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Ecology is a priority

All-Ukrainian with international participation student

English-speaking conference

(March 11, 2026, Kharkiv, Ukraine)

Under the General Editorship of
N. V. Maksymenko, DSc (Geography), Professor,
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The publications contain the proceedings, which address the modern ecological problems and ways of their solution, applied ecological research and ecological consequences of the Russian-Ukrainian war.

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KEY ASPECTS OF THE NEED TO STUDY THE MECHANISMS OF URBAN HEAT ISLAND'S FORMATION

The publication examines the main aspects that determine the need to study the conditions for the creation of an elevated temperature background in the urban landscape, known as a "heat island." Climatic, anthropogenic, social, and economic aspects are considered.

Key words: climate, heat island, urban landscape, heat wave, climate risks, bioclimatic comfort.

Increasing urbanization: the expansion of built-up areas, densification of the urban environment, and reduction of natural areas cause a significant increase in temperatures in cities compared to surrounding rural areas. This exacerbates the urban heat island effect, which has a negative impact on the microclimate, energy consumption, and public health.

Deterioration of the environment: an increase in the proportion of artificial surfaces with low albedo (asphalt, concrete), transport emissions, and a lack of sufficient green spaces lead to overheating of areas, deterioration of air quality, and a reduction in bioclimatic comfort.

Climate change: global and regional climate change increases the frequency and duration of heat waves, making the problem of heat islands critical for Ukrainian cities. Research into the mechanisms of their formation and ways to reduce their impact is becoming an important part of adapting to climate risks.

Social significance: Overheating of urban landscapes worsens living conditions, increases the number of heat stresses, exacerbates chronic diseases, and reduces the productivity and comfort of city dwellers. Ecological ways to reduce the impact of heat islands can improve the overall well-being of the population.

Ukraine's international commitments: In accordance with the UN Framework Convention on Climate Change and other international agreements, the state must implement measures to adapt cities to climate change. Reducing the impact of urban heat islands is one of the key areas for implementing these obligations. Economic aspect: effective strategies for reducing UHI reduce the cost of cooling buildings, promote the development of "green infrastructure," and create new jobs in the field of environmental planning and urban greening.

Taking these factors into account, research into the mechanisms of urban heat island formation and ways to reduce its impact is relevant and necessary for the sustainable development of urbanized areas in Ukraine.

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ENVIRONMENTAL SITUATION AND WAYS OF SUSTAINABLE DEVELOPMENT OF THE TOWN OF VYSHNIVETS, TERNOPIL REGION (UKRAINE)

The aim of the study is to analyse the environmental problems of Vyshnivets and to justify ways of developing the town that are most consistent with the strategic goals of sustainable development.

Key words: pollution, land use, green spaces, household waste, Zero Waste, Sustainable Energy Positive and Zero Carbon Communities.

Vyshnivets is a town in the Kremenets District of the Ternopil Region (Ukraine). Its population is 3,179. The study of the environmental situation in the town of Vyshnivets was based on a systematic analysis, with the first stage being the collection of information, including the processing of scientific literature and cartographic sources, Google Earth aerospace satellite images; the collection of statistical information on the structure of land use in the town of Vyshnivets; field research, including the collection of information on sources of environmental pollution, the condition and structure of green spaces; laboratory studies of the ecological state of the Horyn River and other water bodies in terms of physical, chemical and hydrobiological indicators. The second stage is the processing and analysis of the information: researching the land use structure of Vyshnivets, determining its compliance with European standards, analysing the level of air pollution, assessing the ecological state of water bodies, identifying the main factors affecting the soil, and researching waste management issues in the settlement. Stage three – justification of sustainable development paths for the town of Vyshnivets, including recommendations on ensuring energy efficiency, opportunities for implementing the strategic directions of Sustainable Energy Positive and Zero Carbon Communities, optimisation of land use in the town, analysis of opportunities for implementing the Zero Waste initiative.

The analysis of statistical data on the land use structure of the town revealed that more than 40% of the territory of Vyshnivets is covered by natural vegetation, including forests (13.3%), perennial plantations (21.1%), hayfields and pastures (5.3%), and nature conservation areas (0.74%), while another 4.2% of the territory is covered by water bodies (the remaining 33.7% is arable land, 19.9% is built-up area, and 1.8% is other land).

The level of greening in the town is high (44.3 hectares/1,000 people), which is close to the optimal level (45 hectares/1,000 people).

The town of Vyshnivets has a kindergarten, a secondary school, a music school, and a vocational lyceum, where green spaces cover only 11.3% of the territory, which indicates an insufficient level of greening of educational institutions, since the level of greening of streets should be at least 25%, and green areas near schools should be 45-50% [1].

The area of green spaces for public use, including squares, boulevards, plantings on slopes, embankments and others, which are freely accessible for recreation, in Vyshnivets is 0.26 hectares. In addition, almost 8 hectares are occupied by Vyshnivets Park, a landmark of landscape architecture of national importance in Ukraine. Thus, green areas for public use amount to 24.7 m^2 per person, which corresponds to European standards.

The almost complete absence of special-purpose green spaces, namely green spaces along transport routes (along the M19 (E85) and T 2009 motorways), is a cause for concern.

The analysis of the state of the complex green zone of the town of Vyshnivets allows us to conclude that it is somewhat asymmetrical, namely, the main part of forests and other wooded areas is located in the western part of the settlement.

The condition of green spaces is mostly good, sometimes satisfactory, with almost no trees in poor condition. The town authorities are taking care of the reconstruction of green spaces. In the central part of the city, new trees and flowers were planted on the square, lawn grass was laid, and an irrigation and lighting system was installed. The town's biodiversity could also be enriched by planting exotic species in its central part: ginkgo (*Ginkgo biloba*), vinegar-trees (*Smooth sumac*), tulip trees *(Liriodendron)*, and manna trees (*Fraxinus ornus*), magnolia, Manchurian walnut (*Juglans mandshurica)* and other exotic species.

The main source of air pollution in the town of Vyshnivets is motor vehicles. The traffic load along the highway is over 20,000 vehicles per day, on the road to the town of Lanivtsi – about 16,000 vehicles per day, on the largest streets in the central and western parts of the town – it varies between 8,000 and 10,000 vehicles per day and 4,000 to 6,000 vehicles per day, respectively. In total, 230 tonnes of CO_2 are emitted annually from motor vehicles.

Other sources of atmospheric pollution are industrial enterprises (with a total area of 15.28 hectares, 1.4% of the territory), among which the largest are the Vyshnivets Building Materials Plant and the Vyshnivets Loam Quarry (total emissions of pollutants into the atmosphere is 63.98 tonnes/year). The greatest impact on the geological environment occurs at the Vyshnivets loam deposit, where the mineral is extracted using an open-pit method (quarry) with a motor transport system and temporary external waste disposal.

Today, 33.7% (365.2 hectares) of land in the town of Vyshnivets is under plough. Land degradation occurs in some places as a result of prolonged use of agrochemicals, depletion of nutrients, monoculture cultivation, soil contamination, and erosion due to the use of agricultural machinery.

Another source of soil pollution is household waste, especially in and around the Kryvchikiv landfill [2].

There are 45.6 hectares of water bodies in the town of Vyshnivets, including 2 hectares of natural watercourses (rivers and streams) and 43.6 hectares of ponds. The Vyshnivets pond is the largest (26.5 hectares) and is in good ecological condition. According to our research, the intensity of the smell of water in the pond does not exceed 2 points (weak), and is fishy in nature; the transparency of the water at the ring is considered acceptable (35 cm); the turbidity of the water is also acceptable (26.1), and the colour is satisfactory (30^0). Therefore, the analysis of the physical parameters of the water proves that they are acceptable for the use of this water body for recreational purposes. The ecological state of the Horyn River within the boundaries of the town of Vyshnivets is satisfactory. The banks of the river, especially the left bank, are covered with trees and shrubs. The right bank consists mainly of pastures and hayfields.

In order for the town of Vyshnivets to best meet the strategic goals of sustainable development and become an environmentally friendly, optimally landscaped town, the following action plan is proposed: improving air quality; developing a sustainable mobility system; improving procedures for the collection, reuse and disposal of household waste; changes in the field of energy efficiency and the use of renewable energy sources; development of comfortable and functional buildings with maximum energy efficiency and minimum CO_2 emissions; expansion of green spaces near educational institutions and along transport routes and introduction of new ecological elements throughout the settlement in order to improve living conditions for residents and increase the diversity of flora and fauna. Priority in the development of bicycle transport. Create efficient, comfortable and environmentally friendly public transport; optimise motor vehicle traffic in the town; make bicycles a more attractive means of transport for a larger number of residents; form a "short-distance town".

We propose transforming Vyshnivets into an energy-independent town that covers its own energy needs and produces more energy than it consumes annually. With regard to the implementation of the PED (energy-positive district) concept in Vyshnivets, we must strive to achieve climate neutrality and energy independence within the framework of the Sustainable Energy Positive and Zero Carbon Communities strategy. Methods for achieving PED: using more energy-efficient technologies in buildings; using renewable, carbon-free energy sources to meet demand; using cascading local energy flows with surplus energy. The town's residents are positive about the installation of solar panels, and many are installing alternative energy sources on or near their buildings at their own expense.

To transition the community to a zero-waste system, the following steps can be taken. Adopt organic waste management programmes (including for food waste). Introduce recycling programmes in residential areas and/or financial incentive and reimbursement systems. Plan the gradual introduction of a "pay-as-you-throw" tariff structure or other financial incentives for the population to encourage them to throw away less and recycle more. Thus, it is necessary to improve the waste management system and promote waste minimisation.

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PRIMITIVE AGRICULTURAL SYSTEMS AS THE FIRST STAGE OF ANTHROPOGENIC LANDSCAPE TRANSFORMATION

The shifting agriculture (land fallow crop system) and slash-and-burn agriculture are analyzed as the first stage of anthropogenic landscape transformation. Based on a literature review, the sequence of management stages is reconstructed, the mechanisms of impact on steppe and forest landscapes are identified, and the spatio-temporal boundaries of their distribution are determined. It is established that both systems were based on the extensive depletion of natural resources without artificial restoration, which led to soil degradation, hydrological imbalance, and the formation of secondary anthropogenic landscapes. This understanding is essential for the development of modern sustainable agricultural technologies.

Key words: primitive agricultural systems, shifting agriculture, slash-and-burn agriculture, anthropogenic landscape transformation, soil degradation.

Modern agricultural landscapes are the result of centuries-long human-nature interaction. Understanding the initial stages of this process allows for a deeper assessment of the scale of anthropogenic impact on the environment, the causes of soil degradation, and biodiversity loss. Primitive agricultural systems, while considered archaic, established the fundamental mechanisms of extensive farming, which in a transformed form can still be traced today.

The objective of this study is to analyze the ecological features and consequences of primitive agricultural systems (exemplified by the land fallow system and slash-and-burn agriculture) as the first large-scale stage of anthropogenic transformation of natural landscapes.

The study is based on the analysis of scientific literature, historical sources, and the synthesis of data on agricultural systems. Descriptive, comparative-historical, and analytical methods were employed, allowing for the reconstruction of the sequence of management stages and the assessment of their impact on the vertical structure of landscapes.

A comprehensive analysis of primitive agricultural systems identifies them as the initial destructive stage of anthropogenic landscape transformation, where the primary mechanism was the disruption of natural self-renewal cycles. The process of converting natural landscapes into agricultural landscapes occurred through clearly defined stages, each of which deepened the level of human intervention.

The land fallow system was predominantly widespread in the steppe and forest-steppe zones of Eastern Europe, particularly within the territory of modern Ukraine (the Black Sea region, the Dnieper region), in the southern regions of the East European Plain, in Western Siberia, Northern Kazakhstan, and other areas with fertile chernozem soils. Chronologically, it spans the period from the Neolithic (6th–4th millennia BCE) to the Early Iron Age, although in some regions of Siberia, elements of the land fallow system persisted until the 17th–18th centuries as a component of extensive agriculture.

Among the peoples and cultures for which the land fallow system was characteristic, the late stage of the Trypillian culture, the Scythians, the Sarmatians, and early Slavic tribes should be noted.

The cycle of the land fallow agricultural system involved a cyclical sequence of stages [1,2]. The first stage, characterized as (1.1) the formation of initial biogenic potential, targeted steppe and meadow landscape complexes with a humus layer accumulated over centuries. Natural state in these complexes was maintained by dense sod and a deep root system of grasses, which provided reliable protection against erosion. However, with the onset of the agricultural cycle at the stage of (1.2) intensive exploitation and sod destruction, a radical disruption of the landscape's vertical connections occurred. Plowing initiated accelerated mineralization of organic matter, allowing high yields to be obtained for 3–5 years exclusively at the expense of the natural resource.

Further agrarian transformation of the landscape inevitably led to (1.3) the stage of soil depletion and agrotechnical crisis, when the rapid exhaustion of nutrients was accompanied by significant weed infestation. Since no effective methods of fertility restoration existed at that time, the only solution was (1.4) the abandonment and natural conservation of the exhausted field. The plot was left "under fallow" for prolonged secondary succession; however, the restored ecosystem already differed significantly from the original one in terms of soil profile structure. This landscape cycle concluded with the stage of (1.5) spatial expansion, when the community moved on to the development of new virgin land, which scaled up anthropogenic transformation to new territories and turned continuous tracts into a mosaic of degraded plots.

The slash-and-burn system dominated the forest zone of Europe and Asia. In Eastern Europe, it encompassed Polissia, the Carpathians, and the forested areas of the central and northern regions of the East European Plain; in Northern Europe, it was widespread in Scandinavia, Finland, and northern Germany; to the east, its range extended to Siberia and the Far East. The chronology of the system was exceptionally long: from the Neolithic to the Middle Ages, and in some regions (Polissia, Scandinavia, Siberia) it persisted until the 19th – early 20th centuries. In Eastern Finland, the system functioned on a rotational principle with a cycle of 20–40 years between repeated burnings of the same plot. Among the ethnic groups and cultures for which the slash-and-burn system was characteristic were the Finno-Ugric peoples, the Balts, the early Slavs (Krivichs, Drevlians, Vyatichi), as well as the Germanic tribes of Scandinavia. In Sweden, in particular, this practice is known as *"svedjebruk"* and was widespread from the Middle Ages until the 17th century, especially in regions with a developed ironworking industry [3].

Processes similar in depth of impact but different in mechanism were observed in forest landscapes due to the introduction of the *slash-and-burn system* [4]. Here, the starting point was (2.1) the state of primary forest landscapes with phanerophytic (woody) plant formations and a closed biogeochemical cycle, where nutrients were accumulated mainly in tree biomass. The stage of (2.2) mechanical destruction of the forest's layered structure through clear-cutting led to the instantaneous exposure of the soil and the destruction of the forest litter. The central factor of transformation was

(2.3) pyrogenic fertility stimulation, when the burning of wood released a vast amount of mineral compounds in the form of ash, which temporarily neutralized the acidity of forest soils. However, this effect was short-lived and quickly transitioned into the phase of (2.4) degradation and intensified leaching. Without the protection of the forest canopy, the soil underwent accelerated podzolization, and the mineral resources of the ash were rapidly depleted, forcing farmers to abandon the plot. The final stage was (2.5) the formation of secondary anthropogenic landscapes, where fallow lands were replaced by secondary forest stands with a simplified biological structure and a disturbed hydrological balance. Each new cycle of this system irreversibly reduced the area of primary forests, consolidating the landscape's transition into the category of anthropogenically transformed land.

The conducted analysis confirms that the land fallow system and slash-and-burn agriculture constituted the first large-scale stage of anthropogenic landscape transformation, establishing the fundamental mechanisms of extensive nature management. In the steppe zone, the land fallow system led to the disruption of vertical connections between vegetation and the soil profile, activating erosion and degradation of chernozems, while in the forest zone, slash-and-burn agriculture caused not only the mechanical destruction of tree vegetation but also profound chemical changes in soils due to the pyrogenic factor, which formed secondary landscapes with a disturbed hydrological balance. Both systems, widespread from the Neolithic to the Middle Ages across Europe and Asia (particularly in Ukraine—the Trypillia culture, Scythians, early Slavs, Finno-Ugric peoples of Polissia), are united by their extensive character, the absence of artificial fertility restoration, and a constant need for new lands, which determined the spatial expansion of anthropogenic impact. Understanding these historical ecological consequences is key for the modern sustainable development of agricultural landscapes, as it allows us to recognize the necessity of restoring natural self-regulation mechanisms and avoiding the repetition of destructive past models.

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THE IMPORTANCE OF SURVEYS IN MEDICAL-ECOLOGICAL RESEARCH

The article substantiates the significance of a sociological survey of two categories of respondents: ordinary citizens and medical professionals regarding the medical consequences of the environmental impact of the atmosphere on humans.

Key words: medical and environmental research, surveys, respondents, environmental factors, health, questions.

Incorporating a questionnaire survey into the design of a medical and environmental study is a necessary step to obtain data that cannot be easily or at all identified through instrumental methods or analysis of official statistics alone. As noted by specialists of the State Institution "O.M. Marzeiev Institute for Public Health of the National Academy of Medical Sciences of Ukraine," questionnaire surveys represent a method of empirical research that allows for the collection of information on various issues in a relatively short time and with minimal costs, while achieving a high level of mass participation in the study. In the context of studying the impact of environmental factors, particularly aerosol substances, on human health, the survey fulfills several key functions. Firstly, it allows for the assessment of subjective risk perception, i.e., determining the population's awareness of harmful factors and their sources. Secondly, the questionnaire enables the recording of health complaints, specifically respiratory symptoms, which have not yet developed into diagnosed diseases, a crucial aspect for preventive medicine. Furthermore, the questionnaire helps clarify individual exposure characteristics, such as occupational activity or the use of protective equipment, allowing for adjustments to data obtained from objective environmental monitoring. It is important to emphasize that the anonymity of the survey, as declared in both provided forms, is critically important as it increases the sincerity of respondents regarding sensitive health and behavior issues, which in turn enhances the validity of the obtained data.

To achieve the research objectives, two questionnaires were developed, targeted at different audiences, allowing for a comparative analysis. The first questionnaire, available at the link https://docs.google.com/forms/d/18rnCm28d-JBsxjx4drthGfXFp8BDtEieXmI0a7diaRM/edit, is designed for a broad range of respondents who may potentially be exposed to aerosols in everyday life or at the workplace. Its purpose is to assess the general awareness of citizens, their subjective assessment of pollution levels, and the prevalence of respiratory symptoms. The second questionnaire, available at the link https://docs.google.com/forms/d/1-KIHT_smYTck-KaqKeyCZq77_G4t8O5bk_vZ1S-t-gE/edit, is aimed at medical students. This group is unique because, on one hand, they are part of the general population and are also exposed to environmental factors, and on the other hand, they represent the future professional community. Their level of knowledge will influence diagnosis, prevention, and educational work among patients.

Both questionnaires contain a common block of socio-demographic questions, specifically about age and gender, as well as questions concerning awareness of aerosol substances and their impact on health. However, there are fundamental differences between them, reflected in the structure and focus of the questions. The first questionnaire focuses on the respondent's own personal experience, as evidenced by questions such as: "Is your professional activity associated with exposure to aerosol substances?", "What sources of aerosol substances most frequently affect you?", and "Do you experience any respiratory symptoms?". It is built on the principle of a "patient-centered" survey for collecting epidemiological data, allowing for the identification of correlations between exposure and its effects at the individual level. In contrast, the second questionnaire is aimed at assessing the external situation and professional training. Its key questions, such as "Do you consider the level of information provided to medical students about the harm of aerosol substances to be sufficient?" and "In your opinion, what diseases may be associated with long-term exposure to aerosol substances?", require the respondent to provide a professional opinion rather than personal disclosures. Thus, the second questionnaire is a tool for assessing professional competencies and educational needs, exemplifying a survey of future experts.

Based on the developed tools, the expectations from the study were as follows. First, it was planned to obtain quantitative data on the prevalence of respiratory symptoms among the population depending on professional activity and subjective assessment of air quality. The hypothesis that individuals whose activities are associated with aerosol exposure complain more frequently of respiratory symptoms was expected to be confirmed. Second, it was anticipated that the study would reveal the level of awareness among different population groups regarding sources of danger and means of protection, which would help identify target groups for health education activities. Third, concerning the second questionnaire, it was expected to determine whether a gap exists between the academic knowledge of medical students and their perception of real environmental threats. It was anticipated that student responses would indicate the need to strengthen interdisciplinary connections in the teaching of internal medicine and hygiene, as well as the necessity to update curricula considering modern data on the impact of aerosols.

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MAIN PATHWAYS OF MICROPLASTIC MIGRATION IN THE ENVIRONMENT: SYSTEMATIZATION OF CURRENT KNOWLEDGE

The publication systematizes modern scientific data on microplastic migration pathways in the environment. The key vectors of transport – hrough aquatic systems, atmospheric transfer, and soil migration – are characterized. It is established that atmospheric transport plays a crucial role in the contamination of remote regions, including polar areas.

Key words: microplastics, migration pathways, aquatic systems, atmospheric transport, soil pollution.

Microplastic, defined as plastic particles smaller than 5 mm, is currently considered one of the most widespread and persistent environmental pollutants. In recent decades, it has been detected in all natural environments – from the ocean floor to polar glaciers and high-mountain ecosystems [5, 9]. The global nature of this phenomenon necessitates a profound understanding of the pathways and mechanisms of microplastic migration in the landscape. The aim of this paper is to systematize current scientific data on the main vectors of microplastic transport between natural environments—aquatic, atmospheric, and soil.

Main sources of microplastic entry into the environment. Microplastics are classified into primary, which are intentionally manufactured for cosmetic products (scrubs, toothpastes) and industrial granules, and secondary, which result from the physical, chemical, and biological degradation of larger plastic items under the influence of ultraviolet radiation, abrasion, and other factors [5]. One of the most significant sources is the washing of synthetic textiles: according to research data, hundreds of thousands of tons of plastic microfibers enter the environment annually [8]. Another substantial source is the abrasion of automobile tires and road surfaces, which generates a considerable amount of microplastic that settles on road surfaces and subsequently migrates. It is estimated that tires are the largest source of primary microplastics, producing approximately 6.3 million tons per year [4, 8].

Aquatic migration as the main transit pathway. The hydrological network plays a key role in transporting microplastics from terrestrial sources to final water bodies. Microplastics enter water bodies with wastewater (from laundry, cosmetic rinsing), surface runoff from agricultural lands, roads, and landfills, as well as with atmospheric precipitation [5, 9]. The behavior of particles in water is determined by their density: light types of plastic (polyethylene, polypropylene) remain on the surface for a long time and are transported by currents over vast distances, while heavier ones (PET, PVC) quickly sink and accumulate in bottom sediments [1].

Current research indicates more complex mechanisms of microplastic retention in river ecosystems. Key factors influencing particle retention include: the presence of benthic algae, bottom structure (rocky beds retain plastic better than sandy ones), and water flow intensity. Sudden changes in hydrological regime, particularly during floods, lead to the secondary mobilization of plastic accumulated in bottom sediments and its further transport [1]. Ultimately, rivers act as the main suppliers of microplastics to the World Ocean, which becomes the final reservoir for a significant portion of these pollutants.

Atmospheric transport as a factor of global distribution. Airborne migration is the least studied but extremely important pathway that explains the detection of microplastics in the most remote regions of the planet [2, 7]. For a long time, it was believed that the ocean was the main source of microplastics in the atmosphere, but recent research refutes this assumption. The main source of atmospheric microplastics is land: road dust (products of tire and brake abrasion), microfibers shed from synthetic clothing during wear, and particles from industrial zones and landfills [2, 8].

Particle size determines their fate in the atmosphere: large particles quickly settle near the source, while the smallest ones (including nanoplastics) can remain in the air for extended periods and be transported over transcontinental distances. Modeling confirms that particles emitted into the atmosphere on continents reach the Arctic and settle on snow and ice [2, 7]. Removal of microplastics from the atmosphere occurs through dry deposition or washout by precipitation. Studies in forested areas have shown that airborne microplastics initially settle on tree leaves, and then with rain and leaf litter, enter the soil [5]. The concentration of plastic in the upper layer of forest litter is the highest, which allows forests to be considered as natural indicators of atmospheric pollution.

Soil migration and its consequences. Soils act not only as a final depot for a significant portion of microplastics but also as an active environment for their transformation and secondary mobilization [3, 6]. The main pathways of entry include the use of sewage sludge as fertilizer (all plastic that has settled in treatment facilities is transferred to fields), the degradation of mulch film in agriculture, and atmospheric deposition [3].

In soil, microplastics are affected by biota: earthworms, insects, and rodents contribute to their vertical movement (bioturbation). Furthermore, particles can migrate deeper with groundwater [3, 6]. The impact of microplastics on soil processes is multifaceted. Research indicates that they can alter the physicochemical properties of soil: increasing alkalinity, raising carbon content, and affecting the structure of microbial communities [6].

The most alarming finding is that microplastics, particularly mixtures of different types, can activate microbiological processes leading to a loss of soil fertility and an increase in greenhouse gas emissions [3, 6]. Thus, soil contamination with microplastics poses a direct threat not only to the productivity of agroecosystems but also to the global climate.

Factors influencing migration capacity. The intensity and range of microplastic transport are determined by a combination of factors. Particle size is critical: nanoplastics can penetrate cell membranes and traverse the most remote distances in the atmosphere [5, 6]. Shape affects the retention capacity in the environment: fibers tend to "cling" more easily to soil particles and vegetation, whereas spherical fragments can be freely transported by water [1]. Density determines behavior in the water column. The chemical persistence of plastic ensures its preservation in the environment for hundreds of years, making migration processes practically irreversible [1, 5]. A biofilm forms on the particle surface, which over time alters their density and can cause even light types of plastic to sink.

Based on the analysis of current scientific literature, microplastics are capable of active migration between all natural environments [5, 9]. The aquatic network serves as the main transit channel from terrestrial sources to the ocean, with sedimentation and secondary mobilization processes in rivers being key to understanding the plastic balance [1]. Atmospheric transport, previously underestimated, is now recognized as a decisive factor in the global distribution of microplastics, including their entry into polar regions and high-mountain ecosystems [2, 7]. Soils function as a long-term reservoir from which plastic can be remobilized, while also actively influencing biogeochemical cycles, particularly greenhouse gas emissions [3, 6]. Understanding these complex interrelated processes is a prerequisite for developing effective strategies to mitigate the impacts of plastic pollution, which should focus on terrestrial sources, improvement of treatment systems, and changes in consumption patterns.

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JUSTIFICATION FOR THE USE OF DENDROCHRONOLOGY METHODS TO ASSESS THE STATE OF GREEN INFRASTRUCTURE IN KYIV CITY

The publication substantiates the necessity and expediency of using dendrochronology and dendroindication methods to determine the ecological state of green infrastructure in Kyiv, namely tree stands. It has been proven that radial growth dynamics are an objective bioindicator of the complex impact on the environment.

Key words: green infrastructure, dendrochronology, dendroindication, radial growth, bioindicator, urban landscape.

Urban green spaces are subject to intense anthropogenic pressure and climatic stress factors caused by climate change, which reduces their resilience and ecological functions. The radial growth of trees is an objective bioindicator of the complex impact of the urban environment, including air pollution, soil degradation, heat stress, and changes in the water regime on urban plantings. Studying the dynamics of radial growth allows us to objectively assess the current state and viability of tree plantations and predict their resilience [1].

As Kyiv is the largest city in Ukraine, it is subject to all the negative effects of the urban environment on plant communities. Therefore, one of the indicators of environmental quality is the ecological assessment of the state of green spaces in Kyiv by analyzing the dynamics of radial growth and establishing links between the radial growth of trees and climatic and anthropogenic factors. The object of the study should be green spaces (forest cultures, park plantings, street plantings) in the territory of Kyiv, growing in conditions of intense anthropogenic load.

Such research should focus on studying the dynamics of radial growth of dominant tree species (lime, maple, chestnut, etc.) in Kyiv's plantings and the relationship between radial tree growth and key environmental factors (air pollution, recreational load, climatic factors).

The value of the study lies in the implementation of scientifically based dendroecological data and recommendations developed on their basis into the practice of urban green infrastructure management, as well as in the use of the results obtained in scientific and educational activities.

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GREEN-BLUE INFRASTRUCTURE AS A BACKBONE FOR SUSTAINABLE POST-WAR URBAN RENEWAL IN KHARKIV

The study examines the potential for integrating green-blue infrastructure (GBI) into Kharkiv's post-war recovery strategy. The author analyzes the transition from rigid engineering systems to nature-based solutions. Special attention is given to the concept of the "sponge city" as a tool for climate adaptation and the psychological rehabilitation of urban spaces in areas with a high level of destruction.

Key words: green-blue infrastructure, Kharkiv, urban resilience, nature-based solutions, post-war recovery, sponge city.

The full-scale military aggression has caused catastrophic destruction of Kharkiv's urban fabric, requiring not merely mechanical reconstruction but a fundamental rethinking of the urban planning paradigm. Traditional "grey" engineering networks (concreted storm drains, closed collectors) have demonstrated their vulnerability and low adaptability to extreme stresses. In this context, green-blue infrastructure (GBI) emerges as a strategic framework for building an ecologically resilient city. According to the European Commission, GBI is a strategically planned network of natural and semi-natural areas that provides a wide range of ecosystem services [1].

Kharkiv possesses a unique green-blue network formed by the Lopan, Kharkiv, Udy, and Nemishlya rivers. However, decades of industrialization have transformed these arteries into degraded channels. Contemporary scholarly works, including the collective monograph edited by N. Maksymenko and A. Shkaruba, emphasizes that cities in the post-Soviet space are particularly characterized by the fragmentation of ecological corridors [2]. Post-war reconstruction provides an opportunity to reintegrate these elements into a unified system through the use of nature-based solutions.

Contemporary urbanism proposes a transition to the "sponge city" model, which envisions the landscape's ability to absorb and purify water at the point of rainfall. As noted in [3], the "Sponge City" strategy is the most effective means of addressing the impacts of global climate change in urban environments [3]. This approach is particularly relevant for Kharkiv due to its high building density and the deteriorated state of its stormwater drainage systems.

For example, in the Northern Saltovka district, where infrastructure destruction is most extensive, it is more appropriate to create sunken green areas instead of restoring continuous asphalt surfaces. These "green pockets" not only reduce the load on the drainage system but also filter heavy metals and residues of petroleum products, the quantities of which have increased due to hostilities. Additionally, the reconstruction of pedestrian zones and parking lots using permeable materials will promote the natural replenishment of groundwater.

Beyond ecological functions, GBI plays a critical role in the psychological recovery of residents. As emphasized in [4], Kharkiv's urban resilience depends on the ability of spaces to support the overcoming of collective trauma. Access to quality "blue" and "green" spaces within a 15-minute walking distance significantly reduces stress levels.

Moreover, green-blue corridors can serve as the basis for safe routes. From a civil protection perspective, a decentralized GBI system is significantly more resilient to attacks than a centralized pipeline: damage to a single rain garden does not paralyze the drainage system of the entire district. This aligns with UNECE analytical reports on the economic aspects of Ukraine's reconstruction, which emphasize the importance of decentralizing critical systems [5].

The integration of green-blue infrastructure into Kharkiv's Master Plan (particularly in the context of the Norman Foster Foundation concept) is not only an environmental priority but also a matter of economic efficiency and national security. Creating an adaptive framework will allow Kharkiv to transform the consequences of destruction into a foundation for a modern, healthy, and resilient metropolis that meets European sustainable development standards.

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URBAN FARMING: IMPLEMENTATION PERSPECTIVES IN UKRAINE

The theses explore the potential for implementing urban agriculture in Ukraine within the context of global sustainable development challenges and the consequences of the full-scale war. The study analyzes Ukraine-specific drivers of this sector's development, including the need to rebuild the destroyed cities, disruptions in logistics chains, and the demand for social reintegration. Technological aspects—such as brownfield redevelopment, AgriTech solutions, and energy autonomy—are examined as a foundation for establishing a sustainable urban food system. Key barriers (regulatory, economic, and administrative) are identified, and the conditions necessary for the systematic integration of urban agriculture into Ukraine's post-war recovery policy are outlined.

Key words: urban farming, post-war reconstruction, food security, AgriTech, brownfields, energy efficiency.

Contemporary global challenges – climate change, urbanization, and resource depletion – have intensified the search for alternative models of production and consumption. Urban agriculture is increasingly viewed not as an amateur activity, but as a powerful instrument of urban planning, economic development, and environmental security.

The main objective of this study is a comprehensive examination of the potential for implementing urban agriculture in the Ukrainian context, as well as the identification and analysis of the key barriers hindering its development.

For Ukraine, this topic has gained critical importance in the light of the realities of war and its future recovery. First, the war has caused large-scale destruction of urban infrastructure, creating opportunities to redesign neighborhoods according to "green" development principles with integrated agrosystems. Second, disruptions in logistics chains and the occupation of agricultural land have demonstrated the importance of local food production as an element of strategic food autonomy. Third, urban farming can serve as a tool for social reintegration and therapeutic support for the affected populations [1].

The development of urban agriculture in Ukraine requires critical reassessment of foreign experience in the light of local specificities. Among these, particular attention should be paid to the high cost of energy resources, instability of power supply, and the significant stock of abandoned industrial areas known as brownfields. The combination of these factors defines the technological trajectory of urban farming in Ukraine and necessitates the search for context-adapted solutions.

Former industrial sites located within urban areas represent an important resource potential for the placement of agro-production complexes. Closed-loop technologies, in particular hydroponics and aeroponics, create opportunities to use such facilities without costly soil remediation, as plants receive nutrients directly from aqueous solutions. This approach completely eliminates the risk of contaminant migration from industrial substrates. Particular attention in this context should be given to aeroponics, in which the root system remains suspended in the air environment and is periodically misted with a nutrient solution. This method ensures maximum aeration and reduces water consumption by 95-98 % compared to traditional soil-based agriculture [2].

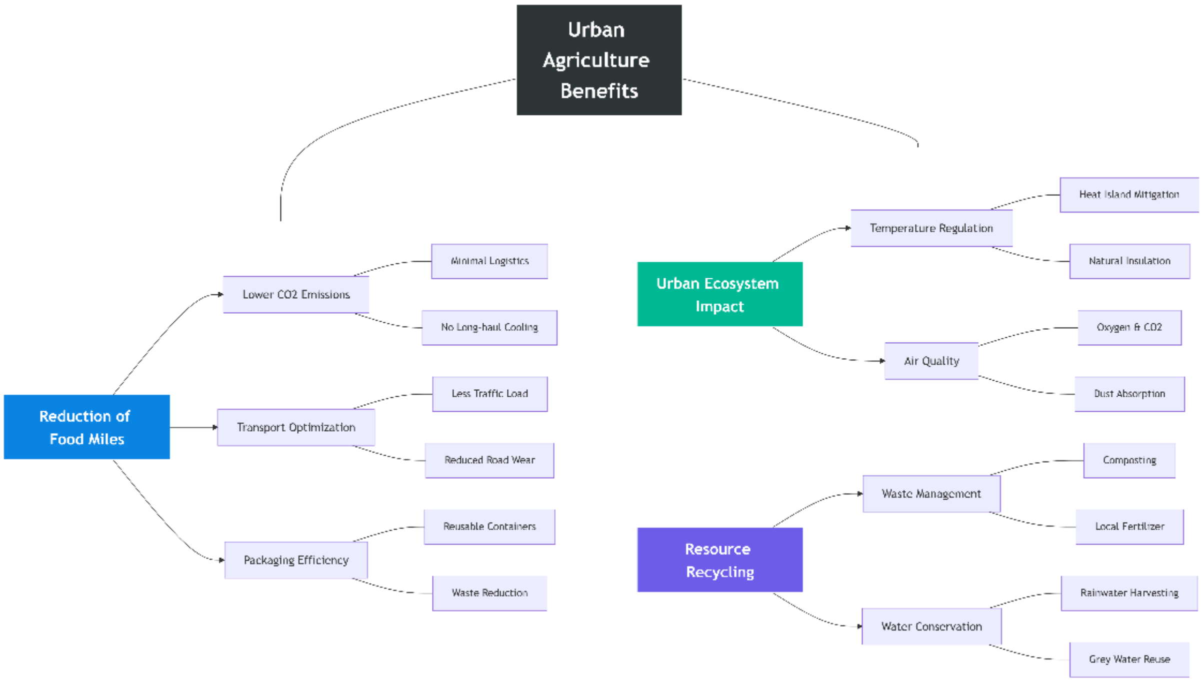

Fig. 1. Advantages of using urban agricultural production

It is also important to emphasize the unique resource Ukraine possesses – a strong IT community with well-developed expertise in artificial intelligence and automation. The integration of these competencies with agricultural technologies creates preconditions for the formation of a national AgriTech school. A modern urban farm is a complex engineering facility where dozens of parameters must be maintained within specified ranges: air temperature, relative humidity, carbon dioxide concentration, light intensity and spectral composition, as well as the pH level and electrical conductivity of the nutrient solution. The implementation of multi-level automation systems based on sensor networks and machine learning makes it possible to optimize these parameters, thereby increasing yield and product quality while reducing dependence on imported technologies. At the same time, artificial intelligence does not replace the agronomist; rather, it assumes routine monitoring operations, enabling specialists to focus on the strategic aspects of production [3].

The events of recent years have necessitated reassessment of attitudes toward centralized energy supply, as urban agro-industrial complexes are critically dependent on an uninterrupted power supply. A viable technological solution lies in integrating renewable energy sources directly into the architecture of farming facilities, primarily solar photovoltaic panels that can be installed on rooftops and building façades. Particularly promising is the use of the roofs of former industrial buildings, which typically offer large surface areas and sufficient load-bearing capacity. A hybrid energy supply model should be considered optimal, combining solar generation as the primary daytime source, battery storage systems for accumulating surplus energy, and connection to the centralized grid as a backup option. Taken together, these solutions enable the creation of agro-production facilities capable of operating autonomously for extended periods [4].

When assessing the potential of urban agriculture in Ukraine, it is important to consider both the set of factors that may stimulate its development and the obstacles to be overcome. Among the favorable factors, the high level of human capital is particularly significant: Ukraine possesses a powerful school of engineers and programmers capable of developing complex automated systems for agricultural production. Equally important is the spatial resource. As a result of the deindustrialization of the 1990s and the destruction caused by the war, Ukrainian cities have accumulated a substantial stock of vacant industrial premises that can be relatively quickly adapted to agro-production needs. It is also necessary to mention the financial instruments of the European Union. Having obtained a candidate status for the membership, Ukraine has gained access to programs aimed at supporting the green transition and circular economy, in particular, Horizon Europe and LIFE. Finally, the war has highlighted the attention to food security issues, generating demand for local, fresh products with minimal logistical distance – needs that urban farms are fully capable of meeting [2].

At the same time, the development of urban agriculture in Ukraine faces a number of serious barriers. The main obstacle remains the imperfection of the regulatory framework: current legislation does not provide a clear definition of urban agriculture as a type of activity and does not regulate the use of rooftop structures or basement spaces for plant cultivation, creating significant risks for potential investors. Economic barriers are primarily associated with the high energy intensity of production. The cost of electricity for industrial consumers in Ukraine is among the highest in Europe relative to the population's purchasing power, and in the absence of special tariffs, the economics of such projects appear vulnerable. Administrative challenges should not be underestimated either. Product certification procedures, designed for traditional agriculture, are poorly adapted to hydroponic and aeroponic technologies, requiring substantial time and financial investment. Finally, the high entry threshold into the sector– driven by the significant cost of equipment for industrial-scale vertical farms and the lack of specialized credit programs – makes this business accessible only to a limited circle of investors [1].

Urban agriculture in Ukraine has significant development potential, particularly in the context of post-war reconstruction. It is capable of addressing not only food security but also social, environmental, and economic challenges, transforming cities into more resilient and self-sufficient ecosystems. However, realization of this potential is impossible without systemic changes. Priority measures should include: adapting legislation to regulate the status of urban farms, developing incentive programs (such as preferential tariffs and grants), and initiating pilot projects at the municipal level (for example, "municipal gardens") to test effective management models and integration into the urban environment.

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USE OF ECOSYSTEM SERVICES IN GENERAL SECONDARY EDUCATION INSTITUTIONS

The publication presents the results of research into the use of environmental services based on general secondary education institutions.
Key words: ecosystem services, general secondary education institutions, education.

The research was conducted in the context of aggravating global environmental problems – climate change, loss of biodiversity, degradation of natural resources, which necessitates the formation of an environmentally conscious generation capable of making responsible decisions regarding environmental conservation. In this context, education plays a key role, since it is in general secondary education institutions that the foundations of ecological culture, a valuable attitude towards nature, and awareness of the interrelationships between human activity and the functioning of ecosystems are laid.

The concept of "ecosystem services", or "ecological services", includes all useful resources and benefits that humans can receive from nature. The fundamental human needs for habitat and food, and therefore the standard of living of humans, directly depend on them [1].

In secondary education institutions, environmental services can be effectively used as a powerful educational resource for the formation of students' environmental competence, a responsible attitude towards the environment and practical skills for a sustainable lifestyle. They make it possible to make learning not abstract, but applied, when schoolchildren realize that natural processes directly affect the quality of their lives. The educational space of the school, the school grounds, a park or other green area near the educational institution can turn into a kind of "living laboratory", where theoretical knowledge about the functioning of ecosystems acquires real meaning and practical confirmation. In such an environment, a holistic vision of the relationships between man and nature is formed, which is the basis of ecological thinking.

First of all, environmental services are directly related to the natural environment surrounding the school. Green spaces in the schoolyard perform a number of regulatory functions: they clean the air from dust and harmful impurities, reduce the concentration of carbon dioxide, contribute to increasing air humidity during the dry season, soften the microclimate, provide natural shade and reduce the level of noise pollution. These processes can be the subject of observations, measurements and research work of students during biology, geography, ecology or integrated natural science lessons. For example, schoolchildren can compare the air temperature in the shaded and open part of the yard, analyze the species composition of plants or study the impact of green spaces on the condition of the soil. This approach contributes to a deeper understanding of the relationship between human activity and natural processes [2].

No less important are cultural environmental services, which have significant educational potential. These include recreational, aesthetic, cognitive and spiritual benefits that a person receives from nature. Being in a green environment has a positive effect on the psycho-emotional state of students, reduces stress levels, increases concentration and efficiency. Conducting field trips, excursions to natural objects, organizing school gardens or corners of wildlife create conditions for direct contact of children with the environment. In the process of such activities, students not only learn educational material, but also gain personal experience of interaction with nature, which forms a valuable attitude towards it and strengthens motivation to preserve it.

Integration of environmental services into the educational process can be carried out through various practical approaches. The organization of educational and research sites allows you to study soil formation, the cycle of substances, the features of plant growth and development, the role of pollinating insects in maintaining biodiversity. Students can participate in long-term observations, keep research diaries, analyze results and draw conclusions. Activities of planting and caring for plants, creating flower gardens or mini-ecosystems form responsibility, develop teamwork and allow you to directly see how even minor human actions affect the state of the environment. In this way, knowledge, skills and practical experience are combined.

Another important area is the implementation of school projects on the rational use of natural resources. Waste sorting, composting organic waste, collecting rainwater for irrigation, and implementing energy-saving measures in school premises allow students to demonstrate in practice how responsible behavior contributes to the preservation of environmental services. Students can analyze the volume of resource consumption, develop recommendations for their conservation, and participate in educational campaigns among peers and parents. Such activities form not only environmental knowledge, but also an active life position focused on the principles of sustainable development.

The use of environmental services in secondary education institutions also has a pronounced socio-cultural effect. It contributes to the establishment of cooperation between the school and the local community, the involvement of parents in joint environmental initiatives, the implementation of partnership projects with environmental protection institutions or local government bodies. As a result, the school turns into a center of environmental culture, where environmental thinking becomes part of everyday practice [3].

Therefore, the use of environmental services in secondary education institutions is an effective tool for integrating knowledge about natural systems into real life. It allows you to combine theoretical principles with practical activities, develops students' environmental awareness and responsibility, contributes to the formation of sustainable lifestyle skills, and prepares the younger generation for active participation in solving modern environmental problems.

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STUDYING FACTORS INFLUENCING FOREST ECOSYSTEMS IN ECOLOGICAL EDUCATION PRACTICES

The process of integrating ecological education and upbringing into the educational process through practical learning in the natural environment is examined in the paper. A methodological development for running a summer ecological camp for students in grades 5–7 based at the National Nature Park "Slobozhanskyi" is proposed.

Key words: ecological camp, ecosystems, recreational pressure, ecological education, national nature park.

Recreational pressure on forest ecosystems manifests quietly but relentlessly: trampled paths compact the soil, tree roots lose access to air and water, mechanical damage to bark opens the way for pathogens, and abandoned litter slowly poisons the soil and water bodies. Campfires and their remnants pose a separate environmental problem. These changes accumulate over the years, leading to disruption of the hydrological regime, reduced biodiversity, and gradual transformation of the forest into a less resilient system [4]. Students in grades 5-7, who often visit forest areas during school tours or family outings, rarely have the opportunity to see these processes in dynamics – how a single careless action triggers a chain reaction that affects the entire landscape. As a result, stereotypes of careless behavior persist: walking off the trails is perceived as innocent freedom, breaking branches as part of play, and leaving litter as a temporary issue. Without personal experience, awareness of the consequences of these violations remains abstract, and love for nature does not translate into responsible action.

For the practical application of approaches that combine field research, observation of model animal species (for example, "beaver-engineers" of ecosystems), analysis of cause-and-effect relationships, and rethinking of environmental problems, various methodological developments for the ecological education of schoolchildren are proposed by the author. When preparing methodological developments, all practices must be carefully adapted to age characteristics – in particular, for students in grades 5-7. Students' attention should be focused on short learning segments (no longer than 1.5-2 hours), with the predominant role given to games, visible results, and team interaction. Equipment in field conditions should be as simple as possible (tablet or phone, pencil, paper). Work is best conducted in small groups of 3-5 people, with emotional support provided through daily reflection circles among participants [3] under the slogan "I have done something good – and the forest changed for the better."

The program of the methodological development must be structured so that every child's action produces a visible result within 30-60 minutes (a tent pitched, a beaver dam discovered, a salad made from medicinal herbs, a pantomime performed, a "before/after" drawing created).

One such methodological development is the project for the summer ecological camp "Beaver-Engineers of Ecosystems: Forest Adventures", proposed to be conducted at the facilities of the nature reserve fund, in particular at the National Nature Park "Slobozhanskyi" in Kharkiv region. During the project, schoolchildren are invited to study the beaver as a model species – an "ecosystem engineer." Its activity – building dams from branches and mud, creating ponds, and retaining water – becomes a key example that illustrates how a single species can determine the state of an entire landscape, prevent droughts, and support biodiversity.

The methodological framework of the camp unfolds over three consecutive days, each with a clearly defined goal, corresponding to the principles of age-appropriate pedagogy and ensuring the gradual formation of competencies – from basic practical skills to analytical understanding and a value-based attitude toward nature [2, 3, 4]. It is advisable to involve a scientific staff member of the National Park in the educational process and consultations.

Day One is dedicated to adaptation to the natural environment and the formation of basic skills for safe and responsible presence in the forest. The practical session includes setting up tents according to the principle of minimal impact on soil and vegetation cover. Students quickly receive a visible result – the tent is pitched in compliance with ecological requirements. The day ends with a discussion of typical violations in nature – trampling of paths and mechanical damage to tree bark – with demonstrations of real examples on the camp territory. A "Green Kitchen" contest can also be held – preparing simple dishes from medicinal herbs (salad from young dandelion leaves, tea from rose hips and nettles) – which develops skills in using natural resources and team interaction.

Day Two constitutes the central research block of the project. An excursion to "beaver locations" – key observation sites. Under the guidance of a scientific staff member of the National Park, schoolchildren observe real "hydraulic structures" built by beavers: dams made of branches and mud, felled trees, changes in water levels, and signs of increased biodiversity (presence of waterfowl, amphibians, aquatic plants). Next, students are given creative tasks to clarify cause-and-effect relationships in both the positive and negative aspects of beavers' ecological activity: "What will happen if…?"

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The proposed methodological development combines an educational-scientific approach with the research activities of school-age children, makes ecological education deeply personal and motivating, and demonstrates how cooperation with nature reserve institutions can become a powerful, living tool for fostering environmental culture in the younger generation.

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Applied ecological research

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WATERFALLS OF THE UKRAINIAN CARPATHIANS AS OBJECTS OF RECREATIONAL USE: ENVIRONMENTAL IMPACTS OF TOURISM PRESSURE

The article examines the features of recreational and tourist use of waterfalls in the Carpathian region of Ukraine. Their importance as significant natural tourist attractions that shape the recreational attractiveness of the territory is determined. The main manifestations of recreational and tourist pressure on the natural complexes of waterfalls are analyzed, and the necessity of rational use of these natural resources and the development of ecological tourism is outlined.

Key words: waterfalls, Carpathian region, recreational and tourist pressure, tourism.

The Carpathian region of Ukraine is one of the most important centers for the development of recreation and tourism in the country [2]. Due to its significant natural diversity, picturesque mountain landscapes, dense river network, and a large number of natural attractions, this territory attracts a considerable number of tourists. Among the natural sites that are particularly popular, waterfalls occupy an important place. They are not only interesting geomorphological formations but also serve as significant recreational resources actively used in tourism activities.

Waterfalls of the Carpathian region are mainly formed on mountain rivers and streams, where significant elevation differences contribute to the formation of water cascades [1]. Most of them are located within forested areas or within protected natural territories, which increases their natural and aesthetic value. Such sites often become important elements of tourist routes and excursion programs [6, 7]. They are visited both by organized tourist groups and individual travelers, which contributes to the active development of recreational use of these territories.

The significant popularity of waterfalls is explained by their accessibility, spectacular appearance, and the possibility of combining visits with other types of recreation, including hiking tourism, ecological excursions, and nature studies. Many waterfalls in the Carpathians are located near settlements or tourist centers, which facilitates access to them [5]. For this reason, they often become objects of mass visitation. As a result, considerable recreational and tourist pressure is formed on the natural complexes in which they are located.

Recreational and tourist pressure manifests itself in various forms of impact on the natural environment (Fig. 1) [3]. The most common include trampling of vegetation, soil compaction, the formation of unauthorized trails, accumulation of household waste, and disturbance of the natural condition of surrounding areas (Fig. 1, b). This impact becomes especially noticeable in places where there is no proper infrastructure for receiving tourists. Under conditions of intensive visitation, natural landscapes may undergo significant changes, which negatively affects their ecological condition.

a) image from July 2022

b) image from July 2025

Fig. 1. Changes in tourist trails in the area of the Synevyr National Nature Park during 2022-2025 [8].

Waterfalls of the Carpathian region are often located within protected areas, including national nature parks and other objects of the nature reserve fund [2, 6, 7]. Within such territories, natural complexes are under special protection; however, tourist activity also plays an important role here. It contributes to the promotion of natural heritage and the formation of environmental awareness among the population. At the same time, excessive or uncontrolled visitation may pose a threat to the preservation of natural ecosystems.

One of the important tasks of modern nature management is to combine recreational use of territories with the preservation of their natural properties [3]. For this purpose, it is necessary to carry out rational planning of tourist activities, taking into account the characteristics of natural landscapes and their resistance to anthropogenic impacts. In many cases, it is advisable to arrange special tourist routes, install information boards, and create viewing platforms and recreation areas. Such measures allow tourist flows to be directed and help reduce the negative impact on the natural environment.

An important direction in regulating recreational pressure is also the development of ecological tourism. Its main goal is the harmonious combination of cognitive activity with careful treatment of nature. Within ecological tourism, considerable attention is paid to environmental education and the formation of a responsible attitude toward natural resources. This contributes to the preservation of natural sites and ensures their sustainable use in the future.

The Carpathian region has significant potential for the development of various forms of tourism, including nature-based, ecological, and educational tourism [2]. Waterfalls are important elements of the natural heritage of this region and can serve as key objects of tourist interest. However, effective use of these resources requires a comprehensive approach that includes scientific research, monitoring of the condition of natural complexes, and the implementation of measures for their protection.

Waterfalls of the Carpathian region play an important role in the development of tourism activities and in shaping the recreational attractiveness of the territory [1, 2]. At the same time, the increase in the number of visitors leads to a rise in recreational and tourist pressure on natural complexes [3]. In order to preserve these unique natural objects, it is necessary to ensure the rational use of natural resources, implement environmental protection measures, and develop environmentally responsible forms of tourism.

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ENVIRONMENTAL INDICATORS IN THE CERTIFICATION OF AGRICULTURAL ENTERPRISES IN UKRAINE: SIGNIFICANCE AND RELEVANCE IN 2026

This article examines the role of environmental indicators in the certification of Ukraine's agricultural sector as of 2026, focusing on their necessity for EU integration and post-war land recovery. As these indicators serve as critical tools for supporting the global competitiveness and sustainability of Ukrainian agriculture in an unstable geopolitical climate.

Key words: certification, environmental indicators, GHG emissions

Introduction. Environmental indicators are the basis of certification in the agricultural sector, serving as measurable parameters for verifying the sustainability of production. They cover greenhouse gas (GHG) emissions, soil condition, water management and biodiversity conservation. For Ukraine, which has about 41 million hectares of arable land, integrating these indicators into certification systems is critical to ensuring resilience in the face of land degradation, the effects of war and climate change. Certification not only confirms compliance with international standards, but also opens up access to capital markets and long-term sustainability [2, 6].

Overview of certification systems in the agricultural sector of Ukraine.

Ukrainian enterprises use a combination of international and national schemes based on environmental metrics:

- Organic certification: Regulated by the Law of Ukraine on Organic Production (harmonized with EU Regulation 2018/848). Key indicators: absence of synthetic pesticides, organic matter content in soil and biodiversity [1].
- ISCC (International Sustainability and Carbon Certification): Used by over 260 operators. Key indicator is GHG emissions (clCO_2e/t$ of product) and traceability of the supply chain.
- GLOBALG.A.P.: Focuses on good agricultural practices, water efficiency and integrated plant protection.
- Dinak system: National tool for assessing compliance with sustainable development standards, structuring indicators according to environmental, economic and social vectors [4].
- Restoration Certification (FoodChain ID & CE-LAB): A new initiative in 2026 focusing on the certification of post-conflict reclaimed lands, including phytoremediation and soil safety [8].

Key Environmental Indicators in Certification.

According to the EU taxonomy and FAO guidelines, the following priority groups of indicators are distinguished in the Ukrainian context [2, 7]:

1. GHG emissions and carbon footprint: Measured in tons of CO_{2e}/ha. UNFCCC data (2023) indicate that Ukrainian crop production is competitive in terms of

emissions compared to EU countries [9]. Particular attention is paid to carbon sequestration in the soil to achieve Net Zero goals.

2. Soil condition and health: Assessed through humus content, pH level and nutrient balance. In 2026, monitoring of heavy metal contamination on 7.5 million hectares of war-affected lands is critical.

3. Water management and chemicalization: Indicators include irrigation efficiency and Nitrogen Use Efficiency (NUE). Certification requires compliance with the Do No Significant Harm (DNSH) criterion for aquatic ecosystems [7].

4. Biodiversity: Monitoring areas under cover crops, preserving natural habitats, and avoiding conversion of lands with high levels of biodiversity.

Why it matters: the 2026 context.

The relevance of environmental indicators is due to five key factors:

1. EU integration and Green Deal: Ukraine, as a candidate for EU membership, is adapting its policy to the Farm to Fork Strategy. This involves reducing pesticide use by 50% and expanding organic land to 25% by 2030 [1, 5].

2. Post-war reconstruction: Initiatives such as FoodChain ID–CE-LAB allow returning damaged land to circulation, providing environmental guarantees of product safety for premium markets [8].

3. Climate resilience: The use of indicators stimulates the implementation of precision agriculture, which increases the adaptability of farms to extreme weather conditions.

4. Economic preferences: ESG compliance opens access to "green" financing. EY experts emphasize that a national sustainability criterion is necessary to attract investments in the recovery of the sector (the need is estimated at over 29 billion USD) [7].

5. Data harmonization: The transition to the FSDN (Farm Sustainability Data Network) requires Ukrainian farmers to standardize reporting on environmental metrics [3].

Challenges and Prospects. The high cost of certification for small farmers and data scarcity due to military operations remain major obstacles. However, the development of remote sensing and blockchain technologies allows for the automation of data collection.

Conclusion. Environmental indicators have been transformed from a voluntary tool into a mandatory condition for the survival of agribusiness. In 2026, they are the key to economic recovery, environmental protection, and successful European integration of Ukraine.

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RADIAL GROWTH OF COMMON HORSE CHESTNUT IN GREEN STANDS OF KHARKIV CITY

In order to establish the ability of common horse chestnut to adapt to climate change and the impact of the chestnut miner (*Cameraria ohridella* Deschka & Dimic (*Lepidoptera: Gracillariidae*)) invasion, a study of the radial growth of trees was conducted, which is a measure of cambial activity and indicates the condition of the tree and depends on the impact of environmental conditions.

Key words: Aesculus hippocastanum L., radial growth of trees, climate, *Cameraria ohridella* Deschka & Dimic (*Lepidoptera: Gracillariidae*)

Horse chestnut (*Aesculus hippocastanum* L.) is an integral element of urban landscapes, but it is currently under double pressure: rapid climate change and the expansion of the chestnut miner (*Cameraria ohridella*). The radial growth of trees is a reliable indicator of their cambial activity and general physiological state [1, 2].

The global temperature of the Earth has already increased by 0.8 °C compared to the pre-industrial period, which has led to numerous problems – mass outbreaks of pests, increased weather variability, increased frequency of heat waves, floods, fires in ecosystems, etc. The invasion of the chestnut miner was first recorded in Europe in 1984 in the area of Lake Ohrid in Macedonia. This species of pest has spread to most European countries, migrating at a speed of approximately 60 km/year. The chestnut miner crossed the border of Ukraine in 1998, and in 2007 reached Kharkiv. The caterpillar, which feeds on the parenchyma of the leaves, causes browning and dehydration of the leaves, which can be shed in summer. As a result of the chestnut miner feeding on horse chestnut leaves, which lasts from May to September, it can be up to 98% of the photosynthetic area was lost. Due to warming, in the green areas of Kharkiv, the chestnut miner develops in three generations per year [1].

The aim of the work is to assess the dynamics of radial growth of common horse chestnut in the green areas of Kharkiv and to establish the degree of influence of climatic factors and defoliation caused by the miner on the condition of trees.

The work used comparative and dendrochronological analyses to assess the dynamics of growth. Statistical processing and correlation analysis were carried out to establish the relationship between the width of the annual ring and meteorological data (temperature, precipitation) of the Kharkiv meteorological station for two periods: before the mass invasion of the pest (1986-2004) and during the active influence of bio-abiotic stressors (2005-2023).

A comparison of the two periods revealed a critical decrease in radial growth trees: from 2.57 ± 0.19 mm (1986-2004) to 1.10 ± 0.06 mm (2005–2023). The overall decrease in growth intensity was 56-57%. A sharp decrease in radial growth was recorded in 2005-2006, which coincides with the beginning of the mass spread of Cameraria ohridella in the region. During the first few years, this decrease was rapid, and after this period the decrease in growth slowed down. The decrease in radial growth of the common horse chestnut occurred against the background of increasing temperatures and anthropogenic load (pollution from road transport and recreation) [1].

During 2005-2023, compared to 1986-2004, a significant warming was recorded. The average temperature of the hydrological year increased in the second period by 1.49 °C, and the growing season (April-August) – by 1.52 °C. At the same time, the moisture deficit increased in the second period: the amount of precipitation decreased by 83 mm per hydrological year.

Correlation analysis between radial growth indices and climatic factors showed that during the first period (until 2005) there was a significant positive relationship between growth and winter temperatures (R=0.52, significance level 0.05). In the second period, this relationship changed its vector to negative [1].

Precipitation during the growing season (April-August) remains a consistently positive factor for tree growth in both periods, but its deficit against the background of heat increases the stress state of the stands [1].

Conclusions. A sharp decrease in the width of annual rings (by 56%) in 2005-2023 compared to the previous 1986-2004 indicates a deep suppression of the viability of *Aesculus hippocastanum* L. in Kharkiv. This is due to a synergistic effect: depletion of trees due to the annual loss of photosynthetic surface (up to 98% due to the chestnut miner) and increased aridity of the climate. It was found that precipitation had a positive effect on growth, unlike temperature, which had a negative effect on radial growth. This is characteristic of both periods. The trend of radial growth of trees decreased until 2023. At the same time, during 2008-2023, this decrease was insignificant. It is necessary to continue monitoring the common horse chestnut using dendrochronological methods in green stands of Kharkiv.

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STUDY OF ORGANIC CARBON STOCKS IN THE SOIL OF OLD-GROWTH FORESTS OF THE VODODILNO-VERKHOVYNSKYI RIDGE

One of the most important factors of climate change is the level of CO_2 in the atmosphere. An increase in the amount of carbon dioxide leads to warming of the atmosphere. This causes glacial periods and interglacial periods, the so-called global warming phases. Due to the sequestration capacity of forest ecosystems to store organic carbon, they perform a thermoregulatory function. Studying the quantitative capacity to retain organic carbon in different pools of forest ecosystems is a priority task for developing methods to control the volume of Carbon dioxide on Earth.

Soil is one of the largest and most stable reservoirs for the accumulation and storage of organic carbon. Determining the stocks of organic carbon in this pool leads to an understanding of the mechanisms regulating and cycle in the biosphere. In this study, the stocks of organic carbon were determined in the soil pool of old-growth forests of the Vododilno-Verkhovynskyi Ridge in the Ukrainian Carpathians.

The research area is located within the Vododilno-Verkhovynskyi Ridge, namely its northern and southern slopes. The length of the studied territory is 20 km, from Mt. Pikui to Mt. Zhurivka. The boundary between Lviv Oblast (northern macroslope) and Transcarpation Oblast (southern macroslope) runs along the mountain ridge. In geomorphological terms, the study area belongs to the Vododilno-Verkhovynskyi region of the Ukrainian Carpathians, specifically to the district of the Verkhovynskyi Middle-Mountain Watershed Ridge.

In this territory, 26 research plots were established. The forest stands are represented by sycamore-beech forests, beech old-growth forests, and fir-beech forests. The dominant soil type in the study area is brown forest soils (Nature of Lviv Region, 1972). Within these plots (100 m²; 10×10 m), soil samples ($n = 3$) were collected using a frame measuring 25×25 cm [1-3]. The content of organic carbon in soil was determined by the dichromate oxidation method. Soil samples were collected from the most active soil layer at a depth of 0–30 cm from each genetic horizon with threefold replication.

According to the analysis of 26 research plots, the total humus stocks in soils ranged from 3.36 to 10.59 $t \cdot ha^{-1}$. Such a wide range indicates high heterogeneity of conditions for the accumulation of organic matter and different degrees of development of the humus horizon in the study area.

The total stocks of organic carbon in soils were characterized by significant variability. The values of this indicator ranged from 20.22 to 65.86 $t \cdot ha^{-1}$, shows the diversity of soil conditions, microrelief, and structural organization of forest ecosystems within the study area. The mean value of total soil organic carbon stocks across the entire sample was 33.93 ± 9.36 $t \cdot ha^{-1}$. The median value of organic carbon stocks in soil is 31.89 $t \cdot ha^{-1}$. At the same time, the standard deviation and median indicate high inter-plot variability of this indicator.

The results obtained show that even within the same forest type, significant internal heterogeneity in total soil organic carbon stocks was observed. At the same time, integration of stocks to a depth of 0–30 cm allows assessment of the overall potential of soils for long-term sequestration of organic carbon regardless of variations in the thickness of individual horizons. Areas with increased organic carbon reserves in soils are mainly concentrated in old-growth forest massifs of older age groups on the northern macroslope, younger stands are characterized by average and lower values of total reserves. This spatial distribution shows the role of forest type in shaping the soil organic carbon pool.

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ENVIRONMENTAL IMPACTS OF OVERTOURISM AND APPROACHES TO THEIR ASSESSMENT

The article examines the main environmental risks of overtourism and approaches to their assessment in the context of sustainable tourism.
Keywords: overtourism; environmental risks; sustainable tourism; tourist pressure.

The problem of overtourism is one of the most pressing issues in contemporary tourism geography and environmental studies, as the rapid growth of tourist flows generates significant anthropogenic pressure on natural complexes and resources. According to *National Geographic*, overtourism occurs when the number of visitors exceeds the ecological, social, or infrastructural capacity of a destination, leading to environmental degradation and a decline in the quality of life of local residents [1].

Globalization processes and improved transport accessibility contribute to the continuous growth of tourist flows, which is particularly evident in the world's most popular tourist regions. Scientific research indicates that intensive tourism development is accompanied by increased consumption of natural resources, growing volumes of waste, and higher levels of environmental pollution [2]. At the same time, tourism can contribute to sustainable development only under conditions of rational resource use and effective control of tourist pressure [3].

One of the main environmental risks of overtourism is the degradation of natural landscapes. Intensive visitation leads to soil compaction, destruction of vegetation cover, and the intensification of erosion processes. The study Tourism and Land Use Change highlights that tourism drives land-use change through the development of previously natural areas, the construction of roads, and the creation of tourism infrastructure, which significantly alters ecosystems and landscape structure [4]. The authors note that "changes in land-use structure are among the most long-term environmental consequences of tourism development" [4].

Coastal and mountainous ecosystems are particularly vulnerable to overtourism. For example, mass tourism in Mediterranean region has caused significant reductions in natural areas due to hotel construction and transport network expansion [4]. In mountainous areas, intensive tourist flows lead to trail degradation and increase the risk of landslides and soil erosion [5].

Environmental pollution is another major issue associated with overtourism. An increase in tourist numbers is accompanied by the accumulation of solid waste, water contamination, and rising noise levels. Research highlights that excessive tourist flows may overload waste management and sewage systems, resulting in the pollution of natural water bodies [5].

In popular tourist regions, restrictions on access to natural areas are often introduced to reduce anthropogenic pressure on ecosystems (Fig. 1). For example, some countries limit the number of visitors to protected areas or introduce additional environmental fees to finance conservation measures [6]. Such initiatives are aimed at reducing the negative impact of tourism on natural resources and biodiversity [6].

Fig. 1. The installation of a large mesh barrier to block the well-known Instagram view of Mount Fuji made newspaper headlines in 2024 [6].

The problem of overtourism is particularly acute in marine ecosystems. Mass tourism leads to coral reef damage, marine water pollution, and the disruption of marine habitats. According to the Global Sustainable Tourism Council, the establishment of marine protected areas helps mitigate the negative impacts of tourism and supports ecosystem recovery. The report states that marine protected areas help regulate tourist flows and restrict environmentally harmful activities [7].

A significant environmental risk of overtourism is the increase in greenhouse gas emissions. Tourist travel, especially air transportation, contributes to the growing carbon footprint of the tourism sector. Transport remains one of the primary sources of tourism-related climate impacts; therefore, climate indicators must be considered when assessing tourism pressure [8].

The identification of environmental risks associated with overtourism involves a set of methodological approaches. One of the most widely used methods is the determination of recreational carrying capacity, which defines the maximum permissible number of visitors without disrupting ecological balance [3]. Exceeding carrying capacity is one of the key indicators of overtourism [1].

Another important approach is the analysis of land-use changes through geographic information systems (GIS) and remote sensing technologies. These methods make it possible to detect environmental degradation and assess the scale of anthropogenic impacts [4].

Various indicators are used to assess the environmental risks of overtourism, including:

- the level of anthropogenic pressure on a territory;
- the area of transformed natural landscapes;
- the volume of waste generation;
- the level of water pollution;
- the state of biodiversity [5].

A comprehensive assessment of these indicators makes it possible to determine the degree of environmental risk associated with tourism activities and to develop effective strategies for managing tourist flows [3].

Thus, overtourism poses a serious threat to the natural environment, leading to landscape degradation, pollution, and disruption of ecological balance. The application of modern methods for identifying and assessing environmental risks enables the timely detection of negative trends and the implementation of sustainable tourism development measures. Rational management of tourist flows is a necessary condition for preserving natural resources and ensuring the environmental safety of tourist regions [3].

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IRRIGATION EFFICIENCY AS A FACTOR IN STABILIZING AGRICULTURAL PRODUCTION IN CONDITIONS OF WATER RESOURCE DEFICIT

Efficient irrigation is key to stabilizing Ukrainian agriculture under water scarcity. Modern techniques, especially drip irrigation, improve water use and crop yields while supporting sustainable farming.

Key words: irrigation, drip irrigation, water scarcity, agriculture, sustainability

The predicted and already quite noticeable climate change is of great concern to Ukrainian farmers, as their business is directly linked to available natural resources: land and water. The problem of water scarcity will eventually affect everyone involved in the agricultural sector, because water is, unfortunately, a finite resource.

It is important to act proactively and inform the public about the predicted changes. The idea of economical water consumption should become a priority in the educational activities of environmentalists. As part of the preparation of Ukraine's agricultural sector for EU accession, the Ukrainian Center for European Policy conducted a survey among farmers on their attitude towards the introduction of environmental requirements in agricultural activities. One of the areas of research concerned water, or more precisely, the Water Framework Directive, which aims to prevent further deterioration of water resources and improve their condition [1].

The survey results showed that insufficient information is an obstacle to the implementation and further enforcement of environmental requirements. Ukraine lacks sufficient water resources to provide crops with the necessary amount of irrigation water. Surface freshwater bodies in Ukraine cover only 4.0% of the country's total territory. Water reserves in Ukraine are replenished by precipitation. They are also insufficient. With a norm of 700 mm, the average amount of precipitation in Ukraine reaches only 568 mm per year. According to the National Academy of Agrarian Sciences, in February 2025, Ukraine faced the lowest level of soil moisture in the last seven years. The total amount of precipitation for the period from November to January was only 79.6 mm, which is significantly less than the long-term average of 117 mm [2].

Insufficient rainfall and water for irrigation can cause significant financial losses to entrepreneurs and even lead to the liquidation of agricultural enterprises. Ukrainian agricultural enterprises are located in different agroclimatic zones and therefore have unequal access to water. Information about the shifting boundaries of agroclimatic zones will allow farmers to take a new approach to the selection of crops and plan agricultural production. The shortage of fresh water in Ukraine will continue to grow, so the principles of rational and economically efficient use of water resources must be laid down as the basis of state policy on water use. Only irrigation can cover the water shortage and regulate the water balance of the soil in natural conditions. In regions where irrigation is used, the harvest can be twice as large, which makes investments in irrigation systems strategically important. Water is used most efficiently and economically in drip irrigation systems. Flood and sprinkler (aerosol) irrigation, on the contrary, leads to excessive loss of large amounts of water. A significant advantage of drip irrigation is that evaporation is minimized and water goes directly to the roots of plants.

The drip irrigation technology was invented by Israeli inventor and hydraulic engineer Simcha Blass. He is respectfully known around the world as the "Water Man." Blass and his followers planned a water management system, thought through the infrastructure for water transportation in detail, and developed technologies for testing, purifying, and saving water. Rafi Megudar, the man who continued Blass's work, explains the advantages of drip irrigation as follows: "When we give plants too much water—which is what happens with flood and sprinkler irrigation—we flood the roots and deprive them of oxygen. The plants experience stress. Then we don't give them water for a while, and they experience another kind of stress. This repeats itself over and over again throughout the growing season. If water drips regularly onto the roots of the plant, we keep it calm and allow it to do what it does best" [3].

A drip irrigation system is a whole infrastructure, and when installing it, climatic, topographic, agrotechnical, safety, and economic factors must be taken into account. It is especially important that the drip irrigation system be purchased from a trusted manufacturer and installed by highly qualified specialists.

A drip irrigation system is an expensive project and therefore requires significant investment. The equipment is the most expensive part. Operating the system is also energy-intensive. The highlight is that Israeli inventors have developed a self-flowing version of the equipment for developing countries that do not have energy sources [3].

The shift in agroclimatic zones has led to an increase in demand for the installation of irrigation systems. However, given the situation in our country related to military operations, banks are reluctant to finance long-term and capital-intensive irrigation projects, and the state is currently not investing in the restoration of main canals and water infrastructure [4].

Today, Ukraine suffers from a shortage of water, so water resources in Ukraine must be controlled and protected at the state and community levels. The use of such effective irrigation techniques as drip irrigation will certainly contribute to water conservation.

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TRENDS OF MODERN CLIMATE CHANGE ACCORDING TO DATA FROM THE ZHYTOMYR WEATHER STATION

The results of studies of seasonal changes in the distribution of climatic factors (temperature and precipitation) during 1975-1999 and 2000-2024 are presented.
Key words: temperature, precipitation, climate change, Zhytomyr weather station

The study of modern climate change is important for the territory of Polissya, where the transformation of the temperature regime and changes in the distribution of atmospheric precipitation significantly affect the functioning of natural ecosystems. An increase in air temperature, increased xerophytization of the climate and the formation of warm, low-snow winters can change the hydrothermal conditions for vegetation development, complicating the natural restoration of forest ecosystems in significant areas of disturbed territories [1, 2].

Analysis of climatic indicators according to the data of the Zhytomyr weather station for two periods (1975–1999 and 2000–2024) showed significant changes in the temperature regime. The average annual air temperature in the first period was 7.2 °C, while in the second – 9.15 °C, which is 1.95 °C (21%) more. At the same time, there is a tendency to reduce the average annual amount of precipitation: in 1975–1999 it was 651 mm, and in 2000–2024 – 609 mm, i.e. 42 mm (6%) less [1].

Changes in climatic parameters have a pronounced seasonal nature. The greatest increase in temperature was recorded in the summer months, where the average values exceed the indicators of the previous period by 2.25 °C. Significant changes are also observed in the winter-spring period: the temperature in January increased by 28%, in February by 52%, and in March by more than three times. Thus, the most intense warming occurs in the winter months and at the beginning of spring (Fig. 1).

Analysis of the precipitation regime showed their seasonal redistribution. During January-May in 2000–2024, the amount of precipitation increased by 79 mm (21%) compared to 1975–1999, while in the summer months (June-August) there was a decrease in precipitation by 73 mm (22%). This trend may contribute to the intensification of droughts in the warm period of the year (Fig. 1).

The results obtained can be used to assess the response of forest ecosystems of Polissya to modern climate change and predict their dynamics under conditions of further warming. The combination of detected changes in temperature and hydrothermal regimes forms new conditions for the functioning of forest ecosystems of Polissya and is an important factor in changes in their productivity, stability, and natural regeneration.

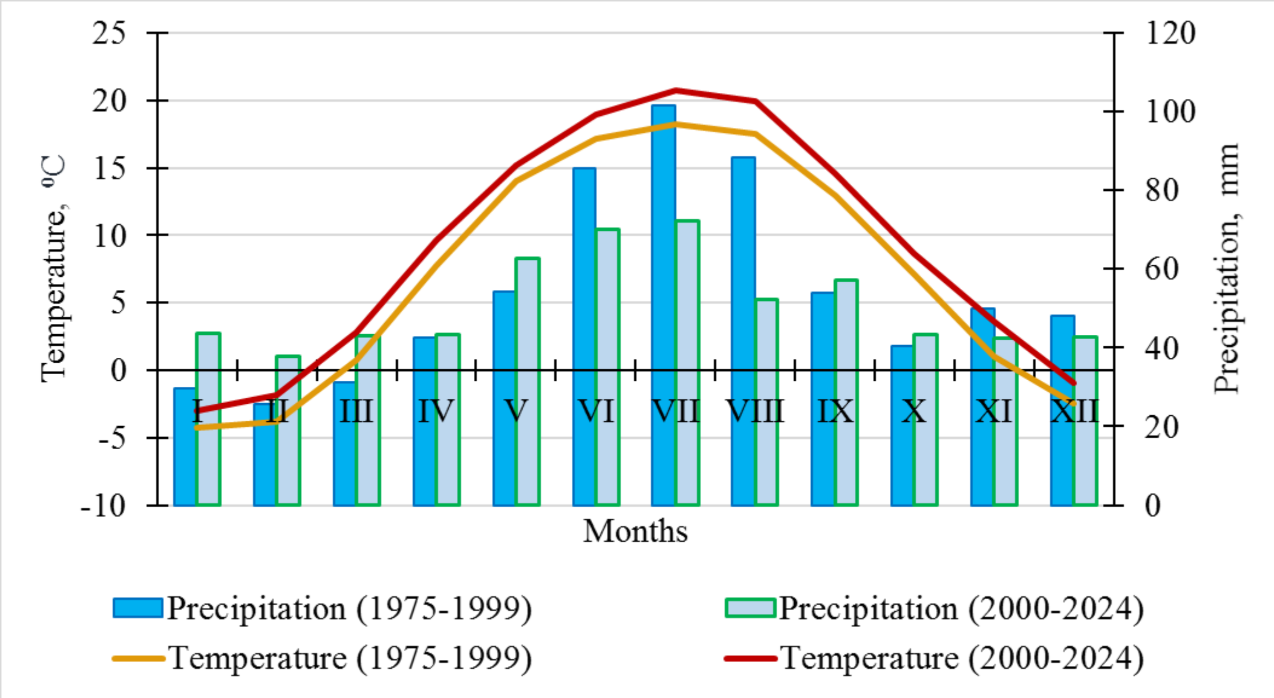

Fig. 1. Climatogram according to the Zhytomyr weather station.

Conclusions.

1. Analysis of the climatic data of the Zhytomyr weather station showed a steady warming trend: in 2000–2024, the average annual air temperature increased by 1.95 °C (21%) compared to 1975–1999.
2. A decrease in the average annual precipitation by 42 mm (6%) and its seasonal redistribution were established – an increase in the winter-spring period and a decrease in the summer.
3. The combination of detected changes in temperature and hydrothermal regimes forms new conditions for the functioning of forest ecosystems of Polissya and is an important factor in changes in their productivity, stability, and natural regeneration.

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LANDSCAPE ATTRACTIVENESS FOR THE TOURISTS NEEDS: ESSENCE, METHODS OF ASSESSMENT, IMPACT OF HOSTILITIES

The publication covers the essence of landscape attractiveness, the main approaches to its assessment, focuses on the change in indicators that attract tourists after outbreak of hostilities

Key words: landscape attractiveness, assessment of the territory's tourist attractiveness, impact of hostilities, Kharkiv region.

The landscape attractiveness as a concept is related to many sciences, in particular: landscape science, environmental psychology, spatial planning, geography of tourism, etc, and represents the results of perception (assessment) by observers of aesthetic and other qualitative landscapes values. The evolution of the interpretation of the essence of this term covers the association with such concepts as scenic beauty, visual quality of the landscape, aesthetic advantage/aesthetic appeal of the territory, perception of the environment (Daniel, 2001; Tveit et al., 2006). At the same time, in the works (Kaplan & Kaplan, 1989), coherence, complexity, readability and mystery are defined as key factors forming aesthetic preferences for landscapes. In modern research, the landscape attractiveness is considered as a multivariate quantity that encompasses visual aesthetics, ecological properties, cultural meanings and emotional reactions (Daniel & Vining, 1983; Ode, etc., 2008). Ukrainian researchers, in particular Grodzynskyi M.D. Savytska O.V, emphasized the systemic, structural and cultural dimensions of landscape attractiveness, integrating ecological, aesthetic and socio-geographical perspectives [1]. Hrynasiuk, A.R proposes to assess the attractiveness of landscapes by the factor-component structure, involving both the compositional characteristics of landscapes: relief, hydrography, flora and fauna, and anthropogenic activity, historical originality and authenticity of the territory, suitability of the territory for tourism development [2, 3].

The main methods for assessing the landscape attractiveness traditionally include the component-wise analysis (expert-based assessment, objective approach to assessment), which involves the assessment of landscapes structural components: landforms, surface waters, vegetation, anthropogenic activities, etc., according to specially developed scale of assessment. This approach in his research in the 60s of the twentieth century was used by D. Linton, who identified landforms and environmental objects located on them as two main components of the landscape [4]. Landscape Character Assessment (LCA) as a combination of physical qualities of the territory was considered Tveit et al. (2006), Carlson (2001), Martín and Otero (2012). Ukrainian researchers, as mentioned above, use expert assessment systems based on geomorphological expressiveness, diversity of vegetation, mosaic structure of the landscape, anthropogenic load, as well as the authenticity of the territory, its suitability for tourism development, etc. [1-3]. The disadvantage the component-wise analysis is the consideration of the landscape as a set of certain elements, and not a single whole.

The subjective approach to assessing the landscape attractiveness involves the use of emotional impact the landscape on a person as an evaluation criterion. For example, the Scenic Beauty Estimation (SBE) method developed by Daniel and Boster (1976), applies photographic stimuli and statistical modelling for linking the physical landscape features to human preferences. These techniques often use visual stimuli (photos, panoramas, VR scenes) and statistical regression to identify key predictors of benefits (Sevenant & Antrop, 2011). Among the Ukrainian scientists who used a subjective approach to assessing the landscape attractiveness, it is necessary to highlight the scientific paper Hrynasiuk, A.R., Novosad, O.V., Ilyin, L.V., Ilyina, O.V., & Ierko, I.V, where the subjective assessment of landscape attractiveness based on qualitative indicators and bipolar rating scales was also used, where people's (experts/respondents) survey results was used to evaluated the emotional perception of landscape properties [3], as well as the research of Golubtsov O.G., which summarizes methodological approaches and presents the results of analysis and evaluation of landscapes in the context of their perception by a person, including such features as: diversity, originality of landscapes and their aesthetic attractiveness [5].

In general, the analysis of scientific publications showed that list of features that increase the landscape attractiveness for tourists includes:

1. Natural components: dismemberment of the relief, water bodies, biodiversity;
2. Objects of historical, cultural and architectural heritage: cultural monuments, architectural objects, places related to the life of outstanding personalities, etc.

In the last time, GIS and spatial modelling have been added to the methods for assessing the landscape attractiveness, which allow assessing the attractiveness of the landscape by using functions of panoramic, modelling and landscape metrics (Bishop & Hulse, 1994; Оде та ін., 2009), and also the rapid development of assessing the landscape attractiveness based on artificial intelligence. Zhou, Zhang, and Zhu (2025) applied Multimodal Large Language Models to Google Street View images to assess urban visual appeal, achieving high compliance with human estimates.

Along with this, it should be pointed out the complexity of accurate and unambiguous calculation of the attractiveness of landscapes, especially according to the subjective approach, due to the difficulty of taking into account numerous individual characteristics of respondents, where a particular judgment is influenced by a number of factors, such as: the respondent's age, his attitude to nature, the level of education, and even cultural customs and traditions. So, Buijs, A. E., Elands, B. H. M., & Langers, F. (2009) explore how differ the ideas about nature and landscape preferences of immigrants from Islamic countries and the native Dutch.

The other problematic issue is the impermanence of previously identified level of landscape attractiveness: it might be changed over time as result of change opinion by group of people or due to change in certain external circumstances. For instance, after outbreak of hostilities in previously assessed territory. Research Zeid A. Kassouha (2019) on the example of Bosnia and Herzegovina indicated that, after hostilities, hybrid tourist landscapes are formed, where natural objects are combined with the memory of the war. These landscapes can become touristically attractive not only according to the existing criteria of attractiveness relevant for peacetime, but also as objects of war memory (memory tourism) [6]. Taking into account the constant interest of society in visiting places associated with military events, such places should be analyzed as an integral part of post-war landscapes. Thus, when allocating spaces - areas for assessing the landscape attractiveness when applying the Golubtsov O.G. methodology [5], it is necessary to single out and designate the territories containing objects of memory about military operations. In Kharkiv region, such objects include the ruins of Northern Saltivka in Kharkiv - one of the most destroyed residential areas of the city (example of an urban landscape); a forest with mass graves in Izyum (an example of a forest landscape); territories and coastal landscapes of the Pecheneg and Oskil reservoirs (examples of aquatic natural complexes); natural and anthropogenic complexes with preserved traces of war located in the border areas of Kharkiv region and places of active hostilities (Vovchansk, Kupyansk, etc.). A separate group consists of landscapes containing damaged/destroyed objects of tourist heritage, such as: architectural monuments of the IX century "Polovtsian Stone Women" in Izyum, the museum of G.S. Skovoroda in Skovorodynivka, architectural monuments of the XIX-XX centuries, old apartment buildings in Balakliya, Izyum, Berestyn and other settlements.

So, the landscape attractiveness, including for tourists, is a multidimensional concept formed by visual, environmental, cultural and psychological factors. Perspective direction of research includes conducting comprehensive landscape and geographical research that combines the analysis of physical changes in landscapes with an assessment of tourist perception, as well as further studies of the impact of hostilities on the landscape attractiveness for the tourists needs in Ukraine in general and within Kharkiv region in particular.

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ANNUAL DYNAMICS OF LANDSCAPE FIRES IN THE KHARKIV REGION IN 2025 UNDER CONDITIONS OF ARMED CONFLICT

A comprehensive analysis of the annual fire dynamics in the Kharkiv region in 2025 was conducted using satellite-derived data from the FIRMS (NASA) system. The study demonstrates that pyrogenic activity in the region is shaped by a combination of seasonal climatic factors, land-use practices, and the direct impacts of ongoing military operations. A total of 1,191 fires were recorded, affecting 47,495.03 hectares. The results reveal pronounced monthly fluctuations in both the number of fires and burned area: a spring peak in April (111 fires, 5,734.09 ha), a summer maximum in July–August (489 fires, 19,264.48 ha), and an absolute peak in September (409 fires, 14,751.1 ha). Over 80% of all fires occurred during the April–September period. The findings highlight that wartime ignition sources – missile strikes, artillery shelling, and explosions – significantly amplify natural and anthropogenic fire drivers. This analysis underscores the importance of continuous monitoring to assess ecological consequences for forest and steppe landscapes and to support future post-war restoration planning.

Key words: pyrogenic activity, wildfires, armed conflict, Kharkiv region, EFFIS, FIRMS, landscape transformation.

Pyrogenic activity is one of the key factors in the transformation of terrestrial landscapes, particularly in regions with a high level of anthropogenic pressure. The Kharkiv region belongs to areas where natural (climatic) and anthropogenic (agricultural) factors have traditionally determined the fire regime. However, since 2022, the region has been under conditions of ongoing armed conflict, which fundamentally changes the structure of pyrogenic load: traditional ignition sources (uncontrolled agricultural burns, careless handling of fire) are now supplemented by military factors – missile strikes, artillery shelling, ammunition detonation, and the burning of military equipment.

The relevance of this study is determined by the need for a quantitative assessment of the impact of hostilities on the region's fire regime. Understanding the temporal patterns of fire occurrence is essential for forecasting fire risks, assessing the cumulative load on forest and steppe landscapes, and planning measures for the post-war restoration of degraded areas.

The aim of the study is to analyze the annual dynamics of pyrogenic activity in the Kharkiv region for 2025, identify periods of the highest fire intensity, and determine the total burned areas under conditions of armed conflict.

Materials and methods. The study is based on satellite monitoring data from the FIRMS system (Fire Information for Resource Management System, NASA), obtained from MODIS and VIIRS sensors, for the period from January 1 to December 31, 2025 [1]. The analysis covers two quantitative indicators: the total number of fires (n) and the area burned (S, ha), on a monthly basis. Statistical data processing involved determining monthly and seasonal peaks of activity, calculating the share of each month in the annual fire structure, as well as qualitatively comparing the obtained dynamics with probable causes of ignition (natural, anthropogenic, military).

Results. During 2025, according to FIRMS data, 1,191 fire incidents were recorded in the Kharkiv region, with a total burned area of 47,495.03 hectares. The temporal distribution of fires reveals a clear seasonal cyclicity: winter dormancy (January–February), spring increase (March–April), summer peak (July–August), and autumn maximum (September). Monthly dynamics of fire incidents and burned area are detailed in Fig. 1.

Fig. 1. Monthly Dynamics of Fire Incidents and Burned Area in 2025

As can be seen from Fig. 1, the monthly distribution of fires is markedly uneven. Synchrony is observed between the increase in the number of fires and the growth of burned areas; however, during peak months (April, July, September), a disproportion between these indicators is evident, indicating the occurrence of individual large fires with significant spread areas.

The annual cycle of pyrogenic activity begins with minimal indicators during the winter period. In January, only 2 fires were recorded over 39.93 ha, and in February – 4 fires (112.26 ha). Low temperatures, snow cover, and increased humidity prevented fire spread, which corresponds to the climatic norm for the region.

In March, a gradual increase in activity is observed: 12 fires, 555.01 ha. This is associated with snowmelt, drying of last year's vegetation, and the start of agricultural work. April demonstrates a sharp increase in indicators – 111 fires (9.3% of the annual total) and 5,734.09 ha (12.1% of the annual area). This increase is due to a combination of traditional factors (spring burns) and military actions, which in some areas made timely firefighting impossible.

In May, activity decreases slightly: 60 fires (2,754.56 ha); in June – 54 fires (1,561.94 ha). This decline is likely related to the regrowth of green mass and increased soil moisture, which reduces landscape flammability.

July marks the beginning of the summer peak: 279 fires (23.4% of the annual total) and 11,970.6 ha (25.2% of the annual area). August is also characterized by high activity – 210 fires, 7,293.88 ha. High temperatures, lack of precipitation, and the accumulation of dry biomass created conditions for rapid fire spread, while ongoing military operations served as an additional source of ignition.

The absolute maximum was recorded in September: 409 fires, accounting for 34.3% of the annual total, and 14,751.1 ha of burned area (31.1% of the annual total). This month is critical not only due to the highest number of incidents but also due to the largest area burned. In the autumn of 2025, the accumulation of dry vegetation, high air temperatures in the first half of the month, and the intensity of hostilities caused an unprecedented surge in pyrogenic activity.

In October, a sharp decline occurs: 50 fires (2,721.67 ha), which is explained by lower temperatures, increased humidity, and autumn precipitation. November and December are characterized by a complete absence of recorded fires, corresponding to the seasonal dormancy.

Conclusions. In 2025, pyrogenic activity in the Kharkiv region was characterized by 1,191 fires and a total burned area of 47,495.03 hectares. The temporal distribution of fires confirms a distinct seasonal dynamic: a minimum in the winter months (January–February), a spring increase with a peak in April (111 fires, 5,734.09 ha), a summer maximum in July–August (489 fires, 19,264.48 ha), and an absolute peak in September (409 fires, 14,751.1 ha). Over 80% of all fires and burned areas occurred during the April–September period. A disproportion between the number of fires and the burned area was observed during the peak months (April, July, September), indicating the occurrence of individual large fires with significant spread areas. This may result from both natural conditions (accumulation of combustible materials, dry weather) and military factors that complicate timely firefighting.

Military operations serve as a significant additional source of ignition, particularly in areas close to the contact line and during periods when natural fire danger is moderate. This underscores the need to incorporate the military factor into fire risk prediction models. The obtained results demonstrate that the highest level of fire danger occurs in July–September; therefore, it is advisable to concentrate maximum efforts on monitoring, prevention, and rapid response during this period to minimize ecological and economic losses.

The conducted analysis provides a basis for long-term monitoring of pyrogenic landscape transformation, assessment of the cumulative impact on forest and steppe ecosystems, and the development of strategies for post-war restoration of degraded areas. Further research should focus on spatial fire modeling and quantitative assessment of ecological consequences.

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ECOLOGICAL ANALYSIS OF SURFACE WATER QUALITY IN THE SOUTHERN BUG RIVER WITHIN THE MYKOLAIV REGION

This study presents an ecological assessment of the surface waters of the Southern Bug River within the Mykolaiv region under conditions of anthropogenic and military impact. The dynamics of key water quality indicators were analyzed and a regression-based forecast of major pollutants, including phosphate and ammonium ions, sulfates, chlorides, BOD_5, and dissolved oxygen, was developed. The results help to evaluate current environmental risks and support the development of measures for improving water quality during the post-war recovery period.

Key words: surface waters, ecological analysis, anthropogenic pressure, water pollution, correlation analysis, regression modeling, forecasting.

Under the conditions of the ongoing war in Ukraine, issues related to water supply and water security have become increasingly urgent. Ukraine possesses a developed water management infrastructure that includes large multifunctional reservoirs, dams of hydroelectric power plants, cooling systems for nuclear power plants, and other strategic facilities. Military actions pose significant environmental risks to this infrastructure and may lead to serious ecological consequences. Therefore, studying anthropogenic impacts, including those associated with military activities, is particularly important for the Southern Bug River, which serves as a key natural resource supporting the ecological stability, social needs, and economic development of the Mykolaiv region.

The aim of this study is to evaluate the anthropogenic and military influences on the surface waters of the Southern Bug River within the Mykolaiv region used for drinking water supply, as well as to forecast possible changes in the ecological situation and to propose measures for improving water quality during the post-war recovery period.

The research applied comparative analysis methods and computer-based statistical processing of monitoring data. Correlation analysis was used to determine relationships between indicators, while regression modeling was employed to predict future changes in water quality parameters.

The study presents the results of assessing the impact of anthropogenic and military pressures on the ecological state of surface waters of the Southern Bug River within the Mykolaiv region. The monitoring point was located at the 153 km section of the river near the village of Oleksiivka (Pankratove), which serves as the drinking water intake for the city of Yuzhnoukrainsk (Mykolaiv region) (47°86′87″ N, 31°11′97″ E).

Based on regression models, a forecast of anthropogenic load from the main pollutants was developed. Predicted concentrations were determined for phosphate ions, ammonium ions, sulfate ions, chloride ions, biochemical oxygen demand (BOD_5), and dissolved oxygen in the surface waters of the Southern Bug River.

The research provides a comprehensive ecological assessment of surface water quality in the Southern Bug River near the city of Yuzhnoukrainsk (Mykolaiv region) for the period 2003–2024.

Particular attention was paid to the dynamics of key hydrochemical indicators, including concentrations of phosphate ions, ammonium, sulfate ions, chloride ions, biochemical oxygen demand (BOD_5), and dissolved oxygen.

The results indicate that the aquatic ecosystem of the Southern Bug River in the Oleksiivka (Pankratove) area experiences a persistent biogenic and organic load, which intensified during the period from 2020 to 2024.

An increase in nitrogen compounds, phosphates, surfactants, and herbicides suggests a continuous influence of domestic wastewater and agricultural runoff. At the same time, trends in COD/BOD_5 values combined with decreasing dissolved oxygen concentrations indicate deterioration of aeration conditions and a growing risk of hypoxic processes in the river ecosystem.

Regression-based forecasting allowed estimating future levels of anthropogenic pressure from key pollutants and determining projected concentrations of phosphate ions, ammonium ions, sulfate ions, chloride ions, BOD_5, and dissolved oxygen in the surface waters of the Southern Bug River.

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POSSIBILITIES OF USING WATER FROM CENTRALIZED WATER SUPPLY IN THE CITY OF DRUZHKIVKA

The results of the study of tap water samples from a centralized water supply source in different districts of Druzhkivka are presented. It was determined that the water samples exceeded the maximum permissible limit by 1.6 times for hardness, and by 2 times for chlorides. Given the existing excesses of hardness and chlorides, the use of tap water for drinking purposes is not recommended due to the possible impact on human health.

Key words: tap water, centralized water supply, water treatment, water hardness, nitrites, chlorides.

Martial law in the country provokes an increase in the scale of the problem of access to drinking water. Under conditions of military influence, water supply to settlements is significantly complicated or impossible. The use of clean water is also limited by its quality, which deteriorates due to insufficient purification [4]. In conditions of post-war reconstruction, the problem of limited access and quality of drinking water will become a priority. The restoration of cities that have undergone significant military influence is based on the complete reconstruction of water supply systems. Post-war reconstruction will include monitoring water quality, resuming water intake from surface water bodies, restoring water purification, water treatment and water supply systems to cities and settlements, and expanding the centralized water supply network. This problem is currently particularly acute in frontline settlements.

The object of the study was the quality indicators of tap water in the frontline city of Druzhkivka in the Donetsk region. Water supply in the city is limited and hourly according to schedules. There are 5 microdistricts and a private sector in Druzhkivka. Their water supply is provided through the city water utility, which takes water from the Siverskyi Donets-Donbas canal. To determine the suitability of tap water for drinking purposes, 7 water samples were taken from a centralized water supply source in 5 microdistricts of the city of Druzhkivka (microdistricts No. 7, No. 8, No. 9, No. 10 and the central one). Sampling took place in the summer of 2025.

Laboratory analysis of water samples was performed in the educational and research laboratory of analytical environmental research of the educational and scientific institute of ecology, green energy and sustainable development of V. N. Karazin Kharkiv National University. The results obtained were compared with the regulatory indicators of the "State Sanitary Norms and Rules..." [1] for tap water (Appendix 2, table 1.1 sanitary and chemical indicators of safety and quality of drinking water, valid from April 2022).

According to the results of the laboratory stage of research, chlorides, nitrates, nitrites, pH and hardness were determined in tap water samples. Nitrates were not detected in tap water samples at all. The obtained nitrite concentrations in tap water samples were on average 0.01-0.04 mg/liter, which corresponds to the established MPC limits of 0.1 mg/liter. The pH values in tap water samples are 7.008-8.01 pH units and are within the MPC limits (6.5-8.5 pH units).

The results of the laboratory analysis determined that the standards were exceeded for only two indicators. The hardness analysis of tap water samples with a value of 11.0 mmol/liter demonstrates an excess of the standard (≤7.0 mmol/liter) by 1.6 times, and the determined chloride concentrations of 520 mg/liter exceed the norm by 2 times (≤250 mg/liter).

Thus, the detected excesses of hardness indicators make it impossible to use tap water as drinking water without additional water treatment. The use of water with high hardness indicators can lead to the accumulation of salts in the human body. The consequences of this can manifest themselves in the form of diseases of internal organs. It is also not recommended to use hard water for external use, which can negatively affect the skin and hair. Excess hardness indicators can disrupt the acid balance of the skin, cause itching and exacerbation of such a serious disease as eczema. It is known from publications that in most cases, doctors do not associate water hardness with the formation of kidney stones, however, some experts in their studies suggest possible risks of kidney stones during long-term use of water with increased hardness indicators. Also, doctors, studying the effect of hard water on the digestive system, note a violation of this process with the appearance of heartburn, dry cough, chest pain or the appearance of ulcers. Of the positive factors, it is still known that the presence of calcium in drinking water, which is well absorbed by the human body, can positively affect the quality of bones and reduce the risks of osteopathic diseases. Also, increased water hardness affects the heating elements of household appliances (dishwashers and washing machines), and scale quickly appears in kettles, plaque forms on plumbing fixtures, which creates problems when using the devices. To soften water, you can use a three-stage filter to reduce hardness, an ion-exchange softener, a reverse osmosis filter [2].

Chloride concentrations above the established MPC make tap water unsuitable for consumption, as it can cause gastrointestinal upset, and it is also not recommended for cooking. To reduce chloride concentrations in tap water, it is also advisable to use the reverse osmosis method [3], the essence of which is represented by the process of mechanical water purification at the molecular level through special membranes that allow water molecules to pass through, while retaining all other impurities (up to 99%).

Given the determined indicators of exceeding the standards for hardness and chlorides in water samples, the use of tap water in the city of Druzhkivka for drinking purposes is not recommended.

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ECOLOGICAL CONSEQUENCES OF WAR

The study considers the consequences of Russian-Ukranian war from the point of view of environmental damage. Much attention is paid to the Kakhovka Hydroelectric Power Plant damage and its consequences.
Key words: war, damage, agricultural productivity, flooding.

Today, a very big war, which Russia leads, is still going on in the territory of Ukraine. At the moment, Russia causes significant damage to our country environment. The consequences are serious, for example: a blow to the Kakhovka Hydroelectric Power Plant. The explosion of HPP has caused damage to the environment of the southern part of Ukraine. First of all, what happened, was a severe flooding of the area that most of the villages along the Dnipro River were flooded. In addition, explosion caused a rise in the water level of the Dnipro River.

The flooding damaged the land and also severely disrupted agricultural productivity. Russian terror-attack caused an outbreak of a dangerous disease called colera. As a result of which, the local population suffered, having already been affected by the flooding. After the flood, the water became heavily contaminated and began flowing into the Black Sea, after which Ukraine's neighbours found human belongings, dead animals, and unexploded shells. Prior to this, the explosion at the Kakhovka HPP caused a risk of water shortage for the Zaporozhia Nuclear Power Plant, which is located in the city of Energodar.

If the talk about Zaporizhia Nuclear Power Plant, so as of today, Nuclear Power plant locates under the control of russian army, which hides military equipment near the reactor blocks. This raises many questions for the IAEA, which decided to ignore safety. If the Nuclear Power Plant explodes, this will be the most terrible environmental disaster, incomparable to the Chernobyl explosion.

Firstly, what happens after the explosion, will be the release of radioactive elements into the air, which will spread across the entire territory of Ukraine and also reach Ukraine's nearest neighbors. In addition, the spill of radioactive contamination of the river Dnipro would severely pollute the water and make the nearby lands of Zaporizzska, and especially Khersonska regions, unsuitable for farming. If the radioactive water harms the lands of Ukraine, then the risk that it will flow from the Dnipro River into the Black Sea will be high.

As a result, the water in the Black Sea could become heavily contaminated with radiation. This, of course, will have very serious consequences not only for Ukraine, but for the whole Black Sea region.

In conclusion, I want to say that the environmental consequences of Russian terror for Ukraine are serious, and what is most surprising is that organizations such as the IAEA only express concern.

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TRANSFORMATION OF WATER AND LAND RESOURCES IN THE LOZOVA DISTRICT, KHARKIV REGION, UKRAINE: THE IMPACT OF CLIMATE CHANGE AND WAR

The paper analyzes the water and land resources of the Lozova district, Kharkiv region, identifies the main environmental problems and the impact of hostilities. Measures for rational use of nature and restoration of resource potential are proposed.

Key words: water resources, land resources, applied geographical analysis, environmental problems, soil degradation, war impact, sustainable development.

Lozova district is located in the southeastern part of the Kharkiv region and is one of the key agrarian and industrial districts of the region, where the natural resource potential directly determines the socio-economic development of the area. Applied geographical analysis of water and land resources of the district in the context of modern climatic and military challenges makes it possible to comprehensively assess the transformation processes taking place in the natural environment and determine priority directions for adaptive management.

The climate of the area is temperate continental with a tendency to increase average annual temperatures. The average temperature in July is about +21°C, in January, about -5°C, but in recent years there has been an increase in temperature indicators and an increase in the number of extreme weather events – prolonged droughts, heat waves and heavy rainfall. The annual amount of precipitation is from 450 to 550 mm with a predominance in the warm season, but their distribution becomes uneven. Such a transformation of climatic parameters directly affects the hydrological regime and the state of land resources.

Water resources of the district are formed by the transit flow of the Siverskyi Donets river, local river flow, groundwater and artificial reservoirs. Within the district, there are a significant number of ponds and reservoirs that are used for water supply, fish farming and irrigation. However, the region is characterized by general water availability accounts for only about 1.8% of Ukraine's total water resources in Ukraine, which indicates high vulnerability to climate change [1].

As a result of the increase in temperature and the decrease in effective moisture, shallowness waters of small rivers and ponds, a decrease in the groundwater level and a deterioration in water quality are observed. A decrease in flow contributes to the accumulation of pollutants and the development of eutrophication processes, which is manifested which is manifested in mass summer algal blooms. Thus, applied hydroecological analysis indicates the need to introduce systematic monitoring of hydrochemical indicators and water balance of the territory.

The land resources of the Lozova district are represented mainly by ordinary and typical chernozems, which have high natural fertility. However, modern climatic changes intensify degradation processes. Uneven precipitation leads to the development of water erosion on the slopes, and frequent droughts are deflationary processes and a decrease in soil moisture reserves. Processes of dehumification, soil compaction, and a decline in agrophysical properties are observed. According to regional reports on the state of the environment, the region is characterized by an increase in the area of degraded lands due to the irrational structure of crops, insufficient application of organic fertilizers and insufficient implementation of soil protection technologies [2].

An additional powerful factor in the transformation of natural resources was the hostilities that began in 2022. The Lozova city territorial community has suffered missile strikes and infrastructure damage, which led to damage to water supply facilities, soil contamination with ammunition fragments and an increase in man-made load on the environment. Disruption of sewage treatment facilities and water supply networks creates risks of secondary pollution of surface and groundwater. In addition, the displacement of the population and the change in the structure of land use affected the agrolandscape organization of the territory. Thus, the war factor has exacerbated existing climate risks and formed new environmental challenges [3].

Applied geographical analysis allows us to identify a number of priority areas of resource management. In the field of water use, it is advisable to introduce integrated water resources management at the basin level, restore small rivers through channel rehabilitation in compliance with environmental standards, create coastal protection zones and optimize water intake. A promising direction is artificial groundwater replenishment and the introduction of water-saving technologies in agriculture, in particular drip irrigation.

In the field of land use, the transition to adaptive agriculture is important: minimal or zero tillage, the use of green manure, agroforestry, restoration of forest belts and contour land-use planning and land reclamation measures. It is expedient to develop a local geographic information system (GIS) for monitoring land and water resources using Earth remote sensing data to assess the dynamics of soil moisture, the state of crops and changes in the hydraulic network.

A comprehensive strategy for sustainable nature management in the Lozova district should combine climate adaptation, environmental rehabilitation of territories affected by hostilities, and the introduction of modern geoenvironmental monitoring tools. This approach will help reduce degradation processes, restore ecosystem functions of water bodies and increase the resilience of agricultural landscapes to climate change and anthropogenic pressures.

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RESTORATION OF LAND DAMAGED BY MILITARY ACTION

This publication addresses the issue of restoring land damaged by military operations in Ukraine. It identifies the main types of soil degradation caused by the war, including mechanical damage, compaction, chemical contamination, and the presence of explosive residues. Particular attention is paid to agricultural, forest, protected, and water protection lands, whose degradation threatens food security, biodiversity, and ecological stability. Based on a review of scientific sources, the text summarizes the main approaches to land restoration, with an emphasis on demining, recultivation, remediation, environmental monitoring, and the implementation of sustainable land use principles.

Keywords: land restoration; war impacts on soil; recultivation; soil contamination; agricultural land; environmental recovery; sustainable development.

Fertile soil is one of the most important natural resources for both Ukraine and the world, as Ukraine accounts for about one-third of the world's black soil [1]. However, as a result of military actions, these valuable resources are suffering significant losses, as it is the upper, most fertile layers of soil that suffer the most [1].

The problem of restoring land damaged by military actions is extremely relevant in the current Ukrainian reality. The scale of the fighting is leading to soil degradation, mechanical damage, compaction, and chemical contamination of the territory—phenomena that negatively affect the physical, chemical, and biological properties of the soil cover. Thus, soils affected by combat operations and the use of heavy equipment show changes in granulometric composition, contamination with heavy metals, and reduced fertility, which complicates their further use in agriculture [2].

War also leads to the appearance of a large number of explosive craters, ammunition fragments, and chemical residues, which can have a long-term toxic effect on the soil and the environment. Affected areas require special monitoring, cleanup, and physical and chemical rehabilitation measures before they can be put back into cultivation or the ecosystem cycle. Land and soil restoration is: a legally guaranteed system of measures; aimed at returning them to their original quality; carried out through recultivation, conservation, reclamation, and other measures provided for by law [3].

According to Ukrainian land legislation, land is divided into nine categories:

1) agricultural land;
2) land for residential and public development;
3) land for nature reserves and other nature conservation purposes;
4) land for health purposes;
5) land for recreational purposes;
6) land for historical and cultural purposes;
7) land for forestry purposes;
8) land for water resources;
9) land for industry, transport, communications, energy, defense, and other purposes.

In modern Ukraine, agricultural land is in urgent need of restoration, as it ensures the country's food security and accounts for a significant share of its export potential. Damage to the topsoil, pollution, and mining of these areas directly affect crop yields and the stability of agricultural production [4].

Equally important are lands belonging to the nature reserve fund and forestry, as their degradation leads to a loss of biodiversity, disruption of ecosystem relationships, and a decline in the ecological sustainability of regions. The restoration of such areas is of long-term importance for maintaining ecological balance and climate stability.

Water reserve lands also require special attention, as their pollution creates risks of toxic substance spread, affects drinking water quality, and disrupts the functioning of aquatic ecosystems.

The ecological restoration of land after hostilities is not only an environmental but also a socio-economic necessity: it affects food security, the quality of life of the population, the restoration of the agro-industrial complex, and the sustainable development of regions in the post-war period.

A review of scientific sources has made it possible to systematize the main directions for the restoration of disturbed land. In particular, for areas with mechanical damage, the priority measures are demining and technical recultivation; for compacted soils – deep loosening and structure-forming agrotechnical measures; in the case of chemical contamination – conducting an agrochemical survey and applying remediation methods [1].

The sources analyzed also emphasize the need to prioritize restoration work depending on the degree of damage to the territories and potential environmental risks. A comprehensive approach combining technical recultivation, environmental monitoring, and the introduction of sustainable agricultural technologies is identified as the most effective for post-war rehabilitation of land resources [1, 5].

Understanding these challenges allows for better preparation to overcome them and reduce potential risks. The restoration and reclamation of land affected by military operations is an extremely important task for Ukraine [1].

The war has caused extensive damage to soils in many areas, threatening the country's agricultural potential and environmental security.

Therefore, the restoration of land damaged by military operations should involve the creation of soil and environmental conditions in the affected areas that correspond to the biological characteristics and ecological needs of plants, taking into account the zoological and microbial components in relation to their intended use [6]. Under current conditions, the restoration of land damaged by military operations should be carried out on the basis of the principles of priority, environmental safety, and long-term sustainability of agricultural landscapes.

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MILITARY TECHNOGENESIS: LANDSCAPE TRANSFORMATION AND LONG-TERM ECOLOGICAL DEFORMATIONS

Modern warfare causes long-lasting landscape changes that disrupt ecosystems and soil functions. Post-conflict recovery needs soil restoration, water management, and ecological rehabilitation.

Key words: Military technogenesis, landscape transformation, soil erosion, groundwater, ecosystem restoration, soil compaction, military ecology, war impact.

Introduction: The scale of physical impact on ecosystems. Modern wars with high intensity change the environment more than just by chemical pollution. Scientists now use the term "military technogenesis." This is a process where the physical shape of the Earth's surface changes very quickly because of military activity. Chemical pollution can disappear over time, but physical changes to the land stay for many years and hurt how ecosystems work. Building long lines of trenches and anti-tank ditches turns natural landscapes into artificial systems where water and energy cannot move normally.

Mechanical destruction of the land and erosion risks. Building military structures moves huge amounts of soil. Experts say that building just one kilometer of a deep trench moves more than 1,500 cubic meters of dirt. If we look at hundreds of kilometers of the front line, it means moving millions of tons of soil. This is similar to the work of large industrial mines.

These deep cuts in the ground become the start of erosion. In the steppe regions or on hills, trenches collect rainwater during storms. They act like artificial channels. The water washes the soil away quickly, and the trenches turn into deep ravines. In just one season, such a "military ravine" can become 2–3 times wider, destroying good farmland and changing the natural look of the area.

Water problems and "second-order" consequences. Deep military structures also work as unplanned drainage systems. They catch surface and underground water, which leads to two big problems. First, the land above the trenches becomes too dry because the trench "pulls" the moisture out of the upper soil. This is a "second-order" consequence: plants around the trenches start to die because they do not have enough water. This is very bad for farms.

Second, in low areas (like the Polissia region), trenches often reach the groundwater. This creates standing water and swamps. These changes are very stable. Even if we fill the trenches with dirt later, the water still does not move correctly underground. This can cause the ground to sink or become too wet for many years.

Soil compaction and biological isolation. The movement of heavy tanks and trucks creates a specific problem – soil compaction. The weight of modern military vehicles is so high that it presses the soil down to a depth of 80 cm. This destroys the small holes in the soil, so water and air cannot go inside. Because of this, "technological deserts" appear. Even after the war, plants cannot grow there naturally because their roots cannot break through the hard ground.

Another "second-order" consequence is the fragmentation of the environment. Long lines of ditches and fences become walls for small animals and reptiles. They cannot move to find food or partners. Also, trenches become traps: small animals fall inside and often die because they cannot get out. At the same time, the moved dirt is a perfect place for "invasive" plants (like ragweed). These bad weeds grow very fast and push out the local flowers and grass.

Ways to solve the problem and restoration. To fix the land after military technogenesis, we need a complex plan. It is not enough to just fill the holes. Possible solutions include:

1. 3D Modeling: Using drones and satellite photos to see exactly how the land changed. This helps to calculate how much soil we need to fix the area.
2. Step-by-step restoration: When filling the trenches, we must put the soil back in layers. The most fertile "topsoil" must be put last so that plants can grow again.
3. Phytomelioration: Planting special crops with very deep and strong roots. These roots help to break the hard, compacted soil and bring air back into it.
4. Water balance: Building special barriers inside the filled trenches to stop the underground drainage and return the water to its natural level.

Conclusion. Military technogenesis creates long-term risks that people often forget during a war. However, without a plan to fix the landscape, these areas will stay as "ecological disaster zones." We cannot use this land for farming or living safely. Post-war recovery must be professional. The goal is not just to make the ground flat again, but to return the natural life and water balance to the land.

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COMPARISON OF NDVI IN DIFFERENT PERIODS TO ASSESS CHANGES IN THE STATE OF VEGETATION (KUPYANSK DISTRICT)

Based on the use of satellite images of the Copernicus Sentinel-2 platform for different time periods, a comparative analysis of the distribution of NDVI values was carried out and trends in the density of vegetation cover due to the impact of hostilities were identified. The results obtained can be used to monitor the ecological state of the territory and assess the processes of ecosystem restoration.

Keywords: environmental consequences of the war, NDVI, satellite monitoring, degradation of vegetation cover, Sentinel-2, geographic information systems (GIS), environmental rehabilitation.

Studies of NDVI histograms for the Kupiansk district for 2021, 2022 and 2024, obtained using satellite images (Fig. 1), confirm the impact of hostilities on ecosystems. The graphs below show the distributions of the NDVI index for the region near the city of Kupyansk in the Kharkiv region, obtained from satellite imagery for three different dates: September 15, 2021, September 15, 2022, and September 19, 2024 [2].

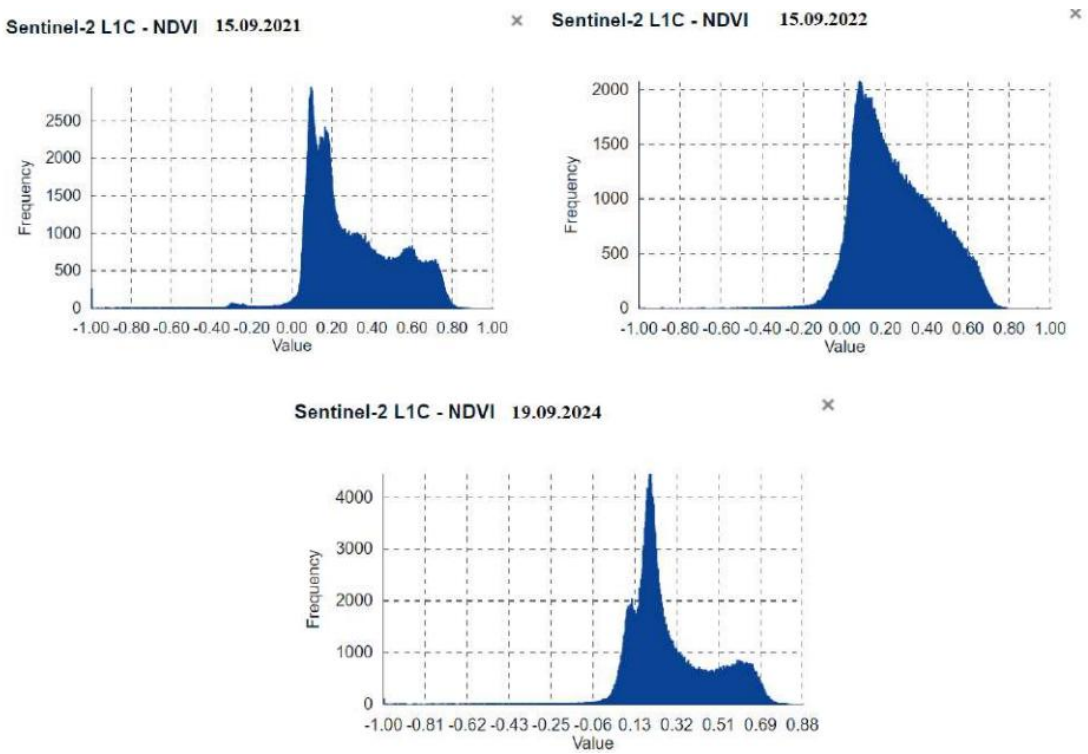

Fig. 1. Investigation of the NDVI index using satellite images in Kupiansk district of Kharkiv region

The horizontal axis (Fig. 1) displays the values of the NDVI index, which ranges from -1 to +1. Higher NDVI values (closer to 1) indicate the presence of dense and healthy vegetation, while lower values (closer to -1) indicate no vegetation or severe damage. The vertical axis (Frequency) displays the number of pixels in the image that have the corresponding NDVI value. The higher the frequency (number), the larger the area of the territory with the appropriate level of vegetation cover [2].

On the graph for 2021 (09/15/2021), the maximum frequency is observed for NDVI values in the range from 0.2 to 0.5. This indicates a moderate level of vegetation, with a predominantly healthy cover, which is typical for late summer – early autumn [2].

The chart for 2022 (15.09.2022) shows a significant shift to lower NDVI values. The peak of the distribution is located in the region of values of 0.1–0.4, which indicates a weakening or degradation of the vegetation cover. This is probably due to hostilities that led to damage to the ecosystem. The chart for 2024 (09/19/2024) shows a recovery, although the peak of NDVI is in the range of 0.2–0.5. However, the overall level of NDVI remains lower compared to 2021 figures, which may indicate a gradual recovery of vegetation after hostilities, but not yet sufficient. The scatterplot shows the change in the mean NDVI value for the Kupiansk district from 2021 to 2024 [1].

Analysis of the percentage change in NDVI shows [3]:

- The decrease in NDVI from 2021 to 2022 is -71.43%. This is a significant drop that indicates severe damage to vegetation due to hostilities and fires.
- Changes from 2021 to 2024: -42.86%. Despite some increase after 2022, NDVI levels remain below the 2021 values, indicating ongoing impacts on the ecological system.

The 2021 NDVI has a larger peak closer to positive values, while the 2022 and 2024 distributions are shifted closer to 0, suggesting less vegetative cover in these years. This graph shows a comparison of the distribution of NDVI index values for three different years: 2021, 2022, and 2024 [2].

It can be used to analyze changes in vegetation cover during this period. Horizontally, NDVI values are plotted, which range from -0.4 to 0.8. The NDVI value is a numerical indicator of the density of vegetation cover. Higher NDVI values (closer to 0.8) indicate a denser and more viable vegetation cover where plants are healthy and actively photosynthesize [3].

Lower NDVI values (closer to 0 or even negative values) indicate degradation or absence of vegetation. This may indicate dead vegetation or exposure to negative factors such as wildfires, fighting, or drought. Vertically (Y-axis) is represented by the frequency of values (Density), that is, how many times a certain value of NDVI occurs in the corresponding year. [1].

The analysis of the histogram makes it possible to draw the following conclusions (Fig. 2) [3]:

- Green NDVI Distribution (2021) – Most NDVI values are in the range of 0.2 to 0.6. This indicates a stable vegetation cover that was viable this year.
- Red NDVI distribution (2022) – the distribution is shifted to the left, with the highest frequency of NDVI values closer to 0. This indicates a significant decrease in the density of vegetation cover compared to 2021. Perhaps this is the result of hostilities or other environmental disasters.
- Blue distribution of NDVI (2024) – the downward trend of NDVI continues. Most values are in the range from 0 to 0.3, which indicates damaged or even

missing vegetation cover. This may be due to the prolonged impact of hostilities and the deterioration of the environmental situation in the region.

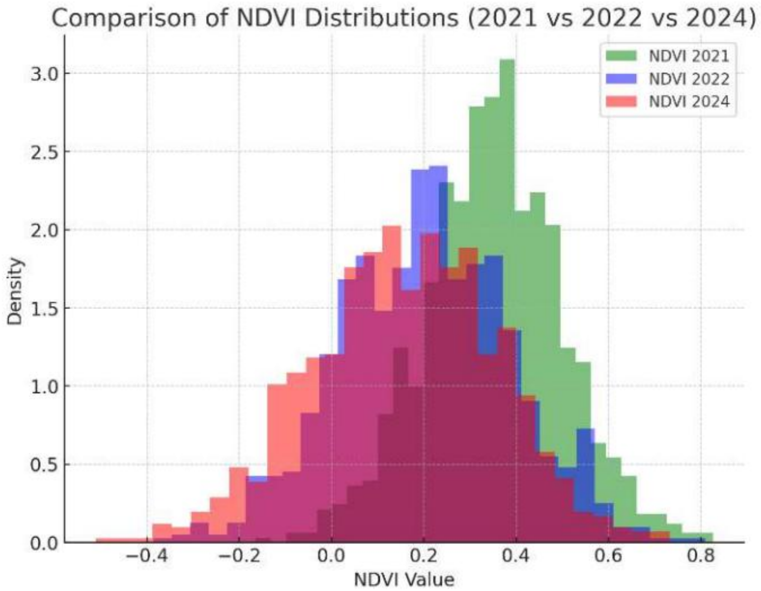

Fig. 2. Comparison of the distribution of the NDVI index for 2021, 2022 and 2024 in the Kupiansk district of Kharkiv region

Thus, the graph clearly shows how the NDVI decreases from 2021 to 2024. This may indicate a significant deterioration in the vegetation cover in the region, probably due to the impact of hostilities. In 2021, vegetation was in a more viable state, but in 2022 and 2024 there is a sharp decline in the number of healthy plants, which may be due to forest fires, hostilities or other environmental factors. This data is useful for monitoring the environmental consequences of the war and planning measures to restore ecosystems

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ECOLOGICAL ASSESSMENT OF THE WIND REGIME IN THE URBANIZED AREA OF KHARKIV

This article considers the problem of wind regime, which plays a crucial role in shaping both favorable and unfavorable air quality conditions in Kharkiv. Seasonal and interannual patterns of wind speed from 2005 to 2021 have been identified, which influence the dispersion or accumulation of pollutants. Periods with winds that effectively disperse pollutants have been identified as winter-spring (December to March). Conversely, periods when conditions favor pollution buildup (wind speeds up to 1 m/s) occur most frequently during the cold season and certain autumn months. The study also uncovered cyclic patterns in the oscillation of the wind speed regime.

Keywords: wind, atmospheric air, pollution, emissions, self-cleaning capacity, dispersion, urban landscape.

The relevance of studying wind in urban landscapes stems from its function as a key mechanism of atmospheric self-purification through the dispersion of transport- and industry-related emissions. However, urban development typically reduces average wind speed by 10–20%, thereby increasing the frequency of calm conditions and contributing to the formation of hazardous environmental situations. In particular, under calm conditions (0–1 m/s), pollutant concentrations increase due to limited air exchange, especially in the presence of temperature inversions. At the same time, at wind speeds of 4–6 m/s, a secondary pollution maximum may be observed in urban areas, associated with emissions from elevated sources under conditions of unstable atmospheric stratification [1].

For the present study, we selected the wind regime of Kharkiv for the period 2005–2021. During the analysis, the authors constructed graphs based on observational data to assess the frequency of wind conditions that promote pollutant dispersion, as well as those that lead to their accumulation near emission sources [2]. The graphs present the following elements: the average wind speed over the study period (linear trend), the distribution of average daily wind speeds by year (points color-coded according to the observation year), and threshold lines whose intersections define conditions favorable to environmental pollution. Wind speeds exceeding 6 m/s correspond to conditions conducive to pollutant dispersion, whereas speeds below 1 m/s indicate conditions favorable to pollutant accumulation near emission sources. As wind speed values in the graphs are expressed in km/h, the threshold values were converted accordingly: 1 m/s corresponds to 3.6 km/h, and 6 m/s corresponds to 21.6 km/h. The corresponding graph is presented in Fig. 1.

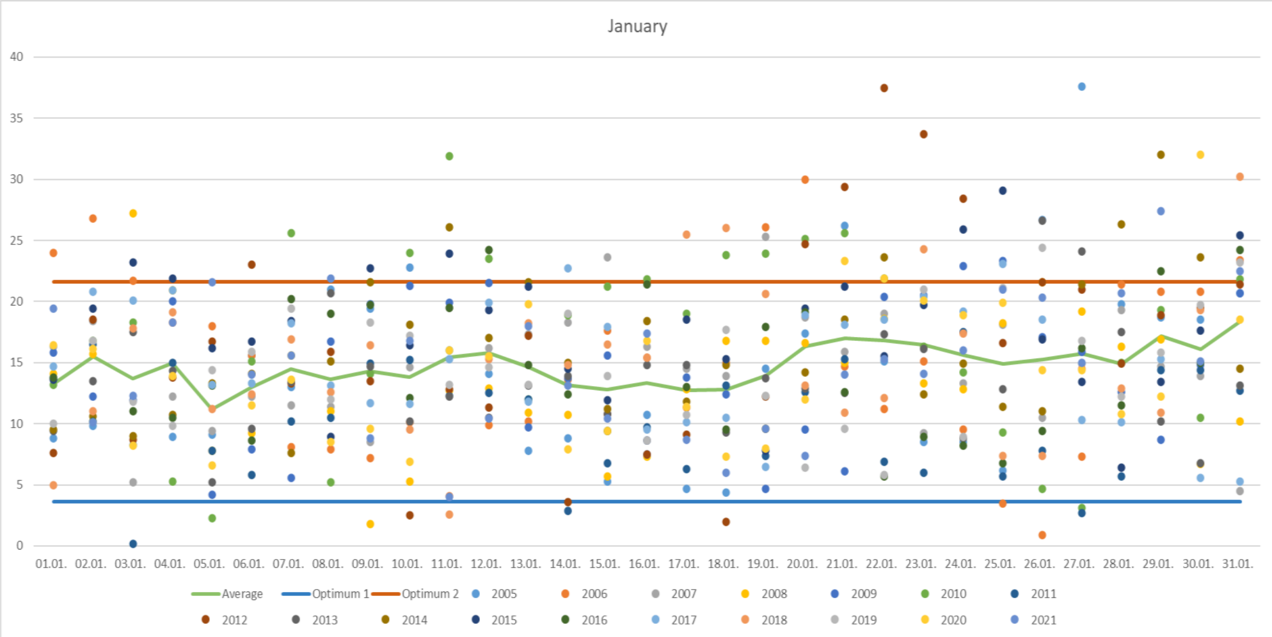

Fig. 1. Dynamics of daily average values of wind speeds in January, Kharkiv, for 2005-2021 [for 2]

According to the graphs, the highest number of cases exceeding the threshold of 21.6 km/h was recorded in December (85), March (76), February (71), and January (63). The lowest values were observed during the summer months: July and August (6 cases each) and June (9 cases). Wind speeds below 3.6 km/h were most frequently recorded in February, October, and November (12 cases each), as well as in January and August (11 cases each). The lowest number of such cases occurred in May (2 cases), and in April and June (3 cases each).

At the interannual scale, the largest number of cases with wind speeds exceeding 21.6 km/h was observed in 2010 and 2012 (40 cases each), followed by 2018 (38 cases). The lowest values were recorded in 2009 (19 cases), as well as in 2005, 2006, 2014, and 2019 (24 cases each). The highest frequency of wind speeds below 3.6 km/h was registered in 2011 (19 cases), followed by 2005 (12 cases), 2006 (10 cases), and 2009 (9 cases). In 2015–2017 and 2020, such values were not observed, whereas in 2013, 2019, and 2021 they were recorded only once.

These patterns are consistent with data from regional environmental reports for Kharkiv Oblast. In particular, in October 2014, the formation of a strong temperature inversion layer resulted in two documented episodes of adverse meteorological conditions associated with elevated levels of air pollution in Kharkiv [3].

Conclusions:

1. The highest recurrence of wind speeds exceeding 6 m/s (21.6 km/h), which ensures effective pollutant dispersion, is characteristic of the winter–spring period (December–March). During the summer months, the frequency of such cases decreases significantly, indicating a reduction in the atmospheric ventilation potential.
2. Conditions favorable for pollutant accumulation (wind speed < 1 m/s, or 3.6 km/h) are most frequently formed during the cold season and in certain autumn

months. This increases the likelihood of high pollution episodes, particularly under temperature inversion conditions.

3. Interannual variability indicates the presence of cyclical fluctuations in the wind speed regime. Years with a higher frequency of strong winds (2010, 2012, 2018) are characterized by greater atmospheric self-purification potential, whereas years with a predominance of weak winds (notably 2011) create conditions conducive to pollutant accumulation.
4. The analysis of long-term wind speed dynamics for 2005–2021 allows us to consider the wind regime as an indicator of environmental risk within the urban area and a basis for forecasting periods with an increased probability of elevated air pollution levels.

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GIS-BASED ASSESSMENT OF THE FORESTBELT NETWORK DENSITY IN KRASNOKUTSK TERRITORIAL COMMUNITY

The study presents a spatial analysis of agroforestry melioration structures in the Krasnokutsk community. Using QGIS software, an inventory of 984 forestbelt segments was conducted. The total length of the protective network is 334.4 km, with a calculated protective coverage of 10.03% of the total area. A 1×1 km grid analysis revealed critical deficit zones, identifying priority areas for forest restoration.

***Key words*:** GIS, forestbelts, agro-landscape protection, spatial analysis, buffer modeling, wind erosion control, land use optimization, linear density analysis, environmental planning, territorial community.

Introduction. Agro-landscapes of Ukraine are characterized by a high level of economic pressure. The most important task of the present time is the regulation of the relationship between society and nature, its rational use and protection, which is understood as the prevention of damage and undesirable consequences of human intervention, as well as scientifically substantiated forecasting of possible changes in the entire complex of phenomena in the environment and directing them in the desired direction during the implementation of planned measures, that is, the construction of natural–anthropogenic systems [1].

Wind erosion (deflation, blowing-out) is the process of destruction of the surface layer of soil and rocks under the action of air flows with the subsequent transport and dispersion of the products of their weathering. The main factor in the development of deflation is wind speed. The intensity of this phenomenon is also determined by the granulometric composition of the soil and the humus content: on sandy loam soils, blowing-out begins already at a wind speed of 3-4 m/s, whereas on clay soils at 7-8 m/s. With increasing wind force, the scale of deflation processes also increases [2]. An effective means of counteracting this process is protective forest belts, which reduce wind flow velocity, form aerodynamic barriers, and create favorable microclimatic conditions [3].

The object of the study is the spatial structure and functional condition of the network of field-protective forest belts within a specially designated part of the Krasnokutsk Territorial Community of the Bohodukhiv District, Kharkiv Oblast [4].

The input data consisted of high-resolution satellite imagery obtained from Google Earth and Bing Maps, which provided the necessary detail for identifying narrow linear plantations. To ensure metric accuracy for distance and area calculations, all layers were projected into the WGS 84 / UTM zone 36N coordinate reference system (EPSG:32636).

The digitization of features Line (MultiLineString) geometry for the initial network inventory, which was subsequently transformed into Polygon geometry through buffer analysis to evaluate the total area of protected agro-landscapes. This multi-stage approach allowed for a comprehensive assessment of the ecological framework within the administrative boundaries of the community [5].

Results. Based on the results of the conducted geoinformation monitoring within the Krasnokutsk Territorial Community, a unified digital database of protective forest plantations was created. The identification of objects made it possible to record 984 linear segments of forestbelts. The total length of the studied network amounts to 334.4 km, while the average length of one continuous segment equals 339.8 m.

To analyze spatial heterogeneity, the indicator of linear density was used, calculated according to the formula:

$$D = \frac{L_{total}}{A_{territory}}$$

Parameter	Value	Units	Description
D	0.74	km/km²	Density of forest belts
L_{total}	334.4	km	Total length of forest belts
$A_{territory}$	450.18	km²	Area of the research zone

D=334.4/450.18=0,742

A key stage of the study was buffer analysis/modeling of the reclamation impact area. A buffer radius of R = 100 m was selected because, according to studies of the aerodynamic properties of linear plantations [6], the ability of forestbelts to reduce wind flow velocity directly correlates with their structure and height (H). Assuming that the average stand height in the study region is 10-12 m, a distance of 100 m corresponds to an influence zone of 8H-10H. It is precisely within this range, as confirmed by data on wind permeability and wind velocity reduction, that the most intensive decrease in air mass velocity is observed. Although the overall wind shadow plume may extend up to 25H, the zone up to 100 m represents an area of guaranteed aerodynamic protection, where turbulence is minimized and the erosive effect of wind is neutralized even under conditions of varying structural permeability (from dense to permeable designs).

The total spatial extent of the calculated buffer zones (area / 10,000) amounts to 4,515.06 ha. The next step is the calculation of efficiency (percentage of protection) using the following formula:

$$P = \frac{A_{protected}}{A_{territory}} \times 100\%$$

Parameter	Value	Units	Description
P	10,029	%	Percentage of territory protection
$A_{territory}$	45,018.52	ha	Total area of the research territory
$A_{protected}$	4,515.06	ha	Area covered by forestbelt buffer zones

P=(4515,06/45018,52)×100%=10,0293%

Spatial analysis indicates that the forest belt network, within a calculated 100-meter zone of aerodynamic influence, provides protection for 10.03% of the community's total territory. Spatial analysis of network density, performed using a regular grid method (1×1 km), revealed significant territorial imbalance (Fig 2.)

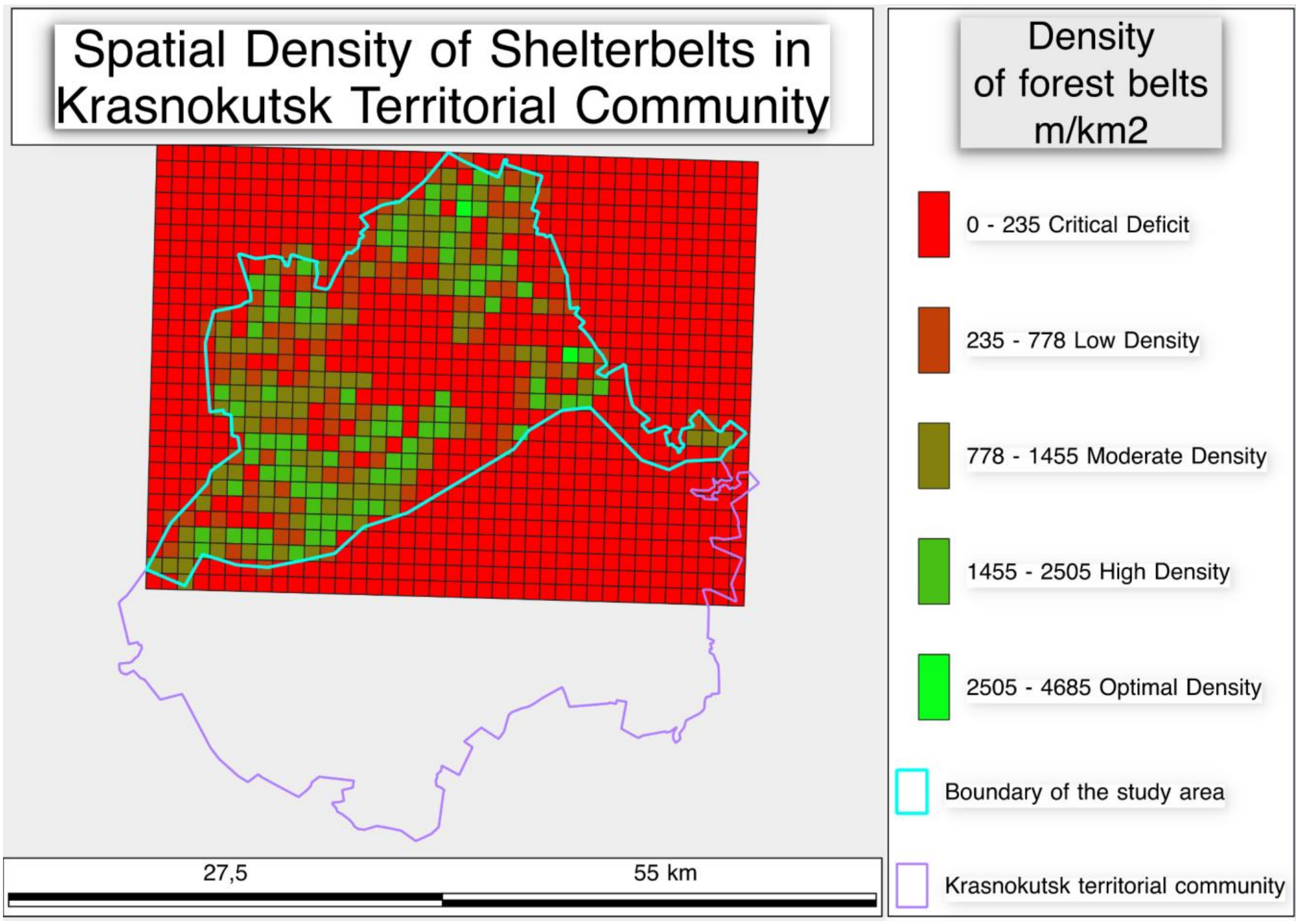

Fig 2. – Schematic map of forestbelts spatial density in the Krasnokutsk Territorial Community

The proposed territorial classification based on forestbelt density is an original development by the author. The zonal gradation was not derived from standard normative templates but was established based on the statistical distribution of actual empirical data. To determine class threshold values, the Jenks Natural Breaks optimization method was applied within the QGIS environment, where indicators of 'optimal density' correspond to the most effective plantation zones identified within the 1x1 km grid.

Conclusion. The GIS-based assessment identified 984 forestbelt segments with a total length of 334.4 km and a linear density of 0.74 km/km². Buffer modeling (100 m) demonstrated that 10.03% of the territory falls within the effective protection zone. Grid-based analysis using the Jenks Natural Breaks method revealed spatial imbalance and priority areas for restoration.

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