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Restoration of floodplains' natural vegetation of Polissia to reduce the effects of climate change

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Global climate change has a wide range of regional-level consequences. The most sensitive environmental parameters are those related to the water cycle. At the same time, several natural stabilizers reduce the negative impact of climate change. One of the most prevalent stabilizers is the vegetation of river floodplains. Using geobotanical methods, we surveyed the floodplains of the Prypiat, Stohid, Horyn, Sluch, Ubort, Slovechna, Noryn, Uzh, Irsha, Teteriv, Dnipro, and Desna rivers and their main tributaries within the Ukrainian Polissia. According to Braun-Blanquet's ecological-floristic classification, we found that this vegetation consists of 11 classes, 32 orders, 57 alliances, and 204 associations. Synphytoindicative analysis revealed that these plant communities strongly stabilize climate change and its consequences. These plant communities absorb and accumulate carbon from the atmosphere in the form of phytomass or peat deposits. They also slow the passage of precipitation water, which prevents water erosion and the eutrophication of water bodies. They also create a specific microclimate around water bodies, preventing increased evaporation of moisture from the soil and rivers. However, this vegetation suffers from direct anthropogenic pressure and the same climate changes. If climatic factors deviate from submicrotheral (mild cold), subaridophytic-subumbrophytic (moderate drought and shading), semioceanic, and subcryophytic (moderate dryness and cold), the functioning of typical floodplain vegetation is suppressed and its recovery is slowed down. Currently, climate change has progressed to a point where floodplain vegetation is unable to fully perform its stabilizing function. Even if we immediately implement measures to restore floodplain vegetation, it will take time to regain its capacity to stabilize the climate. In this regard, it is important to use hydroengineering measures and projects alongside the restoration of natural processes. The success of this combination will have a global impact on the quality and quantity of natural resources, the preservation of habitat and species diversity, and the stabilization of climate change.

Keywords: phytocenotic diversity; climatic factors; water resources; classification of vegetation; synphytoindication analysis.

Introduction

One of the consequences of global climate change has been a critical shortage of water resources in many regions of the world, including Ukraine (Gosling & Arnell, 2016). Several factors contribute to the depletion of fresh water reserves, which are used as drinking water, for irrigation of agricultural land, and for hygienic, technical, or industrial needs (Liu et al., 2023). In the Polissia region, most of the fresh water reserves are accumulated in man-made reservoirs formed as a result of river flow regulation, and to a lesser extent in the upper horizons of groundwater to which artesian wells are connected. Water in reservoirs and wells down to 20 m deep is directly or indirectly replenished from atmospheric sources and directly depends on climatic conditions and their changes (Jain et al., 2024). This is not only about global warming, which causes a shift in the ombroclimate (aridity-humidity balance) towards aridity (Fang et al., 2022). In addition to the rise in the Earth's average temperature, there are even more threatening consequences associated with this process (Li et al., 2024). These changes are forming over the oceans, but their catastrophic consequences are clearly visible on land (Wang et al., 2024).

The regional climate of Polissia is primarily affected by northwestern air currents from the North Atlantic, the warm North Atlantic Current, and, less frequently, the Arctic Seas, the Mediterranean Sea, and the Central Atlantic. Very rarely, the continental part of Eurasia influences the climate. These air currents result in warm, humid summers. In July, the average temperature ranges from +17.0 to +19.5 °C, and the annual amount of precipitation is 550–650 mm. Maximum precipitation occurs in July and June, compensating for active evaporation. Global climate change has caused significant disturbances in the hydrometeorological regime, particularly irregular precipitation. This phenomenon is observed on both global and regional scales, particularly in the Polissia region (Pendergrass & Knutti, 2018). Under normal conditions, several cyclones pass through each month, each lasting 3–4 days, each day providing uniform precipitation at a rate of 5–10% of the monthly norm. However, current climate trends are characterized by short-lived, yet intense, downpours lasting one to two hours. During these downpours, 20% to 60% or more of the monthly precipitation norm can fall. This transformation in precipitation patterns has significant environmental and socioeconomic consequences, particularly for the water balance, agricultural sector, and infrastructure.

Soil is a capillary system with limited permeability. As a result, most of the water simply flows into rivers and returns to the ocean. This results in a moisture deficit in both the fertile soil layer and the aquifers, which provide drinking water to more than half of Polissia's inhabitants (Bartoszek & Matuszko, 2024). A number of natural mechanisms slow down moisture loss from the soil surface and small watercourses, maintaining the water balance in landscape systems. These regulators include riparian wetlands, floodplain meadows, and forest areas. They function as buffer zones that promote moisture accumulation and stabilize the hydrological regime (McKeon et al., 2023). This pressing environmental problem has developed over a long period of time and has reached critical levels in modern conditions, requiring comprehensive scientific analysis and urgent response measures (Yao et al., 2023). Most of the marshes were destroyed by the irrational reclamation of land in the second half of the twentieth century. Additionally, the uncontrolled logging of floodplain forests and the plowing of floodplain meadows have contributed to the exacerbation of rapid water runoff during irregular rainfall. Due to plowing in river valleys and powerful water flows after heavy rains (Sarchani & Tsanis, 2024), large amounts of biogenic compounds, pesticides, polychlorinated biphenyls (PCBs), pharmaceutical and household chemical residues, etc., are washed into rivers and then into the sea. The entry of these toxic substances into aquatic ecosystems causes pollution and eutrophication, negatively affecting biogeochemical processes (Scholz et al., 2023). In ocean waters, these pollutants lead to the mass destruction of phytoplankton, which is a key biological sink for carbon dioxide on the planet (Walsh, 1978). A reduction in phytoplankton biomass disrupts the global carbon cycle. This triggers a new phase of climate change, caused by the intensification of the greenhouse effect due to increased CO_2 concentrations in the atmosphere. Another factor contributing to the degradation of small rivers' water regimes is the relatively high ambient temperature, which promotes the intense evaporation of moisture from the upper soil horizons in the summer and prevents the formation of stable snow cover in the winter. This leads to a loss of water resources for biota and human needs (Saleem et al., 2024). Additionally, the increase in water vapor in the atmosphere contributes to the greenhouse effect (Zhou et al., 2021).

In temperate latitudes of plain Europe, the absence of snow cover in winter has a complex impact on hydrological and ecological processes. According to Raunkiaer's data, the region should have an average snow cover thickness of about 30 cm from December to mid-March. This ensures the gradual saturation of soil horizons with moisture due to the melting of snow from below, influenced by ground heat. Furthermore, soil freezing to a depth of several tens of centimeters helps regulate the population of soil fauna, particularly pests of agroecosystems. The absence of spring floods, which typically occur as a result of snowmelt in late March or early April, reduces the area of river flooding. This reduction is critical for fish spawning and maintaining the stability of floodplain vegetation (Wohl, 2025). Disrupting these processes triggers a cyclical chain reaction that includes the degradation of floodplain ecosystems and the loss of their stabilizing function.

Restoring the natural vegetation of floodplains can mitigate several negative effects of global climate change. Changes in the vertical structure of water-edge forests and shrubs, resulting from the accumulation of aboveground phytomass, lead to reduced evaporation by preventing excessive insolation (Khomiak et al., 2024a). At the same time, water flow slows down mechanically, preventing its rapid movement into rivers and reducing soil erosion (Harbar et al., 2021). Additionally, floodplain vegetation creates full-niche ecosystems that prevent the infiltration by invasive species such as *Solidago canadensis* L. and *Heracleum sosnowskyi* Manden (Khomiak et al., 2024c). Research on the impact of floodplain ecosystems on the consequences of global climate change is particularly important in Ukraine because many of these ecosystems have been damaged by military operations (Khomiak et al., 2024b).

The objectives of the study were to create and analyze models of natural vegetation restoration in the floodplains of small rivers in the upper reaches of Polissia, as well as to examine their impact on specific regional manifestations of global climate change. To this end, the following tasks were formulated: classify the floodplain vegetation of the Ukrainian Polissia; build synphytoindication models of the microclimate of natural floodplain ecosystems; determine the potential impact of floodplain vegetation in the Ukrainian Polissia on regional consequences of global climate change.

Materials and methods

The research materials consisted of standard geobotanical descriptions collected from the floodplains of small rivers in the upper reaches of the Ukrainian Polissia region between 2004 and 2025. Field research was conducted using the route-expedition method. The study covered the Prypiat, Stohid, Horyn, Sluch, Ubort, Slovechna, Noryn, Uzh, Irsha, Teteriv, Dnipro, and Desna rivers, as well as their largest tributaries. With the exception of the floodplains of the Noryn and Ubort rivers, the descriptions were made once. The Noryn and Ubort rivers were studied for the first time between 2004 and 2007, and again between 2019 and 2021. We used the approaches of the Swiss-French Braun-Blanquet school (Braun-Blanquet, 1964) to describe the vegetation cover. Descriptions were made on visually homogeneous plots differentiated by physiognomy, edaphic conditions, microrelief, and dominant flora. Plot sizes corresponded to the height of the dominant species: 2 x 2 m for meadows, 10x10 m for shrubs and young forests, and 25 x 25 m for mature forests. For ribbon-like vegetation, we adapted the plot sizes to their natural boundaries (Yakubenko et al., 2020). We recorded the descriptions using the Turboveg 2.0 program.

Synphytoindication methods were used to model the ecological spectra of communities. Environmental factor values were measured using unified Didukh-Pluta scales (Didukh, 2012). Indication analysis of the plant communities was performed using the Simagrel 1.12 program based on the Ecodbase 5D database (Khomiak et al., 2024). Both the five- and seven-point scales of the Braun-Blanquet school were employed. The degree of anthropogenic transformation of ecosystems was described using the 18-point Didukh-Khomiak scale (Khomiak et al., 2024d). The indicator of natural ecosystem dynamics was determined using a 21-point scale developed by the authors (Khomiak et al., 2024a).

Descriptions stored in the Turboveg database were classified using the JUICE 7.0 program and identified using *Prodromus of the Vegetation of Ukraine* (Dubyna et al., 2019). The names of higher vascular plant species are given in accordance with the recommendations of *Vascular Plants of Ukraine: A Nomenclatural Checklist* (Mosyakin & Fedoronchuk, 1999).

Results

Within the scope of the study of the floodplain ecosystems, the consideration of plant communities was limited to syntaxa of natural vegetation. The only exceptions were classes whose phytocenoses can be formed both as a result of natural processes and under the influence of anthropogenic factors. This approach allows us to maintain the phytocenotic reliability of the analysis while considering the potential role of transformed ecosystems in maintaining the ecological functionality of floodplains. These are the classes *Robinietea* Jurco ex Hadac et Sofron 1980, *Galio-Urticetea* Passrge et Kopecký 1969, and *Bidentetea tripartiti* Tx. et al. ex von Rochow 1951. The natural vegetation of floodplains belongs to 11 classes, 32 orders, 57 alliances, and 204 associations (Table 1).

Each of the above classes has its own characteristics in terms of its distribution across the various elements of the floodplain. In areas bordering the riverbed that are regularly flooded, vegetation belonging to the *Phragmiti-Magnocaricetea* class prevails. The most common association here is *Phragmitetum australis* Savič 1926. This association also occupies a dominant position in terms of area. This association's vegetation is found in both the water-edge part of the riverbed and the wet depressions of the floodplain. Plant communities belonging to the *Littorelletea uniflorae* and *Isoëto-Nanojuncetea* classes mainly occur in the narrow water-edge strips alongside river channels where other flora is less prevalent. Such phytocenoses form due to specific hydrological conditions, particularly significant seasonal or daily fluctuations in water levels. The commonest association within these classes is *Juncetum bufonii* Felföldy 1942. Despite its frequency of occurrence, it is characterised by a limited spatial distribution compared with other types of floodplain vegetation. Under oligotrophic or meso-oligotrophic conditions in the floodplains of river headwaters, characterised by low water levels and high waterlogging, plant communities belonging to the *Scheuchzerio palustris–Caricetea fuscae* and *Oxycocco–Sphagnetea* classes predominantly form. These phytocenoses are most prevalent in the northern regions of the Ukrainian Polissia, particularly on the right bank. According to the results of many years of monitoring wetland ecosystems, there has recently been a trend towards a gradual reduction in the area of sites maintaining vegetation close to the nomenclature type. This dynamic indicates the transformation of natural phytocenoses under the influence of climate change and anthropogenic pressure, requiring further research and the development of conservation measures.

Table 1
Phytocenotic diversity of plant community classes in the floodplains of the Ukrainian Polissia

Classes of plant communities	Orders of plant communities	Alliances of plant communities	Associations of plant communities
Phragmiti-Magnocaricetea Klika in Klika et Novak 1941	4	7	40
Littorelletea uniflorae Br.-Bl. et Tüxen in Westhoff et al. 1946	1	2	5
Isoëto-Nanojuncetea Br.-Bl. et Tx. in Br.-Bl. et al. 1952	1	1	3
Scheuchzerio palustris-Caricetea fuscae Tx. 1937	2	3	21
Oxycocco-Sphagnetea Br.-Bl. et Tüxen ex Westhoff et Paschier 1946	1	1	13
Molinio-Arrhenatheretea R.Tx 1937	3	7	29
Trifolio-Geranietea Th.Müll 1962	2	4	12
Epilobietea angustifolii Tx. et Preising ex von Rochow 1951	1	3	5
Robinietea Jurco ex Hadac et Sofron 1980	2	5	8
Rhamno-Prunetea Rivas Goday et Borja Carbonell ex Tüxen 1962	1	3	5
Lonicero-Rubetea plicati Haveman, Schaminée et Stortelder in Stortelder et al. 1993	1	2	3
Vaccinio-Piceetea Br.-Bl. in Br.-Bl. et al. 1939	2	2	10
Carpino-Fagetea sylvaticae Jakucs ex Passarge 1968	3	4	9
Salicetea purpurea Moor 1958	1	4	9
Alnetea glutinosae Br.-Bl. et Tüxen ex Westhoff, Dijk et al. 1946	1	1	8
Molinio-Betuletea pubescentis Pass. 1968	1	1	1
Pyrolo-Pinetea sylvestris Korneck 1974	2	1	1
Franguletea Doing ex Westhoff in Westhoff et Den Held 1969	3	1	2
Galio-Urticetea Passrge et Kopecký 1969	3	3	11
Bidentetea tripartiti Tx. et al. ex von Rochow 1951	1	2	10

The ecosystems of cereal fields are formed by vegetation of the classes *Molinio-Arrhenatheretea*, *Trifolio-Geranietea,* and partly *Epilobietea angustifolii* (association *Calamagrostietum epigei* Juraszek 1928). The largest areas and diversity are found in the phytocenoses of the class *Molinio-Arrhenatheretea*. In the part of the floodplain closer to the riverbed, there are narrow strips of wet meadows of the order *Molinietalia caeruleae* Koch 1926 (most often these are associations of *Juncetum effusi* (Pauca 1941) Soó 1947, *Scirpetum sylvatici* Ralski 1931, *Lysimachio vulgaris-Filipenduletum* Balátová-Tuláčková 1978). Moderately moist and insolated areas are occupied by grasses of the order *Arrhenatheretalia elatioris* Tüxen 1931 (the most common associations are *Trifolio-Festucetum rubrae* Oberdorfer 1957, *Anthoxantho odorati-Agrostietum tenuis* Sillinger 1933, *Poëtum pratensis* Ravarut, Cazac et Turenschi 1956). Open areas located with poor, well-drained soils are occupied by mesophytic and mesoxerophytic vegetation of the class *Epilobietea angustifolii* (association *Calamagrostietum epigei* Juraszek 1928) and the order *Galietalia veri* Mirk. et Naum. 1986 of the class *Molinio-Arrhenatheretea* (the most common associations: *Agrostio vinealis-Calamagrostietum epigei* Shelyag-Sosonko et al. ex Shelyag-Sosonko et al. 1985, *Agrostietum vinealis-tenuis* Shelyag et al. 1985, *Carici praecoci-Alopecuretum pratensis* Mirkin in Denisova et al. 1986, *Poëtum angustifoliae* Shelyag-Sosonko et al. 1986, *Bromopsietum inermis* Shvergunova et al. 1984, *Achillea submiefolium-Dactyletum glomeratae* Smetana, Derpoluk, Krasova 1997). The nodular vegetation of the *Trifolio-Geranietea* class is quite rare. Most nodular communities are synanthropic. On the river side, they are occupied by cenoses of the *Phragmiti-Magnocaricetea* and *Bidentetea tripartiti* classes. In other cases, these are semi-shrubby thickets of the class *Epilobietea angustifolii* (associations *Rubo-Chamaenerietum angustifolii* Hadač et al. 1969 and *Rubetum idaei* Gams 1927) or nitrified forest edges of the *Galio-Urticetea* class (most often these are associations of *Cuscuto europaeae-Convolvuletum sepium* Tx. (1947) 1950, *Eupatorietum cannabini* R. Tx. 1937, *Calystegio-Angelicetum archangelicae litoralis* Pass. (1957) 1959, *Elytrigio repentis-Aegopodietum podagrariae* Tüxen 1967).

Shrub vegetation is represented by willow shrubs of the *Franguletea* class, thorny-prickly shrubs of the *Rhamno-Prunetea* class, and swampy young forests of the *Molinio-Betuletea pubescentis* class. Willow shrub communities occupy noticeably large areas. They stretch in a strip along the riverbed and form compact groups in wet areas of the floodplain. Two associations were observed there: *Salicetum pentandro-cinereae* Pass 1961 and *Betulo-Salicetum repentis* Oberd. 1964. The first association is one of the commonest groups of phanerophytes in the floodplains of Polissia rivers. The second association is quite rare and occurs mainly in its northern part. Shrubs of this class are more common in the southern part. They rarely enter river floodplains, preferring the steep slopes of river valleys. Groups of the *Molinio-Betuletea pubescentis* class are occasionally found on swampy floodplains covered with forest.

The tree vegetation of floodplains is quite diverse. However, most often it consists of the *Salicetea purpurea* and *Alnetea glutinosae* classes. Riparian willow forests include the following associations: *Salicetum albae* Issler 1926, *Myosotido palustris-Salicetum albae* Shevchyk et V. Solomakha 1996, *Poo nemoralis-Salicetum albae* Shevchyk et V. Solomakha 1996, *Salici-Populetum* Meijer Drees 1936, *Populetum nigro-albae* Slavnić 1952, *Salici acutifoliae-Amorphetum fruticosae* Senchylo et al. 1999, *Salicetum triandrae* Malcuit ex Noirfalise in Lebrun et al. 1955; *Rubo caesii-Amorphion fruticosae* Shevchyk et Solomakha 1996: *Aristolochio-Salicetum albae* Shevchyk et Solomakha 1996; *Galio veri-Aristolochion clematidis* Shevchyk et V. Solomakha in Shevchyk et al. 1996: *Galio veri-Aristolochietum clematidis* Shevchyk et V. Solomakha in Shevchyk et al. 1996. Alder forests are represented by the associations *Ribo nigri-Alnetum* Solińska-Górnicka (1975) 1987, *Carici acutiformis-Alnetum* Scamoni 1935, *Carici elongatae-Alnetum* Schwickerath 1933, *Mnio affini-Alnetum glutinosae* Grygora, Vorobyov et Solomakha 2005, *Calamagrostio canescenti-Alnetum glutinosae* Mikoška1956, *Angelico sylvestri-Alnetum* Borhidi 1966, *Carici elatae-Alnetum glutinosae* Franz 1990, *Sphagno squarrosi-Alnetum glutinosae* Solińska-Górnicka (1975) 1987. The rest of the forest vegetation classes are somewhat less common. In the most synanthropic areas, the area and diversity of plant communities of the *Robinietea* class increase, and in the late stages of autogenous succession within ecotopes with rich edaphic conditions and minimal anthropogenic pressure, the forest vegetation of the *Carpino-Fagetea sylvaticae* class is noticeable.

The main stabilizing potential of floodplain vegetation in relation to global climate change is associated with the specific microclimate it forms. According to the synphytoindicative analysis, the classes we have described are characterized by fairly narrow ecological spectra (Table 2). They are submicrotheral (mild cold), subaridophytic-subumbrophytic (moderate drought and shading), semioceanic, and subcryophytic (moderate dryness and cold).

Table 2
Synphytoindicative characteristics of climatic factors of plant community classes in the Ukrainian Polissia region found in floodplains (mean ± standard deviation)

Classes of plant communities	Average values of environmental factors and their measurement errors (scores on the unified Didukh-Plyuta scale)				
	thermal regime	ombro regime	continentality	cryogenic regime	lighting conditions
Phragmiti-Magnocaricetea Klika in Klika et Novak 1941	8.37 ± 0.25	11.67 ± 0.35	8.68 ± 0.26	7.76 ± 0.23	7.48 ± 0.22
Littorelletea uniflorae Br.-Bl. et Tüxen in Westhoff et al. 1946	7.92 ± 0.24	12.90 ± 0.39	8.08 ± 0.24	7.60 ± 0.23	7.27 ± 0.22
Isoëto-Nanojuncetea Br.-Bl. et Tx. in Br.-Bl. et al. 1952	8.66 ± 0.26	11.64 ± 0.35	8.41 ± 0.25	7.17 ± 0.22	7.32 ± 0.22
Scheuchzerio palustris-Caricetea fuscae Tx. 1937	7.43 ± 0.22	13.76 ± 0.41	8.51 ± 0.26	7.27 ± 0.22	7.29 ± 0.22
Oxycocco-Sphagnetea Br.-Bl. et Tüxen ex Westhoff et Paschier 1946	6.49 ± 0.19	14.18 ± 0.43	8.93 ± 0.27	7.34 ± 0.22	7.58 ± 0.23
Molinio-Arrhenatheretea R.Tx 1937	8.18 ± 0.25	12.52 ± 0.38	8.78 ± 0.26	7.79 ± 0.23	7.27 ± 0.22
Trifolio-Geranietea Th.Müll 1962	8.49 ± 0.25	12.44 ± 0.37	8.53 ± 0.26	8.23 ± 0.25	7.08 ± 0.21
Epilobietea angustifolii Tx. et Preising ex von Rochow 1951	8.33 ± 0.25	12.72 ± 0.38	8.89 ± 0.27	7.45 ± 0.22	6.97 ± 0.21
Robinietea Jurco ex Hadac et Sofron 1980	8.69 ± 0.26	13,17 ± 0,40	8.54 ± 0.26	8.19 ± 0.25	6.57 ± 0.20
Rhamno-Prunetea Rivas Goday et Borja Carbonell ex Tüxen 1962	8.85 ± 0.27	12.93 ± 0.39	8.24 ± 0.25	8.42 ± 0.25	6.33 ± 0.19
Lonicero-Rubetea plicati Haveman, Schaminée et Stortelder in Stortelder et al. 1993	8.20 ± 0.25	12.87 ± 0.39	8.75 ± 0.26	7.72 ± 0.23	6.79 ± 0.20
Vaccinio-Piceetea Br.-Bl. in Br.-Bl. et al. 1939	7.50 ± 0.23	13.87 ± 0.42	8.74 ± 0.26	7.60 ± 0.23	6.43 ± 0.19
Carpino-Fagetea sylvaticae Jakucs ex Passarge 1968	8.49 ± 0.25	13.46 ± 0.40	7.93 ± 0.24	8.27 ± 0.25	5.27 ± 0.16
Salicetea purpurea Moor 1958	8.74 ± 0.26	12.19 ± 0.37	8.83 ± 0.26	7.94 ± 0.24	6,99 ± 0,21
Alnetea glutinosae Br.-Bl. et Tüxen ex Westhoff, Dijk et al. 1946	8.35 ± 0.25	13.34 ± 0.40	8.38 ± 0.25	7.78 ± 0.23	6.42 ± 0.19
Molinio-Betuletea pubescentis Pass. 1968	7.40 ± 0.22	13.63 ± 0.41	8.72 ± 0.26	7.53 ± 0.23	6.76 ± 0.20
Pyrolo-Pinetea sylvestris Korneck 1974	7.89 ± 0.24	13.03 ± 0.39	8.83 ± 0.26	7.79 ± 0.23	7.24 ± 0.22
Franguletea Doing ex Westhoff in Westhoff et Den Held 1969	8.26 ± 0.25	13.13 ± 0.39	8.83 ± 0.26	7.74 ± 0.23	6.89 ± 0.21
Galio-Urticetea Passrge et Kopecký 1969	8.44 ± 0.25	12.93 ± 0.39	8.29 ± 0.25	8.01 ± 0.24	6.24 ± 0.19
Bidentetea tripartiti Tx. et al. ex von Rochow 1951	8.75 ± 0.26	12.14 ± 0.36	8.68 ± 0.26	7.92 ± 0.24	7.45 ± 0.22

Discussion

The analysis of the ecological spectrum of natural vegetation classes in floodplains based on climatic indicators points to two aspects related to climate change. On the one hand, natural vegetation has several mechanisms that can mitigate the negative effects of these changes. On the other hand, some of these communities will be suppressed or even displaced under the pressure of climate change, which will lead to the loss of their positive impact on river water supply. Current observations indicate a shift in climate zones from south to north and an increase in continentality and seasonality of precipitation (Beguería et al., 2025). In this regard, there will be an increase in thermoregime and continentality indicators and a decrease in ombrotic (precipitation) and cryogenic (freezing) indicators. In this case, some of the natural vegetation classes of floodplains are under threat. In particular, this refers to sphagnum bogs of the *Oxycocco-Sphagnetea* class. We can already observe their displacement by wet meadow vegetation and intensive overgrowth with tree and shrub vegetation (Harbar et al., 2021). Its average values are 6.49 ± 0.19 for the thermal regime, 14.18 ± 0.43 for the ombroclimate regime, 8.93 ± 0.27 for continentality, and 7.34 ± 0.22 for the cryoclimate regime. Since sphagnum mosses form the basis of the vegetation of this class, it can accumulate a large amount of moisture, which is several times greater than its own phytomass. This will prevent rapid water loss during irregular rainfall (Liu et al., 2023). Sphagnum bogs play a key role in maintaining the hydrological regime of small river headwaters, ensuring their gradual feeding due to the slow inflow of water. During field studies conducted in 2019–2021, the phenomenon of reverse water movement was recorded: After rainy periods, water from rivers originating in swampy floodplains did not flow down the riverbed but returned to the swamp. This indicates a critical level of dehydration of such ecosystems, which is likely related to an increase in thermal load.

Within ecotopes with *Oxycocco–Sphagnetea* class vegetation, a significant amount of organic matter accumulates in the form of peat, which serves as a long-term reservoir of carbon removed from the atmosphere. The drying up of oligotrophic and meso-oligotrophic bogs, as well as their transformation into meadow phytocenoses, disrupts the balance between peat accumulation and peat decomposition processes. As a result, greenhouse gases are released, in particular CO_2, CH_4, and other products of organic mineralization, thereby exacerbating the effects of global climate change (Khomiak et al., 2024a).

The restoration of such wetland ecosystems is of strategic importance for mitigating the effects of climate change (Jain et al., 2024). However, renaturation technologies must consider the sensitivity of sphagnum bogs to a reduction in the water regime, which can lead to the suppression of their functioning. In this regard, it is advisable to create forest-wetland complexes instead of open peat areas. The inclusion of tree and shrub vegetation in the form of protective strips between moss areas helps to reduce insolation, stabilize the thermal regime, and increase the humidity of the environment, which is critical for maintaining the viability of sphagnum phytocenoses.

Tree and shrub vegetation classes that are well adapted to water-edge areas are also capable of locally reducing water evaporation directly from rivers and parts of floodplains. Due to their multi-layered structure, they slow down the movement of rainwater in summer and snowmelt in spring (Pendergrass & Knutti, 2018). Through photosynthesis and phytomass accumulation, they shift the balance between oxygen and carbon dioxide in the atmosphere, slowing down global climate change (Sarchani & Tsanis, 2024). This function is best performed by plants of the class *Salicetea purpurea*, *Alnetea glutinosae*, *Molinio-Betuletea pubescentis*, *Franguletea* and the order *Alno-Fraxinetalia excelsioris* Passarge 1968 of the class *Carpino-Fagetea sylvaticae*. Each class of floodplain vegetation is characterized by specific ecological requirements and varying potential to influence the effects of global climate change. The communities of the *Alno-Fraxinetalia excelsioris* order demonstrate a high capacity to stabilize the microclimate and regulate the water regime, but their formation requires a long time, specific edaphic conditions, and a low level of anthropogenic transformation of the territory (McKeon et al., 2023).

At the same time, alder forests of the *Alnetea glutinosae* class have limitations in terms of environmental safety: Symbiotic nitrobacteria functioning in the soils of these ecosystems contribute to the accumulation of nitrogen compounds, which can increase the risk of eutrophication of water bodies (Li et al., 2024).

The vegetation of the *Salicetea purpureae* class demonstrates the highest adaptive potential to modern climate change. These communities are well-adapted to increased temperatures, increased continentality, and decreased rainfall and cryogenic conditions. In addition, they are characterized by high tolerance to anthropogenic factors, which makes them promising for use in transformed floodplains. The formation of vertically structured phytocenoses within this class occurs much faster than in the floodplain oak forests of the *Carpino-Fagetea sylvaticae* class.

In cases where the time of forest vegetation formation is a critical factor, the riparian shrub communities of the *Franguletea* class can perform an effective ecological function, ensuring rapid biomass recovery and stabilization of microclimatic conditions. The formation of natural vegetation in river floodplains contributes to the normal functioning of rivers that originate in the Prypiat River valley and its southern outskirts. Vegetation reduces water level fluctuations, promotes more continuous water flow, decreases the rate of their eutrophication (Scholz, et al., 2023) and pollution from washed-away substances, and has a positive impact on the regional and global climate. This not only stabilizes natural ecosystems in terms of the quantity of ecosystem services they provide, but also improves water supply to the population and sustains agricultural production at a high level in terms of quantity and quality of products (Saleem et al., 2024). Restoring natural vegetation is a long process that requires significant resources and time. Even if large-scale environmental projects are launched immediately, there is a high probability that the pace of autogenous succession will not match the speed of current climate change. In this regard, in parallel with the formation of natural ecosystem stabilizers, there is a need to apply specialized hydraulic engineering measures that have a compensatory function. In particular, such measures are relevant not only for maintaining the hydrological balance, but also for optimizing the conditions necessary for the successful restoration of plant communities.

The self-restoration process has several advantages, in particular ecological adaptability, preservation of local biota, and minimization of intervention. Nonetheless, it also carries risks. The main ones are the impact of climatic factors on the rate of succession, as well as the threat of invasion by transformative species capable of disrupting the structure and functionality of regenerating phytocenoses (Khomiak et al., 2024c).

The integration of three approaches (preserving remnants of natural vegetation, implementing hydroengineering solutions, and targeted ecosystem restoration) has the potential to create sustainable landscape systems. Such systems can ensure the long-term conservation of water resources, maintain biodiversity, and reduce the intensity of the negative effects of global climate change.

Conclusions

The natural vegetation of the floodplains belongs to 11 classes, 32 orders, 57 alliances, and 204 associations according to the classification of the Braun-Blanquet ecological-floristic school.

Floodplain vegetation plays a key role in stabilizing ecosystem processes that are directly linked to global climate change. Its stabilizing potential is due to its ability to form a specific microclimate, accumulate and remove carbon dioxide from the atmosphere, reduce emissions of other greenhouse gases, slow down surface runoff after precipitation, and prevent water erosion and eutrophication processes in water bodies.

The results of synphytoindicative analysis indicate that the natural vegetation of floodplains is characterized by narrow ecological amplitudes of climatic factors. In particular, these phytocenoses belong to the submicrothermal, subaridophytic-subumbrophytic, semioceanic, and subcryophytic types, which indicates their high sensitivity to changes in temperature, humidity, and continentality of the climate.

Sustainable landscape systems could be formed through the integration of three strategic direction: preservation of remnants of natural vegetation, implementation of hydroengineering measures, and implementation of ecosystem restoration projects. Such systems can ensure the long-term conservation of water resources, maintain biodiversity, and reduce the intensity of the negative effects of global climate change.

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