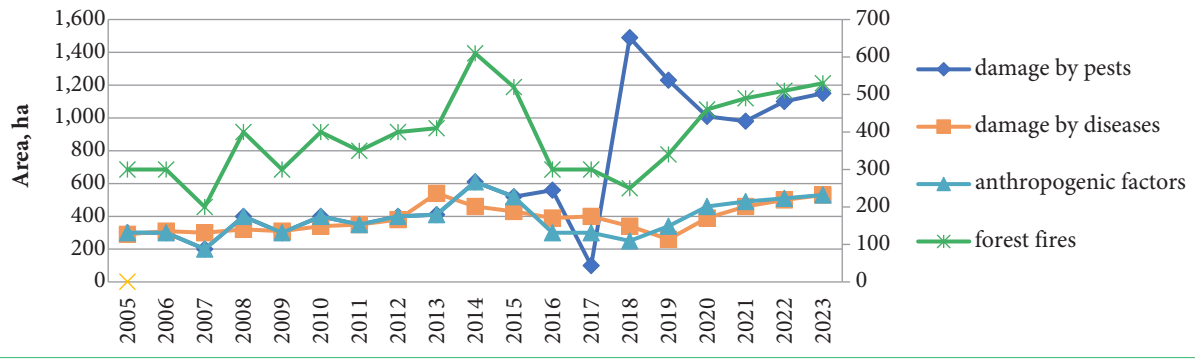

Figure 7. Dynamics of mortality of coniferous tree species, 2005-2023

Source: compiled by the author based on General characteristics of the forests of Ukraine (n.d.), Sales of forest products within Ukraine by type (2024)

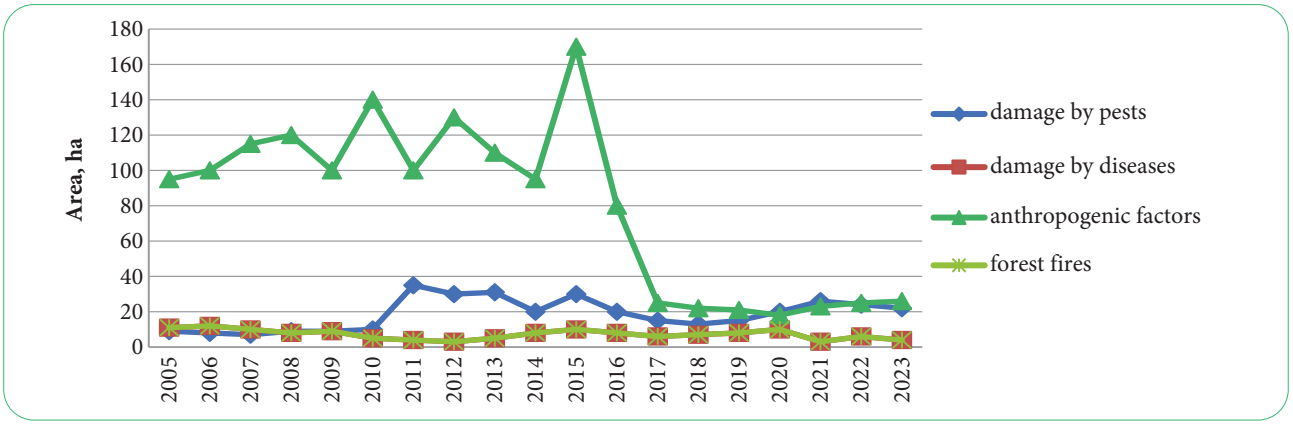

Figure 8. Dynamics of mortality of deciduous tree species, 2005-2023

Source: compiled by the author based on State Agency of Forest Resources of Ukraine (n.d.), Sales of forest products within Ukraine by type (2024)

Summarising the analysis of data for the period from 2005 to 2023, it can be determined that there is an increase in damage from diseases and pests of conifers, which indicates a deterioration in the condition of forests and their vulnerability to phytopathological factors. A stable trend of anthropogenic factors has been established for most years, including deforestation. There is also an increase in the number of forest fires, which is a result of both climate change and human activity. As for deciduous tree species, it is worth noting that in 2011 there was a sharp increase in the impact of pests. The impact of anthropogenic factors has been decreasing in most years, but high values were noted in 2007 and 2010. There is also a general trend of increasing forest fires over time, especially in 2017 and 2018.

Overall, the analysis demonstrates the threats faced by forest ecosystems and points to the need to take measures to protect and sustainably use them. In particular, the following adaptation and forest management strategies can be developed to ensure the sustainability and conservation of Western Polissia ecosystems in the context of identified impacts and threats. Monitoring and early diagnosis: establishing a system for continuous monitoring of forest conditions to detect damage from pests, diseases, climate change and forest fires in a timely manner; use of advanced technologies such as drones and satellite sensing to collect data and visualise the state of forests. Biodiversity and ecosystem restoration: preserving and restoring biodiversity by preserving natural forest complexes and regulating forestry; implementation of programmes to preserve rare and endangered species of plants and animals that are an integral part of ecosystems. Adaptation to climate change: developing and implementing climate change adaptation strategies, including protecting forests from rising temperatures, droughts, and other climate extremes; introduction of climate-resistant tree and plant species. Preventing forest fires: implementing preventive measures to prevent forest fires, such as clearing undergrowth, creating firebreaks, and educating local residents on fire safety; development and implementation of emergency and rapid response plans in case of fire. Sustainable use of forest resources: managing forest resources based on the principles of sustainable forestry, including the balanced use, restoration and conservation of forest resources; introducing forestry certification to ensure compliance with sustainable forestry requirements. These strategies are aimed at ensuring the resilience and conservation of Western Polissia ecosystems in the face of growing threats and impacts, and their implementation can help conserve valuable forest resources and ensure sustainable use for many years to come.

Discussion

Climate change is one of the biggest challenges facing the world, with a significant impact on forest ecosystems. As such, A. Zerva (2022) noted that forests are sensitive to climate change, so climate change has a huge impact on species distribution, growth rates and forest structure. Climate change is having a major impact on forest ecosystems, altering tree growth and reproduction. As temperatures rise, the chronology of tree life cycles changes, with budding, leafing and flowering occurring too early. A similar opinion is expressed by Z. Zeng *et al.* (2020), according to which climate change affects forest ecosystems both directly and indirectly, changing their structure and functioning. Rising temperatures directly affect the rate of photosynthesis and respiration of plants, and indirectly increase the risk of damage from phytopathogens. In general, climate change is seen as one of the main obstacles to sustainable development due to its impact on health, infrastructure, population, agriculture and forest ecosystems. It can also cause a deterioration in living conditions in many regions of the world (Zhang *et al.*, 2022).

According to Z. Zhao *et al.* (2021), there were unprecedented changes in the climate system during the twentieth century. These changes can be traced back to an increase in average annual temperature, changes in the quantity and quality of precipitation, and an increase in the intensity and frequency of abnormal events. It is widely accepted that climate change is closely linked to greenhouse gas

emissions, especially over the past 150 years. Therefore, the term "climate change" has become synonymous with "human-induced climate change". Climate change is most adversely affected by rising air temperatures and changes in precipitation. These factors influence changes in the growing season and the composition of forest ecosystems. Analysis of the study by K. Yuan *et al.* (2021) and the modelling of changes in climate indicators confirm an increase in air temperature by 0.7°C annually. According to the study, the optimal temperature for photosynthesis in forests depends on the type of ecosystem: for deciduous trees – 17.5°C, for conifers – 16°C. Precipitation affects the intensity of photosynthesis only at low values – less than 60 mm. H. Xie *et al.* (2021), on the other hand, believe that changes in climatic parameters at the beginning of the growing season contribute to improved conditions for photosynthesis in forest plantations. However, excessively high summer temperatures can harm the condition of coniferous forests, as this factor only increases over time.

In contrast, A.A. Argiriou *et al.* (2023) suggest that reduced precipitation in August and September can negatively affect plant development. However, in the long term, the increase in the length of the growing season caused by the early onset of plant physiological activity may have a positive impact. This change can help increase the efficiency of forest ecosystems in absorbing carbon dioxide, which is important for the climate balance. In general, most authors agree that global warming is causing significant changes in the environment, which have already led to certain negative environmental impacts and may further deepen in the future. Anomalies of high temperatures alternating with coolness, prolonged absence of precipitation, as well as sudden heavy rains and other adverse weather events, lead to the degradation of forest ecosystems (Salimi *et al.*, 2021; Tian *et al.*, 2023).

Climate change harms forest ecosystems, as rising temperatures lead to changes in the composition of forest species, increase the frequency and intensity of forest fires, and promote the spread of pests and diseases, which threaten forest health. G. Forzieri *et al.* (2022) argue that these changes are affecting the ability of forests to respond to various climate factors, leading to a decrease in their resilience. Another proof of this and confirmation of the results is the opinion of M. Nigatu Gebeyehu & F. Hailu Hirpo (2019), who believe that climate change is leading to the transformation of zonal vegetation types, changes in the ratio of forest formations and forest types, as well as deterioration of forest viability and resistance to pests and diseases. In addition, they contribute to an increase in the intensity of forest drying and outbreaks of massive pest reproduction. Climate change has a significant impact on the forest ecosystems of Western Polissia, a region with many forests and rich biodiversity. Although the climate here is favourable for plant diversity, the peculiarities of the local location and atmospheric processes create conditions for the occurrence of natural meteorological events that can be catastrophic and cause significant damage (Boychenko & Karamushka, 2020). The wetland ecosystems typical of Polissia are particularly sensitive to such environmental changes. Studies point to a specific destruction of birch-rich habitats in the bogs of the left bank of Polissia, which is associated with extreme weather conditions. These ecosystems are important, and they are very sensitive to any changes in the environment, as confirmed in the study (Gautam *et al.*, 2021).

Natural climatic zones, forest species composition, and local growing conditions play an important role in how climate change will affect specific forests. According to L. Gustafsson *et al.* (2020), climate change is also causing significant changes in the biological productivity of forests, which affects the amount of available forest resources. This creates new challenges for the forestry and woodworking industries, which require the development of measures to adapt to the new conditions. These changes must be addressed to ensure forest sustainability and effective forest management in a changing climate. A comparison of the results with previous studies in this area confirms the consistency and complementarity of the findings. For instance, studies by M.M. Qaderi *et al.* (2019) and R.A. Slesak *et al.* (2022) also indicate that to effectively respond to the challenges posed by climate change and to forecast the volume of forest resources in the future, it is necessary to have a detailed understanding of forest productivity and condition in the medium and long term. L. Yang *et al.* (2022) emphasise that it is necessary to implement the principles of sustainable forestry and develop adaptation strategies that consider the natural and climatic zones and bio-ecological characteristics of forest species. This will reduce the vulnerability of forests to climate change and help preserve them for future generations.

The study confirms the opinion of Y. Li *et al.* (2020), who emphasise that the transition to sustainable forestry and the implementation of forest adaptation strategies to climate change significantly increase their resilience. Adaptation strategies should be based on the principles of sustainable forestry, addressing the natural and climatic zones and bio-ecological characteristics of forest species. This includes selecting appropriate reforestation methods, monitoring forest conditions, and integrating new technologies and approaches to forest management. In this way, the negative impact of climate change can be reduced, and forest plantations can be preserved. The findings of Q. Wang *et al.* (2023) also resonate with the present study, which found that the forestry industry reduces its vulnerability to climate change through strategic interventions. This includes implementing adaptation measures, such as developing tree varieties that are more resilient to new climate conditions and conserving biodiversity to create more resilient ecosystems. Reducing the vulnerability of the forest sector and improving its adaptive capacity has a positive impact on the environment, helping to maintain the ecological sustainability of forests (Navarro-Cerrillo *et al.*, 2023).

Thus, climate change has become a key objective of global environmental policy and a challenge for forest management strategies. Forestry managers need to be aware of their role in reducing the vulnerability of not only

the forestry sector but also other sectors of the economy and agriculture. There is ambiguity regarding the development of effective mechanisms for a socially acceptable, internationally coordinated climate policy strategy that could withstand market constraints and promote appropriate institutional development. However, the forestry sector has great potential to mitigate the negative effects of climate change, but this requires the development of regional adaptation and optimisation strategies.

Conclusions

The study found that between 2000 and 2023, the average air temperature in the Western Polissia Region increased by 2°C and there is a tendency to increase the number of warm months over the years, which indicates global warming associated with climate change. In addition, conditions in this area are becoming drier over time, which creates a moisture deficit for forest ecosystems. These changes affect forests, causing a decrease in species biodiversity and disruption of ecological balance in forest ecosystems. The study also established that the decline in biodiversity is caused by factors such as climate change, anthropogenic impacts, environmental destruction, and the loss of habitat for plants due to forest fires.

An analysis of data for the period from 2005 to 2023 confirmed that in the Western Polissia Region, in the Rivne Region, there is an increase in damage from diseases and pests of both coniferous and deciduous tree species, which indicates a deterioration in the condition of forests and their vulnerability to phytopathological factors. There is an increase in climatic factors, in particular temperature risk, which negatively affects forest health. The increase in the number of forest fires can be caused by both climate change and human activity, which underscores the need to strengthen forest protection measures.

To minimise the negative impacts of climate change, it is necessary to adapt technologies, water management, and urban planning. This includes monitoring and predicting climate change, adapting forestry to new conditions, ensuring climate change resilience, and enhancing the environmental sustainability of the region. Measures must be taken to preserve forest biodiversity, prevent the spread of diseases and pests, and maintain ecological balance in the region. The results of the study are limited to the specific area of Western Polissia in Ukraine and cannot be fully generalised to other areas or climatic zones. The prospect of further research is to use models to predict the impact of future climate change on forest ecosystems.

Acknowledgements

None.

Conflict of Interest

None.

References

[1] Appiagyei, B.D., Belhoucine-Guezouguli, L., Bessah, E., Morsli, B., & Fernandes, P.A.M. (2022). A review on climate change impacts on forest ecosystem services in the Mediterranean Basin. *Journal of Landscape Ecology*, 15(1), 1-26. doi: 10.2478/jlecol-2022-0001.

[2] Argiriou, A.A., Li, Z., Armaos, V., Mamara, A., Shi, Y., & Yan, Z. (2023). Homogenised monthly and daily temperature and precipitation time series in China and Greece since 1960. *Advances in Atmospheric Sciences*, 40(7), 1326-1336. doi: 10.1007/s00376-022-2246-4.

[3] Boychenko, S.H., & Karamushka, V. (2020). Climate change processes impact on wetland ecosystems of Polissia Region in Ukraine. In *Book of abstracts "Oral presentations given on-line at BUP symposium 2020"* (p. 8). Uppsala: Uppsala University.

[4] Environmental passport of Rivne Region. (2021). Retrieved from https://mepr.gov.ua/wp-content/uploads/2022/11/Ekologichnyj-pasport-Rivnenskoyi-oblasti-za-2021-rik.pdf.

[5] Forzieri, G., Dakos, V., McDowell, N.G., Ramdane, A., & Cescatti, A. (2022). Emerging signals of declining forest resilience under climate change. *Nature*, 608, 534-539. doi: 10.1038/s41586-022-04959-9.

[6] Gautam, P., Lal, B., Panda, B., Bihari, P., Chatterjee, D., Singh, T., Nayak, P., & Nayak, A. (2021). Alteration in agronomic practices to utilize rice fallows for higher system productivity and sustainability. *Field Crops Research*, 260, article number 108005. doi: 10.1016/j.fcr.2020.108005.

[7] General characteristics of the forests of Ukraine. (n.d.). Retrieved from https://forest.gov.ua/napryamki-diyalnosti/lisi-ukrayini/zagalna-harakteristika-lisiv-ukrayini.

[8] Gustafsson, L., Bauhus, J., Asbeck, T., Augustynczik, A.L.D., Basile, M., Frey, J., Gutzat, F., Hanewinkel, M., Helbach, J., Jonker, M., Knuff, A., Messier, C., Penner, J., Pyttel, P., Reif, A., Storch, F., Winiger, N., Winkel, G., Yousefpour, R., & Storch, I. (2019). Retention as an integrated biodiversity conservation approach for continuous-cover forestry in Europe. *Ambio*, 49, 85-97. doi: 10.1007/s13280-019-01190-1.

[9] Homer, C., Dewitz, J., Jin, S., Xian, G., Costello, C., Danielson, P., Gass, L., Funk, M., Wickham, J., Stehman, S., Auch, R., & Riitters, K. (2020). Conterminous United States land cover change patterns 2001-2016 from the 2016 national land cover database. *ISPRS Journal of Photogrammetry and Remote Sensing*, 162, 184-199. doi: 10.1016/j.isprsjprs.2020.02.019.

[10] Hurtt, G.C., Chini, L., Sahajpal, R., Frolking, S., Bodirsky, B.L., Calvin, K., Doelman, J.C., Fisk, J., Fujimori, S., Goldewijk, K.K., Hasegawa, T., Havlik, P., Heinimann, A., Humpenöder, F., Jungclaus, J., Kaplan, J.O., Kennedy, J., Krisztin, T., Lawrence, D., Lawrence, P., Ma, L., Mertz, O., Pongratz, J., Popp, A., Poulter, B., Riahi, K., Shevliakova, E., Stehfest, E., Thornton, P., Tubiello, F.N., van Vuuren, D.P., & Zhang, X. (2020). Harmonization of global land use change and management for the period 850-2100 (LUH2) for CMIP6. *Geoscientific Model Development*, 13(11), 5425-5464. doi: 10.5194/gmd-13-5425-2020.

[11] Kimeichuk, I., & Kaidyk, O. (2022). Natural afforestation of the fallows in the Western Polissia. *Ukrainian Journal of Forest and Wood Science*, 13(4), 41-51. doi: 10.31548/forest.13(4).2022.41-51.

[12] Lavnyy, V., Spathelf, P., Kravchuk, R., Vytseha, R., & Yakhnytskyy, V. (2022). Silvicultural options to promote natural regeneration of Scots pine (*Pinus sylvestris* L.) in Western Ukrainian forests. *Journal of Forest Science*, 68(8), 298-310. doi: 10.17221/73/2022-jfs.

[13] Li, Y., Piao, S., Chen, A., Ciais, P., & Li, L.Z.X. (2019). Local and teleconnected temperature effects of afforestation and vegetation greening in China. *National Science Review*, 7(5), 897-912. doi: 10.1093/nsr/nwz132.

[14] Lyu, Q., Liu, J., Liu, J., Luo, Y., Chen, L., Chen, G., Zhao, K., Chen, Y., Fan, C., & Li, X. (2021). Response of plant diversity and soil physicochemical properties to different gap sizes in a *Pinus massoniana* plantation. *PeerJ*, 9, article number e12222. doi: 10.7717/peerj.12222.

[15] Mpanda, M., Kashindye, A., Aynekulu, E., Jonas, E., Rosenstock, T.S., & Giliba, R.A. (2021). Forests, farms, and fallows: The dynamics of tree cover transition in the southern part of the Uluguru mountains, Tanzania. *Land*, 10(6), article number 571. doi: 10.3390/land10060571.

[16] National environmental policy. (n.d.). Retrieved from https://mepr.gov.ua/diyalnist/natsionalna-ekologichna-polityka/.

[17] Navarro-Cerrillo, R.M., Cachinero-Vivar, A.M., Ruiz-Gómez, F.J., Camarero, J.J., González-Pérez, J.A., & Pérez-Priego, S. (2023). Planted or natural pine forests, which one will better recover after drought? Insights from tree growth and stable C and H isotopes. *Forests*, 14(3), article number 573. doi: 10.3390/f14030573.

[18] Nigatu Gebeyehu, M., & Hailu Hirpo, F. (2019). Review on effect of climate change on forest ecosystem. *International Journal of Environmental Sciences & Natural Resources*, 17(4), article number 555968. doi: 10.19080/IJESNR.2019.17.555968.

[19] Nunes, L.J.R., Meireles, C.I.R., Gomes, C.J.P., & Ribeiro, N.M.C.A. (2021). The impact of climate change on forest development: A sustainable approach to management models applied to Mediterranean-type climate regions. *Plants*, 11(1), article number 69. doi: 10.3390/plants11010069.

[20] Qaderi, M.M., Martel, A.B., & Dixon, S.L. (2019). Environmental factors influence plant vascular system and water regulation. *Plants*, 8(3), article number 65. doi: 10.3390/plants8030065.

[21] Rivne Meteorological Station. (n.d.). Retrieved from https://pogoda.rovno.ua/.

[22] Sales of forest products within Ukraine by type. (2024). Retrieved from https://www.ukrstat.gov.ua/operativ/operativ2021/sg/lis/lis_u/arh_real_lis_pr_u.htm.

[23] Salimi, S., Almuktar, S.A.A.A.N., & Scholz, M. (2021). Impact of climate change on wetland ecosystems: A critical review of experimental wetlands. *Journal of Environmental Management*, 286, article number 112160. doi: 10.1016/j.jenvman.2021.112160.

[24] Slesak, R.A., Kelso, S.G., & Windmuller-Campione, M.A. (2022). Effect of biochar and manual vegetation control on early growth and survival of planted Jack pine (*Pinus banksiana* Lamb.) seedlings in Northern Minnesota. *Forest Science*, 68(1), 104-112. doi: 10.1093/forsci/fxab053.

[25] Somerfield, P.J., Clarcke, K.R., & Warwick, R.M. (2008). Simpson index. In *Encyclopedia of ecology* (pp. 3252-3255). Amsterdam: Elsevier. doi: 10.1016/B978-008045405-4.00133-6.

[26] State Audit Service of Ukraine. (2020). *Auditor's report on the results of the state financial audit of the State Enterprise "Rokytnivskyi State Special Forestry Agro-Industrial Enterprise" for the period from 01.12.2016 to 30.11.2019*. Rokytne: Western Office of the State Audit Service Office in Rivne Region.

[27] Tian, P., Jian, B., Li, J., Cai, X., Wei, J., & Zhang, G. (2023). Land-use-change-induced cooling and precipitation reduction in China: Insights from CMIP6 models. *Sustainability*, 15(16), article number 12191. doi: 10.3390/su151612191.

[28] Wang, Q., Cai, X., Tang, J., Yang, L., Wang, J., & Xu, Y. (2023). Climate feedbacks associated with land-use and land-cover change on hydrological extremes over the Yangtze River Delta Region, China. *Journal of Hydrology*, 623, article number 129855. doi: 10.1016/j.jhydrol.2023.129855.

[29] Xie, H., Tang, Y., Yu, M., & Wang, G.G. (2021). The effects of afforestation tree species mixing on soil organic carbon stock, nutrients accumulation, and understory vegetation diversity on reclaimed coastal lands in Eastern China. *Global Ecology and Conservation*, 26, article number e01478. doi: 10.1016/j.gecco.2021.e01478.

[30] Yang, L., Zeng, Y., Xu, L., Li, M., Wang, H., Zou, Y., & Lu, Y. (2022). Perennial woodlands benefit parasitoid diversity, but annual flowering fallows enhance parasitism of wheat aphids in an agricultural landscape. *Agriculture, Ecosystems & Environment*, 340, article number 108184. doi: 10.1016/j.agee.2022.108184.

[31] Yuan, K., Zhu, Q., Zheng, S., Zhao, L., Chen, M., Riley, W.J., Cai, X., Ma, H., Li, F., Wu, H., & Chen, L. (2021). Deforestation reshapes land-surface energy-flux partitioning. *Environmental Research Letters*, 16(2), article number 024014. doi: 10.1088/1748-9326/abd8f9.
[32] Zeng, Z., Wang, D., Yang, L., Wu, J., Ziegler, A.D., Liu, M., Ciais, P., Searchinger, T.D., Yang, Z.L., Chen, D., Chen, A., Li, L.Z., Piao, S., Taylor, D., Cai, X., Pan, M., Peng, L., Lin, P., Gower, D., Feng, Y., Zheng, C., Guan, K., Lian, X., Wang, T., Wang, L., Jeong, S.-J., Wei, Z., Sheffield, J., Caylor, K., & Wood, E.F. (2020). Deforestation-induced warming over tropical mountain regions regulated by elevation. *Nature Geoscience*, 14, 23-29. doi: 10.1038/s41561-020-00666-0.
[33] Zerva, A. (2022). The impacts of climate change on the forest ecosystems of the Mediterranean. In E. Manolas & W. Leal Filho (Eds.), *The academic language of climate change: An introduction for students and non-native speakers* (pp. 145-149). Leeds: Emerald Publishing Limited. doi: 10.1108/978-1-80382-911-120221021.
[34] Zhang, Y., Han, J., Wang, L., Jing, X., Wang, Y., & Liu, P. (2022). Response of *Pinus tabuliformis* saplings to continuous autumn fertilization treatments in the mountains of Eastern Liaoning Province, China. *PeerJ*, 10, article number e12853. doi: 10.7717/peerj.12853.
[35] Zhao, Z., Zhao, Z., Fu, B., Wu, D., Wang, J., & Tang, W. (2021). Available heavy metal concentrations and their influencing factors in cropland and fallows of different age in tropical area. *Polish Journal of Environmental Studies*, 30(2), 1935-1942. doi: 10.15244/pjoes/126372.

Вплив кліматичних змін на лісові екосистеми Західного Полісся

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Анотація. Кліматичні зміни впливають на лісові екосистеми призводячи до змін у розподілі видів дерев, екологічних взаємозв'язках та функціонуванні лісових рослинних угруповань. Метою дослідження було проаналізувати вплив кліматичних змін на лісові екосистеми в Західному Поліссі України. Для досягнення поставленої мети впродовж 2005-2023 років на території Державного підприємства «Дослідне господарство "Городецьке"» здійснено вивчення поточного стану лісової екосистеми, проаналізовано вплив на неї змін клімату та проведено детальні лісопатологічні рекогносцирувальні обстеження деревостанів. Також визначено індекси біорізноманіття та проведено аналіз темпів деградації та загибелі лісових масивів, використовуючи дані польових досліджень та супутникові знімки. У результаті дослідження встановлено, що кліматичні зміни в зоні Західного Полісся мають значний вплив на лісові екосистеми, спричиняючи зміни в складі лісів, поширення хвороб і шкідників, а також зменшення природного біорізноманіття. Встановлено, що для забезпечення їхнього сталого функціонування та збереження необхідне вжиття конкретних заходів, включаючи ранню діагностику стану лісів, адаптацію до змін клімату, запобігання лісовим пожежам та використання лісових ресурсів на основі принципів сталого лісового господарства. Впровадження таких стратегій може сприяти збереженню екологічної різноманітності та сталому розвитку регіону на майбутні роки. Отримані результати мають вагоме значення для екологічного управління та збереження природних ресурсів у зоні Західного Полісся, оскільки надають можливість визначити конкретні стратегії та заходи для адаптації лісових екосистем до змін клімату та інших екологічних викликів

Ключові слова: деревостан; фітопатогени; природні угруповання; деградація; біорізноманіття