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Monitoring climate change dynamics in protected areas of Volyn Region

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SUMMARY

Nature reserves and national parks constitute the most valuable part of the nature reserve fund and are key elements of the ecological network. In recent decades, their ecosystems have been significantly affected by climate change. Research into the manifestations of climate change within protected areas makes it possible to develop effective adaptation mechanisms and identify ways to prevent or minimize negative impacts on biota, particularly rare and vulnerable species. The aim of the work is to conduct a comparative analysis of the dynamics of climate indicators in the Cheremsky Nature Reserve, Shatsk National Nature Park, Kivertsi National Nature Park "Tsumanska Pushcha" and Prypiat-Stokhid National Nature Park, to study regional manifestations of climate change, its possible impact on biodiversity, and to visualize the results. We compared climatic indicators in the four largest protected areas of Volyn during 2014-2024 with each other and with the climatic norm; assessed the possible impact of climate change on biota; developed two interactive maps to visualize changes in temperature, humidity, precipitation, cloud cover, snow cover, and atmospheric phenomena.

Introduction

Contemporary climate change can significantly affect the stability of natural complexes, especially vulnerable ecosystems and biological species. Research into the manifestations of such changes in nature protected areas makes it possible to develop effective adaptation mechanisms and find ways to prevent or minimize their negative impact on biota. The significance and role of studying climate change within nature conservation areas was substantiated by Ranius, et al. (2023), Duncanson, et al. (2023). The Ukrainian Polissya region is already experiencing a significant negative impact from climate change. First and foremost, this means a greater spread of forest diseases (Shvidenko, Buksha, Krakovska, & Lakyda, 2017; Getmanchuk et al, 2017) and fires in ecosystems (Karamushka, Kuchma, Boychenko, & Nazarova, 2023; Fedoniuk et al, 2025). This determines the relevance of the analysis for the largest objects of the Nature Reserve Fund in Volyn region: Cheremsky Nature Reserve, Shatsky National Nature Park, Kivertsy National Nature Park "Tsumanska Pushcha" and "Prypiat-Stokhid" National Nature Park, which form the core of the region's ecological network (Petlin, Fesiuk & Karpiuk, 2021; Fedoniuk, Kartava, Ivantsiv, 2016). The authors began this study by assessing climate change in the Volyn region as a whole and in the Cheremsky Nature Reserve in particular (Fedoniuk et al, 2023), extended the methodology used to these protected areas.

Method and/or Theory

The research materials include archival meteorological data from weather stations in Manevychi, Lutsk, Liubeshiv, and Svitiaz (www.ecad.eu), Chronicles of Nature of the Cheremsky Nature Reserve, Shatsky National Nature Park, Kivertsy National Nature Park "Tsumanska Pushcha", and Pripyat-Stokhid National Nature Park for 2014–2024, the results of statistical processing and graphical representation of meteorological indicators. The following indicators were analyzed: average, minimum, and maximum air temperature; relative humidity; annual and maximum daily precipitation; average and maximum wind speed, total and lower cloud cover, duration and height of snow cover, and meteorological phenomena: rain, snow, fog, blizzard and thunderstorm. To assess the moisture conditions of the territory and its impact on wetland complexes, evaporation and the moisture coefficient were calculated using N. Ivanov's method. A comparison was made with the climatic norm for the period 1991–2020. Standard methods of statistical and mathematical and graphical analysis were used in MS Excel. The development of electronic climate monitoring maps took into account the experience of creating similar types of cartographic resources and their intended use (Balabukh, 2017; Leta, Karabiniuk, Mykyta, Kachailo, 2023, and others).

Results

Analysis of the results obtained allows us to make the following generalizations regarding the dynamics of the main meteorological indicators: 1) temperature indicators underwent the greatest changes (Fig. 1). The average annual air temperature during 2014-2024 ranged from 9.3°C (Cheremsky Nature Reserve) to +9.7°C (Kivertsi National Nature Park "Tsumanska Pushcha"), while in Shatsk National Nature Park and Pripyat-Stokhid National Nature Park it was +9.5°C, which is 1.2–2.1°C higher than the climatic norm. The greatest deviation from the climatic norm was recorded at the Svitiaz station (by 2.1°C). Thus, warming processes are clearly evident in the region. For the average minimum temperature, the deviation from the norm was 1–1.5°C, with the greatest deviation recorded at the Kivertsi National Nature Park "Tsumanska Pushcha." In none of the 11 years did the absolute minimum temperatures at the four stations reach the lowest value recorded in the past (to -34°C). The absolute minimum temperature increased by almost 10°C. Maximum temperatures also tend to increase.

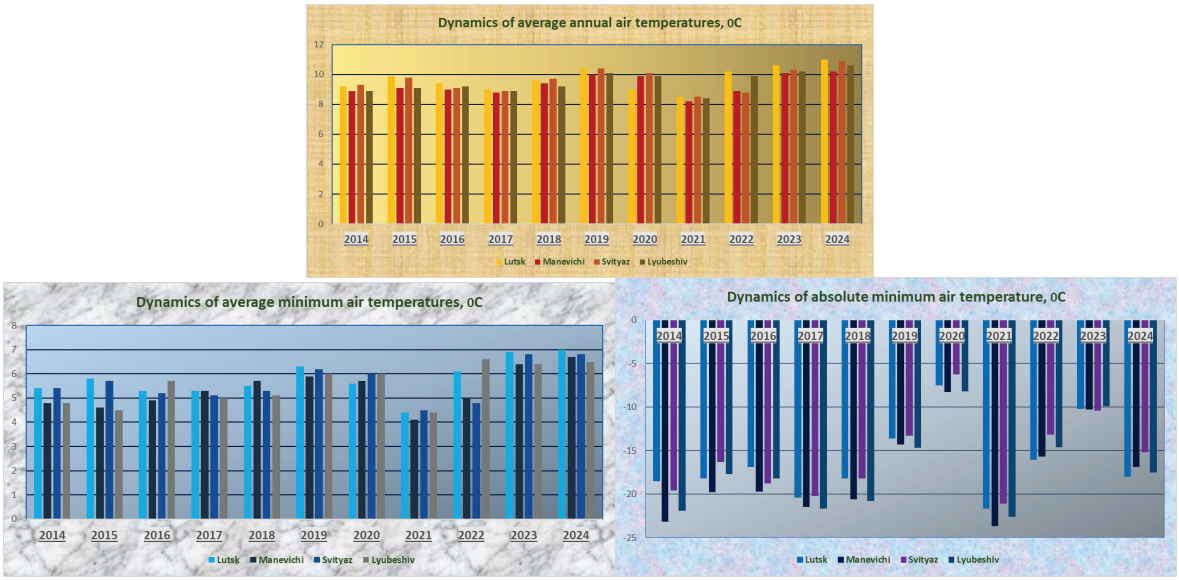

Figure 1 *Comparative diagrams of the dynamics of average annual, average minimum air temperature, and absolute minimum temperature during 2014–2024 in four protected natural areas.*

The relative humidity was 1-2.5% below the climatic norm for three stations. Only at the Svitiaz station was it within the climatic norm. The average wind speed was close to 2.0-2.75 m/s, with a decrease in wind speed of 0.5 m/s characteristic of all stations. Maximum wind gusts varied significantly (from 6 m/s to 24 m/s); it is worth noting the high instability of wind parameters in certain years. Total and lower cloud cover decreased by 0.5–0.6 points compared to the norm, except for Shatsk National Nature Park, where they were within the norm and were the highest among the four stations (7.0 points for total cloud cover and 4.8 points for lower cloud cover). Average annual precipitation ranged from 654 mm (Cheremsky Nature Reserve) to 549 mm (Kivertsky National Nature Park "Tsumanska Pushcha"). At three of the four stations studied, precipitation exceeded the climatic norm over an 11-year period: Svitiaz – by 79 mm, Manevychi – by 39 mm, Lyubeshiv – by 11 mm. Only at the Lutsk station was there a decrease in the average annual amount of atmospheric precipitation compared to the norm by 12 mm. The duration of stable snow cover ranged from 2-3 days (all stations, winter 2024/2025) to 83-84 days (Shatsk National Nature Park, 2018, Kivertsi National Nature Park "Tsumanska Pushcha," 2018, Cheremsky Nature Reserve, 2021). On average, it was 50-60% less than the climatic norm. The average duration of snow cover ranged from 41 days in Kivertsi National Nature Park "Tsumanska Pushcha" to 29 days in Shatsk National Nature Park. The maximum height of snow cover was significantly lower than normal (from 1–5 cm to 30–31 cm, with a normal range of 80 cm–100 cm). The highest maximum snow depth was in the Kivertsi National Nature Park "Tsumanska Pushcha" and the Cheremsky Nature Reserve (30 cm), and the lowest was in the Shatsk National Nature Park (21 cm).

An analysis of the recurrence of a number of meteorological phenomena typical for the region (rain, snow, fog, blizzard and thunderstorm) showed the following trends: the annual number of days with precipitation (rain) is quite variable, but there is a tendency for it to decrease by 15–20%. The same trend was observed for the number of days with snow (their number decreased by 20–35%). The number of days with blizzards is significantly below normal (1–2 days compared to the norm of 5–7). The number of days with fog (19–20 during the year) is slightly below normal (22–25 days). The average annual number of days with thunderstorms, with a norm of 20 days, is 35–40% higher, which indicates an increase in the intensity of convective processes.

A number of indicators that are important for assessing moisture content were calculated. These are the evaporation rate and the moisture coefficient. Evaporation from the surface in some years

exceeded the annual precipitation (Fig. 2), and in these years, the moisture coefficient was less than 1, which is atypical for Polissya and indicates a trend towards increasing aridity of the climate, a decrease in soil moisture reserves, and deterioration in the nutrition regime of surface and underground water bodies.

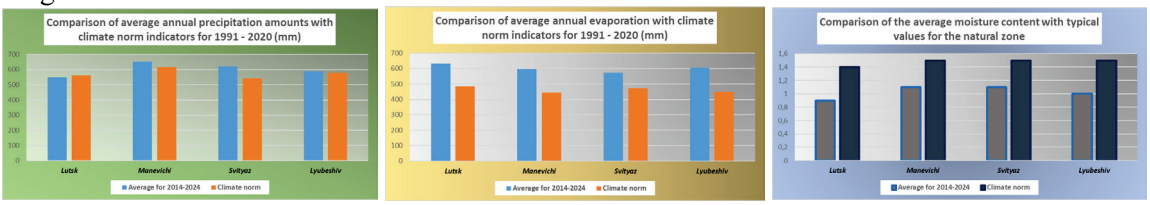

Figure 2 *Comparison of average annual precipitation, evaporation, and moisture coefficient in 2014–2024 and the climatic norm of these indicators in four protected natural areas.*

This trend is quite threatening for wetland complexes (it was in 2018-2019 that the lowest levels of Lake Svityaz were recorded). Thus, despite a slight increase in precipitation compared to the climatic norm, the rapid rise in air temperatures is intensifying evaporation processes, which in turn will lead to a decrease in soil and groundwater levels. Natural complexes may be negatively affected by increasing aridity, declining soil moisture reserves, and lowering water tables.

All results obtained during the study were summarized, presented graphically, and grouped into thematic layers on two online maps (Fig. 3). For each of the four protected areas, there are 24 diagrams showing the dynamics of individual climate indicators, assessment tables of the impact of climate change on biota, tables of average climate indicators and moisture parameters for the study period. Two thematic map layers were developed for each map: "Dynamics of climatic indicators" and "Potential impact of climate change on rare biodiversity components." Climatic indicators on the maps are presented in tables for each of the 11 years (2014–2024), and the averaging and diagrams of the dynamics of individual indicators are made for a 10-year period (2014–2023). It is advisable to update the indicators and diagrams averaged over a 10-year period every 5 or 10 years. At the same time, it is planned to add a summary table of average annual climate indicators to the maps every year, in the process of annual monitoring of climate change dynamics.

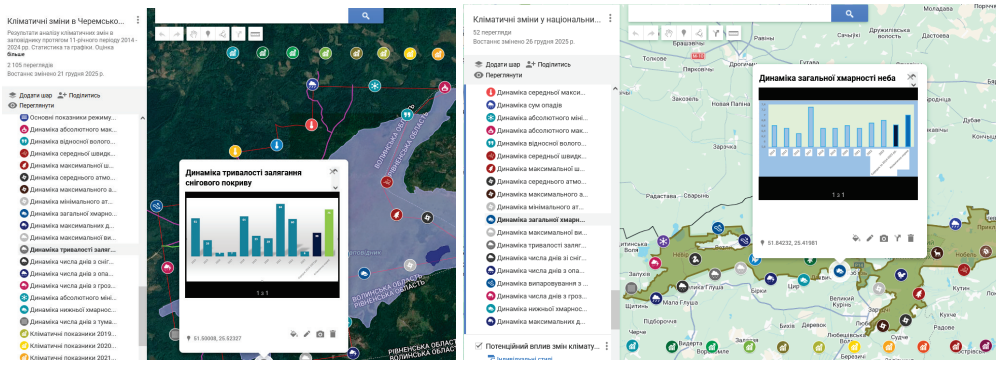

Figure 3 *Interface of the developed online maps "Climate Change in the Cheremsky Nature Reserve" and "Climate Change in the National Parks of Volyn."*

The online maps "Climate Change in the Cheremsky Nature Reserve" (https://surl.li/ttoxnd) and "Climate Change in the National Nature Parks of Volhynia" (http://surl.li/etqjag) will help track climate change dynamics in Volyn's nature reserves and will also be used as an educational and informational resource. It is possible to create a geoportal that will combine online maps of climate change in nature conservation areas of a specific natural region (for example, the Polissya zone) and specialists who will fill them with content.

Conclusions

Thus, the analysis revealed that regional manifestations of climate change are clearly evident in all sites, but they are more noticeable in Shatsk National Nature Park and Kivertsi National Nature Park "Tsumanska Pushcha" (higher temperature indicators and intense dynamics of meteorological phenomena). All four protected areas show a 15–25% increase compared to the climatic norm for average annual, monthly, minimum, and maximum air temperatures. There is a 2–5% decrease in relative air humidity compared to the norm. A slight increase in average annual precipitation has been noted, with a generally high variability of this indicator. The dynamics of a number of meteorological phenomena have changed: a reduction in the number of days with precipitation, especially snow, a decrease in the height and duration of snow cover, a reduction in the number of days with snowstorms (to complete absence in some years), and a fairly significant increase in the number of thunderstorms (by 30–40%). The calculated evaporation rates are significantly higher than the climatic norm (by 20–35%). Accordingly, the moisture coefficient is decreasing, i.e., aridity in the region is increasing. Therefore, in the near future, hydrological and biological natural complexes will be affected by these changes. In particular, it is possible that groundwater and lake levels will decrease, the area of waterlogged and swampy areas will shrink, and abiotic conditions for hydrophilic species of flora and fauna will deteriorate.

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