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English Language Supervisor N. I. Cherkashyna

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N. I. Cherkashyna, English Language Supervisor

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***Technical group*:**

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Address: 6, Svobody Sq., Kharkiv, 61022, Ukraine

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Berezovskyi O. I., *PhD student*
V. N. Karazin Kharkiv National University
Cherkashyna N. I., *English Language Supervisor*

SOIL EROSION MODELING IN UKRAINE

This publication examines the impact of soil erosion on agricultural land productivity and ecological stability in Ukraine, focusing on the consequences of erosion processes and the measures needed to mitigate their effects. It emphasizes the crucial role of soil quality in sustaining agricultural production and maintaining ecological health. Despite the country's vast agricultural land, Ukraine faces significant challenges such as widespread erosion, soil degradation, and substantial losses in soil fertility. The study highlights the importance of using advanced modelling techniques, such as the Water Erosion Prediction Project (WEPP), alongside modern technologies like GIS, for assessing and managing erosion risks, as well as for developing sustainable soil management strategies.

Key words: soil erosion, agricultural land, ecological stability, soil fertility, Water Erosion Prediction Project (WEPP), GIS, soil management, erosion mitigation.

Ukraine is one of the leading agricultural countries in the world, with enormous potential for agricultural development and holds one-third of the world's chernozem soils. It occupies top positions in global agricultural markets for the production and processing of sunflower oil, grains, honey, and sugar [1].

Agricultural land accounts for 70.3% of the total area of the country, with 81% being arable land. Chernozem soils are the most widespread, covering 60.6% of the total agricultural land area, while dark gray forest soils make up 21.3%.

The steppe zone, which covers 41.5% of Ukraine's territory, is the largest natural complex, containing more than 76% of agricultural land, of which 63% is arable land. The forest-steppe zone occupies 33% of the country's territory and has a high level of cultivated meadows and fertile land for agriculture. The Polissya region, where most of the territory is covered with forests and shrubs, has many pastures, while the areas of cultivated land are much smaller.

Soils are an essential component of the environment and determine the efficiency of agricultural production, which depends on their condition [2]. However, erosion is the primary process of soil degradation in Ukraine's agricultural landscapes, causing significant economic and ecological losses. The intensification of erosion processes leads to considerable soil degradation and substantial losses in agriculture.

In Ukraine, more than 16 million hectares of land have been affected by erosion, and these processes continue to affect one-fifth of the remaining unoccupied land. The loss of humus, the main organic component of the soil, is especially dangerous, as the humus level on these lands has decreased by 30-70%. Gully erosion is widespread over large areas, affecting about 157,000 hectares and forming approximately 600,000 gullies.

Analysis shows that the highest level of soil erosion is observed in the Luhansk region, where eroded lands cover large areas. The lowest intensity of erosion processes is recorded in Volyn, Rivne, Zhytomyr, and Chernihiv regions, where the level of erosion is significantly lower compared to other areas.

Annually, Ukraine loses between 300 and 600 million tons of soil due to erosion. This has serious ecological and economic consequences, as it is accompanied by the loss of vital elements such as humus, nitrogen, phosphorus, and potassium. Humus losses can reach up to 15 million tons annually, nitrogen – 0.9 million tons, phosphorus – 900,000 tons, and potassium – 12 million tons. These losses significantly exceed the amount of nutrients provided by fertilizers.

Due to erosion processes, yields on eroded soils decrease by 20-60% compared to non-eroded soils, resulting in significant crop losses. Experts estimate these losses at 9 to 12 million tons of grain annually, leading to damages exceeding 10 billion dollars per year.

Wind erosion is a serious problem, as over 6 million hectares of land are exposed to it annually, and during dust storms, this figure can reach 20 million hectares.

Water erosion also has a significant impact on Ukraine's agricultural land. It destroys over 13.3 million hectares of land, which accounts for 32% of the total agricultural land area, of which 10.6 million hectares are arable land. Moreover, Ukraine has over 4.5 million hectares of severely and moderately eroded land, with another 68,000 hectares having no humus horizon, significantly reducing their fertility and productivity.

To ensure sustainable agricultural development in Ukraine, it is important to implement a comprehensive set of measures to combat erosion. These should include both agro-reclamation and hydro-reclamation measures, organizational and management strategies, and forestry practices that will help restore soils and preserve their fertility. The design of such measures must be based on precise scientific data, detailed calculations, and an integrated approach, which will allow for effective counteraction to erosion processes and reduce the negative impact on the country's ecological situation [3, 4].

There are numerous models used or recommended for assessing the intensity of erosion processes that lead to soil degradation. One of the most recognized and promising is the Water Erosion Prediction Project (WEPP) model, a theoretical mathematical model that is actively applied to predict water erosion of soils.

The WEPP project was initiated in 1985 and can model various physical processes, such as water runoff, soil particle detachment, sediment transport, water infiltration, plant growth, interaction of raindrops with the soil, sedimentation, and decomposition of organic residues [5].

The Water Erosion Prediction Project (WEPP) model integrates various scientific disciplines such as agronomy, hydrology, hydraulics, and erosion mechanics to accurately predict erosion processes on watersheds and hill slopes. It allows for modeling and evaluating numerous factors affecting erosion processes, such as climatic conditions, land use types, and topography. Using this model, one can study processes related to snow accumulation and melting, deep percolation of groundwater, as well as interactions of various ecosystem components on slopes affected by erosion.

WEPP includes several key modules, such as "Climate," "Topography," "Agro-field," and "Soils." Each of these modules contains specific parameters necessary for detailed erosion process modeling, including climate characteristics, topography, agro-field conditions (vegetation cover), and soil types. This model enables accurate predictions regarding the transportation of runoff and water flow across the landscape to the watershed outlet. There are two main modeling modes: long-term and single-event, which allow for both short-term and long-term erosion loss predictions.

For accurate modeling, various input data are used, such as the relief of the area, vegetation on agricultural land, soil types, land cultivation practices, and local climatic conditions. These data allow not only to forecast the intensity of erosion but also to develop land resource management strategies that minimize the negative effects of erosion on agriculture and the environment [6].

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Binkovskyi A. O., *PhD student*
V. N. Karazin Kharkiv National University
Cherkashyna N. I., *English Language Supervisor*

THE FOREST FUND OF UKRAINE AND THE CONDITIONS OF WAR

This publication examines the impact of forestry management and land use on the sustainability of forest ecosystems in Ukraine, particularly in the context of the ongoing war and environmental challenges. It highlights the vital role of forests in maintaining ecological stability, regulating carbon balance, and preserving biodiversity. Despite the significant forest areas in Ukraine, the country faces challenges such as low forest cover, poor sanitary conditions of forests, and significant damage caused by military conflict. The study also discusses the importance of using modern technologies, such as satellite remote sensing and GIS, for monitoring forest changes and supporting restoration efforts.

Key words: forest ecosystems, Ukraine, ecological stability, carbon balance, biodiversity, satellite remote sensing, GIS, war impact, forest restoration.

Despite the adoption of international environmental protection documents, the state of the environment continues to deteriorate, making the preservation of the stability of the climate system one of the key global issues. Forests play an important role in regulating the carbon balance of the atmosphere, preserving biodiversity, and ensuring natural resources. Their significance is widely recognized and unquestionable, as forest ecosystems support not only the balance of the climate system but also many other ecological processes [1].

Ukraine's forest fund covers 10.4 million hectares, of which 9.6 million hectares are covered by forest vegetation. The forest cover of the country is 15.9%, which, despite significant forest areas, is relatively low for the effective regulation of climatic processes, soil and water resource preservation, erosion control, and ensuring stable wood supplies. However, Ukraine ranks 9th in Europe in terms of forest area and 7th in terms of wood reserves. Uneven conditions for forest cultivation lead to the uneven distribution of forests across the territory. Forest cover in different natural zones varies significantly, and in many zones, it does not reach the optimal level required for ecological stability [1-3].

The wood stock in Ukrainian forests is estimated at 2.3 billion cubic meters. The annual increase in wood volume is 35 million cubic meters, and the average increase per hectare in the State Forestry Agency forests is 3.9 cubic meters. This varies depending on the region: from 5.0 cubic meters in the Carpathians to 2.5 cubic meters in the Steppe zone. The gradual increase in wood stocks confirms both the economic and environmental potential of forests. The average stock per hectare in Ukraine is 235 cubic meters, and in the State Forestry Agency forests, it is 251 cubic meters, placing Ukraine in 10th place in Europe [4].

The low average wood stock in Ukraine is due to the fact that forests of reformed agricultural enterprises are sparse and in unsatisfactory sanitary condition. This requires significant efforts to restore and improve their productivity.

According to the Land and Forest Codes [5], forests in Ukraine can belong to the state, communities, or private owners. Most of the forests are state-owned.

Approximately 1.3 million hectares (13%) of forests can be transferred to communal ownership, while the share of private forests does not exceed 0.1%. Currently, about 800,000 hectares of forest land are not under use. State-owned forests are assigned to various permanent users, with the largest share (73%) managed by the State Forestry Agency.

Russian aggression has caused significant losses to Ukraine's forest fund. A total of 2.9 million hectares of forests have been damaged, and about 1 million hectares are either under occupation or in combat zones. This creates serious problems for forest restoration and forestry activities in Ukraine. Forest pollution by unexploded ordnance is one of the greatest challenges for the forestry sector in wartime. To date, 690,000 hectares of forests require demining, and this figure is growing due to the de-occupation of territories and new mine-laying along the Belarusian border [6].

In addition, destroyed forestry facilities, including machinery and equipment taken by Russian forces from de-occupied enterprises, significantly complicate the restoration process. The greatest damage occurred due to the destruction of the State Forestry Enterprise "Ukrderzhlisproekt" and the seed center in Lyman, which was opened to supply planting material for enterprises in eastern Ukraine.

Due to the large areas requiring monitoring, restoration, and forest management in wartime conditions, traditional methods of observation are becoming limited. Modern Earth remote sensing methods, particularly the use of satellite data, are becoming indispensable for monitoring forest changes. Satellite data, such as images from Sentinel and Landsat satellites, enable effective monitoring of forest cover. Specifically, Sentinel-1 satellites with a resolution of 10 meters and Sentinel-2 satellites with high resolution (10-30 meters) allow for detecting forest cover changes, including damage to forests, changes in their structure, and area [7].

Spectral indices, including NDVI (Normalized Difference Vegetation Index), as well as geographic information systems such as ArcGIS, are used for analyzing and mapping forest disturbances. These systems ensure accuracy in processing satellite images and creating damage maps of forests.

Despite significant damage, Ukraine's forestry sector has great potential for restoration. The use of modern technologies, such as remote sensing and integrated geographic information systems, significantly improves the process of monitoring, managing, and restoring forest resources. Key steps for forest restoration will also include improving the sanitary condition of forests, increasing their area, and ensuring sustainable forest resource management to maintain ecological balance in the country.

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Katanov O., *student*
Odesa I. I. Mechnikov National University
***Blaha A.**, PhD student*

SHORT-TERM FORECASTS AND ASSESSMENT OF THE THREAT OF LOW WATER ON THE RIVERS OF SOUTHERN UKRAINE

Forecasting of low- river flows plays a key role in ensuring sustainable water use and water resources management in the arid southern region of Ukraine. In the context of climate change and anthropogenic impact on water resources, predictive monitoring of low river flows attracts special attention, which should ensure reliable, uninterrupted operation of economic facilities, as well as in assessing low water levels in rivers.

The aim of the work is a short-term forecast of average water flows for a decade and an assessment of the threat of low water levels on the rivers of Southern Ukraine.

The object of the study is the low runoff of the rivers of Southern Ukraine - the rivers of the Southern Bug basin, the rivers of the North-Western Black Sea region and the Lower Dnieper sub-basin. The hydrological regime of the rivers is characterized by the climatic, hydrogeological, orographic and hydrographic features of the territories.

The dry weather flow of rivers is the flow of the summer, autumn and winter periods, when the rivers receive their nutrition mainly only from groundwater and only occasionally have an inflow from rain or from melting snow during periods of winter thaws.

On rivers, the lowest low water level is characteristic of the summer-autumn period, when groundwater, which forms the water flow, is depleted. The winter low water level is somewhat higher due to the river being fed by meltwater during thaws. But in some dry winters, the low water level is low, as in summer. Forecasts of low water level are issued after the end of the spring flood, during the period when there is practically no precipitation, and the underground component of the runoff almost does not change over time.

The Department of Land Hydrology of the I. I. Mechnikov ONU, based on the developed method of territorial forecasts of average decadal water flows of rivers in Southern Ukraine, carries out current forecasting of river water levels, which allows assessing the degree of low water (hydrological drought) of rivers during the low water level period, which negatively affects the vital activity of the population and the ecological situation in water bodies.

According to the "Regulations on the procedure for assessing and reporting on low water (hydrological drought) in water bodies of land in Ukraine" [1], low water is a period in the hydrological regime of water bodies with small and very small water flows, the formation and maintenance of which has a dangerous impact on economic sectors, economic objects, the life of the population and the environment.

The basis of the forecast of low water flows in the dry weather flow period of rivers in the basin of the Southern Ukraine River is the solution of the water balance equation in the form of dependencies generalized for a number of the water gauge station (WGS).

The forecast of low water flows of the low-water period of rivers in the Southern Bug basin is based on the solution of the water balance equation in the form of regional dependencies of water flow in the closing section as a function of water reserves in the channel. Such dependencies are generalized for a number of hydrological posts of Southern Ukraine, taking into account the climatic patterns of precipitation distribution over the territory [2].

The forecast release date is taken as the 10th, 20th, or 30(31st) day of each month, the period for the forecast is one calendar decade, i.e. 10 days.

The work forecasts average water flows for the third decade of January 2025. Thus, according to the Ukrainian Hydrometeorological Center of the State Emergency Service of Ukraine htpps://meteo.gov.ua, during January 2025, abnormally high air temperatures for the middle of winter prevailed in the country. In the Southern Bug River basin, the average monthly air temperature in January was 5.0-5.6 °C higher than the climatic norm, almost the same as in March or November and was observed in 2007 and 2020 over the past 25 years.

Against the background of a significant deficit of precipitation (20-44% of the January norm), the average monthly water content of the winter low water of the Southern Bug River and its tributaries was less than the norm (close to low water) and amounted to 28-39%. During February, with a decrease in air temperatures, the winter low water regime was maintained on the country's rivers, with increased ice formation processes. Due to a significant deficit of precipitation, the water content in most rivers of the country in February decreased compared to January and was mainly 30-50% of the norm. A difficult hydrological situation (low water) was maintained on most rivers of Southern Ukraine – 4-20% of the norm.

The average water flows predicted by the method of territorial forecasts for the third decade of January of this year on the rivers of the Southern Bug, Northwestern Black Sea and Lower Dnieper basins were equal to or less than the minimum water flows of the winter period for the entire series of hydrological observations on the rivers. Such results indicate that the water content of the winter low water level was predicted to be lower than the norm and close to low water.

Thus, short-term forecasts of water flows in the low water period allow for an early assessment of low water levels on the rivers of Southern Ukraine and the identification of the threat of limited water resources for water management and hydropower complexes, drinking and industrial water intakes, and other large economic facilities.

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Borovenskiy A. S., *PhD student*
V. N. Karazin Kharkiv National University
Titenko G. V., *PhD (Geography), Associate Professor*
Shamaeva Yu. Yu., *English Language Supervisor*

CURRENT STATUS OF ENVIRONMENTAL CERTIFICATION OF AGRICULTURAL ENTERPRISES IN UKRAINE

The theses substantiate the state of environmental certification of agricultural enterprises in Ukraine with a focus on the most widespread certification according to the ISCC (International Sustainability Carbon Certification) standard in the context of growing demand for agricultural products from which biofuels are produced in the European Union.

Key words: environmental certification, biofuels, ISCC, farm.

In the contemporary world, issues of sustainable development and environmental responsibility are gaining increasing importance, especially in the field of agriculture. Agriculture is one of the most important sectors of the Ukrainian economy, ensuring food security and contributing to the country's export potential. In connection with the growing requirements for environmental safety and product quality, environmental certification is gaining special importance. Consumers and international partners are increasingly interested in the origin and environmental friendliness of agricultural products. In this context, environmental certification plays a key role, providing confirmation of the compliance of production with environmental standards and requirements and improving the competitiveness of Ukrainian producers in international markets.

Ecological certification involves verifying the compliance of agricultural products with environmental standards, which include the use of organic technologies without the use of synthetic fertilizers and pesticides; rational use of land and water resources; adherence to the principles of biodiversity and the implementation of measures to reduce greenhouse gas emissions.

When determining the impact of environmental certification on the agricultural sector, the following main positive signs and consequences should be noted. This is, in particular, firstly, an increase in product quality, since environmentally certified products meet strict environmental standards, which increases their attractiveness to consumers. Secondly, this is an expansion of export opportunities, since certification according to international standards (for example, USDA Organic, EU Organic, Global G.A.P.) opens access to European and world markets. Thirdly, this is the presence of real economic benefits, which is due to the fact that producers of ecological products can receive preferential prices and access to grant programs. Fourthly, this is a reduction in the negative impact on the environment, since certification stimulates the use of sustainable farming methods.

The analysis of the current state of environmental certification of agricultural enterprises in Ukraine is implemented using the example of one of the leading international certification systems - ISCC (International Sustainability and Carbon Certification). The main principles of this standard are based on the European Union

Directive on renewable energy sources [1]. The priority content direction of this ISCC EU standard is aimed at the production of agricultural raw materials used for the production of biofuels. It is this focus area that is currently the most relevant and in demand in Ukraine. ISCC certification is voluntary, therefore there is no legislative framework for this in Ukraine.

A feature and mandatory attribute of each ISCC EU certification is the use of alternative raw materials. This can include various wastes, residues, ecologically grown agricultural raw materials, forest biomass, etc.

The ISCC EU certification process involves several key steps:

1. Application & Documentation Review. Organizations submit necessary documents outlining their sustainability practices.
2. Audit & Verification. Independent certification bodies conduct on-site audits to verify compliance with ISCC standards.
3. Certification Decision. If requirements are met, a certificate is issued for one year, subject to periodic audits.
4. Continuous Monitoring & Compliance. Companies must demonstrate ongoing adherence to sustainability principles.

The ISCC standard provides for transparency, clarity and traceability of the entire supply chain and all its components (elements) from the agricultural producer to the final biofuel producer [2]. Figure 1 shows a typical supply chain and processing of raw materials into biofuels.

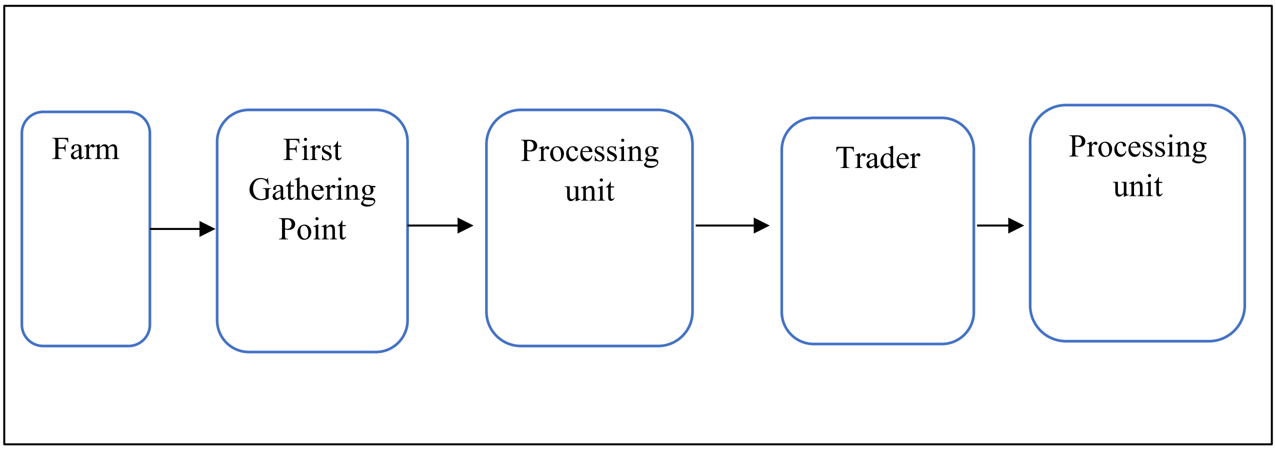

Fig. 1. Typical supply chain and processing of raw materials into biofuels according to the ISCC standard

Given that Ukraine is an agrarian country, as well as the fact that the demand for biofuels is constantly growing on the world market, there is currently a constant increase in the need for environmental certification of agricultural enterprises, in particular according to the ISCC standard. As of January 2025, 263 ISCC certificates [3] were issued in Ukraine for farms and FGP (First Gathering Point), and given that FGP can involve many farms in the process, from one to several hundred, we can conclude that now the number of agricultural enterprises covered by this standard is already in the four-digit range, and this number will continue to grow. Therefore, farms need greater awareness and information about sustainable agricultural production.

Despite significant advantages, environmental certification in Ukraine faces such challenges as: the high cost of the certification process for small farmers; insufficient awareness of agricultural producers about the benefits of certification; lack of effective state incentives and support.

We consider it appropriate in the future to expand state and international programs to support environmental certification; to raise the level of awareness of farmers through educational cases, including microcredit courses, advanced training courses, practical conferences, trainings and master classes. Also, with the gradual implementation of European and world experience in environmental certification, the issue of improving the legislative framework adapted to European standards will remain relevant.

Environmental certification is an important tool for ensuring the sustainable development of Ukrainian agriculture. It contributes to improving product quality, expanding export opportunities and minimizing negative impact on the environment. For its further development, the active participation of the state, international organizations and producers themselves in creating favorable conditions for the implementation of environmental standards is necessary.

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Bubyr O. M., *PhD student*
V. N. Karazin Kharkiv National University
Prasul Yu. I., *PhD (Geography), Associate Professor*

ANALYSIS OF ENVIRONMENTAL THREATS TO TOURIST-RECREATIONAL HERITAGE SITES IN KHARKIV REGION CAUSED BY RUSSIAN MILITARY INVASION

The publication presents the results of studies impact of Russia's military invasion on tourist-recreational heritage sites in the context of existing and potential environmental threats to natural and historical-cultural heritage sites in the Kharkiv region.

Key words: environmental threats, tourist-recreational heritage, impact of the hostilities, Kharkiv region.

The impact of the Russia's military invasion on the environment is quite significant: destroyed settlements, sizable destruction of energy and transport infrastructure, as well as pollution of atmospheric air, soils, water bodies, and forest areas with military-technogenic origin substances. Currently, Ukraine is one of the most contaminated with munitions countries in the world. It is highly difficult to accurately assess the consequences of Russia's military invasion to the environment during of warfare, but way back to 2019, was noted that in Ukraine was a threat of the appearance environmental refugees in case the environmental disaster on occupied lands due to military actions [1]. Full-scale Russian military invasion into Ukraine on February 24, 2022 only spread and deepened these threats.

During the three years of the war, a number of scientific publications regarding to ecological threats on the environment caused by the war has been accumulated. The most attention has been paid to the analysis of ecological threats to natural resources, which is considered in the publications of the Ukraine War Environmental Consequences working group, Ukrainian Nature Conservation Group (UNCG), individual authors, in particular Roman L.Yu. [2], Kolmakova V.M. [3] and others. At the same time, the issue of covering the environmental threats to tourist-recreational heritage sites is given relatively a little care: the available publications are mainly devoted to the features of developing the tourism sector during the war (Roik Oksana, Nedzvetska Olga, 2022), to the prospects for developing of military tourism in Ukraine (Barvinok N. V, 2022, Gurova D, 2024), as well as the degree of damage to certain tourist-recreational heritage sites as a result of hostilities. At the same time, it is worth highlighting the work of Antonenko, V., Khutkyi, V, devoted to the consideration of environmental damage caused to natural tourist resources as a result of Russian military aggression in Ukraine [4].

The impact of military aggression on tourist-recreational heritage sites is manifested in two main areas, such as: a) pollution the territory with substances of military-technogenic origin, b) damage/destruction of natural, historical and cultural tourist sites and tourist infrastructure sites. Environmental threats, as circumstances that are likely to cause damage, harm or pose a threat to the environment, exist in each of the above mention areas.

Chemical pollution from shelling and missiles is the most common environmental threat to tourist-recreational heritage sites located in places of direct hostilities or adjacent territories. Chemical compounds formed during the detonation of missiles include carbon and nitrogen compounds such as CO_2, CO, N_2, N_2O and NO_2, NO and others toxic elements. The consequences of this are the oxidation of soils, wood, turf and structures. Through the cycle of substances, metal impurities migrate into groundwater, sometimes critically polluting it. A third of the territory of the Kharkiv region, including the northern, north-eastern, and eastern parts, were involved in military operations and, accordingly, have the potential for environmental pollution from shelling and missiles.

The ecological threat of destruction of forests and related tourist-recreational heritage sites becomes particularly relevant during fires caused by shelling. Moreover, these fires can occur both as a result of shelling in the forest itself and spread to forest from fires at industrial enterprises, engineering communications and infrastructure facilities, including critical ones. In the latter case, in addition to atmospheric air pollution by combustion products and loss of forest massifs, environmental threats of soil and water pollution by chemical toxicants from affected enterprises are added. In 2024, according to the State Emergency Service, fires within the Kharkiv region covered more than 13 thousand hectares, with the forest areas of the Izyum district being particularly hardly affected. About 40-45% of the Kharkiv region's forests are currently mined or damaged by fires as a result of hostilities.

Among the objects of the region's nature reserve fund, according to UNCG, the greatest losses were suffered by the regional landscape park "Velikoburlutsky steppe" and the National Nature Park "Dvorichansky", which are located right on the contact line – from hostilities, movement of equipment, and shell explosions. In Dvorichansky Park, it may be impossible to restore the flora in some chalk areas. Nature reserves in the north of the Kharkiv region were also severely damaged. In all of the suffering territories, there is an ecological threat of contamination by substances of military-technogenic origin, and in places of military operations and adjacent areas – mining of the territory, such as within the Vovchansky reserve.

Tourist-recreational heritage sites related to water resources are characterized by such environmental threats as: contamination by substances of military-technogenic origin, destruction of ecosystems as a result of military operations. Typical examples for the Kharkiv region are the destruction of the Oskil reservoir's hydraulic structures, and the infrastructure of Pechenig and Krasnopavlivka reservoirs.

Cultural and historical tourist-recreational heritage sites are also damaged and destroyed during hostilities. Among the most notable damaged or destroyed cultural heritage sites of the region are the 9th-century architectural monuments "Polovtsian Stone Women" in Izyum, the local history museum in Kupyansk, the Holy Ascension Cathedral in Izyum, which was significantly damaged by shelling, and the Grigoriy Skovoroda Museum in Skovorodynivka, the exposition of which was destroyed as a result of a fire after a missile hit in May 2022 (Fig. 1). The wooden church of the Archangel Michael of God in the village of Ruski Tyshky also burned down.

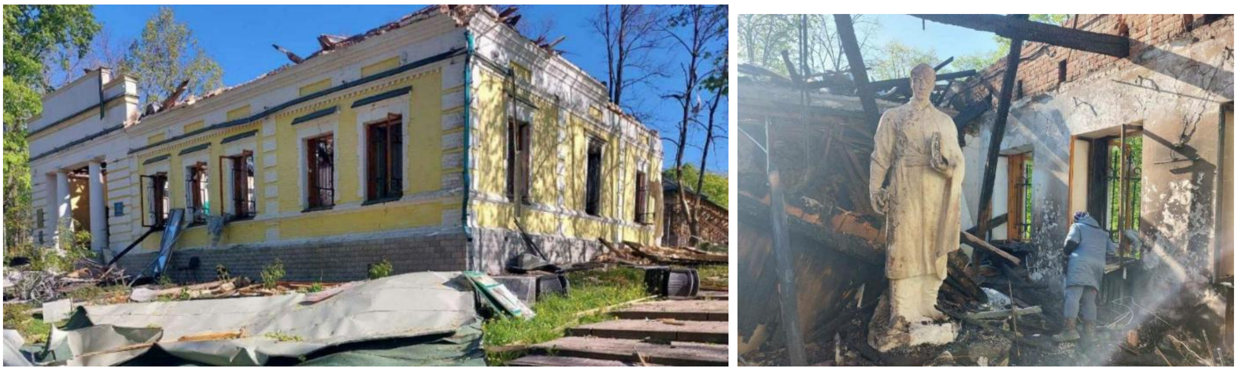

Fig. 1. Museum of Grigoriy Skovorody in the village of Skovorodynivka after being hit by a missile on May 6, 2022 [5]

It should be noted that the consequences of the destruction of historical-cultural heritage sites due to Russian military aggression, in addition to the direct loss of these sites, are the spread of environmental threats related both to contamination with substances of military-technogenic origin, including the presence of unexploded ordnance, mined territory, etc., and to the danger to visitors due to possible collapses of affected structures.

In general, the analysis of existing and potentially possible environmental threats to tourist-recreational heritage sites is a primary condition for determining the offline/online modes for organizing tours during the revival of regional tourism in post-war Ukraine. Currently, the primary task is to generalize and systematize the current state of tourist-recreational heritage sites in Kharkiv region in the form of a GIS database indicating the degree of damage from hostilities and the existing potential for derivative environmental threats.

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Chermnykh M. O., *student*
V. N. Karazin Kharkiv National University,
***Koval I. M.**, DrSc (Agriculture), Professor*

DENDROINDICATION OF HORSE CHESTNUT IN GREEN PLANTINGS OF KHARKIV AND LVIV

The results of studies of the radial growth of horse chestnut (*Aesculus hippocastanum* L.) in green spaces of the cities of Lviv and Kharkiv under the influence of a complex of environmental factors are presented in the thesis.

Key words: radial increment of *Aesculus hippocastanum*, climatic factors, *Cameraria ohridella* Deschka & Dimic (Lepidoptera: Gracillariidae

The horse chestnut (*Aesculus hippocastanum* L.) is a useful species for urban ecosystems. Horse chestnut trees are mainly used as plants for street landscaping and maintaining the visual appeal of the environment. The horse chestnut is quite vulnerable to climate change.

Currently, it is also suffering from the invasion of the chestnut leaf miner (*Cameraria ohridella* Deschka & Dimic, 1986 (Lepidoptera: Gracillariidae) and the effects of anthropogenic pressure [3, 4]. The chestnut leaf miner crossed the border from the Hungarian side in 1998, so this year its first appearance was recorded in Transcarpathia, in 2002 - in Lviv, and in 2007-2008 in Kharkiv [3].

Horse chestnut infected with the chestnut borer has premature defoliation, which leads to a decrease in photosynthesis, resulting in a deterioration in the radial growth of trees. The radial growth of trees is an integral indicator that reflects the state of the tree during ontogenesis and is a bioindicator [2, 3].

The aim of the study is to assess the impact of climate change and the horse chestnut leaf miner on the ring width of the horse chestnut in medieval green plantations of the cities of Lviv and Kharkiv.

Standard dendrochronological methods were used in the research[1].

The radial growth of trees in medieval plantations was compared for the period before the outbreak of the horse chestnut leaf miner (1982-2001) and after it (2002-2021) for Lviv and for 1990-2006 and 2007-2023 for Kharkiv. The temperatures for the hydrological year for these periods were also compared according to the data of the Lviv and Kharkiv weather stations. It was found that in the first period for Kharkiv the radial growth was 2.57±0.19 mm, and in the second period – 1.10±0.06, i.e. there was a decrease in growth by 57% (Fig. 1, 2). For Lviv, in the first period, the radial growth was 2.57±0.16 mm, and in the second period – 1.30±0.14. That is, the tree increment decreased in 2007-2023 compared to 2007-2023 by 49%.

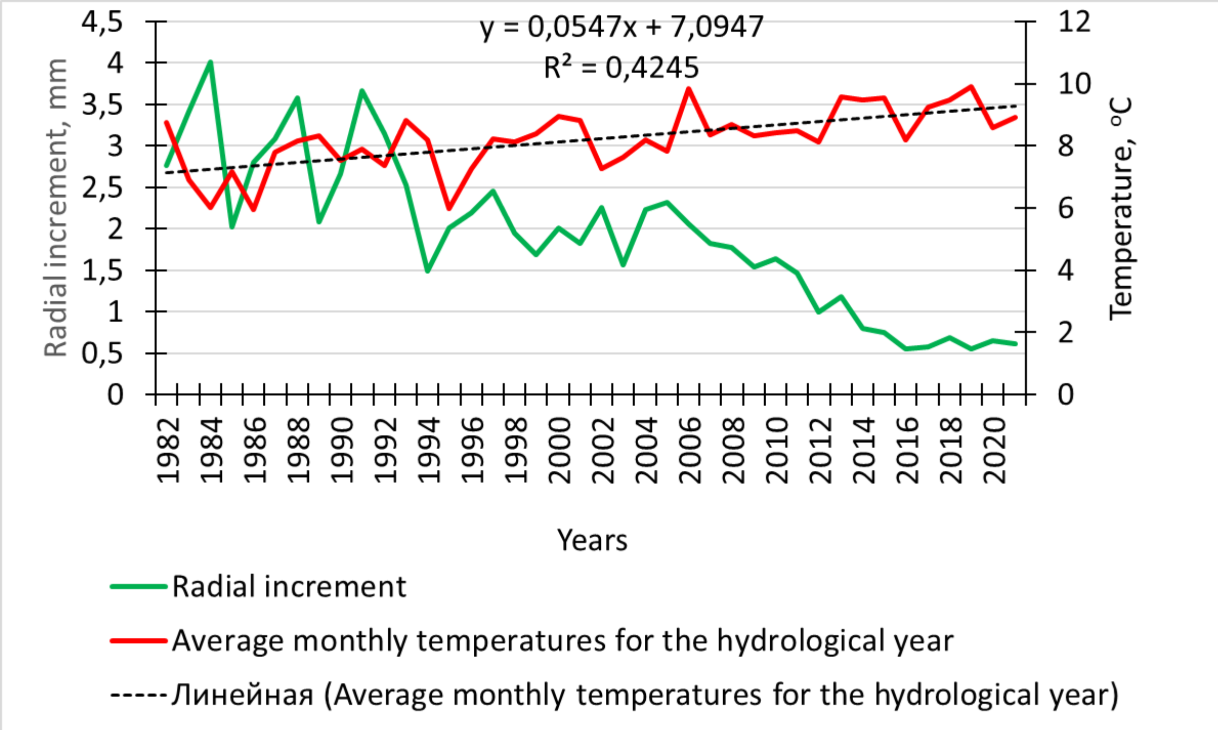

Fig. 1. Dynamics of radial increment of horse chestnut in green plantings of Lviv and temperatures of the hydrological year according to the data of the Lviv Meteorological Station

Temperatures for the hydrological year for the period before the invasion of the chestnut leaf miner were 7.73±0.21 and 8.70±0.17 for Lviv, and 8.28±0.20 and 9.74±0.16 for Kharkiv, respectively. That is, temperatures increased in the first period for Lviv by 0.98°C, and for Kharkiv by 1.5°C.

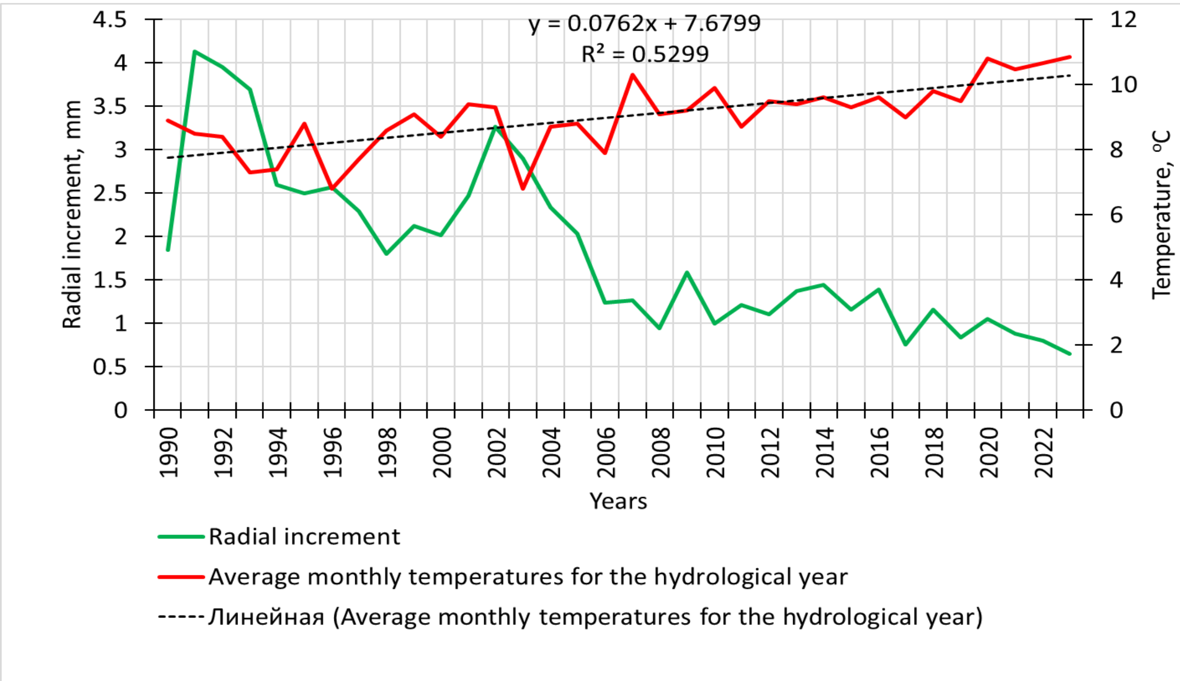

Fig. 2. Dynamics of radial growth of the horse chestnut in green plantings of Kharkiv and temperature of the hydrological year according to data from the Kharkiv meteorological station

Conclusions

1. When comparing the radial increment of the horse chestnut for the periods before the beginning of the chestnut leaf miner invasion (1982-2001) and after it (2002-2021) in Lviv and, respectively, for Kharkiv for 1990-2006 and 2007-2023, the decrease in the tree increment was half as much in the second period compared to the first period, despite the fact that the chestnut miner arrived to Kharkiv 5 years later than in Lviv.
2. The decrease in radial increment of the horse chestnut occurred against the background of increasing temperatures and anthropogenic load (pollution from road transport and recreation).

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Dolia D. S., *student*
V. N. Karazin Kharkiv National University
Maksymenko N. V., *DrSc (Geography), Professor,*
Cherkashyna N. I., *English Language Supervisor*

THE UNITED STATES' WITHDRAWAL FROM THE PARIS CLIMATE AGREEMENT: A THREAT OR NOT?

The article highlights the main reasons and potential consequences of the United States' withdrawal from the Paris Climate Agreement, which may lead to undesirable outcomes for our planet.

Key words: climate, air pollution, temperature, warming, greenhouse gases, climate agreement.

In 2015, the Kyoto Protocol was replaced by the Paris Agreement. On December 12 of the same year, it was signed, and on November 4, 2016, it was adopted after its ratification by 55 parties to the UN Framework Convention on Climate Change, which account for more than 55% of global greenhouse gas emissions [1]. As of March 2025, 195 countries have joined it, of which 194 states, including Ukraine, have ratified the ratification procedure [2].

The main goal is to keep warming at a level "well below 2ºC" and make every effort to limit it to 1.5ºC. The agreement itself, namely in Articles 6 and 9, spells out provisions on cooperation and financing by highly developed countries of developing countries [2, 4]. However, these mechanisms are quite specific in themselves, since by supporting less developed countries, more developed countries imply jeopardizing their economies, which is not satisfactory for all states, for example, for the United States of America under the presidency of Donald Trump.

In November 2019, the US administration officially announced to the UN that they were starting withdrawal procedures, which led to the fact that on November 4, 2020, they officially withdrew from the climate agreement. But it didn't take long for President Joe Biden to sign a second executive order in January 2021 to return the United States. Today we again have a repetition of the scenario of 2019, in which the process of this country's withdrawal from the Paris Climate Agreement is underway [5].

Analyzing the statistics of world air pollution with carbon dioxide (CO_2), until 2006 the world leader in pollution was the United States of America, with emissions of 6.13 billion tons for 2005. This link was then taken over by China, where as of 2023, 11.9 billion tons of carbon dioxide were emitted, which is 31.5% of the world's total. Despite this, the United States also has huge emissions of 4.91 billion tons as of 2023, which is 13% of global air pollution. But at the same time, we see that the difference between the figures for 2005 and 2023 is 1.22 billion tons, which is quite a significant indicator [3].

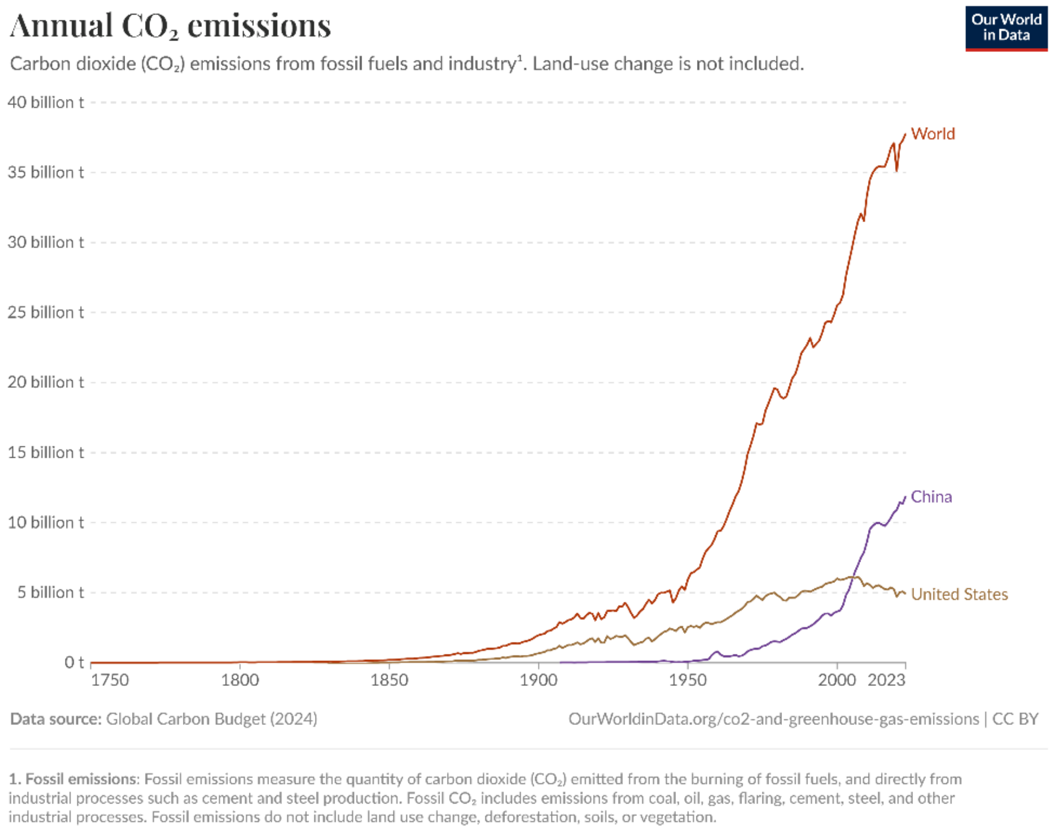

Fig. 1. Annual CO_2 emission [3].

These signs are, in fact, a strong indicator that the United States of America has quite good results in the environmental sphere. But the question arises of how all these indicators will change without an agreement. Since, having the largest economy in the world, they paid the largest contributions of about 21% [8], which without such financing and without the technological support of less developed countries could lead to unpredictable situations. Currently, there are very poor air quality indicators in China (126 AQI), Vietnam (125 AQI), India (112 AQI), South Korea (104 AQI), Poland (93 AQI), Thailand (91 AQI) and so on. And if funding and the introduction of technologies are stopped, the list of countries will continue to be replenished, which can already be dangerous for the atmosphere [6].

If we accept that America can make all this contribution to its economy, it can affect the increase in the amount of emissions of hazardous substances, fine particles and carbon dioxide into the atmosphere with excessive extraction of oil, raw material, etc., as demonstrated by the statistics of air pollution by carbon monoxide between 2016 and 2020, where the amount of emissions from industry and other related processes increased from 10.6 to 12.1 million tons. At the same time, there was a significant jump in the period from 2016 to 2017, where the indicators increased from 10.6 to 14.1 million tons [7].

Therefore, summing up, we have a situation where one of the most economically developed countries is withdrawing from the agreement, aimed at maintaining the mark of 1.5^{0}C. Of course, as stated, funding will continue to come from the United States, but not with state funds. It follows that funding in the field of ecology will continue to take place, but not in the same way as before. There are also some fears that, despite today's statistics, air pollution with carbon dioxide and carbon monoxide may increase.

Therefore, in order to keep our planet from pollution and away from heating, it is necessary to reconsider the content of the Paris Agreement and provide a more correct interpretation of assistance, depending on pollution and the economic prosperity of the country, taking into account further pollution.

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Gololobov V. V., *PhD student*
V. N. Karazin Kharkiv National University
Cherkashyna N. I., *English Language Supervisor*

EFFECTIVENESS OF BIOLOGICAL PRODUCTS IN THE PROTECTION OF *AESCULUS HIPPOCASTANUM*

This publication presents the results of field studies using biological products with complex action to protect *Aesculus hippocastanum* plantations from the horse-chestnut leaf miner (*Cameraria ohridella*) and rust. The use of biological products has proven to be effective in maintaining the healthy state of urban green spaces.

Key words: phytopathological state, biological protection, chestnut leaf miner.

Recently, natural and urban green spaces in Ukraine have been facing a serious threat from invasive insect species, in particular, moths (Lepidoptera: Gracillariidae). These pests have adapted to modern conditions, such as high levels of anthropogenic pollution, lack of moisture, and the use of insecticides. Their ability to reproduce rapidly and form several generations in a year makes them particularly dangerous for tree species that are the basis of urban forest parks, parks, squares, and alley plantings [1]. One of the most well-known representatives of this group is the chestnut moth (*Cameraria ohridella*), which affects the leaves of the common chestnut (*Aesculus hippocastanum* L.). This pest was first discovered in 1984–1985 in natural forests near Lake Ohrid in Macedonia, on the border with Albania. It quickly spread across Western and Central Europe, and later to Ukraine.

The main damage caused by the chestnut borer is the formation of numerous mines on the leaves of trees. This leads to premature yellowing and leaf fall, which in turn weakens the trees, making them more vulnerable to diseases and other pests. As a result, this can lead to a significant deterioration of urban green spaces, which are an important element of ecological balance and a comfortable environment for city residents.

In order to combat this pest, it is important to take into account environmental aspects, namely, to minimize environmental impact and preserve the biodiversity of urban ecosystems, to increase the resistance of trees to pests by caring for plantations, in particular, to use biological methods of plant protection.

Field studies were conducted to study the effectiveness of the use of biological products of complex action on green plantations of common chestnut in urban landscapes. They included the use of biological products with different effects: to protect plants from pathogens, insect pests and ticks. The work was carried out on the alley plantations of low-growing chestnut species located on the territory of the State Biotechnological University in the village of Dokuchaevske (Kharkiv district, Kharkiv region).

The main agronomic technique was foliar treatment of the trees. For this purpose, we used a tank mixture of preparations, which was applied by standard spraying. All treatments were carried out in the evening to minimize the impact on beneficial insects and prevent evaporation of the products during a hot day. The procedure was repeated regularly, starting from the beginning of the growing season, with an interval of 10–12 days.

For the field experiment, we used biological products from the Ukrainian biotechnology company BTU, which specializes in the production of microbiological products for the agricultural sector [2]. Two main products were used in the study in the doses recommended by the manufacturer: «MIKOHELP», a multicomponent biofungicide that provides comprehensive plant protection against diseases, and «ACTOVERM» 1.8%, a biological product with insecticidal and acaricidal effects designed to control insect pests and ticks. To improve the effectiveness of the treatment, «LIPOSAM» bioadhesive was added to the tank mixture, which ensures better retention of the products on the leaf surface. This combination of biological products made it possible to provide comprehensive plant protection, combining the fight against diseases, pests and ticks, which is important for maintaining the healthy condition of trees in urban areas.

The results of the field experiment were recorded by means of photographic documentation, which is shown in Figs. 1–2. Chestnut leaves were used as an indicator of plant health, since it is on them that the symptoms of diseases and damage are most clearly manifested. A significant number of necrotic lesions are observed on the leaves of chestnuts that have not been treated. They look like spots of various sizes and shapes that cover most of the leaf surface. Necrosis is concentrated mainly along the edges of the leaf blade and between the veins. The green color of the leaves is almost completely lost, they acquire a brownish tint and look dry.

In contrast, the leaves of chestnuts that were treated with biological products have a complete structure without visible damage. There are no necrotic lesions, and the leaf blade retains its natural green color and turgor. On both surfaces of the leaves (adaxial and abaxial), there were no signs of fungal or bacterial diseases, as well as traces of damage caused by insect pests.

Photosynthetic pigments are important indicators of the physiological state of plants, as they are actively involved in the formation of adaptive responses to stressful conditions. Carotenoids serve as protective agents that are important structural components of photosynthetic complexes and membranes and play an important role in the light harvesting mechanism of photosynthetic plants. Protection against reactive oxygen species, which is realized by quenching singlet oxygen and excited states of photosensitizing molecules, as well as by removing free radicals, is one of the main biological functions of Car. Car molecules help in the formation of protein subunits of photosynthetic complexes by gluing their protein components together. In addition to their aforementioned essential functions, Car molecules play an essential role in the formation and maintenance of proper cellular architecture, and potentially in the protection of the photosynthetic apparatus under stress [3].

The ratio of Chl(a+b)/Car for treated leaves is 6.36, and for untreated leaves – 2.19. These data indicate a high level of stress experienced by plants due to disease and pest damage.

These results confirm the effectiveness of the applied biological products for the protection of chestnuts from diseases and pests, which is important for maintaining a healthy state of plants in urban areas.

Fig. 1. Photographic recording of the phytosanitary condition of chestnut trees: without treatments.

Fig. 2. Photographic recording of the phytosanitary condition of chestnut trees: with treatments.

To maximize the effectiveness of biological protection, we recommend combining biological treatment with other plant care methods, such as timely removal of fallen leaves. Healthy, unaffected leaves of trees can be composted in an environmentally friendly way using in-situ technology [4].

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Horoshkov S. V., *student*
V. N. Karazin Kharkiv National University
***Nekos A. N.**, DrSc (Geography), Professor*

DIGITAL TWINS IN ENVIRONMENTAL MONITORING: INNOVATIVE CAPABILITIES AND PROSPECTS

The publication presents the results of studies on the use of digital twins as an environmental monitoring tool that enables forecasting of environmental changes and developing natural resource management technologies to ensure sustainable development.

Key words: digital twins, environmental monitoring, digital models, monitoring, ecosystems.

In today's world, modern digital technologies such as the Internet of Things (IoT), Big Data, Artificial Intelligence (AI), blockchain, and cloud technologies play a key role in environmental protection. One of the most promising solutions is digital twins of ecosystems – innovative virtual models that allow for analyzing ecological processes, predicting risks (such as environmental disasters), and finding optimal ways to minimize them [1]. This technology opens new horizons for sustainable development and conservation of natural resources. For instance, IoT enables real-time monitoring of environmental conditions, from carbon emissions to the state of water resources, allowing enterprises to promptly adapt their production processes to minimize negative environmental impacts [2, 3].

According to scientific research, the implementation of digital twins in environmental monitoring improves the accuracy of natural disaster prediction by more than 70%. It is important to note that this technology allows for creating not only static models but also dynamic systems that are constantly updated based on data from thousands of sensors. The integration of such systems with satellite data for Earth remote sensing provides an unprecedented level of detail in the analysis of ecological processes.

Today, digital twins are actively used in environmental research, monitoring of natural areas, and management of urban ecosystems. Virtual models allow for tracking changes in the environment in real time, making it possible to make informed decisions and respond promptly to emergencies.

One of the key areas of application for this technology is the urban environment [4]. ABI Research predicts that using digital twins for more efficient urban planning will help cities save approximately €259.26 billion by 2030 [5].

The creation of digital twins of cities contributes to optimizing logistics of transport flows, reducing air pollution levels, and increasing the efficiency of energy resource use. They also play an important role in designing green infrastructure and adapting cities to climate change. The implementation of such systems allows for reducing the carbon footprint in cities and optimizing energy consumption.

Beyond urban planning, digital twins are actively used for restoring natural ecosystems. Digital models of river basins help assess water quality in water bodies, predict changes in water balance, and optimize resource use. Such technologies are particularly important for countries experiencing significant impacts from anthropogenic activities, including Ukraine. The use of digital twins in water resource monitoring allows for predicting natural disasters and meteorological phenomena [6].

Another promising field is the use of digital twins in agriculture. Thanks to such models, it is possible to analyze soil conditions, moisture levels, predict crop yields, and minimize the use of agrochemicals. This not only contributes to increasing the efficiency of the agricultural sector but also helps reduce negative environmental impacts. According to Agrimetrics, the implementation of digital twins in agriculture can increase crop yields by 20-25% while simultaneously reducing pesticide use by 30% [7].

The integration of digital twins with artificial intelligence systems and big data opens even broader possibilities. The use of complex algorithms allows not only for recording changes, but also predicting their consequences with an accuracy of up to 87% with a forecasting horizon of up to one year. Analysis of historical data on climate change helps create models that predict future natural phenomena and allow for promptly implementing preventive measures.

Special attention should be paid to the potential of digital twins in monitoring and restoring forest ecosystems. The use of this technology allows for creating detailed three-dimensional models of forest areas, tracking the dynamics of their development, and evaluating the effectiveness of forest restoration work. The integration of remote sensing data and ground sensors ensures modeling accuracy when assessing the state of tree stands and predicting potential threats.

The development of digital twins in Ukraine could be an important step toward environmental sustainability. According to expert estimates, the implementation of these technologies can reduce the costs of mitigating the consequences of environmental disasters by 45-60% and accelerate the recovery process of affected territories by 35%. Creating the basic infrastructure of digital twins for key ecosystems in Ukraine will require investment, but the economic effect from their implementation will significantly exceed the initial costs.

In the future, this technology may become an indispensable tool in combating climate change, managing natural resources, and preserving biodiversity. The experience of leading countries shows that investments in the development of digital twins of ecosystems pay off on average within 3-4 years due to optimized resource use and prevention of environmental catastrophes.

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Kalashnikov R. R., *student*
V. N. Karazin Kharkiv National University, Kharkiv, Ukraine,
***Maksymenko N. V.**, DrSc (Geography), Professor*
***Cherkashyna N. I.**, English Language Supervisor*

MODERN TECHNOLOGIES FOR POST-WAR FOREST LANDSCAPE RESTORATION

The armed conflict in Ukraine has caused large-scale environmental consequences, particularly due to the destruction of forested areas, which affects climate stability and the ecological balance of the regions. The study examines modern technological approaches to addressing these issues, specifically the use of drones for automated tree planting. The prospects for ecological restoration of territories and the necessity of a comprehensive approach to the revitalization of natural landscapes after the war are analyzed.
Key words: armed conflict, ecosystem, forest landscapes, deforestation, biodiversity, ecological restoration, drones.

Military actions and related forest fires have led to the loss of significant forest areas. According to information provided by the State Forest Resources Agency of Ukraine and the UWEC Work Group, as of June 2024, 708.9 thousand hectares of forest lands have been affected by the war, of which 893.9 hectares are considered completely destroyed. The total damage caused to forests amounts to 2 million 457 thousand hryvnias [1]. However, the State Forest Resources Agency noted that these figures may change, as accurate damage assessment is complicated by the extensive mining of many affected areas. Forest fires that occurred directly as a result of hostilities have caused greenhouse gas emissions equivalent to 6.75 million tons of CO_2, which is comparable to the annual emissions of the entire country of Armenia. Moreover, Ukraine has lost a significant capacity for carbon absorption, as the burned forests no longer fulfil their role in capturing carbon, further exacerbating the issue of climate change and forcing the country to seek ways to restore its forest resources [2]. The goal of this study is to assess the potential for rapid forest restoration after hostilities through modern technologies, such as drones for forest planting. Russia's full-scale invasion of Ukraine has had massive environmental consequences not only for our country but for the entire world. These consequences have no borders. Since February 24, 2022, over 150 million tons of CO_2 emissions have been released into the atmosphere, triggered by fires and military actions. Nearly 3,600 cases of environmental damage have already been recorded in Ukraine, with the total estimated cost amounting to 2.2 trillion hryvnias [5]. One of the promising methods for the ecological restoration of damaged forests is the use of drones for automated tree planting. This approach significantly accelerates the reforestation process while minimizing human intervention in hazardous areas, especially in regions contaminated with mines and explosive remnants of war. Dendra Systems is one of the leading companies specializing in large-scale ecosystem restoration using drones. Their technology incorporates artificial intelligence to analyse terrain, select optimal planting locations, and automate seed dispersal via drones. This approach enables Dendra Systems to plant up to 120 trees simultaneously, accelerating reforestation 150 times faster than traditional methods [6]. This technology not only helps Ukraine restore forests destroyed by the war but also serves as an innovative solution for the entire world in the fight against climate change and land degradation. The armed conflict in Ukraine has caused severe environmental consequences, including large-scale destruction of forested areas. This complicates the restoration of natural ecosystems, reduces biodiversity, and exacerbates climate change due to significant greenhouse gas emissions. To address these issues, modern technological approaches, such as drones for automated tree planting, are being utilized. A comprehensive approach to ecological restoration, combining technological innovations and international support, is crucial for the rehabilitation of natural resources after the war.

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Kapustynskyi A. I., *PhD student*
Institute of Ecology of the Carpathians, NAS of Ukraine
Nature Reserve "Medobory"

DENSITY DYNAMICS OF THE BREEDING BIRD POPULATION OF THE SECONDARY YOUNG FORESTS OF THE "MEDOBORY" NATURE RESERVE (2016–2023)

The dynamics of the breeding bird population of the secondary young forests of the "Medobory" nature reserve for the period from 2016 to 2023 is studyed.
Key words: reserve, birds, density, nesting sites, young forests.

The study of the bird fauna of the "Medobory" Nature Reserve is important for understanding the impact of natural processes and climate change on the species diversity of birds, especially in conditions of natural forest succession. The research was conducted on the stationary ornithological transect OM-3, which was established in 1998 in secondary young stands consisting of the Norway maple *Acer platanoides* and the European ash *Fraxinus excelsior*. Today, the forest stand is dominated by small-leaved linden *Tilia cordata*, European ash, Norway maple, and common hornbeam *Carpinus betulus*, which form a natural stand after the disappearance of the pedunculate oak *Quercus robur*. The age of the forest ranges from 60 to 85 years, and the crown density reaches 0.9-1.0. Bird surveys on the transect in 1998-2009 were conducted by Ya. I. Kapelyukh (2010). The analysis of the breeding bird community covers the period 2016-2023 (Kapustynskyi, 2017). The studies were conducted using the generally accepted method of linear transects (Lugovoy, Guziy, 1992). The aim of the work was to study changes in bird communities in the process of natural forest succession, from young trees to maturing and mature forest stands.

Analysis of the research results showed that the breeding bird community is characterized by significant fluctuations in bird density. The highest density parameters were observed in 2016 (257.9 pairs/km²), 2019 (272.4 pairs/km²) and 2023 (280.6 pairs/km²), which were associated with favorable weather conditions during spring and summer. In 2020, a sharp decline in bird density to 151.6 pairs/km² was noted, which was caused by the weather conditions of the season, which led to a delay in development and a decrease in the number of invertebrates – the main food for birds. At the same time, during 2020-2023, a stable increase in the number of crown-nesting species was observed, which in forest ecosystems with older stands cover a significant share of the bird population.

A long period of observations allows us to track the gradual changes in the species composition and density of the birds that occur during the transition from shrub to typical forest bird complexes. These changes are directly related to changes in feeding and breeding conditions in habitats that are formed depending on the age of the stand and the stage of forest development.

Studies have shown that the number of species of birds during the nesting period varies within 10-17 species. Crown-nesting species are dominant, which is facilitated by the formation of a mature forest with high crown density. However, due to the lack of a sufficient number of hollows, which is associated with the shortage of old trees, the number of hollow-nesting birds remains limited.

Important factors in changes in bird density are weather conditions, such as temperature and precipitation, which affect the food base and resource availability.

Studies for the period 2016-2023 showed that the characteristics of bird communities of secondary young stands of the Medobory nature reserve change with the age of the forest: now there are practically no species associated with shrub biocenoses, and the number of crown- and hollow-nesters is increasing. In addition, a noticeable dependence of the number of birds on weather conditions have been noted, in particular temperature fluctuations and precipitation, which primarily affect the availability of food. These results emphasize the importance of monitoring birds in forest ecosystems, since natural changes in the age structure of forests significantly affect the features of the formation and structure of breeding bird communities.

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Kashkabash D. E., *student*
V. N. Karazin Kharkiv National University
Klieshch A. A., *PhD ((Geography), Associate Professor,*
Cherkashyna N. I*., English Language Supervisor*

ASSESSING RECREATIONAL AREAS OF PUBLIC GREEN SPACES FOR THE POPULATION IN THE INDUSTRIAL DISTRICT OF KHARKIV

The study evaluates the provision of public green recreational spaces in the Industrialnyi District of Kharkiv. The results show that the district exceeds the recommended greening standards, ensuring a satisfactory level of recreational space for its population.

Key words: recreational zones, green spaces, urban planning, public-use zones, greening norm, Industrialnyi District, Kharkiv.

The green spaces of the Industrialnyi District of Kharkiv are classified into three types of functional recreational zones: restricted-use, public-use, and special-use. The primary purpose of public-use recreational zones is to meet the daily recreation needs of city residents [1]. Therefore, assessing their adequacy in relation to the population size is a crucial aspect both for determining the level of social needs fulfilment and for regulating anthropogenic pressure on these areas.

Figure 1 shows the location and territorial configuration of public green recreational areas in the Industrialnyi district of Kharkiv. The total area of all land plots with public green areas is 1,929,100 m², which makes up 4.26% of the total area of the district. During the study, two subtypes of recreational zones were identified in the district, namely:

- *recreational zone with a high level of amenities* that provides residents of the settlement with organized recreational spaces. This subtype of the recreational zone includes Zelenyi Hai Park (1), V. Mayakovsky Culture and Recreation Park (2), as well as three squares: Traktorozavodskyi Square (3), Oleksandrivskyi Square (4), and Huliver Square (5). The assessment of the population's provision with recreational facilities in this subzone, conducted in 2022, revealed a rather low value of the greening norm indicator (4.88 m² per person) [2].
- *recreational zone for the preservation of valuable natural landscape features,* which aims to combine the creation of conditions for public recreation with the maximum revelation of landscape features and minimal impact on the natural environment. According to the zoning scheme of the territory, as part of the urban planning documentation of Kharkiv, this subzone may include seven areas.

According to the spatial distribution, two groups of recreational sites of this type can be distinguished: those located in the northern (1-4) and eastern (5-7) parts of the district. The current condition of these areas indicates the absence of any infrastructure necessary for organizing mass recreation for the population (Figure 2).

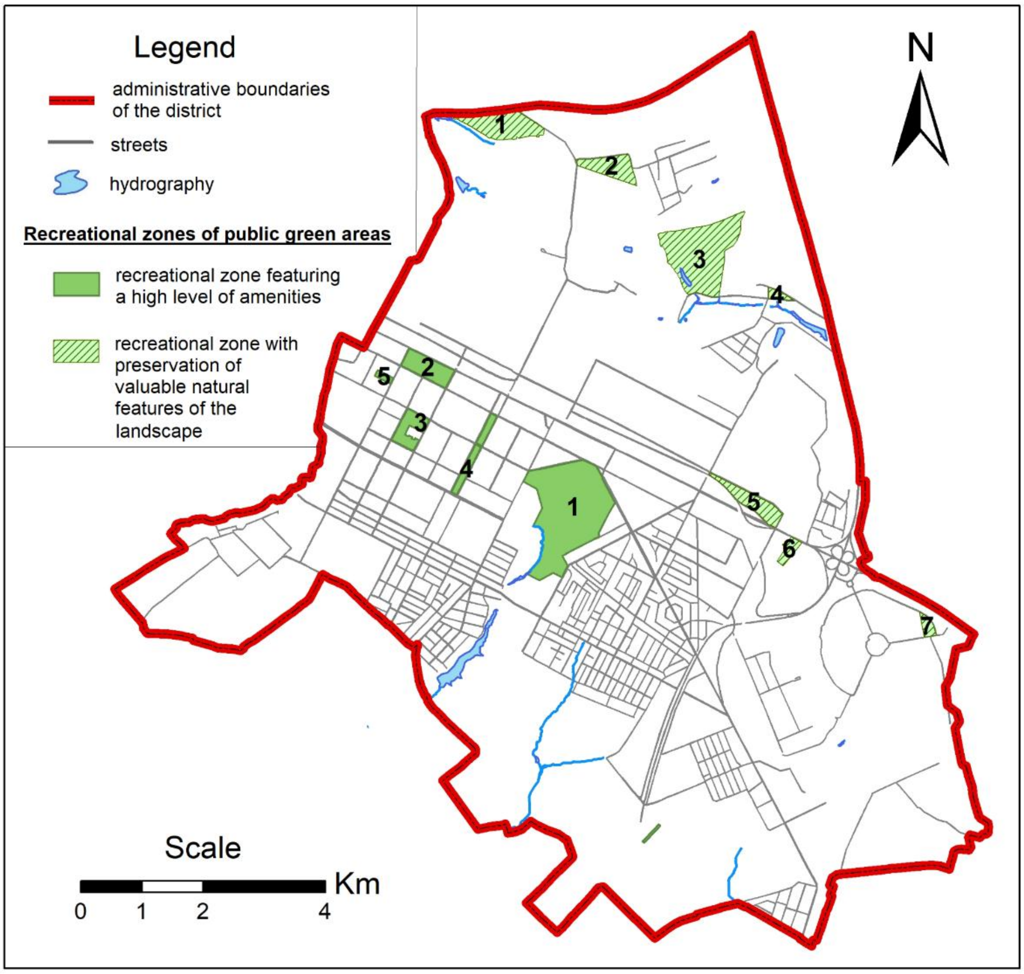

Fig.1. Recreational zones of public green areas in the Industrial District of Kharkiv (The interpretation of the numbers is provided in the text)

A brief description of these recreational areas, based on satellite imagery analysis, is provided below:

- *Site 1* is covered with herbaceous vegetation and has windbreaks along the roadsides. The strip of land along the northern boundary is used for summer cottages; to the south it borders the Kulychivsky cemetery.
- *Site 2* is predominantly covered with tree vegetation, some of which is ploughed for garden plots.
- *Site 3* is the largest in area and has a mixed vegetation, including tree and herbaceous vegetation, as well as bare ground. It is heavily littered.
- *Site 4* is a wasteland covered mainly by herbaceous vegetation.
- *Site 5* is covered with dense tree vegetation. It is surrounded by industrial areas and elements of the tramway junction.
- *Site 6* is covered with herbaceous vegetation and borders on a residential area. It is actively used for amateur sports competitions and training.
- *Site 7* is covered with tree vegetation and borders on a residential area.

It is evident that for the effective recreational use of these areas, it is necessary to develop concepts for their specificity and plans for their design as part of the city's green infrastructure.

a b

Fig. 2. Typical views of the recreational area for the preservation of valuable natural features of the landscape (a - *Site 1*; b - *Site 3* from Fig. 1)

The population of the Industrialnyi District as of 01.01.2022 was 153.8 thousand people (10.7% of the total city population). According to estimates by the city authorities, the approximate population of Kharkiv as of 01.04.2024 is about 1.3 million people, which is 0.1 million less than the pre-war figure [3]. Considering this level of decrease, it can be assumed that the current population of the Industrialnyi District is approximately 139.9 thousand people.

Thus, the level of provision of the population of the Industrialnyi District with green spaces of recreational zones for general use is 13.78 m² per person, which corresponds to a satisfactory level. According to the recommended standards [4] established for cities in the Forest-Steppe zone, the minimum area of green spaces for general use should range from 6 to 11 m² per person, depending on the status of the area (city-wide or district level). Therefore, the greening indicator in the Industrialnyi District exceeds the normative values, indicating a relatively favorable level of provision of the population with green spaces for general use.

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Khaduskina K. V., *student*
V. N. Karazin Kharkiv National University, Kharkiv, Ukraine
***Nekos A. N.**, DrSc (Geography), Professor*

COMPARATIVE ANALYSIS OF SURFACE WATER QUALITY OF THE RIVERS IN THE SIVERSKY DONETS BASIN

This study focuses on the water quality of the Kazennyi Torets and Kryvyi Torets rivers, which are vital sources of water for the population of Druzhkivka, Donetsk region. Due to the region's water shortage exacerbated by the ongoing conflict, these rivers have become crucial for supplying water for domestic and economic purposes. The study compares the results of water sample analyses from these rivers at two monitoring posts during both the winter and summer of 2024–2025, assessing key water quality indicators such as nitrates, nitrites, and chlorides. The findings show significant seasonal variation, with chloride concentrations in summer being much higher than in winter, and nitrates exceeding the permissible levels in some cases. The results highlight the need for ongoing monitoring and management of water resources in the region, especially considering the added stress caused by the conflict.

Key words: water quality, Kazennyi Torets River, Kryvyi Torets River, water monitoring

Water supply for the population of Donetsk region is an urgent problem. These regions have always been distinguished by a lack of water resources. Water supply to the city is largely carried out through the Siversky Donets-Donbas canal. With the beginning of the armed conflict, the shortage of clean water has increased significantly. Therefore, the search for additional sources of clean water in the region has become extremely necessary. Given this, the Kazennyi Torets and Kryvyi Torets rivers were chosen as the objects of the study. Due to the water shortage caused by martial law, rivers play a significant role in providing the local population with water resources. The rivers flow through the city of Druzhkivka. It belongs to the category of small cities by population, which as of 01.01.2023 was 31937 people [1]. The city's population uses surface water of rivers for economic, domestic and other purposes.

This study compares the results of water sample analyses from the Kazennyi Torets and Kryvyi Torets rivers with monitoring data from observation posts identified by the State Agency for Water Resources [2] with water samples from the same rivers taken during the author's own research.

The first monitoring post is on the Kryvyi Torets river (1 kilometer, Karlivska dam, technical water intake). The second monitoring post is on the Kazennyi Torets river (55 kilometers from the city of Druzhkivka, below the confluence of the Kryvyi Torets river into the Kazennyi Torets river below the city, technical water intake) [2].

The date of water sample collection is 01.21.2025 (winter period). The sample analysis was carried out at the Water Monitoring Laboratory of the Eastern Region. Water samples from these rivers, which were taken during our own research, were taken (in the summer – 01.08.2024) in two sections: the first section on the Kryvyi Torets River (central part of the city of Druzhkivka), the second section - the place where the Kryvyi Torets River flows into the Kazennyi Torets River. The place of water sample collection is located near the monitoring observation posts. The sample analysis was performed in the educational and research laboratory of analytical ecological research of Institute of Environmental Sciences of V. N. Karazin Kharkiv National University. As can be seen, the water samples were taken at different times of the year, therefore a comparative analysis of the quality indicators of river waters is important. The concentrations of nitrates, nitrites and chlorides were determined in surface water samples from two rivers. In water samples taken in the summer in the first section, the nitrate concentration was found to be 23 mg/dm^3 – no exceedances (according to the "Hygienic Standards..." [3] the Maximum Permissible Concentration is 45.0 mg/dm^3), nitrites – 0.001 mg/dm^3 (Maximum Permissible Concentration – 3.3 mg/dm^3), which corresponds to the standard, chlorides – 1416 mg/dm^3 (Maximum Permissible Concentration – 350.0 mg/dm^3), this indicates an excess of the Maximum Permissible Concentration by 4 times.

The results of the analysis of water samples taken in winter at the first monitoring post are as follows: nitrate ions – 25.76 mg/dm^3, nitrite ions – 0.50 mg/dm^3, chloride ions – 369.20 mg/dm^3 [2], exceeding the Maximum Permissible Concentration by 1.1 times.

Thus, comparing the concentrations of chlorides in water samples (winter 2025, Kryvyi Torets River), it was determined that these indicators are 4 times lower than in water samples taken in the summer of 2024. Nitrates and nitrites in both cases of seasonal water sampling remain within the standards.

At the second site in the water samples taken in the summer of 2024 (the confluence of the Kryvyi Torets River into the Kazennyi Torets River), the nitrate concentration was 84 mg/dm^3, which exceeds the norm by 1.9 times, nitrites – 0.002 mg/dm^3, which is within the Maximum Permissible Concentration, chlorides – 1368 mg/dm^3, which indicates an excess of the standards by 4 times.

The results of the analysis of water samples taken in the winter of 2025 at the second monitoring observation post of the river. Kazennyi Torets (55 kilometers from the city of Druzhkivka, below the confluence of the Kryvyi Torets River into the Kazennyi Torets River below the city, technical water intake) shows the following concentrations: nitrate ions 20.44 mg/dm^3, nitrite ions 0.61 mg/dm^3, chloride ions 454.40 mg/dm^3 [2], exceeding the Maximum Permissible Concentration by 1.3 times. Comparing the concentrations of chlorides in water samples (winter 2025, Kazennyi Torets River), it was determined that these indicators are 3 times lower than in water samples taken in the summer of 2024. Nitrate concentrations in water samples (winter 2025, Kazennyi Torets River) are 4 times lower than in water samples taken in the summer of 2024. Nitrite is within the standards.

Comparison of the results showed that the concentration of nitrates in water samples taken in the winter of 2025 is 4 times lower than in water samples taken in the summer of 2024. At the same time, the concentration of nitrites in both cases is within the norms. As for the comparison of the concentration of chlorides in water samples taken in the winter of 2025 from the Kazennyi Torets River, they are 3 times lower than in water samples taken in the summer of 2024. This is explained by the fact that the concentration of chloride ions in surface waters varies according to the seasons of the year and the total mineralization of the water body. Accordingly, in the summer-winter period, mineralization acquires the highest values. With increasing mineralization, the relative content of chloride ions in water also increases [5,6,7].

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Kochetyha D. V. *student*
V. N. Karazin Kharkiv National University, Kharkiv, Ukraine,
Maksymenko N. V., *DrSc (Geography), Professor,*
Cherkashyna N. I., *English Language Supervisor,*

OVERVIEW OF THE IMPACT OF HOSTILITIES ON THE FORESTRY OF VOVCHANSK UNITED TERRITORIAL COMMUNITY

The article is devoted to the study of the damage caused to the forest landscapes of the Vovchansk united territorial community. Based on a map from Texty.org.ua, the article analyses changes in the duration of the occupation of the territory and, as a result, the degree of forest degradation. Specific examples of fires caused by shelling are given.

Key words: forest landscapes, Vovchansk community, fires, hostilities, environmental impact, occupation.

Due to hostilities, a significant part of the forests in the territory of Vovchanska united territorial community was destroyed. Direct damage from the aggressor's actions was recorded in the form of mines, forest fires, violations of the integrity of farms and environmental pollution. Since February 2022, the region's forest resources have been under threat of occupation and direct destruction. To assess the damage and potential harm, a review of the state of forest plantations for the period up to 2025 was carried out. It is known that the total area of Ukraine's forests is 10.4 million hectares, of which 9.6 million hectares are covered with forest vegetation. The country's forest cover is 15.9%. A significant number of forest plantations are located in Polissya and the Carpathians. Ukraine's forests perform water protection, sanitation and hygiene functions. Despite their small number, forests also play an important role as sinks for greenhouse gases, which are considered to be the main drivers of climate change. However, the growing anthropogenic load, industrial emissions and fires are disrupting the natural resilience and environment that shape the functions of forest ecosystems. Analysing the map of hostilities presented on the Texty.org.ua website by the independent publication Texty, I conducted a study of the situation in the Vovchansk amalgamated territorial community (UTC) (Fig. 1). Taking into account the geographical location of the community, the dynamics of changes in the front line and the events recorded, conclusions were drawn about the state of the region's forest plantations and the possibility of further restoration. The map, which is regularly updated, has become an important source for analysing the development of hostilities and their impact on the region's resources.

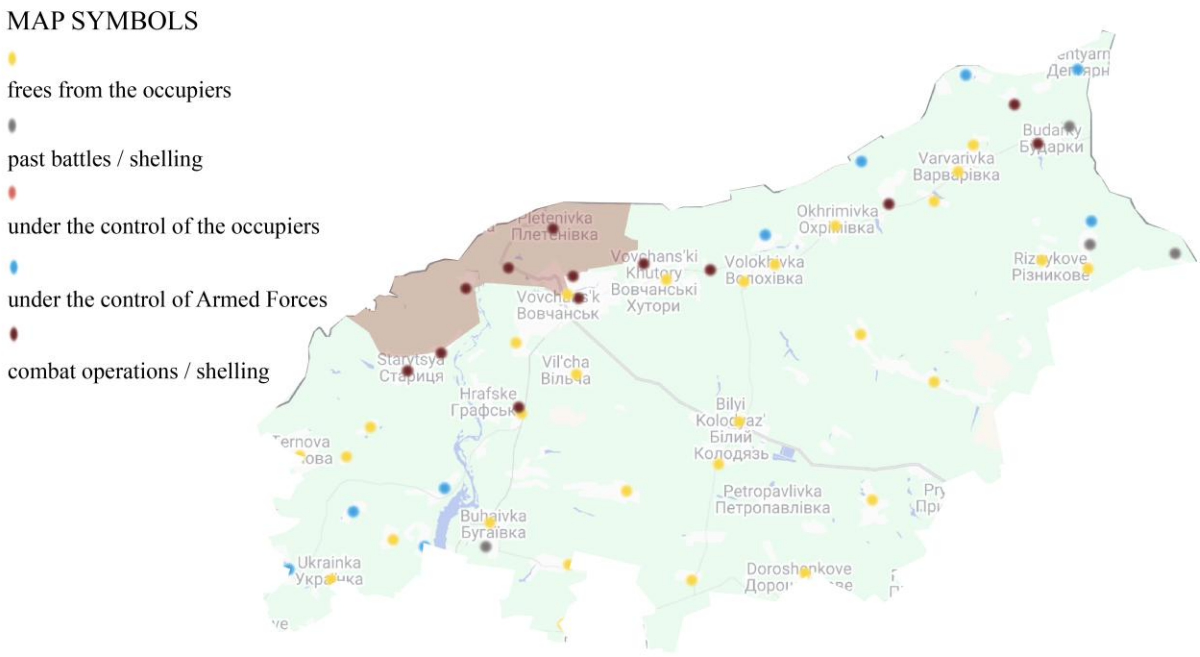

Fig. 1. Vovchanska ATC on the map of hostilities [1]

Since November 2022, about 2.4 million hectares of Ukrainian forests have been occupied, which corresponds to 22.8% of their total area. During the war, hostilities took place on an area of 3 million hectares of Ukrainian forests. Significant areas of nature reserves were also affected. Currently, the borders of the occupation still exist and are changing every day. As of March 2025, Figure 1 shows the occupied territories of the Vovchanska UTC such as Pletenivka, Hatyshche, Ohirtseve, Buhrovatka and many other settlements that are subject to enemy aggression every day. According to the State Forestry Agency, as of 2024, the largest number of fires was recorded in Kharkiv region (464 cases on an area of 13681.8 ha), 12 cases of fires with a total area of 11,540.2 ha, of which 97.4 ha were caused by wildfires. The main causes of forest fires are plantation fires caused by Russian aggression (45%) [2].The territory of Vovchanska UTC has been a hotspot since the beginning of the full-scale invasion, as evidenced by the aggressor's actions over the past three years. The latest event to be covered in the Vovchanska community in the Kharkiv region was a fire caused by Russian shelling on 28 May, which destroyed dozens of buildings. This was reported on Facebook by the Main Directorate of the State Emergency Service in Kharkiv region, Ukrinform reports. A large-scale fire with a total area of more than 15 hectares. The coniferous litter of the pine forest was burning, and the fire partially spread to the crowns of trees and the private sector. The flames destroyed dozens of residential and commercial buildings. Vovchansk nd other settlements of Chuguiv district, Lipetsk community of Kharkiv district are subjected to artillery shelling and air strikes by bombs and drones on a daily basis. The enemy's actions are becoming increasingly large-scale and aggressive, destroying forests in Ukraine. Despite the significant losses caused by the hostilities, the Ukrainian forestry sector has demonstrated resilience and the ability to recover. Thanks to the efforts of government and volunteer organisations, programmes are already being developed to restore damaged forests, reclaim land and combat the effects of mines. Ukraine receives significant international support in the area of demining. The State Emergency Service of Ukraine has created a website where citizens can see the contamination zones and the extent of demining work being carried out in the country [3]. It is also positive that even in the difficult conditions of the war, Ukraine continues to implement environmental initiatives aimed at preserving the natural balance, reforesting degraded areas and improving forestry policy. The State Forestry Agency proposes new solutions to improve the state of Ukraine's forest resources, including the introduction of the principles of close-to-nature forestry, development of side businesses, transition to mechanised logging using modern logging equipment, full digitalisation of the forest management system, and transformation of all business processes.

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Korkhov O., *student*
V. N. Karazin Kharkiv National University

ECOLOGICAL CONSEQUENCES OF THE WAR IN UKRAINE: CHALLENGES FOR OIL AND GAS PRODUCTION IN EASTERN

The war in Ukraine has had serious environmental, economic and geopolitical consequences, particularly in the east of the country, where the largest reserves of natural resources such as oil, gas, coal and metals are located. The conflict has disrupted the extraction and exploration of these resources due to intense fighting, mineralisation of the territories and the destruction of infrastructure.
Key words: natural resources, environmental impacts, economic recovery, oil, gas, Dnipro-Donetsk Basin

The ongoing war in Ukraine has caused significant environmental, economic, and geopolitical consequences, particularly in the eastern regions, which hold the country's most valuable deposits of hydrocarbons and other natural resources. Eastern Ukraine is home to the Dnipro-Donetsk Basin, which contains over 80% of Ukraine's natural gas reserves and a significant portion of its oil production. Additionally, the region is rich in coal, iron ore, rock salt, gypsum, and rare earth metals. However, the escalation of military activity and extensive landmining have severely disrupted the exploration and extraction of these resources. Ukraine is currently recognized as one of the most heavily mined countries in the world, which presents unprecedented challenges for both the energy sector and environmental security.

The Dnipro-Donetsk Basin, one of the largest hydrocarbon-bearing structures in Europe, extends across the eastern part of Ukraine and serves as a key source of energy for both domestic consumption and export. The basin's geological structure consists of folded Paleozoic and Mesozoic formations with oil and gas traps located at depths between 2,000 and 5,000 meters. Proven reserves in this area are estimated at over 1.1 trillion cubic meters of natural gas and 220 million tons of oil. However, the destruction of infrastructure and the threat posed by landmines have made it nearly impossible to conduct drilling and extraction operations. The direct damage caused by artillery strikes and explosives has destabilized underground structures, increased the risk of blowouts, and compromised the safety of drilling equipment.

Military activity has also impacted coal mining in the Donbas region, which traditionally accounted for over 60% of Ukraine's coal production. Flooding of underground mines due to damaged drainage and ventilation systems has led to the accumulation of methane, increasing the risk of underground explosions and spontaneous combustion. Acid mine drainage (AMD) from abandoned or flooded mines has resulted in the contamination of nearby rivers and groundwater, affecting drinking water quality and agricultural productivity. The combination of methane release and acid mine drainage poses a dual threat to both the environment and human health.

In addition to hydrocarbons and coal, Eastern Ukraine holds significant deposits of iron ore, rock salt, gypsum, and rare earth metals. The Kryvyi Rih Iron Ore Basin, located in the eastern part of the country, has been a major source of iron ore for Ukraine's steel industry. However, ongoing military operations and instability have limited access to mining sites, disrupted supply chains, and increased operational costs. Rock salt production, which is concentrated in the Soledar region, has also been affected by structural damage to mining facilities and transportation infrastructure. Soledar is known for its massive underground salt deposits, which have been mined for centuries and serve as a key source of domestic and industrial salt.

Environmental damage resulting from the war is not limited to mining sites. The destruction of oil refineries and natural gas processing facilities has resulted in the uncontrolled release of hydrocarbons into the atmosphere and surrounding ecosystems. Oil spills and gas leaks have contaminated soil and water supplies, leading to long-term environmental degradation. In some cases, groundwater contamination has reached critical levels, making it unsafe for human consumption and agricultural use. The destruction of pipelines and transport infrastructure has also hindered Ukraine's ability to export energy resources, further weakening the national economy.

Landmining and unexploded ordnance present a long-term obstacle to resource extraction and environmental recovery. According to recent estimates, over 170,000 square kilometers of Ukrainian territory is contaminated with landmines and explosive remnants of war (ERW), making Ukraine the most heavily mined country in the world. The process of demining is costly and time-consuming, with the cost of clearing one square kilometer estimated at between €300,000 and €500,000. Moreover, demining efforts are complicated by the presence of active conflict zones and ongoing shelling.

From a geopolitical perspective, the disruption of oil and gas production in Ukraine has contributed to the broader European energy crisis. Before the war, Ukraine served as a key transit route for Russian natural gas exports to Europe, supplying over 40% of Europe's gas needs. The destruction of pipeline infrastructure and production facilities has forced European countries to seek alternative sources of energy, driving up global energy prices and increasing dependence on liquefied natural gas (LNG) imports.

Restoring Ukraine's natural resource sector will require a coordinated effort at both the national and international levels. Key priorities include large-scale demining, infrastructure reconstruction, and environmental rehabilitation. Developing and implementing sustainable extraction practices will be crucial for ensuring long-term environmental security and resource independence. Investment in modern exploration and extraction technologies, including enhanced oil recovery (EOR) and carbon capture and storage (CCS), could improve the efficiency and safety of future operations. Moreover, strengthening Ukraine's legal framework for environmental protection and industrial safety will help mitigate the long-term impact of military activity on the resource sector.

Ukraine's resource potential remains a critical asset for the country's post-war recovery and future economic growth. Successfully addressing the environmental and industrial challenges caused by the war will not only restore Ukraine's capacity for resource extraction but also strengthen its geopolitical position as a key player in the European energy market.

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Kosogov S. O., *student*
V. N. Karazin Kharkiv National University
Achasov A. B., *DrSc (Agricultural), Professor,*
Cherkashyna N. I., *English Language Supervisor*

IMPACT OF INTENSIVE SUNFLOWER CULTIVATION ON SOIL FERTILITY

This publication presents the results of studies evaluating the impact of intensive sunflower cultivation on soil fertility. Sunflower is a crop that actively depletes nutrients such as potassium, nitrogen, and phosphorus, leading to soil degradation in the absence of proper crop rotation management and fertilizer application. Additionally, sunflower cultivation disrupts the soil's water balance and increases the risk of erosion, especially in arid regions.

Key words: soil fertility, sunflower, crop rotation, degradation, water balance.

Intensive sunflower cultivation significantly affects soil fertility, as this crop requires large amounts of nutrients, water, and optimal physical properties of the soil. Sunflower actively depletes reserves of potassium, nitrogen, and phosphorus, which can lead to soil degradation, especially in the absence of proper fertilization and crop rotation. Additionally, sunflower cultivation disrupts the soil's water balance, which is particularly important in arid regions where water resources are limited.

For every ton of sunflower production, a significant amount of nutrients is removed: 113 kg of potassium, 58 kg of nitrogen, and 30 kg of phosphorus. Without additional fertilization, this leads to soil depletion [1]. Sunflower also actively absorbs moisture from deeper soil layers, which disrupts the water balance and increases the risk of erosion, especially on slopes with a gradient greater than 3° [2]. This worsens the soil's resistance to erosion and negatively affects fertility, as the depletion of organic matter and humus – the foundation of soil fertility – reduces its ability to regenerate.

An important aspect of intensive sunflower cultivation is the lack of crop rotation, which contributes to the accumulation of toxic substances and the development of pathogenic microorganisms in the soil. This, in turn, reduces the soil's ability to maintain a healthy environment for plants and negatively impacts yield [3]. The displacement of perennial grasses, especially in steppe regions, due to the expansion of sunflower cultivation areas, deteriorates soil structure and decreases its fertility, as these grasses play an important role in maintaining the stability of soil structure.

Soil density is an important indicator of its fertility, as it determines microbiological activity and water regime. Soil compaction, which may occur as a result of intensive cultivation, reduces the soil's ability to exchange water, decreases hydraulic conductivity, and reduces oxygen permeability. This limits the development of the plant's root system and lowers crop yields. Canadian studies show that soil compaction can reduce yields by up to 33% [4].

Sunflower cultivation also significantly affects the chemical composition of the soil, particularly the levels of nitrogen, potassium, and phosphorus. Without crop rotation, sunflower cultivation can lead to a decrease in nitrogen content in the soil while simultaneously increasing potassium levels [5]. This can have a negative impact on subsequent crops as the balance of nutrients is disturbed. A significant portion of the nutrients absorbed by the plant remains in the plant residues. After decomposition, the soil is enriched with organic matter, although this process is slow due to the high C:N ratio, which limits the rate of decomposition of organic residues [2, 5].

Intensive sunflower cultivation without proper crop rotation management, fertilization, and other agronomic practices can significantly degrade soil fertility, causing depletion of nutrient reserves, disruption of water balance, and changes in the structural properties of the soil. This can lead to soil degradation and reduced productivity. To restore soil fertility, it is necessary to implement crop rotations that include crops that enrich the soil with organic matter. The application of these measures will help maintain soil environment stability and preserve its productivity in the long term.

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Kot A. G., *PhD student*
V. N. Karazin Kharkiv National University
Cherkashyna N. I., *English Language Supervisor*

MODELING THE IMPACT OF EROSION ON SOIL FERTILITY AND CROP YIELDS

This publication examines soil erosion as a major environmental issue that degrades land, reduces fertility, and threatens food security. It highlights the role of mathematical modelling and remote sensing in assessing erosion risks and developing conservation strategies. The study compares three land management scenarios: no intervention, soil conservation measures, and adaptive management. Predictive modelling helps evaluate long-term impacts and optimize sustainable land use practices.

Key words: soil erosion, land degradation, soil fertility, remote sensing, soil conservation, adaptive management, predictive modelling.

Soil erosion is a major environmental problem that leads to land degradation, reduced soil fertility, and decreased agricultural productivity, threatening food security [1]. FAO projections suggest that global food production needs to increase by 70% by 2050, which could worsen soil conditions. Therefore, land degradation from erosion remains a key challenge [2, 3].

Mathematical modeling, especially using Geographic Information Systems (GIS), is a crucial tool in assessing erosion risks and developing soil protection strategies. This study analyzes soil erosion dynamics and its economic consequences through cartographic analysis, statistical modeling, and economic evaluation, comparing two land management scenarios.

A scenario-based approach is important for studying soil erosion, allowing the assessment of potential outcomes under different management strategies. This approach helps identify the most effective soil conservation practices, considering both environmental and economic sustainability [4]. To address soil erosion, it is essential to develop diverse land management strategies that consider both natural and human factors. Scenario modeling helps predict the consequences of different interventions and compares erosion control methods' effectiveness. Evaluating potential scenarios aids in understanding erosion evolution and making informed decisions about soil preservation and sustainable land use.

This study examines three land management scenarios:

1. No-intervention scenario.

Erosion develops according to natural processes without human influence, assessing land degradation trends without protective measures.

2. Soil conservation scenario.

Measures such as crop rotation, perennial plants, or vegetation cover reduce erosion rates and preserve soil fertility, with potential short-term agricultural impacts.

3. Adaptive management scenario.

Continuous adjustment of agronomic measures based on monitoring soil conditions and erosion processes, accounting for changing climate and land use.

Soil erosion significantly impacts land fertility and agricultural productivity, threatening food security. Mathematical modeling and GIS are essential for assessing erosion risks and developing control strategies. The scenario-based approach helps evaluate different management strategies' ecological and economic consequences. By comparing scenarios such as no intervention, soil conservation, and adaptive management, optimal strategies for soil preservation and sustainable land use can be identified. Considering economic aspects ensures the development of effective erosion control measures that preserve soil fertility and improve agricultural productivity. Evaluating ecological and economic impacts over 5, 10, and 15 years helps plan for long-term soil preservation.

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Kovaliova K. A., *student*
V. N. Karazin Kharkiv National University
***Kryvytska I. A.**, PhD (Biology), Associate Professor*
***Cherkashyna N. I.,** English Language Supervisor*

ASSESSMENT OF POSSIBLE SOIL CONTAMINATION UNDER MILITARY INFLUENCE

During the war in Ukraine, soil contamination has become a significant environmental concern. The military activities have caused mechanical, physical, chemical, and biological damage to the soil, resulting in reduced fertility and the inability to use agricultural land. This study conducted in the Slobozhanske village of Kharkiv oblast revealed that soils were contaminated with heavy metals, including cadmium, lead, chromium, and copper, exceeding background levels and posing serious risks to agriculture and the ecosystem. These contaminants inhibit plant growth and can make crops unfit for consumption.

Key words: soil contamination, heavy metals, Ukraine war, agricultural land, environmental impact.

Since the beginning of the full-scale invasion of Ukraine, the situation with soil contamination has become extremely dire. The negative impacts of the hostilities are associated with many changes in soil structure and quality. These include mechanical impacts from the compaction of military equipment and trenching, physical impacts from vibrations, explosions or fires, chemical impacts from toxic explosives, as well as biological impacts that cause the death of microorganisms, thus disrupting the basic processes that occur in the soil and significantly reducing fertility. In addition, agricultural fields that are mined, cannot be used for growing crops.

In order to determine the ecological condition of soils affected by military operations, we studied their chemical composition.

The soil cover of the study area is chernozem soils of the Forest-Steppe zone of Ukraine.

Field expeditionary research was conducted in 2023-2024. The research included a local survey of chernozem soils of individual land plots within the agrocenoses of the Slobozhanska ATC in the presence of military and man-made impacts on agricultural land near the village of Slobozhanske, Chuhuiv district, Kharkiv region.

Spot sampling of the disturbed soil from craters formed as a result of MLRS, ballistic and cruise missile attacks, and the explosion of guided aerial bombs (GAB) was carried out in accordance with DSTU ISO 10381-1:2004 and DSTU ISO 10381-2:2004, DSTU 7243:2011 [1,2]. The authors applied a combined approach to modified models of radial local distribution of substances and probable soil contamination.

Based on the results of field and laboratory studies in the zones of military impact on the soils of the studied areas of Slobozhanske village, Chuhuiv district, Kharkiv region, we established chemical contamination of soils with heavy metals. Quantitative levels of mobile and potentially available forms of Cd and Pb, Cr and Cu in soils were determined using instrumental methods.

The results of studies on the mobility of the analyzed metals show that background levels were exceeded. Thus, the concentration of Cd was 0.49 mg/kg, which is 9.8

times higher than the background. The concentration of Pb was 1.57 mg/kg, which is 3.1 times higher than the background. Moreover, the background level of Cu in the soil was found to be 1.58 times higher than the background level and Cr was found to be almost 13 times higher.

Thus, we see that agricultural soils that have been affected by military operations, are contaminated. All this can inhibit plant growth, damage the root system and reduce seed germination. Plants can accumulate harmful elements in their leaves, stems and fruits, making them unfit for consumption. It will definitely deteriorate the soil structure due to the death of soil microflora as a result of the toxic effects of the metals under study.

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Kravchenko Ye. I., *student*
Stolov V. O., *PhD student*
V. N. Karazin Kharkiv National University
***Maksymenko N. V.**, DrSc (Geography), Professor*

DETERMINATION OF PUBLIC OPINION ON THE ORGANISATION OF WASTE COLLECTION AND SORTING SYSTEMS IN RURAL AREAS

Based on a survey of the rural population on the current state of household waste collection, the article reveals the degree of readiness for separate waste disposal.
Keywords: recycling, solid waste, environmental impact, surveys, separate collection.

The aim and objectives of the study are to determine public opinion on the organisation of waste collection and sorting systems in the rural population of Kharkiv Oblast and to identify factors and measures that would popularise modern methods of solid waste management among different age groups and encourage them to sort waste at home.

In accordance with the main objective of the study, a survey questionnaire was developed.

Several questions concerned the identity of the respondent: gender, age, type of housing (private house, apartment or dormitory) and place of residence.

The questionnaire then contained the following questions:

1. Do you sort your waste? Yes No

2. For those who answered "No" to question 1: What obstacles prevent you from sorting waste?

- There are no special bins on the street
- It is difficult to organise waste sorting at home
- It takes a lot of time
- There is no certainty that the sorted waste will not end up at a common landfill
- I do not think it is advisable to do this
- I do not understand how to do it properly
- my own version

3. How often do you dispose of household waste?

- Every day
- Several times a week
- Once a week
- Less than once a week

4. Would you be willing to pay extra for sorted waste collection and recycling?

- No, I believe that on the contrary, companies that accept sorted waste should pay the population
- No, I believe that it should be free of charge or the state should provide subsidies to communities to implement such initiatives

- I am ready to make any decision if it improves the waste situation
- Yes, I am ready to pay if it is an official and transparent state programme
- Yes, I am ready to pay in any case, as it is important for reducing household waste and preserving the environment

5. What do you think can encourage people to sort waste?

- Providing each household with special bins
- Providing financial incentives
- Implementation of information campaigns to raise awareness of the population's social responsibility for environmentally friendly waste management
- Installing more sorting bins in each settlement
- Your version.

Using the example of the population of Vodyakhivka village, a survey was conducted regarding unauthorised landfills, with 30% of the population (men, women and children in the ratio of 10% each).

When asked whether the residents sorted their waste, they answered in the negative, as there were no special bins for sorting waste in the village. All the respondents throw out garbage several times a week.

The opinions of the residents surveyed were divided on the willingness to pay for waste collection. Approximately 10% of people are willing to pay, but only if it is an official and transparent government programme. 40% of people believe that companies that accept sorted waste should pay the population. The other 50% are in favour of free waste collection and recycling or the state providing subsidies to communities to implement such initiatives.

What, in the opinion of the villagers, can encourage people to sort waste? The majority of respondents (70%) voted for, firstly, providing each household with special bins to sort waste. 20% of residents said that some financial incentives should be provided to encourage everyone to sort waste. The other 10% think that the best solution to the waste sorting problem would be to introduce information campaigns to raise awareness of the population's social responsibility for environmentally friendly waste management.

Krotko A. S., *PhD student*
V. N. Karazin Kharkiv National University

HISTORY OF USING DRINKING WATER SOURCES IN KHARKIV AS AN ELEMENT OF BLUE INFRASTRUCTURE

The paper analyses the history of the tradition of using water from underground sources for drinking water supply of the city's population. The most popular sources in different periods of the city's history are analysed. Based on the reconnaissance survey, the current state and use of the most popular sources in each administrative district is revealed.

Key words: source, blue infrastructure, groundwater, history of use, popularity, water consumption.

The study of the blue infrastructure of Kharkiv covers such elements as surface water (rivers, lakes, reservoirs, ponds, canals, flooded quarries, etc.) and groundwater that has access to the surface in the form of drinking water sources.

The city of Kharkiv is well endowed with groundwater in terms of hydrogeological conditions, but it is very little used as a source of drinking water. At the same time, there are quite a few natural springs in the city, from which the population of the surrounding areas uses water as drinking water.

In Kharkiv, spring water has been used for drinking purposes since the city was founded. It is known from the literature [1, 2, 3] that the following springs were the most popular:

1. Pavlivski springs (Sarzhyn Yar);
2. Bohomolivskyi spring (Karpivskyi Sad);
3. Hrestova krynytsia (at the bottom of Usivska Street);
4. Bilhorodska krynytsia (at the beginning of Bilhorodska street, now Shevchenka street):
5. Springs at the former Tyuryn dacha and Raschke dacha:
6. Springs along the Nemyshlya River;
7. Springs in the Oleksiivskiy ravine;
8. Springs in the deep ravine (Saltivske village);
9. Osnovyanski springs (in the ravine near the Osnova station);
10. Springs in the Zalyutyn ravine;
11. Kuryazhski springs;
12. Solonytsivka springs

Kharkiv springs were characterised by a relatively large and stable flow rate, up to 6-18 litres per second, and had high water quality. They were located in accessible places at the foot of slopes, in river and beam valleys, within the then urban and suburban areas.

In the centralised water supply of the city in the nineteenth century, the main role was played by the waters of the Bohomolivskyi spring (until 1872), the Khrestova krynytsia and the Pavlivski springs (until 1885) [2].

As the city grew, other springs were brought into intensive use: Oeksiivsky, Zalyutynsky, Osnovyansky springs, springs at the former Tyurinskaya dacha and Rashke dacha, springs on the Nemyshlya River and in the Hlyboky ravine.

The first information about the pollution of the Bogomolivsky, Pavlovsky and other springs dates back to the late nineteenth and early twentieth centuries. Since the springs fed the municipal water supply system, attempts were made to chlorinate the water as a means of cleaning it from bacteriological contamination.

At the beginning of the twentieth century, with the advent of borehole water supply, the city reoriented itself to groundwater, which is deeper and better protected from pollution.

The intensive construction and redevelopment of the city resulted in many springs being covered over, others silted up and their flow rates decreased. The development of industry and utilities caused a gradual deterioration in water quality.

Still, quite a few springs have survived to this day. Their condition varies. For example, the area around the high-flow spring in Sarzhyn Yar has long been landscaped and maintained in satisfactory condition - the spring's flow rate and water chemistry have been relatively stable over a long period of observation. The spring water is used for bottling under the name Kharkivska-1.

The water from the spring on Mineralovodnaya Street (formerly Tyurinska Dacha) was also used for bottling in the recent past as Kharkivska-2, but the plant was closed due to the unfavourable sanitary and epidemiological situation in the area where the spring was fed. At present, its capture facility is partially destroyed, but the city's utilities periodically carry out restoration work.

Later, with the active involvement of the city's environmental protection department, many springs were reconstructed, which significantly increased their popularity among the population. Now the springs are visited by residents not only from the immediate neighbourhood, but also from other parts of the city.

Almost every administrative district of the city has springs with fairly high flow rates:

- Kyivskyi district – springs in Manzhosov Yar (Northern Saltivka), at Turinska Dacha;
- Shevchenkivskyi district – springs in Sarzhyn Yar, Oleksiyivska Balka and on the territory of St Panteleimon's Church;
- Saltivskyi district – springs in Kitlyarchy and Hlyboky Yar;
- Holodnogirskyi district – springs in the Yunist park;
- Novobavarskyi district – a series of springs under the right steep bank of the Lopan River from Moskalivska dam to Novoselivka;
- Nemyshlyansky district – springs in the valley of the Nemyshlya River (Novoproektna Street, Petrenkivska Vodozha, Nemyshlyanska Street), as well as along the Zhykhorets Gully.

In addition to the above-mentioned springs, the following can be classified as managed (or partially managed): "Oleksiivske" (near Klochkivska Street), "Panteleimonivskyi" (on the territory of the church), "Dzhereltse" in Hlybokyi Yar, in the "Yunist" park. The degree of landscaping in the vicinity of the springs varies, which to some extent depends on their popularity and attendance.

Thus, throughout the history of Kharkiv, groundwater sources have been an integral part of the city's blue infrastructure. Currently, due to the unsatisfactory sanitary condition of the territory and the significant impact of industry, municipal facilities and transport on some springs, chemical and bacteriological water pollution is observed. Based on this and given the constant high popularity of springs among Kharkiv residents, there is an urgent need to analyse the condition of the city's springs and develop proposals for streamlining their use.

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Laptiev D. S., *student*
V. N. Karazin Kharkiv National University
***Kryvytska I. A.**, PhD (Biology), Associate Professor*

TOXILOGICAL ASSESSMENT OF SOIL AFFECTED BY RAILWAY INFRASTRUCTURE

The conducted research was devoted to the analysis of phytotoxic properties of soils under the influence of railway transport.

Key words: phytotoxicity, soil, railway transport, biotesting

Railway infrastructure significantly influences soil quality due to construction, exploitation, and maintenance activities. This impact is complex, involving mechanical, chemical, and ecological changes.

The passage of heavy trains and the use of heavy machinery during railway construction cause severe soil compaction. This reduces soil porosity, impairing drainage and aeration. Embankments and excavations alter natural water flow, leading to localized flooding, or, conversely, excessive drying. These processes contribute to the erosion of the fertile topsoil, diminishing soil quality.

The constant vibrations from passing trains can weaken soil structure, particularly in sandy or loose soils, increasing the risk of landslides or collapses.

Railways also contribute to soil contamination with heavy metals, petroleum products, and various chemicals [1].

Heavy metals (such as iron, cadmium, lead, and sinc) accumulate in the soil due to wear or tear on rails, wheels, and braking system. Petroleum products from locomotives contribute to soil pollution, reducing its fertility. Herbicides used by railway companies to control vegetation along tracks can infiltrate the soil and penetrate aquifers. De-icing salts, applied in winter, accumulate in the soi, leading to salinization and reducing its ability to support plant life. Waste materials, such as plastic and metal debris along railway lines, do not decompose and negatively impact soil's physical and chemical properties.

Soil quality also plays a crucial role in maintaining railway infrastructure stability. Soil degradation due to vibrations and contamination can lead to track deformations, increasing the risk of accidents.

Thus, monitoring soil pollution along railways is essential for ensuring environmental safety, preventing land degradation, and minimizing negative effects on human health and ecosystems.

Our study focused on assessing the phytotoxic properties of soil samples collected in Kharkiv, near the railway tracks of Levada Station. Samples were taken 30 meters east of the tracks, on a hill, in an area with residential buildings and a playground. The site contained trees, flower beds, and noticeable amounts of glass, large stones, and minor construction debris.

Toxicological Assessment of Soil Using Phytotoxicity Testing on Avena sativa L.

The toxicological evaluation of soil was conducted by determining its phytotoxic properties through a bioassay method using aqueous soil extracts. The test organism chosen for this study was common oat (*Avena sativa* L.) [2].

We selected oats because they respond quickly to the presence of pollutants in the soil, including heavy metals, pesticides, salts, and petroleum products. Changes in root and shoot growth indicate contamination levels, and their sensitivity allows for the detection of even minimal concentrations of toxic compounds.

By measuring the length of roots and shoots in both the control and experimental samples, we calculated arithmetic means, which were then used to determine deviations in growth between the two groups.

The assessment of soil phytotoxicity revealed that the soil exhibited toxic properties. The deviation in root and shoot length exceeded 20%.

The toxic effect indicator showed an 85.9% reduction in root length and a 91.9% reduction in shoot length compared to the control. Based on the level of contamination, the soil was classified as highly polluted, belonging to the V quality class, with a contamination degree of 1.5 [3]. This is attributed to the significant impact of railway transport, which considerably increases pollution levels in the studied area.

Summarizing our findings, the tested soil exhibited toxic properties. We also recommend using oats (*Avena sativa* L.) as a test organism due to their high sensitivity to pollutants, ease of cultivation, and rapid response. Their ability to detect both acute and chronic contamination makes them a reliable bioindicator for soil phytotoxicity assessment. Oats serve as an effective tool in environmental monitoring, ensuring accurate identification of pollution levels.

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Leleka D., *PhD student*
Institute of Ecology of the Carpathians, NAS of Ukraine

ORGANIC CARBON STORAGE IN THE LITTER OF OLD-GROWTH FORESTS OF THE VODODILNO-VERKHOVYNSKYI RANGE (UKRAINIAN CARPATHIANS)

Climate change has intensified weather extremes, highlighting the importance of understanding CO_2 regulation mechanisms. Forest ecosystems, particularly old-growth forests, play a vital role in carbon sequestration, storing carbon in phytomass, deadwood, and soil. This study focused on organic carbon stocks in forest litter in the Vododilno-Verkhovynskyi Ridge of the Ukrainian Carpathians, revealing significant variation in carbon content depending on slope and terrain. Forest litter, while the smallest carbon reservoir, plays a crucial role in the migration and transformation of organic carbon within the ecosystem.

Key words: climate change, carbon sequestration, forest ecosystems, organic carbon, Ukrainian Carpathians.

Climate change has far-reaching consequences that already affect natural systems and human lives worldwide. The increase in the average temperature over the past century by 0.8-1.2°C has led to abnormal weather events [2]. Therefore, it is crucial to study the regulatory mechanisms controlling CO_2 levels in the atmosphere. One of the largest absorbers and reservoirs of organic carbon is forest ecosystems. Forest ecosystems play a critical role in carbon sequestration, especially old-growth forests, which store carbon in the form of phytomass, deadwood, and soil. Research indicates the high sequestration capacity of forests due to the significant accumulation of organic carbon in deadwood, forest litter, and humus soil horizons [1].

This study aimed to determine the organic carbon stocks in the forest litter of old-growth forests in the Vododilno-Verkhovynskyi Ridge in the Ukrainian Carpathians. Forest litter, as a component of the ecosystem, plays an essential role in the migration of organic carbon from live phytomass to the soil.

The study area is located within the Vododilno-Verkhovynskyi Ridge, specifically on its northern and southern slopes. The investigated area extends 20 km from Mount Pikuy to Mount Zhurivka. The border between the Lviv (northern slopes) and Transcarpathian (southern slopes) regions runs along the mountain range. Geomorphologically, the study area belongs to the Vododilno-Verkhovynskyi region of the Ukrainian Carpathians, specifically to the Verkhovynskyi-Middle-Mountain-Watershed Ridge district. Within this area, 26 plots were established. The tree stands are composed of sycamore maple-beech and beech old-growth forests, with two plots consisting of fir-beech forests. The dominant soil type in the study area is brown forest soils (Nature of Lviv Region, 1972). Within these plots, samples of forest litter (n=3) were collected using a 25×25 cm frame from 100 m^2 (10×10 m) plots [1, 3]. The organic carbon content in the forest litter was determined using the dry ashing method. Soil samples were collected from each genetic horizon in threefold replication.

The study determined that the forest litter stocks in the Verkhovynsko-Vodolilnyi Ridge range from 7.70 to 30.14 $t \cdot ha^{-1}$, while the organic carbon stocks in the litter range from 3.61 to 9.42 $t \cdot ha^{-1}$. This significant variation in stocks is explained by considerable differences in the terrain and slope direction at each site. On northern slopes, the litter is more strongly displaced by wind, so on steep slopes, it is usually less than on gentle ones.

Forest litter, as an ecosystem component, is the smallest reservoir of organic carbon relative to phytomass, coarse woody debris (CWD), and soil. However, the role of litter in the migration and transformation of organic carbon is critically important. It is an easily decomposable component processed by detritivores and has a seasonal replenishment cycle. Due to this, litter ensures a constant and rapid replenishment of organic carbon stocks in the soil.

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Liubov Ye. O., Liubova V. P., *students*
V. N. Karazin Kharkiv National University
***Gololobova O. O**., PhD (Agriculture), Associate Professor,*
***Cherkashyna N. I**., English Language Supervisor*

QUALITY OF DRINKING WATER IN KREMENCHUK DISTRICT OF POLTAVA REGION

The publication presents the results of drinking water quality assessment in Kremenchuk District of Poltava Region

Key words: water sources, nitrates, chlorides, water hardness.

Assessment of drinking water quality is an essential component of ensuring the public health, since the overall level of the well-being of people, as well as reducing the exposure to diseases associated with its use, depends on the water quality. Water resources of Kremenchuk District of Poltava Region have different levels of pollution depending on the water sources, which can significantly affect its safety for consumption. Considering this, our study is aimed at assessing the drinking water quality from different water sources, in particular, wells in the single-family residential neighborhood and water supply networks of the district.

As part of the study, three water samples were analyzed: a sample from a well in the single-family residential neighborhood, tap water from network № 1 (apartment) and tap water from network № 2 (single-family residential neighborhood). The importance of our study is that it allows us to determine the level of water pollution, identify possible health risks and, based on the results, offer recommendations for improving the quality of water supply in the region. The drinking water quality must meet the requirements, namely, the State Sanitary Rules and Regulations 2.2.4-171-10 "Hygienic Requirements to Drinking Water Intended for Human Consumption", approved by the Order of the Ministry of Health of Ukraine of May 12, 2010 No. 400 with amendments approved by the Order of the Ministry of Health of Ukraine No. 341 of February 18, 2022 [1, 2].

One of the main parameters that determine water quality is the pH level. In all three samples, the water showed a pH value within 7.29-7.48. This indicator meets the requirements of sanitary regulations and indicates the absence of a risk of corrosion attack on water pipes and household appliances, as well as the absence of a danger to human health with regular water consumption.

The level of ammonia in water is an important indicator of organic pollution. In all samples, the water had an ammonia level of 0.04 mg/dm^3, which is within the permissible regulations according to the State Sanitary Rules and Regulations 2.2.4-171-10. This indicates the absence of significant organic pollution in the water that could pose health risks, such as poisoning or other diseases associated with toxic compounds [2].

All samples were odorless, which is a good indicator of water quality, in accordance with the requirements of sanitary regulations. The absence of odor indicates that the water does not contain undesirable organic or chemical compounds that could negatively affect taste and be potentially toxic to consumers.

Water transparency is an indicator of the presence of mechanical impurities and colloidal particles. Water transparency varies from 15 cm in a sample from well No. 2 to 25 cm in samples from water supply networks № 1 and № 2. Such values do not exceed the permissible regulations and indicate the presence of a small number of particles. This requires further water purification to improve its quality and ensure health safety.

Nitrates and nitrites are important indicators of water pollution by pesticides and fertilizers. Water from water supply networks № 1 and № 2 contains nitrates at a level of 8 mg/dm^3, which is within the permissible regulations. This level does not pose consumers health risks, since nitrates in such a concentration do not exceed the established standards and do not have a toxic effect.

The chloride content in all water samples is 464 mg/dm^3, which is a permissible value for drinking water, in accordance with the requirements of hygiene standards. However, high levels of chlorides can affect the taste of water, so it is necessary to pay attention to possible methods of reducing this value to improve the consumer properties of water.

The water hardness in the studied samples ranged from 10 to 11 mmol/dm^3, which corresponds to the standards for water in this region. This level does not pose health risks, but for domestic needs, the use of water softening agents may be useful, especially in households with hypersensitivity to hardness.

Thus, a study of drinking water quality in Kremenchuk District of Poltava Region showed that the overall level of water pollution in samples from various water sources (wells and water supply networks) does not exceed the permissible regulations for drinking water. The parameters of pH, ammonia, transparency, hardness, iron, zinc, copper, manganese, cadmium and chromium are within safe values, which indicate the absence of serious public health risks. However, some indicators, such as transparency and chloride levels, require additional control and possible improvement of water purification methods to improve its consumer properties.

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Lysak R. A., *student*
V. N. Karazin Kharkiv National University, Kharkiv, Ukraine,
Maksymenko N. V., *DrSc (Geography), Professor,*
Cherkashyna N. I., *English Language Supervisor,*

POSSIBILITIES OF GIS TECHNOLOGIES IN NATURAL RESEARCH

The article contains analysis of GIS technologies and their use in agriculture.
Key words: GIS, technologies, GIS technologies, agronomy, agriculture, WEPP, water erosion.

Our article [1] describes the importance of GIS technologies in general. In this paper, we want to describe the importance of predicting water erosion in specific conditions and the software that can do it.

The breaking down of solid rock into small particles and their transport by water, like the effects of weather conditions, erosion is a natural geological process, but its speed can increase with erroneous land use practices, which leads to the loss of the upper fertile layer of soil and the deposition of fine soil in ravines, lakes, rivers, bays. There are three classes of water erosion: a) drip erosion, in which raindrops fall on the open surface of the soil, turning it into liquid mud, filling the soil pores and turning the upper soil layer into a structureless, compact mass, which forms a hard crust when dried; b) erosion during surface runoff, when the soil is washed away by streams of water during heavy rain; c) jet erosion due to the formation of depressions on the soil surface by flowing streams of water, which further deepen with subsequent erosion. A small erosion depression is called a furrow, a larger one is called a ravine [2]. Soil erosion is a major problem for agricultural production, affecting soil quality and causing pollutants to enter waterways [3].

In order to have an idea of the consequences of water erosion in the future under certain conditions, you can use the WEPP software.

WEPP is available for use by conservation planners in situations where its advanced functionality such as soil erosion and water management risk statistics, conservation system effectiveness in wet and dry years, and soil hydrology are desired. NRCS regional and state agronomists can assist planners in the use of WEPP. The WEPP model computes both sheet and rill erosion detachment and deposition on various types of hillslopes, as well as the total sediment delivery to the end of the slope along with water budget information. WEPP is available on the world wide web and is compatible with Google Chrome, or Firefox browsers. It accesses a national cloud-based database for soils, climate, crops, operations and other data needed for all model sub processes. Model and database updates or downloads are automated.

WEPP is a process-based, continuous simulation, deterministic model that has seven process-based sub models including: Soil, Climate, Management, Hydrology, Plant Growth, Residue Decomposition, and Erosion.

Daily climate is generated by CLIGEN which produces individual storm parameter estimates, including time to peak, peak intensity, and storm duration over a 100 year simulation period. Additionally when using the digital map feature, PRISM automatically adjusts climate including temperature and precipitation to actual latitude and longitude of the site.

A modified EPIC plant growth model incorporates response to changing environmental conditions such as soil moisture, rainfall, temperature, irrigation and solar radiation. Residue decomposition rate is determined by a process-based decomposition sub model which adjusts for soil and climate conditions of the site.

Hydrology outputs include precipitation, soil evaporation, plant transpiration, runoff, water drainage, irrigation, and soil water balance/hydrologic status that includes average, minimum and maximum over the simulation period. Irrigation water use is estimated based on crop water use, available water capacity of soil and soil water deficit. A 100-year statistical analysis that includes average, wet year, dry year and additional statistical graphs and outputs for rainfall, erosion, irrigation, runoff, crop transpiration, soil evaporation, and sediment delivery is generated for use in risk-based conservation planning [4].

Since soil is the main wealth of Ukraine, it must be cared for appropriately. It is necessary to know in advance what consequences this or that problem will lead to. And WEPP software can help with predicting water erosion.

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Makieieva D. S., *student*
V. N. Karazin Kharkiv National University
***Cherkashyna N. I.**, English Language Supervisor*

TEXTILE PRODUCTS AND EXCESSIVE RESOURCE CONSUMPTION IN MODERN SOCIETY: ANALYSIS OF PROBLEMS AND SOLUTIONS

The publication presents the results of research from various scientific sources and the author's own observations.

Key words: ecology, textile industry, natural resources, pollution, recycling, fast fashion

Fashion is one of the most important sectors of the global economy, with an estimated value of around 2.4 trillion dollars according to the McKinsey Global Fashion Index. Additionally, this industry is the second most harmful to the environment, following the oil industry. The fashion industry is responsible for nearly 10% of global CO_2 emissions and contributes to the annual deforestation of 70 million trees for the production of artificial fibers, mainly derived from petrochemicals such as viscose, polyester, or lyocell. The recycling of these fibers often leads to toxic emissions, adding to the environmental harm caused by the industry [1].

Synthetic fibers continue to dominate, with the production of virgin fossil-based synthetic fibers increasing from 67 million tonnes in 2022 to 75 million tonnes in 2023. Polyester remained the most produced fiber globally, accounting for 57% of total fiber production [2].

Textile production requires significant amounts of water and land resources for growing cotton and other fibers. It is estimated that producing a single cotton t-shirt requires about 2,700 liters of fresh water—enough to meet one person's drinking needs for 2.5 years. In 2020, the textile industry was the third-largest contributor to water resource degradation and land use [3].

Additionally, to increase yields, fertilizers, pesticides, and herbicides are actively used. During harvest, defoliants are applied to separate the fibers from the leaves. Some manufacturers also use chemicals containing heavy metals and chromium for finishing and dyeing cotton fabrics. On average, each person on the planet consumes about 10 kg of cotton products annually [1].

Textile production is responsible for approximately 20% of global clean water pollution, primarily caused by dyeing and finishing processes. A single wash of polyester clothing can release up to 700,000 microplastic fibers, which eventually end up in the food chain. The majority of microplastics from textiles are released during the first few washes. Fast fashion, based on mass production, low prices, and high sales volumes, promotes frequent washing of new garments, exacerbating the problem. Every year, over half a million tonnes of microplastics from synthetic clothing settle on the ocean floors. In addition to this global issue, pollution from garment production has a devastating impact on the health of local populations, wildlife, and ecosystems near textile factories [3].

Every year, the fashion industry consumes 132 million tonnes of coal, and out of over 100 billion clothing items produced annually, 60 billion are discarded within the first year of purchase. As a result, a significant amount of textile waste accumulates in landfills and can also end up in various parts of the world, including the open sea. This contributes to the growing environmental burden caused by the fast fashion model, which emphasizes short product lifecycles and high consumption rates, leading to substantial waste generation [1]. The approach to discarding unwanted clothing has also changed. Increasingly, people are throwing away items instead of donating them for charity or reusing them. Less than half of used clothes are collected for reuse or recycling, and only 1% of old clothes are recycled into new ones. This is due to the fact that technologies enabling the conversion of used clothing into virgin fibers are still in the early stages of development. This shift contributes to the growing volume of textile waste that ends up in landfills, further exacerbating environmental challenges related to fast fashion and waste management [3].

To improve the situation regarding pollution from the textile industry, it is crucial for consumers to be more aware of textile waste pollution and to choose high-quality, durable clothing. Supporting campaigns for the reuse or recycling of clothing, rather than sending it to landfills, is also essential. From a production standpoint, manufacturers must be held responsible for the entire lifecycle of the products they create. This includes the introduction of environmentally safe production technologies for clothing manufacturing. Additionally, improving methods for recycling old clothing into new fibers or other valuable materials is necessary. This approach can reduce the environmental impact and help minimize the adverse effects of fast fashion.

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Makieieva D. S., *student*
V. N. Karazin Kharkiv National University
Rychak N. L., *PhD (Geography), Associate Professor,*
Cherkashyna N. I.*, English Language Supervisor*

ECOLOGICAL STATE OF THE MINOR RIVERS ON THE RIGHT BANK OF THE SIVERSKYI DONETS

The article considers the ecological state of the rivers Velyka Babka, Tetleha, Luhanchyk, Bilenka, Bakhmutka, Homilsha, and Mzha. The independent research used chemical analysis of collected samples and calculation of indicators and substances related to the water quality of the Velyka Babka River. The ecological state of this river was analyzed and compared with the condition of other rivers on the right bank of the Siverskyi Donets using literary sources. As a result of the study, it was determined that the water quality of the rivers Velyka Babka, Tetleha, Homilsha, Mzha, and Luhanchyk corresponds to slightly polluted status; Bilenka is moderately polluted; and Bakhmutka is classified as polluted. The ecological state of the rivers is unsatisfactory.

Key words: minor rivers, environmental assessment, water pollution index

The study examined the ecological state of small rivers on the right bank of the Siverskyi Donets. According to the Water Code of Ukraine, small rivers are defined as water bodies with a catchment area of no more than 2000 km², provided that the river is located within a single physical-geographical zone, and the length of the watercourse does not exceed 100 km [1]. The author has studied the following rivers: Velyka Babka, Tetleha, Luhanchyk, Bilenka, Bakhmutka, Homilsha, and Mzha.

The Velyka Babka River is classified as a low-water river, with an average water discharge of approximately 1 m^3/s. Due to seasonal variations, its flow can fluctuate between 0.5 and 1.5 m^3/s [2]. In recent years, it has been established that the river's water volume has decreased due to the drying up of its tributary streams and the lowering of groundwater levels. Similar drying processes also affect the tributary streams of the Luhanchyk and Mzha rivers. In contrast, the Tetleha, Bilenka, Bakhmutka, and Homilsha rivers have higher water levels, as they are fed by non-drying streams flowing through this region.

Independent field studies were conducted on the Velyka Babka River, involving sample collection during two hydrological regimes: the spring-summer flood period and the autumn low-water period. A chemical analysis was performed to determine the content of the following substances and indicators: pH, nitrates, alkalinity, and hardness. Figures 1 and 2 show the obtained results.

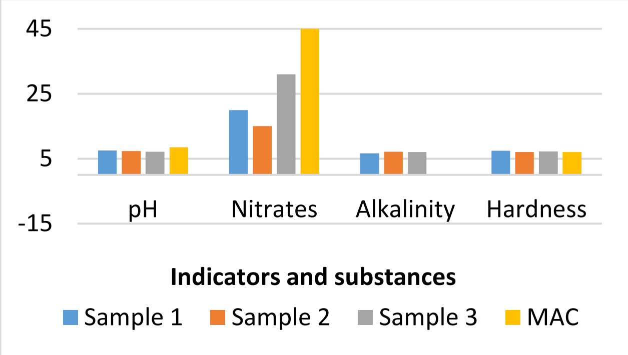

Fig. 1. Chemical analysis during the spring-summer flood period

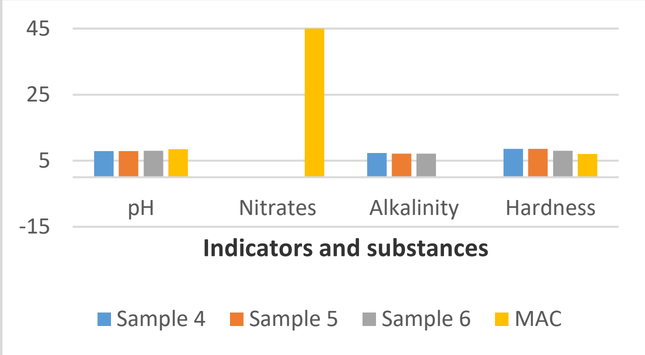

Fig. 2. Chemical analysis during the autumn low-water period

The units of measurement for the graphs are mg/dm³ for pH, alkalinity, and hardness, and mmol/dm³ for alkalinity and hardness. In all six samples, the pH value is within the acceptable range (up to 8.5), nitrates were within the MAC (Maximum Allowable Concentration). However, during the low water period, they were absent. There are no specific MAC norms for alkalinity, but all obtained values are in satisfactory condition. In samples 1–3, the hardness values were: 7.4, 7.0, 7.2. Therefore, samples 1 and 3 slightly exceed the MAC, sample 2 is exactly at the threshold, while in samples 4–6, the hardness is even higher: 8.6, 8.6, 8.0. All these values exceed the MAC. Heavy metal content was also analyzed, and none of the metal indicators exceeded the established MAC, staying within the normal range. The highest concentrations of heavy metals were found in zinc, iron, and copper, while the lowest were in chromium, manganese, and cadmium. During both the high and low water periods, the highest concentration was in zinc, and the lowest was in manganese and cadmium.

The water quality assessment based on the modified IWQ (Integrated Water Quality Index) shows that the Velyka Babka river is moderately polluted (class III). When comparing the results obtained from other sources, we see that rivers such as Tetleha, Homilsha, Mzha, and Luhanchik, tributaries of the Siversky Donets, fall into the same class. The main pollutants in these rivers are petroleum products, advection, and diffuse pollution (nickel, cadmium, lead) from neighboring tributaries. The Bilenka river belongs to moderately polluted rivers (class IV), with the pollutants being salts, soluble organic substances, biogenic components, and pesticides. The Bakhmutka river is classified as a heavily polluted river (class V), with heavy metals, particularly non-radioactive strontium, barium, and lithium, being the primary pollutants. This is associated with industrial activities conducted near this river. The study has found that the ecological condition of the studied rivers is unsatisfactory. A chart with the approximate IWQ values is shown below (fig. 3):

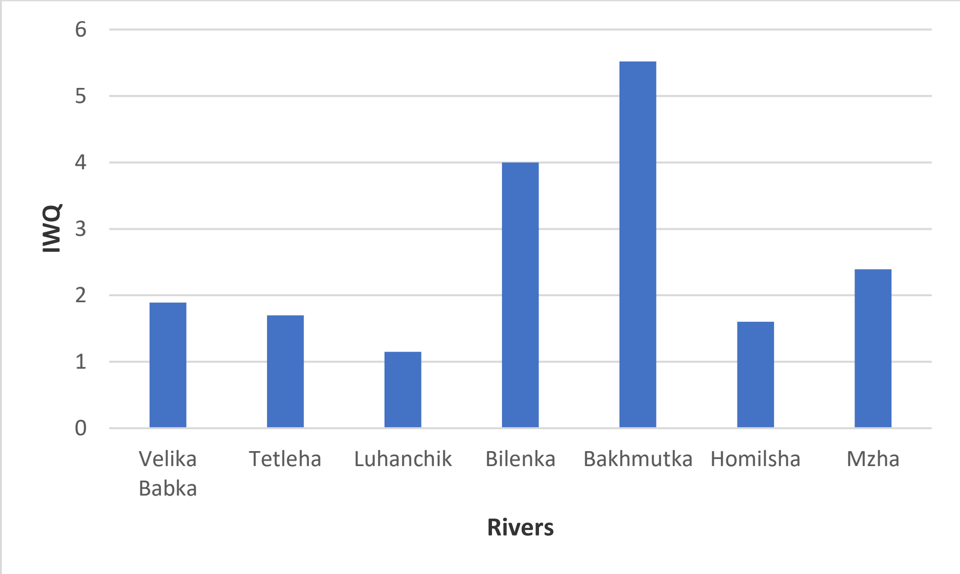

Fig. 3. Integrated Water Quality Index

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Marusyk A. M., *PhD student*
Institute of Ecology of the Carpathians
***Shpakivska I. M.**, PhD (Biology), Associate Professor*

REVIEW OF GIS-BASED ECOSYSTEM SERVICES ASSESSMENT TOOLS FOR NATIONAL NATURE PARKS

The publication presents the results of publication reviews of three ecosystem service assessment tools – ARIES, InVEST, and TESSA focusing on their application in national natural parks. ARIES leverages AI-driven modeling, InVEST provides spatial and economic valuation, and TESSA offers a field-based, site-specific approach, helping park managers make informed conservation decisions.

Key words: ecosystem services, environmental assessment, national nature park management, GIS-based spatial analysis.

National nature parks provide a wide range of ecosystem services, including biodiversity conservation, carbon sequestration, water regulation, and recreational opportunities. Accurately assessing these services is essential for sustainable park management, conservation planning, and policy-making. Several tools have been developed to evaluate ecosystem services, with ARIES (Artificial Intelligence for Environment & Sustainability), InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs), and TESSA (Toolkit for Ecosystem Service Site-based Assessment) being among the most widely used. Each tool offers unique methodologies for quantifying and valuing ecosystem services within national nature parks.

ARIES: AI-Driven Ecosystem Service Modeling. ARIES (ARtificial Intelligence for Ecosystem Services) is an advanced computational framework that integrates artificial intelligence, semantic modeling, and distributed computing to assess ecosystem services. Developed by the Basque Centre for Climate Change (BC3), ARIES automates model selection and execution, allowing dynamic and high-resolution assessments relevant to national nature parks. Key Features are:

● *Comprehensive Service Assessment:* Evaluates provisioning (e.g., fresh water supply), regulating (e.g., climate mitigation through carbon storage), supporting (e.g., nutrient cycling), and cultural services (e.g., ecotourism and recreation).

● *Context-Specific Modeling:* Dynamically selects the most relevant data sources and models to assess national parks' unique environmental and social conditions.

● *AI-Driven Analysis:* Uses machine learning and semantic technologies to integrate complex datasets and predict service changes under different conservation scenarios.

InVEST: Spatially-Explicit Valuation. InVEST, developed by the Natural Capital Project, is a modular, open-source software suite designed to assess ecosystem services through spatially explicit modeling. It translates land-use and conservation scenarios into biophysical and economic estimates of ecosystem services. Key features are:

● *Geospatial Modeling:* Uses land cover maps to evaluate ecosystem services within national nature parks, such as habitat quality, carbon sequestration, and water purification.

● *Scenario Analysis:* Assesses the impact of different land management strategies on park ecosystems, including reforestation, tourism expansion, and habitat restoration.

● *Economic Valuation:* Outputs results in both biophysical (e.g., tons of carbon stored) and economic (e.g., monetary value of tourism benefits) terms.

TESSA: A Site-Based Approach. TESSA (Toolkit for Ecosystem Service Site-based Assessment) provides a practical and cost-effective framework for assessing ecosystem services at the site level, making it particularly useful for national nature parks. Unlike ARIES and InVEST, which rely heavily on geospatial modeling, TESSA focuses on field-based data collection and participatory approaches. Key features are:

● *Site-Specific Assessments:* Tailored for national nature parks and protected areas, providing direct, ground-truthed measurements of ecosystem service provision.

● *Field-Based Data Collection:* Engages park rangers, researchers, and local communities in assessing ecosystem services, such as freshwater availability, flood mitigation, and cultural value.

● *Qualitative and Quantitative Analysis:* Combines numerical data with stakeholder perspectives to capture the full value of services provided by national parks.

● *Decision-Support Tool:* Helps park managers evaluate different conservation scenarios and prioritize actions that enhance ecosystem services.

National nature parks provide essential ecosystem services that support biodiversity, climate regulation, and human well-being. Assessing these services is critical for effective conservation and management. ARIES, InVEST, and TESSA each offer distinct advantages based on scale, data availability, and methodological approach. ARIES provides AI-driven, dynamic assessments suited for large-scale park networks. InVEST enables detailed spatial analysis and economic valuation of ecosystem services in protected areas. TESSA offers a hands-on, field-based approach for local park assessments. By selecting the appropriate tool, national nature park managers and policymakers can enhance conservation efforts while maintaining the ecological and economic benefits provided by these natural landscapes.

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Matisko B. Yu., *PhD student*
V. N. Karazin Kharkiv National University
Krainiukov O. M., *DrSc (Geography), Professor*

IMPROVING METHODOLOGY FOR DETERMINING THE DAMAGE OF SOIL BY POLLUTION AS A RESULT OF ARMED AGGRESSION

Determination of environmental damage and environmental losses is one of the most pressing issues in our time during the war with rf the CMU Resolution No. 326 of 20.03.2022 approved the Procedure for determining such losses with the allocation of land production and land and environmental damage.

Key words: methodology, losses, land pollution, environmental damage.

Determination of environmental damage and environmental losses is one of the most pressing issues in our time during the war with RF. The CMU Resolution No. 326 of 20.03.2022 approved the Procedure for determining such losses with the allocation of land production and land and environmental damage [2]. The relevance of the topic of determining environmental damage is evidenced by a significant number of publications. Both doctrinal approaches to determining environmental damage in the European Union and in Ukraine [1], and applied issues of assessing environmental damage caused by damage to industrial facilities, assessing and compensating for environmental damage, and legal aspects of compensating for environmental damage caused by war are being studied.

The methodology for determining losses involves adjusting the normative monetary valuation using assessment indicators of the hazardousness of substances that pollute the land, and indicators of the amount of pollutant in the volume of polluted land depending on the depth of infiltration. To determine the hazard coefficient of pollutants, the allocation of hazard groups is provided. The first group includes extremely hazardous substances, the maximum allowable or tentatively allowable concentrations of which are less than 0.2 mg/kg of polluted land (MAC/TAC < 0.2 mg/kg). The second group includes highly hazardous substances (MAC/TAC 0.2-0.5 mg/kg). Moderately hazardous and other substances for which MAC/TAC are not established are also distinguished. Taking into account the experience of other countries and scientific research on this topic, such grouping requires clarification. For example, oil and petroleum products, together with extremely toxic arsenic or mercury, are classified as the first hazard group [3]. However, as is known, their toxicity differs significantly. Oil and petroleum products are the general name for many substances that have different compositions and properties. Therefore, it is incorrect to use the general terms "oil" and "petroleum products", as proposed by Methodologies [3, 4] according to DSTU 3437-96 "Petroleum products. Terms and definitions". Oil can be methane, naphthenic, methano-naphthenic, methano-naphthenic-aromatic, and naphthenic-aromatic. By sulfur content, oil is divided into low-sulfur (up to 0.5%), sulfurous (0.5-2%), and high-sulfur (over 2%). Thus, the classification of such pollutants as oil and petroleum products in the first hazard group when determining damage caused by land pollution in the methodologies [3, 4] is incorrect and contradicts existing hygienic regulations in Ukraine regarding the permissible level of chemical substances in the soil.

At present, environmental protection measures for regulating and limiting the entry of environmentally hazardous substances and compounds into the natural environment are generally based on comparing their actual concentrations with the established maximum allowable concentrations of these substances for the relevant component of the natural environment. However, the use of only information about exceeding the MAC of individual chemical substances is insufficient for assessing the ecological state of the territory, as it does not take into account the combined action of multicomponent chemical compounds on the biotic component of ecosystems. This is because the MAC concentration implies the regulation of the isolated impact of chemical substances on the respective test organisms used to establish the MAC, while in real conditions, complex mixtures of substances act, which may result in a combined effect - additivity, synergy, antagonism.

Considering that the list of pollutants (measurement indicators) corresponding to the hazard group is not exhaustive, and if the pollutant is absent from the list, its hazard group is determined by the MAC or TAC value, it is proposed to introduce a soil pollution coefficient into the formula. The advantage of the proposed methodology improvement compared to the existing one is that it allows determining the combined action of all present chemical elements in the studied soils, regardless of concentration, as well as assessing the danger of soil pollution with toxic substances through quantitative assessment of soil pollution based on the levels of growth process inhibition.

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Mazurenko H. O., *student*
V. N. Karazin Kharkiv National University
***Achasov A. B.**, DrSc (Agriculture), Professor*

APPLYING GEOSPATIAL ANALYSIS OF SATELLITE IMAGES IN ASSESSING THE CARBON SEQUESTRATION POTENTIAL OF ERODED SOILS

A literature review of the problem of erosion and the importance of carbon sequestration is carried out. The process of research using the method of geospatial analysis of satellite images is described.

Key words: carbon sequestration, soil erosion, geospatial analysis, agriculture, satellite images.

Soils are an important component of the Earth's ecosystem, playing a key role in maintaining the climate balance through their ability to absorb and store carbon. In addition, soil is the basis for agricultural production and an important source of economic profit. In 2021, the share of agriculture was about 10% of Ukraine's GDP [7].

As a result of intensive and wasteful use of soils, erosion processes can intensify, which can release carbon into the atmosphere in the form of CO_2. In the context of climate change, land degradation and biodiversity loss, soils have become one of the most vulnerable resources. Soils are a large carbon reservoir containing more carbon than the atmosphere and terrestrial vegetation combined. However, soil organic carbon can be released or absorbed, and anthropogenic impacts on soil can turn it into either a sink or a source of greenhouse gases. Already, the degradation of one-third of the world's soils has resulted in the release of up to 78 Gt of carbon into the atmosphere [2].

Ukraine has serious problems with soil erosion, especially on agricultural land. In particular, up to 16 million hectares of agricultural land, which is over 38% of its total area, are subject to erosion processes. Of this area, up to 13 million hectares are arable land, accounting for about 40% of the total area. Every year, up to 740 million tonnes of fertile soil are lost to water and wind erosion, which averages 15 tonnes per hectare and contains up to 24 million tonnes of humus. This leads to an overall shortfall in grain production of 8.6 million tonnes annually. Experts from the Food and Agriculture Organisation of the United Nations estimate that losses from the lack of crop production on eroded soils amount to more than UAH 20 billion a year [5].

The solution could be to introduce an agricultural system that promotes carbon sequestration. Soil carbon sequestration is the process of absorbing carbon dioxide. In this way, atmospheric carbon is converted into carbon in soil organic matter [1].

Soil carbon sequestration is a multi-stage process of converting atmospheric carbon dioxide absorbed by plants during photosynthesis into a complex of specific stable high-molecular weight organic compounds that accumulate in the soil. In this way, the mineral carbon of the atmosphere is converted into the carbon of soil organic matter. Carbon sequestration in soils is driven by the above-ground supply of plant residues, plant litter and underground supply of root litter. Soil microorganisms play an important role in this cycle and in the retention of soil carbon through various direct and/or indirect mechanisms. On average, one hectare of eroded soil can sequester 1 tonne of carbon [6].

Stages of CO_2 sequestration:

1) removal of CO_2 from the atmosphere through plant photosynthesis to plant biomass;

2) transfer of carbon from plant biomass to soil, where it is stored as soil organic carbon in the most labile pool.

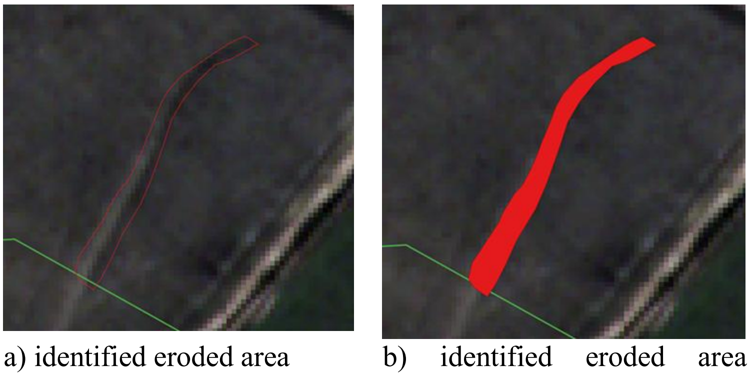
The territory of the Rohanska settlement community was chosen for the study. The Rohanska settlement community is an amalgamated territorial community in Ukraine, located in the Kharkiv district of the Kharkiv region.

The community covers an area of 77.07 km². The soil cover is represented by deep medium-humus black soil [3].

The study used satellite images obtained from the Sentinel Hub platform. The QGIS geographic information system was used to analyse the territory of the Rohan community to determine the area and number of eroded areas.

The geospatial analysis of the territory included visual identification of eroded areas. Heavily eroded soils can be visually identified using satellite imagery, as they are lighter in colour and have an elongated shape in the direction of the slope compared to less eroded and healthy soils.

Erosion is a process that takes years to complete, and the time period can vary significantly depending on the conditions of a particular site. Therefore, the formation of an area of heavily eroded soil can be well tracked over time. For this purpose, three images were selected on the dates: 2021.11.17, 2023.03.26. and 2024.03.11. This time period is sufficient to confirm the eroded area by comparing its condition in the image of 2024.11.03 with the images of 2021.11.17 and 2023.03.26. This allows us to confirm that it is an erosion process. Also, for additional confirmation, images from the Google Earth service were used. This service provides images in higher quality than Sentinel Hub, but does not allow you to choose the date of the image, so Google Earth was not suitable as the main source of data. The identified eroded areas were marked with polygonal objects. These polygonal objects are georeferenced and correspond to the actual area of the object.



a) identified eroded area

b) identified eroded area marked as polygon

Fig. 1. Identified eroded area [4].

During the study, we identified 15 sites with a total area of 0.191 square kilometres or 19.1 hectares of eroded soil. In order to calculate the sequestration potential, the difference between the actual organic carbon content and the normal content for this soil type should be estimated.

The normal organic carbon content of the soils in the study area ranges from 270 to 320 tonnes per hectare, and the maximum value of 320 tonnes was used for the calculations. Heavily eroded soils lose 20% of their organic carbon, which is 64 tonnes per hectare [1]. Thus, the sequestration potential for the entire area of eroded land (191 hectares) is 1222.4 tonnes. The data obtained during the study are rather approximate and require further refinement, including field studies.

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Moskvitina M. Y., *student*
V. N. Karazin Kharkiv National University
***Gololobova O. O.**, PhD (Agricultural), Associate Professor*
***Cherkashyna N. I.**, English Language Supervisor*

INTERNATIONAL EXPERIENCE IN IMPLEMENTING THE PROVISIONS OF THE CARPATHIAN CONVENTION

The publication analyzes the Carpathian Convention as an international treaty for preservation of the Carpathian heritage, its role in the sustainable development of the seven member states, implementation through protocols and recent examples of application.

Key words: Carpathian Convention, sustainable development, biodiversity, environmental conservation, international cooperation, forestry, tourism.

The Carpathian Convention is a key international treaty aimed at preserving the natural and cultural heritage of the Carpathian region. It covers a wide range of environmental, social and economic issues related to the sustainable development of this mountainous region. Seven countries are parties to the Carpathian Convention: Ukraine, Poland, Czech Republic, Slovakia, Hungary, Romania and Serbia.

The Framework Convention on the Protection and Sustainable Development of the Carpathians was opened for signature on May 22, 2003 in Kyiv during the Environment for Europe Ministerial Conference. It entered into force on January 4, 2006. Ukraine ratified the Carpathian Convention on April 7, 2004 [1, 7, 8].

As most of its articles are not directly binding, they mostly define common approaches to solving certain problems, outlining political intentions rather than establishing mandatory requirements for the participating countries. Therefore, the main mechanism for implementing the Convention is the Protocols, which cover specific sectoral issues in the areas of economy, social development and environmental protection within the Carpathian region. At the same time, the growing anthropogenic impact on the Carpathian forests in recent decades requires not only national efforts to protect, conserve and sustainably manage them, but also international regional cooperation [6]. Protocols are adopted and signed during the sessions of the Conference of the Parties. Their entry into force, amendments and additions, as well as withdrawal from them are carried out mutatis mutandis in accordance with Articles 19, 21 (paragraphs 2-4) and Article 22 of the Convention. Only a party to the Convention can become a party to the Protocols [8].

The structure of the Carpathian Convention includes the main treaty and a number of protocols that detail its provisions. The official website of the Convention lists 5 protocols adopted so far, namely the Protocol on the Conservation and Sustainable Use of Biological and Landscape Diversity, the Protocol on Sustainable Forest Management, the Protocol on Sustainable Tourism, the Protocol on Sustainable Transport and the Protocol on Sustainable Development of Agriculture and Rural Areas [9]. According to the official website, Ukraine is a party to all five protocols and has ratified them all. An important role in implementing the provisions of the convention is played by financial mechanisms provided by both the national budgets of the participating countries and international organizations and grant programs.

Having reviewed the materials, one can come across numerous cases of experience in implementing the Carpathian Convention. Below, we will list the most well-known cases at the international level. In September 2024, Poland faced large-scale floods that caused significant destruction in the country. Polish Prime Minister Donald Tusk stated that beavers damaging protective dams and ramparts contributed to the deterioration of the situation. He emphasized the need to take measures to control the beaver population, even if it contradicts environmental considerations [2]. This statement was criticized by environmentalists who emphasize the important role of beavers in maintaining the ecosystem. They point out that beaver activity contributes to the restoration of natural wetlands, which helps to combat both floods and droughts [3]. Thus, the situation has sparked a public debate about the balance between protecting infrastructure and preserving the natural environment. Under the slogan of rational management of the beaver population, Poland has decided to shoot 555 beavers in the Podkarpackie Voivodeship. This is a continuation of the procedure for regulating the number of the species, which is carried out on the basis of an order of the Director of the Regional Environmental Protection Office in Rzeszów. Previously, over 540 individuals were shot on the basis of a similar permit within three years, although the total limit was 900 [4]. This situation is related to the Carpathian Convention, in particular the Protocol on the Conservation of Biological and Landscape Diversity. The shooting of beavers can affect wetland ecosystems and calls into question the balance between species conservation and population management. There are discussions in scientific circles about the effectiveness of this approach, as beavers play an important role in the conservation of aquatic ecosystems. They contribute to the formation of floodplain landscapes, improve water quality, and conserve biodiversity. Given the nature conservation status of the Carpathian region, it is important to develop alternative methods of managing the beaver population, such as environmentally sound relocation or the use of barrier mechanisms [4].

Another science-based case is the Carpathian Wetlands Initiative. In 2024, the Czech Republic hosted an international training course on river and wetland restoration. The event was organized as part of the Carpathian Wetlands Initiative of the Ramsar Convention. The training covered the restoration of streams, river channels, floodplain lakes and reservoirs within urban areas. Particular attention was paid to the technical aspects of restoration and the impact on water flows, water quality, and biodiversity [5]. This activity is most in line with the Protocol on the Conservation and Sustainable Use of Biological and Landscape Diversity. Since the Carpathian Wetlands Initiative aims to restore rivers, wetlands, improve water flows and biodiversity, it directly relates to the provisions of this protocol, which covers the protection of wetland ecosystems, river landscapes and the environmentally balanced use of natural resources.

The next case concerns the implementation of the provisions of the Carpathian Convention in Ukraine, and it is about the ban on jeeping in protected areas of our country. At the beginning of 2025, the Verkhovna Rada of Ukraine banned jeeping in protected areas, which means that off-road vehicles are not allowed in certain areas of the Carpathians. Khrystyna Zhuk from Lviv, who initiated the petition, emphasizes that jeeping in nature reserves was banned before, but the lack of proper control allowed violations that caused soil erosion and damaged mountain ecosystems [10]. This ban is in line with the Protocol on Sustainable Forestry and the Protocol on Sustainable Tourism, as it aims to minimize the anthropogenic impact on the natural landscapes and ecosystems of the Carpathians.

The next case is the massive loss of forests in the High Tatras in Slovakia. On November 19, 2004, a powerful cold front broke into the Tatra region, accompanied by extremely strong winds exceeding 200 km/h. The main impact of the disaster fell on the central part of the mountains, where 12,600 hectares of forest were destroyed. Spruce trees (more than 75%) and pine trees (more than 8%) predominated among the dead trees. By the end of 2005, foresters had managed to repair almost 88% of the damage, and the final completion of the work to overcome the consequences of Hurricane Elizabeth took place in May 2006. After the disaster, artificial reforestation was launched: more than eight million seedlings were planted, of which two-thirds were conifers and the rest were deciduous. At the same time, nature contributed to the self-regeneration of forests in a similar area [11]. For 20 years, the forest has not yet regained the capacity it had before the storm, although local environmental services have been artificially planting trees. The Protocol on Sustainable Forest Management in Slovakia came into force in 2013, as it did in Ukraine [9]. In the future, the forest also needs to be supervised by specialists now at the international level, as implemented by the Carpathian Convention, to preserve natural landscapes and help maintain the ecological balance of the region.

Conclusions. The implementation of the provisions of the Carpathian Convention in different countries demonstrates the desire of the participating states to ensure the conservation of the region's ecosystems. However, the effectiveness of such measures depends on the level of control, funding, and international cooperation. The experience of Poland, the Czech Republic, Ukraine, and Slovakia shows that both active biodiversity management and ecological restoration of natural areas are being carried out under the Carpathian Convention, but challenges related to control and implementation of the norms remain relevant.

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Musykhina M. O., *student*
V. N. Karazin Kharkiv National University
***Klieshch A. A.**, PhD (Geography), Associate Professor,*
***Cherkashyna N. I.**, English Language Supervisor*

ANALYSIS OF THE DYNAMICS OF PETROLEUM PRODUCTS CONTENT IN WASTE WATER OF THE STATE ENTERPRISE "MYRNOHRADVUHILLIA" 5/6 MINE

The publication presents the results of a study on the dynamics of petroleum product concentrations in the wastewater of the "5/6" mine of SE "Myrnohradvuhillia" over the period from March 2022 to June 2024.

Key words: petroleum products, wastewater, "5/6" mine, MAC, environmental monitoring.

The State Enterprise "Myrnohradvuhillia" is one of the largest coal mining complexes in the Donetsk region, comprising several mines specializing in the extraction of both thermal and coking coal. The enterprise includes the "Tsentralna," "Kapitalna," and "5/6" mines, while the "Rodynska" mine, previously part of the company, was decommissioned in 2020.

The intensive industrial activities of the enterprise are accompanied by significant volumes of mine wastewater, generated during mining operations and potentially containing various pollutants. Mine water consists of both underground and surface waters that infiltrate mining workings, complicating resource extraction and development. These waters may contain mechanical, chemical, and bacterial impurities, and in deep mines, they often exhibit high salinity, sometimes exceeding 70 g/L. Additionally, treated mine water is occasionally utilized within enterprises for dust suppression, hydraulic transport of minerals and rock masses, coal beneficiation, and desalination of saline coal, among other purposes. One of the specific pollutants subject to environmental monitoring is petroleum products. Their presence in mine water may result from the use of lubricants, hydraulic fluids, and diesel fuel in mining equipment, as well as accidental spills and inadequacies in wastewater collection and treatment systems. The environmental hazard posed by petroleum products lies in their ability to form stable surface films that limit oxygen exchange and disrupt self-purification processes. Moreover, they can accumulate in aquatic environments as droplets or emulsions, potentially exhibiting toxic effects on aquatic organisms. Consequently, high levels of contamination present significant environmental risks to aquatic ecosystems, necessitating the implementation of effective treatment and monitoring strategies.

The environmental monitoring of mine water and the chemical-analytical examination of wastewater samples were conducted by the in-house laboratory of the sanitary and preventive department "Standart" at SE "Myrnohradvuhillia."The environmental monitoring system for wastewater treatment consists of several stages:

- Mine water is brought to the surface, after which the initial measurement of pollutant concentrations is conducted before treatment.

- The water is treated at specialized purification facilities, followed by measurements of pollutant concentrations after treatment.
- The treated water is directed to Discharge Point No. 1, where it enters a settling pond. A final measurement of pollutant concentrations is conducted before the water is ultimately discharged into natural surface water bodies.

Fig. 1 presents the dynamics of petroleum product content in the wastewater of the "5/6" mine of the State Enterprise "Myrnohradvuhillia" at all monitoring stages. This allows for an analysis of changes in pollutant concentrations over the study period from March 2022 to June 2024.

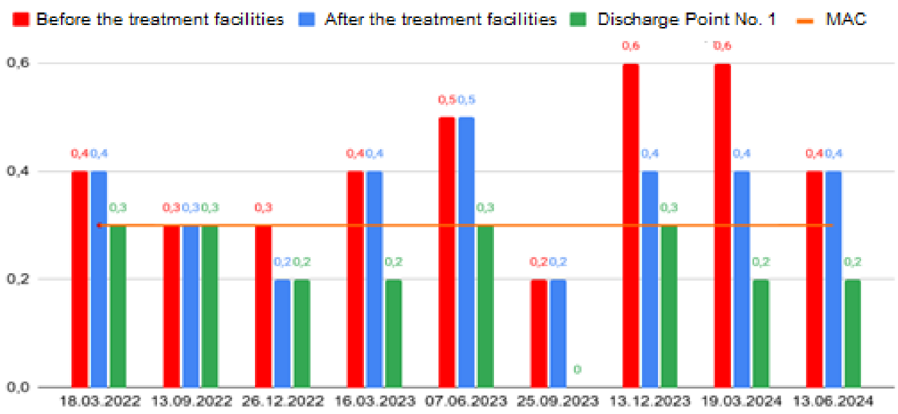

Fig.1. Dynamics of Petroleum Product Content in the Wastewater of the "5/6" Mine of the State Enterprise "Myrnohradvuhillia," mg/dm³

According to the data presented in Figure 1, throughout the entire study period (with the exception of September 25, 2023), the concentration of petroleum products in the wastewater either equaled or exceeded the maximum allowable concentration (MAC). It is noteworthy that after passing through the treatment facilities, the concentration of petroleum products in most observation dates remained virtually unchanged or decreased only slightly, while still exceeding the MAC. In contrast, sedimentation in the discharge pond resulted in a significantly greater reduction in pollutant concentrations, highlighting its importance in the environmental monitoring system for improving wastewater quality.

In light of the ongoing armed aggression by the Russian Federation, it can be assumed that damage to the mine's technological infrastructure or its flooding could lead to an uncontrolled release of wastewater with high petroleum product concentrations exceeding permissible limits. This, in turn, may result in contamination of both surface and groundwater resources.

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Mytsyk B., *student*
Oles Honchar Dnipro National University
Masiuk O. M., *PhD (Biology), Associate Professor*

THE FAUNAL POTENTIAL OF THE PROTECTED AREAS OF THE LOWER PRYSAMARYA

The study conducted on the Samara's Forest landscapes and fauna. The unique natural conditions of the Samara Forest are conducive to the existence of numerous rare plant communities.
Key words: fauna, lower Prysamaryia, Red Data Book species, «Samarskyi Lis – UA0000212».

The Samara Forest is the largest steppe forest in southeastern Ukraine. It is located on the left bank of the Samara River, covering the middle and lower reaches of the river within Pavlohrad and Samar (Novomoskovsk) districts of Dnipro region [1, 6]. This area is of extreme conservation importance due to its unique ecosystems that combine features of floodplain, ravine and boreal forests, as well as steppe and marshlands [1, 4].

The Samara complex is divided into three main areas: upper Prysamaryia – from Pavlohrad to the outskirts of Mezhyrich and Verbky, middle Prysamaryia – from Vyazivok to Orlivshchyna, and lower Prysamaryia – from Novomoskovsk to the river mouth [6]. Landscape diversity includes valley-terrace, valley-foothill, beam and arena-boreal complexes, which form unique natural conditions for the existence of rare species of flora and fauna [1]. The uniqueness of this territory has attracted the attention of many researchers, among whom O. L. Bellegarde stands out. His expeditions contributed to a thorough study of the flora and fauna of the Samara Forest, as well as to the identification of the characteristics of its forest communities. Under his leadership, large-scale studies of the river valley's vegetation and biodiversity were carried out [2]. M. P. Akimov, O. E. Pakhomov, V. V. Brigadirenko and other researchers also made a significant contribution to the study of the region's biodiversity [5].

The formation of the Samara River valley is the result of complex geological and climatic processes that lasted for thousands of years. Glacial and post-glacial stages played a key role in modelling the relief, changing the nature of the river flow and creating a system of floodplain terraces [4]. Hydrographic changes caused by climatic fluctuations led to the formation of numerous branches, oxbows and lakes, which are now important elements of the local ecosystem. Human activity has had a significant impact on the structure of the valley, which was particularly evident in the 20th century, when the region underwent engineering changes due to agricultural development and the construction of large hydraulic structures [4, 6].

The Samara Forest is part of the Emerald Network, which operates under the Bern Convention on the Conservation of Wild Flora and Fauna and Natural Habitats in Europe [3]. It is included in the list of key protected areas of Ukraine under the code "Samarskyi Lis – UA0000212". Within the European Union, this area is part of the Nature 2000 network, which provides an international level of protection for rare species and their habitats [7]. In addition, the forest belongs to the areas that meet the criteria of the Ramsar Convention, which aims to conserve wetlands of global importance [9].

The fauna of the Lower Prysamarya includes 113 species under protection, of which 45 are listed in the Red Data Book of Ukraine, 113 in the Red Data Book of Dnipro Oblast, 4 in the European Red List, and 53 species have a protected status on the IUCN Red List [6]. The most valuable representatives of the region's fauna include rare species of amphibians, reptiles and birds, including Emys orbicularis (European marsh turtle), Vipera renardi (steppe viper) and Platalea leucorodia (otter) [5]. Among mammals, populations of bats, such as Myotis daubentonii (water vesper) and Plecotus auritus (brown ear), which play an important ecological role in regulating insect populations, attract special attention [6]. Aquatic ecosystems are also of high conservation value, as they are home to Acipenser ruthenus (sterlet) and Alosa pontica pontica (Black Sea herring), whose populations are declining due to water pollution and changes in the hydrological regime of the Samara River [5].

The unique natural conditions of the Samara Forest are conducive to the existence of numerous rare plant communities. Habitats corresponding to categories G1.22, G1.8, G3.11 according to the European Ecological Network classification are found here [1, 7]. This makes it possible to consider the Lower Prysamarya as an important biodiversity hotspot and a potential target for further conservation initiatives. However, the current state of the ecosystem is under threat due to active economic activity, deforestation, and water pollution [4]. The absence of a comprehensive conservation programme and proper control over anthropogenic impact can lead to degradation of natural environments and the loss of numerous species of flora and fauna.

The diversity of natural complexes, the presence of unique habitats and rare species of animals and plants make the Lower Prysamarya a valuable natural formation that plays an important role in the overall ecological structure of the region. Its history of formation, associated with natural changes and anthropogenic impact, determines the current appearance of this area, where elements of steppe, forest and wetland ecosystems are intertwined. The Samara Forest continues to be an object of scientific interest and natural.

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Nemoshkalov O. M., *PhD student*
V. N. Karazin Kharkiv National University
Pyriatynskyi National Park

ENVIRONMENTAL AUDIT OF LAND IN KHARKIV DISTRICT OF KHARKIV REGION AFFECTED BY MILITARY OPERATIONS

The ways to avoid risks caused by the consequences of military operations are considered.
Key words: military operations, GIS, agricultural land, satellite images.

The military actions unleashed by the Russian Federation on the territory of Ukraine pose significant risks to the normal functioning of the country's agricultural sector. Experts predict a significant decline in grain production this year.

A poor harvest will not only lead to severe economic consequences within the country. Ukraine is one of the largest producers and suppliers of grain to the global market. Accordingly, food prices are expected to rise significantly globally in the near future, which in turn could cause social and political upheaval in developing countries. Given the current processes of globalization, the consequences of these processes will affect the whole world.

The restoration of agricultural land damaged during hostilities should be based on reliable spatial information that can be obtained from the results of satellite image interpretation.

For the study, the land in Kharkiv district of Kharkiv region of Ukraine was selected, in particular, the part of it that was subjected to active hostilities.

At the first step of the research, a preliminary analysis of available satellite images for the selected area was conducted using the Sentinel Hub Playground service. The service allows you to view the images in the Copernicus project database and even conduct preliminary analysis by creating various index images.

Further work was carried out in the QGIS geographic information system using images with dates. The images were downloaded using the service https://earthexplorer.usgs.gov. For the convenience of the work, the entire territory was divided into rectangles that corresponded to the nomenclature of topographic maps at a scale of 1:10000. After a complete survey of the rectangle, a mark was placed to prevent confusion in the work and to avoid checking the same area twice. For the diagnosis of damaged soils, we used visible range imagery consisting of 5, 4, 3 channels of the Sentinel-2 satellite. For the diagnosis of winter crops, pseudocolor image-indices were used, which were formed from 8, 4, 3 channels. Since the main purpose of the work was to assess the damage to agricultural land, only the following types of land were studied: arable land, pastures, hayfields. Forest lands and urban areas were not studied.

Practical significance of the results. It has been established that the optimal decoding features for the effects of bombing are: circular shape, small size, contrasting color with the background. It was found that the area of damaged land as of April 2022 amounted to 2582.1 hectares. The area of damaged winter crops as of the same date was 386.2 hectares. The main hypothesis of the study was confirmed.

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Nezhentsev A., *PhD student*
Uman National University of Horticulture

THE INFLUENCE OF ROAD TRANSPORT ON THE STATE OF ROADSIDE PHYTOCENOSES

The article presents the results of a study of the roadside vegetation 10-15 m from the paved road surface. The study revealed a pronounced influence of the road as a factor that disrupts the species composition of plant communities, as a result of which species more sensitive to pollution are pushed deeper into the phytocoenosis. The most species-rich roadside areas are "enriched" by invasive species. The nature of vegetation damage caused by chemical pollution was analysed. It was found that the excessive content of exhaust gases in plants negatively affects their growth and development, reduces yields, and worsens its quality.

Key words: road landscapes, roadside strip, phytocoenosis, vegetation, biodiversity, invasive species, chemical pollution.

During the operation of roads, a radical restructuring of the vegetation cover occurs and derivative groups of plant species that are not characteristic of the native phytocenosis are formed. These groups are formed from ruderal species that occur in a roadside strip up to 36 m wide, depending on the area of the site that is disturbed as a result of construction and operation.

In a more local zone up to 11 m wide, gradual invasive pollution occurs due to the entry of new species that are not characteristic of this phytocenosis.

Thus, in the study areas at a distance of 10-15 m from the edge of the highway, the total number of wild herbaceous flowering plants, including single and unique ones, ranged from 15 to 47 specimens [1]. These features are leveled as you approach the roadbed, where the soil is more compacted and its structure is disturbed. Therefore, species that are typical for the original biotope are replaced by species that are characteristic of disturbed habitats: common plantain, dandelion, coltsfoot, creeping wheatgrass, goosefoot, bird's-foot trefoil, field thistle, cereals - bluegrass, white field marigold, and others. In these experiments, a fairly large range of changes in the values of the indicator of species that dominate in the roadside strip up to 5 m wide was noted.

Thus, there is a pronounced effect of the road as a factor that disrupts the species composition of plant communities, as a result of which species that are more sensitive to pollution are displaced deeper into the phytocenosis. This indicates the relative stability of species diversity and the absence of an apparent connection of this indicator with the transport load in areas that have been exploited for a long time.

Obviously, the richest in species roadside areas are "enriched" by invasive species, especially since these areas have a lot of transit traffic. This occurs due to the transfer of plant seeds on the wheels of vehicles, passengers' clothes, animal fur, etc. The most common species are asteraceae and grasses. It should also be noted that the majority of species found in the roadside zone are ruderals, that is, those that are originally adapted to survive in adverse conditions [2].

In recent years, there has been a steady increase in the number of road transport, the main toxic components of which are exhaust gases. Pollution of grass cover near a highway depends on the following factors: age, composition and completeness of plantings, proximity of the emission source, wind direction, relief, weather conditions, concentration of toxic substances. If we consider the pollutants most dangerous for vegetation, then SO_2 will play a leading role here.

Acute damage to herbaceous plants is manifested in the appearance of necrotic areas, mainly between the veins of the leaf, sometimes in plants with narrow leaves - at the tips of the leaves and along the edges. Necrotic lesions are noticeable on both sides of the leaf. The affected parts of the tissue initially look grayish-green, as if wetted with water, but then become dry and change color to brownish-red. In addition, pale cream-colored dots may appear. The appearance of large elongated necrotic areas is often accompanied by a large number of necrotic spots. Large necrotic spots and areas merge, forming a striation between the veins. As the necrotic tissue of the leaf becomes brittle, tears and falls out of the surrounding tissue, the leaves acquire a perforated shape.

Low concentrations of nitrogen oxides in the air can damage the green mass of sensitive plants and have a negative effect on plants even when damage is not yet present. Nitric oxide causes a mutagenic effect in plants, the synthesis of nitrate and nitrite compounds, inhibition of photosynthesis and increased activity of protective enzymes, and above all peroxidase. The greatest effect on plants is exerted by photochemical oxidants and sulfur oxides, which disrupt the normal functioning of the stomatal apparatus and cause the destruction of chlorophyll [1].

The total effect of sulfur dioxide is to increase the permeability and destruction of cell membranes, the rate of dehydration, reduce the intensity of photosynthesis, and reduce the content of ascorbic acid. In this case, the activity of peroxidase can increase by 1.2-4 times, there are violations of the ultrastructure of chloroplasts, especially with a predominance of nitrogenous compounds. As a result of the action of sulfur dioxide on plants, there is a slowdown in their growth, the formation of necrosis at the ends of the leaves and the destruction of the assimilation organs. An increase in the surface area of damaged leaves by sulfur dioxide can lead to a decrease in moisture consumption from the soil, its general waterlogging, which will inevitably affect the quality of the ecotope.

The action of benzo(a)pyrene leads to a disruption of the structure and a change in the nature of pigmentation of leaf tissues. The toxic effect of carbon monoxide on plants is manifested only at its volume concentration of more than one percent. In this case, root growth is enhanced, the activity of some enzymes is inhibited, and the growth rate decreases. The main reactions of plants to excess carbon dioxide are exacerbated in combination with the action of nitric oxide. This is a change in growth rate, a decrease in respiration and conductivity, visually noticeable morphological changes in leaves, branches, and roots.

A significant increase in the level of exhaust gases in the environment leads to a decrease in the intensity of cell divisions in the roots, as well as an increase in the relative number of prophases.

Excessive content of exhaust gases in plants negatively affects their growth and development, reduces production, and worsens its quality. The latter occurs mainly not due to changes in the biochemical composition, but as a result of excessive accumulation of exhaust gases [1].

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Parkhomenko O. O., *student*
V. N. Karazin Kharkiv National University
***Maksymenko N. V.**, DrSc (Geography), Professor,.*
***Cherkashyna N. I.**, English Language Supervisor*

ASSESSMENT OF THE IMPLEMENTATION OF FUNCTIONAL ZONING REGULATIONS BY NATIONAL NATURE PARKS OF UKRAINE

The compliance of the functional zones of the NNPs with the DBN B.2.2-12:2019 "Planning and Development of Territories" is critical for the effective management of protected areas. The study found that out of 53 NNPs in Ukraine, only 19 provided clear information on the areas of functional zones on their official websites. For eighteen NNPs, there is no information on the area of functional zones. Full compliance with the standards was not found in any NNP.

Keywords: nature reserve fund, national natural park, zoning, standard, functional zone.

National parks are important centers of nature conservation and sustainable recreational development. However, effective management of these territories is only possible if the regulatory requirements for functional zoning are strictly adhered to. In accordance with the DBN B.2.2-12:2019, each NNP must have clearly defined functional zones: a reserve zone, a regulated recreation zone, a stationary recreation zone, and an economic zone.

The study analyzed the accessibility and relevance of information on the areas of functional zones in 53 NNPs of Ukraine. It was found that only 19 parks provide clear information on the area of zones on their official websites, while 5 more parks (Shatsk, Kamianska Sich, Ichnianskyi, Verkhovynskyi, Velykyi Luh) have such data in open sources. 11 parks (Buzky Gard, Holosiivskyi, Dzharylgachskyi, Karmeliukove Podillia, Kremenets Mountains, Nyzhniodniprovskyi, Prypiat-Stokhid, Pyriatynskyi, Slobozhanskyi, Uzhanskyi, Cheremoskyi) provided only map schemes without specific figures, and for the remaining 18 parks, there is no information at all.

The results obtained indicate the need to improve the system of submitting information on the functional zones of the NNPs. The introduction of a unified approach to reporting and ensuring open access to this data will contribute to better management of protected areas and increase their compliance with legal norms.

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Pavliuk A. V., *PhD student*
Institute of the Ecology of the Carpathians National Academy of Science of Ukraine
***Shpakivska I. M.**, PhD (Biology), Associate Professor*

ECOSYSTEM SERVICES OF SMALL RIVERS IN TRANSCARPATHIA

The study was conducted on the ecosystem services provided by small rivers
Key words: Small rivers, ecosystem services, biodiversity conservation, water resources, Environmental sustainability, river degradation

The Importance of Small Rivers.

Small rivers in the Transcarpathian region play a crucial role in maintaining ecological stability and supporting biodiversity. These water bodies provide essential ecosystem services, including water supply, habitat preservation, and climate regulation. Their significance extends beyond environmental benefits, as they also contribute to economic and cultural aspects of local communities. However, the overexploitation of these services poses a serious risk to the long-term sustainability of these vital ecosystems.

The extensive river network in Transcarpathia ensures that many ecosystems rely on small rivers for their functioning. These rivers support a wide variety of flora and fauna, serving as natural corridors for species migration and providing spawning grounds for fish. Many endangered species depend on these freshwater habitats for survival, making the conservation of small rivers a priority for maintaining biodiversity. Additionally, these rivers are interconnected with wetlands and groundwater systems, playing a fundamental role in maintaining regional hydrological balance.

Apart from their environmental importance, small rivers are vital for human communities. They provide drinking water for settlements, irrigation for agriculture, and hydropower for energy production. Many local economies, particularly those based on farming, fisheries, and tourism, depend on the sustainable management of these rivers. Furthermore, small rivers contribute to microclimate regulation, helping to moderate temperatures and sustain soil moisture levels. These benefits underline the necessity of preserving these water bodies for both nature and society.

Provisioning Services of Small Rivers

Small rivers provide essential resources that sustain both nature and human communities:

- *Freshwater supply* – Essential for drinking, agriculture, and industrial use.
- *Fisheries and aquatic resources* – Support local economies by providing fish and other aquatic organisms.
- *Construction materials* – Serve as a source of gravel and sand used in infrastructure development.

Regulating and Supporting Services.

These rivers play a fundamental role in regulating natural processes:

- *Water cycle regulation* – Mitigate the effects of floods and droughts by storing and gradually releasing excess rainfall.

- *Self-purification capacity* – Filter pollutants, regulate sediment flow, and support the decomposition of organic matter.
- *Biodiversity conservation* – Provide critical habitats for fish, amphibians, aquatic plants, and microorganisms.
- *Climate moderation* – Help maintain humidity levels and regulate temperature fluctuations.

Cultural and Recreational Services.

Beyond their ecological functions, small rivers have cultural and social significance:

- *Historical and spiritual value* – Many local traditions and folklore are closely connected to rivers.
- *Tourism and recreation* – Provide opportunities for fishing, hiking, and nature-based tourism.
- *Community engagement* – Serve as natural gathering places that strengthen social cohesion.

Overexploitation and Environmental Risks.

Despite their benefits, small rivers face serious threats due to excessive human activity:

- *Overuse of water resources* – Excessive water extraction lowers river levels and threatens aquatic life.
- *Uncontrolled gravel and sand extraction* – Disrupts riverbeds, accelerates erosion, and alters natural water flow.
- *Pollution from agriculture and industry* – Runoff containing pesticides, fertilizers, and industrial waste degrades water quality.
- *Deforestation and soil erosion* – Reduces river depth due to sedimentation and disrupts ecosystems.
- *Hydropower development* – Construction of reservoirs and hydroelectric stations alters river flow, disrupts habitats, and obstructs fish migration.

Conclusion

Small rivers in Transcarpathia provide a wide range of invaluable ecosystem services that support biodiversity, regulate the water cycle, and sustain local communities. However, the increasing exploitation of these services poses a significant risk to their long-term viability. To preserve these natural resources, it is essential to implement sustainable water management practices, regulate resource extraction, and minimize pollution. By recognizing the value of small rivers and taking collective action, we can ensure their continued ability to provide essential ecosystem services for future generations.

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Prokopchuk L. A., *student*
V. N. Karazin Kharkiv National University
***Klieshch A. A.**, PhD (Geography), Associate Professor,*
***Cherkashyna N. I.**, English Language Supervisor*

SPATIAL CHARACTERISTICS OF KHARKIV OBLAST NATURE RESERVE FUND AND CHALLENGES OF DOUBLE ACCOUNTING OF PROTECTED AREAS

The publication presents the results of a study on the spatial features of the nature reserve fund of Kharkiv Oblast and the challenges associated with double accounting of protected areas. The research highlights issues related to hierarchical subordination and overlapping conservation statuses, which affect the accuracy of statistical assessments of protected area coverage.

Key words: nature reserve fund, protected areas, spatial structure, double accounting, Kharkiv Oblast.

Kharkiv oblast has one of the lowest conservation rates among the regions of Ukraine, with the total percentage of protected areas accounting for less than 3%. According to the State Cadastre of Territories and Objects of the Nature Reserve Fund, the statistical total area of protected sites in the oblast amounts to 85,434.9 hectares [1]. At the same time, the indicated total area of protected territories in the region cannot be considered representative for an accurate assessment of the level of conservation, as there are protected objects within the region whose territories are fully or partially included in other objects. As a result, the actual area of all protected territories may be significantly lower than the statistical data (since the same area may be counted in two protected objects simultaneously).

One of the possible reasons for the existence of such spatial relationships is the hierarchical "absorption" of smaller protected objects by larger ones with a higher conservation status and larger area. In Ukraine, it is common to observe a situation where, when creating new national nature parks or regional landscape parks, previously established one or several local protected areas are included within them while retaining their conservation status. As a result, the larger protected object effectively "absorbs" the smaller one, sometimes completely, and sometimes only partially. Another reason for spatial "embedding" or partial "overlap" of protected areas could be the overlapping conservation statuses of protected objects at the same or similar hierarchical levels.

The presence of such complex spatial relationships between protected objects may affect not only the provision of adequate data regarding the actual territorial coverage of the nature reserve fund but also the evaluation of its characteristics based on morphometric indicators. For example, when determining insularity, an error may occur when a small object is considered spatially fragmented and unstable, although it is actually "absorbed" by a larger object. Thus, to ensure reliable data and correct assessments of the nature reserve fund, it is crucial to have a clear understanding of its spatial structure, including consideration of data on double cadastral registration of protected objects.

The research on the current spatial structure of the nature reserve fund of the Kharkiv oblast, based on the analysis of thematic cartographic materials and web services [2], has made it possible to identify protected areas whose territories are fully or partially included in other reserves due to hierarchical subordination or the overlapping of conservation statuses. In total, 8 protected objects were identified as "acceptors" and 13 objects as "donors" of territories for which the overlapping areas were determined using cartometric methods, namely:

1. National Nature Park "Slobozhanskyi":
   - Local Forest Reserve "Volodymyrivska Dacha" – total area: 699 ha.
   - Local Botanical Nature Monument "Murafska Dacha" – total area: 5.2 ha.
2. National Nature Park "Homilshanski Lisy":
   - Local Landscape Reserve "Homilshanska Lisova Dacha" – partially included, total area: 9,092 ha, of which 7,869.32 ha is part of the National Nature Park.
3. National Nature Park "Dvorichanskyi":
   - Local Botanical Reserve "Chervonyi" – total area: 49.8 ha.
   - Local Botanical Reserve "Konopliane" – partially included, total area: 315.9 ha, of which 222.53 ha is part of the National Nature Park.
4. Local Regional Landscape Park "Sokolnyky-Pomirky":
   - Local Botanical Nature Monument "Pomirky" – total area: 120.4 ha.
5. Regional Landscape Park "Velykoburlutskyi Step":
   - Local Forest Reserve "Bozhkove" – total area: 79 ha.
   - Local Forest Reserve "Dehtiarne" – partially included, total area: 179 ha, of which 136.26 ha is part of the Regional Landscape Park.
   - National General Zoological Reserve "Burlutskyi" – partially included, total area: 326 ha, of which 244.17 ha is part of the Regional Landscape Park.
   - National General Zoological Reserve "Katerynivskyi" – partially included, total area: 527 ha, of which 474.32 ha is part of the Regional Landscape Park.
6. Regional Landscape Park "Pechenizke Pole":
   - Local Landscape Reserve "Pechenizkyi" – total area: 365.7 ha.
7. Regional Landscape Park "Oskilskyi":
   - Local Botanical Reserve "Borivskyi" – total area: 18 ha.
8. Local Botanical Reserve "Buhaivskyi":
   - Local Entomological Reserve "Kruhlyi" – total area: 3.7 ha.

Thus, according to the calculations performed, the total area of protected territories that are doubly accounted for in the conservation register amounts to 10,287.40 ha. The obtained results point to the complex hierarchical subordination of protected areas, which can lead to the duplication of areas in statistical reporting, the calculation of conservation level indicators, and create management difficulties for protected objects. Optimizing the registration system, territorial organization, and clarifying the boundaries of objects are important tasks for improving the effectiveness of conservation management not only in Kharkiv but also in other regions of Ukraine.

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Pronenko M. O., *PhD student*
V. N. Karazin Kharkiv National University
Krainyukov O. M., *DrSc (Geography), Professor*

OCCURRENCE, DETECTION AND TOXIC EFFECTS OF MICROPLASTICS ON AQUATIC ORGANISMS

One of the topics of the global problem of our time is investigated - environmental pollution by garbage, namely plastic, which decomposes into microplastics. The article provides the results of the impact of microplastics on living organisms. The focus is on the toxic effect of microplastics when they enter the body

Key words: global problems, environmental problems, toxicity, impact of microplastics

One of the most pressing global environmental problems of our time is microplastics. Microplastics (MP) are defined as plastic particles with a diameter of less than 5mm.

The continuous increase in plastic production worldwide is undoubtedly leading to microplastic pollution. The first study to report the presence of microplastics in the environment was conducted in California in 2011 by Charles Moore [1]. Moore and his colleagues, in their paper "Amount and Type of Plastic Debris Discharged from Two Urban Rivers to Coastal Waters and Beaches in Southern California," conducted a study on microplastic levels in surface waters of the San Gabriel River, the Los Angeles River, and a tributary of Coyote Creek. Their report confirmed significant fluctuations in the level of plastic pollution in wastewater depending on different weather events [1]. For example, according to studies, 5,000 g of polyethylene fabric can release up to 6 million fibers during a wash cycle [2], and a 6,000 g load of laundry can release 700,000 fibers during each wash cycle. wastewater.

It is worth paying special attention to the fact that microplastics enter the environment in large quantities, especially in developing countries, including Ukraine. These groups of pollutants are widespread in ecosystems in the form of plastic pollutants: packaging from pharmaceuticals and personal hygiene products, plastic packaging, food packaging waste, and bottled water packaging. They are often distributed in close proximity to water bodies and thus, together with wastewater during rains and snowmelt, enter water bodies. Microplastics are also transported together with wastewater into the aquatic ecosystem through unauthorized landfills, which are often located in close proximity to water bodies. It should be noted that the COVID-19 pandemic has additionally affected the increase in the amount of microplastics in the ecosystem, since a significant number of various plastic products were produced during this period, which undoubtedly led to an increase in plastic waste [3]. This waste mainly consists of personal protective equipment, such as face masks and disposable gloves.

Studies assessing the potential adverse effects of microplastics on freshwater ecosystems have mainly focused on acute toxicity [4]. Chronic toxicity studies have mainly been conducted using commercial primary microplastics of uniform shape (e.g., 5 μm microspheres), which is not a realistic scenario under normal natural conditions.

In contrast, chronic toxicity studies (21 days) using synthesized polyethylene microplastic fragments and commercial polyethylene pellets for Daphnia magna showed that small-sized microplastic fragments significantly reduced body length and number of offspring of D. magna and significantly reduced algal feeding compared to commercial microplastic pellets. The results obtained in these studies indicate that microplastics fragmented to the micron-scale may pose a greater ecological risk to aquatic organisms [5].

Research results confirm that microplastics are ecotoxic waste (HP14) according to waste classification.

The widespread use of biodegradable plastics (BP) was aimed at reducing the burden on aquatic ecosystems. Biodegradable plastics emerged as an alternative to conventional plastics, the consumption and production of which are constantly increasing and, accordingly, their impact on the state of the ecosystem is increasing. However, polylactic acid (PLA), which is part of biodegradable plastics, begins to decompose at a temperature of about 58 °C. Since we do not find such temperatures in Ukrainian water systems, the decomposition of biodegradable plastics is incompatible with the real conditions encountered in the aquatic environment. Therefore, we can assume that they persist in the aquatic environment and are absorbed by aquatic organisms, similar to conventional plastics. Therefore, when aquatic organisms contact with biodegradable plastics, the effect of exposure to conventional microplastics persists, which can cause extensive physical or chemical damage and lead to genetic changes [6]. Some studies have shown that biodegradable microplastics may also have toxicity similar to the toxicity of conventional microplastics for aquatic organisms. According to D. Green[7], the toxicity of conventional high-density polyethylene plastic and PLA is similar and can affect the diversity, abundance and biomass of oysters Ostreaedulis. As a result of the conducted studies, it was found that polylactic acid has an adverse effect on the health of aquatic organisms such as Ostreaedulis, Daniorerio, Mytilusedulis, Micrcosmusexasperates and Daphniamagna, causing various toxic effects such as oxidative stress, problems with reproductive function. Long-term exposure to microplastics can affect both reproduction and oxidative stress, as well as gene expression [6, 7].

This article aims to draw attention to the problem of microplastics in Ukraine. Presently, Ukraine has practically no policy regulating the monitoring of plastic waste, control of the presence and concentration of microplastics in water bodies. Information on the nature of the distribution of microplastics in water bodies is rather scarce. Ignoring this problem can lead to catastrophic consequences in aquatic ecosystems. Microplastics have been identified as toxicogenic for biotic components, therefore, it is important to focus on the study and application of various methods for detecting microplastics in water bodies and studying their ecotoxicity. Instrumental methods that can be used to detect and quantify microplastics in water bodies: infrared spectroscopy, gas chromatography/mass spectrometry (GC/MS), nuclear magnetic resonance, gel chromatography. One of the widely used spectroscopic methods for polymer identification is Fourier transform infrared microspectroscopy (μ-FTIR). It is also important that there is a need in a comprehensive approach to the prevention and removal of microplastics from water bodies.

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Protsenko A. O., *student*
V. N. Karazin Kharkiv National University
Titenko G. V., *PhD (Geography), Associate Professor*
Cherkashyna N. I., *English Language Supervisor*

THE ENVIRONMENTAL STRATEGY OF THE COMPREHENSIVE SPATIAL DEVELOPMENT PLAN OF THE VELYKOSOROCHYNSK RURAL TERRITORIAL COMMUNITY OF POLTAVA REGION

The integration of ecological aspects into spatial planning is crucial for sustainable regional development. This study examines the ecological component of the comprehensive spatial development plan for the Velykosorochynsk rural territorial community in the Poltava region. The research focuses on key environmental challenges, and sustainable resource management strategies to enhance environmental resilience and long-term ecological stability.

Key words: environmental challenges for communities of Ukraine, Comprehensive Spatial Development Plan.

Spatial planning is a fundamental tool for managing natural and human-made landscapes, ensuring that economic growth aligns with ecological sustainability. The Velykosorochynsk rural territorial community, located in the Poltava region, has diverse natural ecosystems, agricultural lands, and water bodies. However, increasing anthropogenic pressure necessitates a well-developed ecological strategy within the comprehensive spatial development plan.

The comprehensive spatial development plan for the Velykosorochynsk rural territorial community of Poltava region is rooted in a broader context of spatial development strategies that aim to enhance socio-economic conditions and address environmental concerns. The successful implementation of these strategies requires collaboration among state authorities, experts, entrepreneurs, and social representatives in rural areas, ensuring that various development concepts complement one another rather than compete or intersect in conflicting ways.

We see the following among the main environmental challenges for Velykosorochynsk community.

1. Different types of soil degradation resulted from intensive farming.
2. Loss of biodiversity due to anthropogenic transformation of the biota habitat.
3. Consequences of climate change, such as an increase in the frequency of droughts and temperature fluctuations.
4. Direct and indirect impact of military actions on the components of the community's environment, namely the risk of pollution of atmospheric air, water bodies and soil due to rocket attacks, an increase in the number of mobile sources of pollution due to an increase in the population (internally displaced persons), etc.

To keep these problems in mind and, if possible, to solve them, the priorities of the environmental component of the spatial development plan should be outlined. For this purpose, the SWOT analysis method was used and the existing draft of the Comprehensive Spatial Development Plan of the Velykosorochynsk Community was supplemented (Table 1).

Table 1.

SWOT analysis of the environmental content of the comprehensive spatial development plan of the Velykosorochansk community

Strengths	**Weaknesses**
Large territory of the community	Insufficient number of foreign investors
Relatively favorable condition of environmental components	Decrease in the birth rate
Fertile soils (mostly typical black soil)	Aging population and increasing number of people of retirement age (including IDPs)
Availability of free land plots for business development and social infrastructure	Low level of tourism infrastructure development
Developed agricultural culture	Problems with waste disposal
Strong raw material base at community enterprises and households	Poor quality drinking water
Availability of mineral resources (oil, gas, sand, clay)	Poor condition of roads and transportation infrastructure
Active community	Low level of environmental education and awareness
Opportunities	**Threats**
State support for agricultural products	The risk of an expansion of military operations on the territory of Ukraine
Programs to support farms	Climate change (dry summers and warm winters)
Development of alternative energy sources	Deterioration of the economic situation
Popularization of tourism, including green tourism	Outflow of economically active population
Cooperation with international organizations	Aging of the population
Access to grant funding	Environmental pollution due to oil and gas production
	Environmental pollution due to agricultural activities
	Environmental pollution due to an increase in the number of mobile sources of pollution

Note. Author's additions are highlighted in blue.

In our opinion, in order to use the opportunities and minimize the risks identified in Table 1, the environmental component of the spatial development plan of this community should include the following additional aspects of consideration:

- Zoning and Land Use Optimization
- Establishing protected natural areas to conserve biodiversity.
- Promoting agroforestry and sustainable agriculture.
- Introducing buffer zones along rivers and wetlands to prevent contamination.
- Sustainable Water Resource Management
- Green Infrastructure and Ecosystem Services
- Restoration of degraded landscapes through afforestation programs in floodplain areas and on the right bank of the Psel River.
- Promotion of ecotourism and green tourism.
- Increasing resilience to extreme weather events through nature-based solutions.
- Encouraging renewable energy use in community infrastructure.
- Implementing carbon sequestration projects, such as wetland restoration.

The development of an ecological component in spatial planning is vital for the long-term sustainability of rural communities. In the Velykosorochynsk rural territorial community, an integrated approach focusing on biodiversity conservation, sustainable land use, water management, and climate adaptation will ensure a harmonious balance between development and environmental protection

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Radchenko D. R., *student*
V. N. Karazin Kharkiv National University
***Hrechko A. A.**, lecturer, PhD student (Earth sciences)*
***Cherkashyna N. I.**, English Language Supervisor*

ANALYTICAL REVIEW OF 'GREEN RECOVERY' CONCEPT FOR THE RESTORATION OF NORTHERN SALTIVKA USING GREEN INFRASTRUCTURE

The publication states that the post-war recovery of Ukrainian cities should be based on green reconstruction and green transformation for cities with different levels of destruction, and a model of sustainable recovery should be chosen. Attention is focused on the implementation of environmental initiatives: renewable energy, energy saving and green infrastructure. The article identifies the topics for further research on the restoration of the Saltiv district in the context of the development of green and blue infrastructure facilities and the creation of specific cases.
Key words: green infrastructure, military impact, green reconstruction, post-war recovery.

The war in Ukraine has changed typical urban problems, such as pollution, outdated housing stock, shrinking green areas due to the increase in the number of asphalted areas, etc., and has brought to the fore the problems associated with the destruction of buildings, structures and infrastructure, and the waste from their destruction. Despite the fact that the war in Ukraine is not yet over, different visions of post-war reconstruction are increasingly common [1-5].

The first vision of post-war recovery was created in 2022 at the height of the military conflict [1]. The vision discusses the importance of treating cities with different degrees of damage differently:

- less damaged cities need a green transformation that involves development and renewal;
- for cities that have been severely damaged, green reconstruction is needed, which requires restoration, i. e. the creation of a new city equipped with green innovations.

Both approaches are based on sustainable development and involve the creation of green areas, alternative energy sources and energy efficiency in buildings.

The post-war reconstruction plans [2] proclaimed in the UN programme emphasise that the reconstruction of Ukrainian cities should be linked to the goals of sustainable development and should contribute to adaptation to global climate change. The UN Recovery Strategy also sees reconstruction as including 'green initiatives', and green infrastructure facilities can be such initiatives. After all, they improve the microclimate, reduce air pollution, create recreation areas for residents and improve the overall aesthetic appearance of urban areas.

Ukraine's green recovery should include the ecological modernisation of cities, reducing environmental impact, creating sustainable infrastructure and introducing natural ecosystems [3]. The role of the public in policy-making is important, but it faces difficult access to data and a lack of funding. Successful implementation requires joint activities between foreign partners, the state, community and business. This provides an opportunity to build a sustainable environmental development model.

The policy brief presents two models of sustainable recovery of Ukraine after the war [4]:

- pragmatic – 'green minimum', with some environmental elements;
- ambitious – a 'green post-war course', with a fully integrated approach to the transition to a climate-neutral economy.

Both models are aimed at environmentally sustainable reconstruction, but differ in the level of complexity of practical implementation and ambition. The chosen model will set the direction for the future development of green Ukraine.

The NGO Ecoltava [5] has developed approaches to the post-war 'green' recovery of Ukrainian communities, which include measures such as renewable energy, energy saving, reasonable use of resources, climate change adaptation and waste management. The document shows the important areas: water supply, energy, transport, construction, society, landscaping and biodiversity. The recommended methods vary in terms of implementation, from 6 months to 15 years. The document also points out the need to engage the public, seek funding and international experience.

The main ideas in the sources reviewed are similar. This gives a clear idea of the direction to be followed for the correct and effective green recovery of Ukraine. The concept of green-blue infrastructure fits harmoniously into the green recovery programme, as these facilities can help ensure adaptation to global climate change, increase the energy efficiency of buildings, and, if green roofs or walls are used, reduce energy consumption for cooling buildings in hot weather, ensure air purification, etc.

The Northern Saltovka district of Kharkiv is a residential area that, before the full-scale invasion, had a population of 298,600 people, which was 20.7% of the city's population [6]. Due to its location, it was one of the first to suffer as a result of the full-scale invasion. Northern Saltovka is one of the most damaged districts of Kharkiv. The article [7] discusses one of the options for rebuilding this area, which includes such elements of green infrastructure as green roofs, green parking, and mobile greening elements.

Therefore, further research will be aimed at creating a concept for the green reconstruction of the Saltivskyi district of Kharkiv in terms of using the concept of green infrastructure, which can solve urban problems such as air pollution, adapt to global climate change, and will meet the ambitious model of post-war recovery.

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Rieznik T. S., *student*
V. N. Karazin Kharkiv National University
Gololobova O. O., *PhD (Agriculture), Associate Professor*
Cherkashyna N. I., *English Language Supervisor*

ASSESSMENT OF ATMOSPHERIC AIR QUALITY IN KHARKIV AGGLOMERATION

The publication presents the results of indicative measurements of atmospheric air quality in the Kharkiv agglomeration. A significant excess of PM2.5 dust particulate matter content was recorded, which occurred after the fires caused by military operations. The radiation background remained within normal limits throughout the entire observation period.

Key words: atmospheric air quality, indicative measurements, radiation background, particulate matter.

Air quality is one of the key factors affecting public health and ecosystems. Following the signing of the Association Agreement between Ukraine and the European Union, Ukraine has begun the process of harmonizing its national legislation with European environmental standards. Air quality monitoring is regulated by a number of EU directives, among which the key one is Directive 2008/50/EC on air quality and cleaner air for Europe. It sets limit values for pollutants such as PM10, PM2.5, SO_2, NO_2, lead, benzene, CO, and ozone. For example, for PM10, the annual average limit value is 40 µg/m³, and for PM2.5 – 25 µg/m³ in Stage 1 and 20 µg/m³ in Stage 2.

The EU Directives set requirements for monitoring, reporting, and taking measures to improve air quality. In Ukraine, their implementation is gradual, and the lack of full monitoring of such a key pollutant as ozone remains a serious problem.

In today's environment, especially in regions affected by military operations, monitoring and control of air pollution is becoming extremely important.

The air quality in Kharkiv region is formed under the influence of pollutant emissions from stationary and mobile sources. The main stationary sources include industrial enterprises and fuel and energy facilities, while mobile sources are represented by road transport. Kharkiv region is one of the three regions of Ukraine that suffered the most from the hostilities [1], which significantly affected the environmental situation, in particular the state of the air. For example, the shelling of the Epicenter hypermarket on May 25, 2024, caused a fire that lasted 14.5 hours and led to significant air pollution due to the burning of building materials and chemicals. According to the State Environmental Inspectorate, the environmental damage from this incident amounted to more than UAH 4 million [2].

Indicative measurements are an important auxiliary tool for assessing air quality, especially in conditions where the official monitoring system is underdeveloped. They provide operational data on the concentration of key pollutants such as PM2.5, PM10, NO_2, and CO, which is critical for making decisions to improve the environmental situation.

Indicative measurements of pollutants in the air using compact stations do a good job of informing users about the state of the air. The development of a public system of indicative measurements as a component of monitoring can be the basis for identifying places where it is necessary to install reference monitoring stations to control air quality [3].

The purpose of this paper is to analyze the results of indicative air quality measurements in the Kharkiv agglomeration.

The study of atmospheric air quality was carried out from June 1 to June 14, 2024, in the Kharkiv agglomeration using the Eco City public air quality monitoring station [3]. The study analyzes the concentration of PM2.5 particulate matter (Fig. 1) and the level of radiation background (Fig. 2).

The study found that the highest concentrations of PM2.5 were observed from June 4 to 8 and from June 10 to 14, 2024. This is due to fires caused by military operations. A significant decrease in PM2.5 concentrations was observed on June 3, 6, and 7. This was due to the absence of fires and changes in meteorological conditions.

That is, the air quality in the Kharkiv agglomeration was unstable during the study period. Significant exceedance of the permissible concentrations of PM2.5 (category IV of air quality by this indicator) was observed on a significant number of days, which indicates a serious environmental problem in the region.

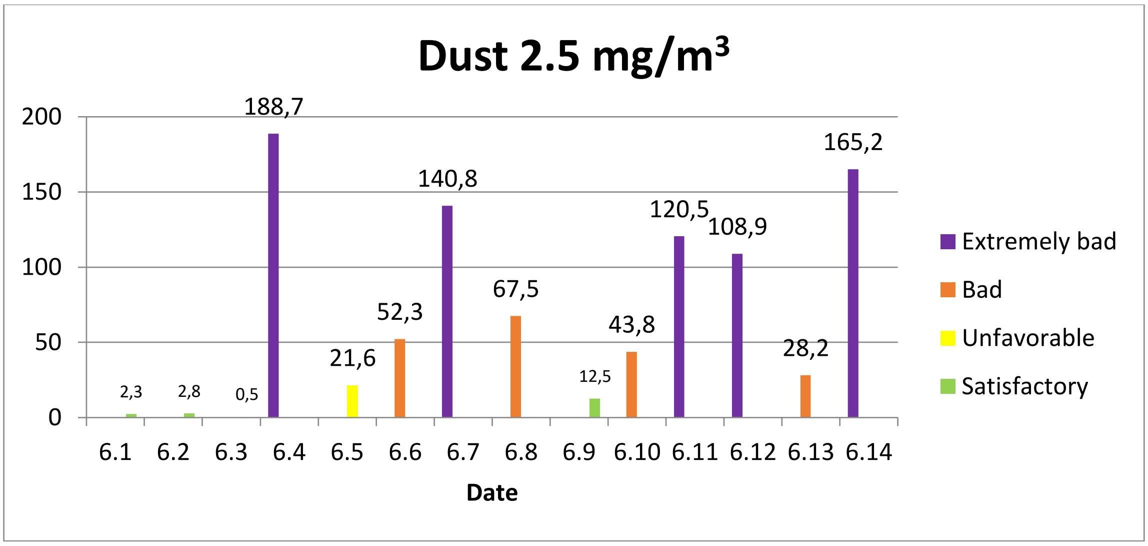

Fig. 1. PM2.5 concentration for the Kharkiv agglomeration from June 1 to June 14, 2024, mgc/m^3.

Such levels of pollutants in the air are dangerous even with short-term exposure. All categories of the population may experience severe exacerbation of reflex reactions and health consequences, even with short-term exposure. Special restrictions, warnings, and recommendations for staying outdoors for any activity are in effect for all categories of the population. We recommend excluding or rescheduling any outdoor activities [4].

The radiation background remained within normal limits during the entire observation period.

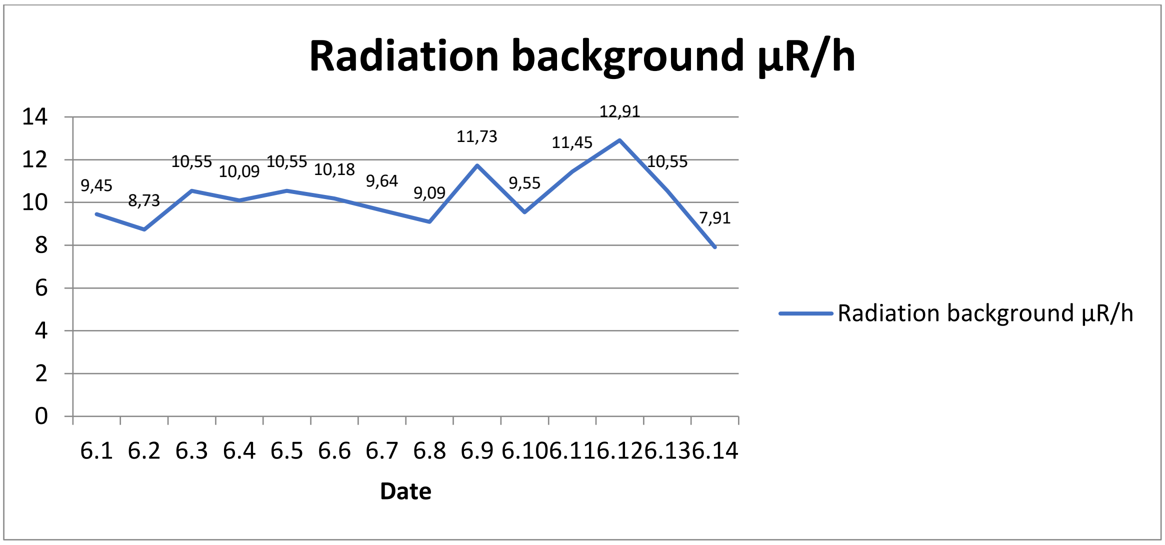

Fig. 2. Radiation background indicators for the Kharkiv agglomeration from June 1 to June 14, 2024, μR/h.

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Ryabikova V. V., *student*
V. N. Karazin Kharkiv National University
***Maksymenko N. V.**, DrSc (Geography), Professor,*
***Cherkashyna N. I.**, English Language Supervisor*

KUPIANSK FORESTRY AFTER DE-OCCUPATION: PROBLEMS AND PROSPECTS FOR RECOVERY

The article discusses the problems faced by the state enterprise "Kupiansk Forestry" after the de-occupation of the territory, as well as the prospects for its restoration. The consequences of the occupation are described, including the destruction of infrastructure, the loss of personnel, the mining of territories and the increase in the number of forest fires. The main tasks that are set for the forestry of Ukraine in the conditions of post-war recovery are presented.

Key words: restoration, forestry, farms, fires, workers.

The unique experience of the Kupiansk Forestry after the de-occupation clearly demonstrates how important it is to restore the sectors of the national economy, in particular forestry, in the territories affected by the occupation in a timely and effective manner [2]. Forestry enterprises not only suffered from destruction, but also suffered significant losses due to the looting of equipment and property, as well as deforestation by occupiers and poachers [3].

One of the main tasks after de-occupation is to restore the functioning of enterprises. In the case of the Kupiansk Forestry, one of the main challenges was the return of qualified specialists and workers who left during the occupation. The restoration of the workforce is a key factor of success, because without professionals it is impossible to conduct activities effectively [4].

Another significant challenge is the demining of territories, in particular forests. Mined areas pose a mortal danger to forestry workers, and it may take up to 10 years for them to be completely demined. At the same time, the safety of workers remains a priority, and only after the completion of demining is it possible to fully resume work [1].

A significant increase in the number of forest fires is a consequence of Russian aggression and hostilities. Fires cause serious damage to forest resources and ecosystems. For example, as a result of shelling during the Russian-Ukrainian war, a third of Ukraine's forest fund suffered, and 600 thousand hectares of forests are still under occupation. In addition, fires at oil depots and industrial enterprises cause air pollution with chemicals. According to the Ministry of Environment [1], as a result of these fires, 46 million tons of pollutants entered the atmosphere.

To minimize the impact of such disasters, it is necessary to apply advanced technologies for early detection and prevention of fires. Installing fire monitoring and early detection systems can significantly reduce the risks and consequences of fires. In addition, it is important to conduct regular education and training for forestry workers on fire safety [2].

It is also important to restore and protect forest resources through forestry and reforestation works. Collecting forest seeds, growing seedlings and tree seedlings and planting them in the ground are important measures to preserve and increase the forest cover of the territory. This will restore ecosystems and ensure the sustainable development of forestry [2].

The success of the restoration depends not only on the efforts of forestry workers, but also on the support of the state and the international community. The provision of financial and technical assistance, as well as coordination of efforts at different levels, will effectively solve problems related to the restoration of forestry in the de-occupied territories [1].

Thus, the restoration of forestry after de-occupation is a complex and multifaceted process that requires coordinated actions, innovative approaches and support from the state and the international community. However, thanks to the efforts of forestry workers and their professional knowledge, this task is quite feasible [4].

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Seliverstov O. Y., *PhD student*
V. N. Karazin Kharkiv National University

EXPERIENCE IN DETECTING ERODED SOILS AREAS USING REMOTE SENSING DATA

This abstract presents the research results on the capabilities of mapping eroded soils using the Kharkiv region as an example using high-resolution satellite data.
Key words: soil erosion, soil mapping, remote sensing.

Erosion is a process in which the soil body is destroyed under the influence of water and wind. The stock of soil resources, which are the basis of agriculture and forestry, is decreasing every year due to annual erosion losses, as well as due to the increase in the intensity and area of use. An important aspect of the soil erosion problem is its impact on the enhancement of the greenhouse effect due to the release of carbon from soils (Lal, 2004).

Global warming is expected to accelerate the rate of erosion (Nearing et al., 2004), creating a system with a positive feedback loop.

Field methods of mapping eroded areas have not become widespread in practice due to their high cost. One of the main methods of remote erosion detection is the interpretation of space and aerial images obtained in the optical range. For such interpretation, uncontrolled and controlled classification can be used (Zizala, 2018). The limitations of this approach include the consideration of only the spectral brightness of object classes (Achasov, 2001).

To increase the accuracy of mapping the distribution of eroded soils, we used additional patterns of the mutual location of eroded areas and features of the image structure in the images (fig. 1).

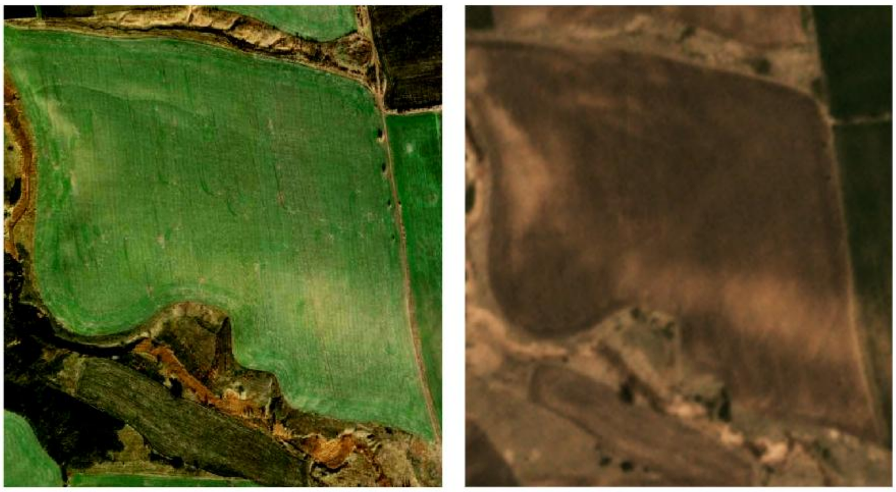

Fig. 1. Eroded lands (light areas) in images under different conditions.

Eroded soils are characterized by alternating light and dark stripes. Light stripes characterize eroded soils, dark ones – non-eroded. These interpretation features are characteristic not only for the physical and geographical conditions of Ukraine, therefore the interpretation method can be successfully used for the interpretation of eroded soils of a similar type and conditions in other countries.

Satellite images from PlanetScope (Education and Research Program) and WorldView-1/2/3 (DigitalGlobe Foundation) were used as the main source of data. Based on the results, the first version of the instructions for visual interpretation of eroded soils was created, with the designation of interpretation features and quantitative parameters of their use.

Field verification of the interpretation results was carried out at two test sites: "Dergachivsky" and "Rogansky" (2020-2021). During field assessments of soil loss volumes, instrumental measurements, photogrammetric and lidar surveys were used (fig. 2).

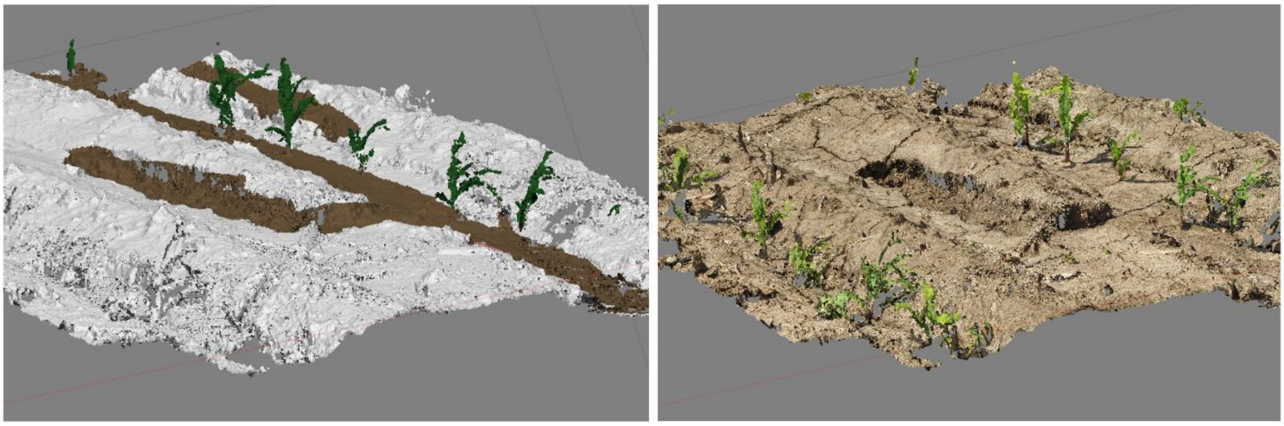

Fig. 2. Fragments of a model for assessing the consequences of water erosion.

The results of the verification confirmed the possibility of using high and medium spatial resolution WorldView (0.5-1.5m) and PlanetScope (3.5m) satellite images for mapping eroded soils and clarified the interpretation methodology.

Shchokina M. M., *PhD student*
V. N. Karazin Kharkiv National University
***Nekos A. N.,** DrSc (Geography), Professor*

ENVIRONMENTAL PROBLEMS OF SMALL BRIDGES: SOLUTIONS AND PROSPECTS

The thesis "Assessment of the environmental condition of small towns in the Kharkiv region (using the city of Lyubotin as an example)" examines various factors that affect the environmental condition of small towns. The author has chosen a small town Lyubotin in Kharkiv region as a test site. The solution to current problems that affect the environmental condition of Lyubotin allows us to implement a new algorithm of actions improving the environmental condition of other small towns.
Key words: small towns, ecological state of cities, methods of studying environmental components

With the advent of the era of socio-economic development, the industrial sector begins to actively expand, which contributes to the dynamic progress of the potential of cities. Cities act as engines of the industrial revolution and at the same time are the cause of the spread of environmental problems in the environment. That is why it is necessary to monitor the environmental condition of cities and develop measures that will prevent the deterioration of the situation. The work "Assessment of the environmental condition of small towns in the Kharkiv region (using the city of Lyubotin as an example)" is aimed at studying the environmental problems of small towns; factors influencing the emergence of environmental problems; introducing new methods and improving existing technologies and methods for preventing and reducing the negative impact of various stationary and mobile sources of pollution that worsen the environment.

In connection with the above, the goal of the dissertation work is formulated: determination and assessment of the ecological state of the small town of Lyubotin

The novelty of the project lies in the development of an algorithm of actions that optimize and reduce the impact of anthropogenic factors on the environment of small towns in the Kharkiv region.

The city chosen for the study as a testing ground is the small city of Lyubotin, Lyubotin community of the Kharkiv region. The area of the Lyubotinsky community is 137.7 km^2, the population is 26,669 people (as of 01.01.2022). The peculiarity of Lyubotin and the settlements of the Lyubotinsky society are: the predominance of private residential development, 30 cascade-type water bodies and 3000 hectares of forests [1].

The relevance of the study lies in the existing domestic and environmental problems of the city: the presence of unauthorized dumps of household waste and improper waste management, the unsatisfactory state of surface and ground water, and, in the long term, the difficult post-war financial recovery [2].

In order to determine the assessment of the ecological state of a small town, it is planned to conduct a study to determine the quality of soils near garbage dumps and enterprises, park and recreational areas, study the quality of water in surface water bodies, study the quality of groundwater from wells and boreholes. As part of the dissertation, it is planned to create a zoning map of the city territory by soil quality; implement GIS technologies to compile a digital database on the environmental situation of Lyubotin; improve methods for determining the ecological state of the city.

Conducting ofthe research consists of three stages.

The first stage is the theoretical scientific component of the dissertation work. This stage includes mastering the regulatory and legislative framework on environmental protection, the natural reserve fund of the Kharkiv region, Ukraine and Europe; review of sources on the environmental situation of small towns in Ukraine; familiarization with the archive materials of the Bayrak forestry, which is located on the territory of the Lyubotin society; study of the archive materials of the local history museum. Lyubotin; consideration of the development strategy of the Lyubotin urban territorial society. The first stage of scientific work requires the use of scientific methods, such as scientific-theoretical, statistical, analogies, analysis, deduction.

At the second stage we conduct the field research, take sampling, performing laboratory tests, creating a database based on the results of analytical studies. It is planned to take soil samples from landfills, household waste landfills, recreation areas, parks, water bodies, green tourism routes and conduct a study of soil quality. It is also planned to study the quality of surface waters according to hydrochemical indicators, as well as water from wells, wells located within the Lyubotinskaya community. During the second stage of work, the following research methods will be introduced: field research and observations, laboratory sampling, comparison, analytical, statistical.

The third stage includes generalization of the obtained results and analytical results. The developed work plan of the third stage includes: a comparative analysis of the obtained results, testing of hypotheses, identification of shortcomings.

The results of the research are presented in the relevant sections of the thesis. As part of the research testing [3, 4], the results will be reported at scientific conferences and published in collections of scientific papers and specialized publications.

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Shevchenko A. O., *student*
V. N. Karazin Kharkiv National University
Kot A. G., *Senior Lecturer*
Cherkashyna N. I., *English Language Supervisor*

INTERNATIONAL PRACTICES OF LAND RESTORATION AFTER WAR AND THEIR IMPLEMENTATION IN UKRAINE

This publication presents an analysis of the environmental consequences of military actions, focusing on soil degradation, contamination with heavy metals and explosives, and the destruction of natural ecosystems. The study examines the experiences of other countries in post-war land restoration and explores the potential application of bioremediation and phytoremediation methods for decontaminating Ukrainian soils. The findings highlight the importance of comprehensive land-use recovery strategies to ensure sustainable environmental rehabilitation.

Key words: soil contamination, military impact, land restoration, bioremediation, phytoremediation.

Military actions cause significant damage to the environment, destroying ecosystems and polluting soil and water. Explosions, military vehicle movement, fires, and other factors greatly deteriorate environmental conditions, even within protected areas. According to the European Information System, over 100,000 hectares of natural ecosystems have been destroyed. In Ukraine, the war has had severe consequences for agricultural land, fertile soils, and natural territories. The threat of contamination with heavy metals and explosive substances requires urgent measures for cleaning and restoration [1].

Before the war, the condition of soils in Ukraine was already critical. About 26% of land (16 million hectares) was classified as eroded, and 15% of these lands required conservation. The main causes were unsustainable agricultural practices and the plowing of slopes. Additionally, 42.7 million hectares of land were used for agriculture, with 40% of them occupied by fertile chernozems. Erosion processes were already destructive, and due to military actions, their impact has intensified [1, 2, 3].

With the onset of the full-scale invasion by the aggressor country, the situation has become even more severe. According to the State Forest Resources Agency of Ukraine, the frequency of wildfires increased 78 times compared to the previous year. Protected areas, including unique steppe habitats and forests along the Siverskyi Donets River, are under threat of destruction. Furthermore, 30% of Ukraine's protected areas have been damaged, and agricultural lands have suffered significant losses due to hostilities. Around 110,000 km^2 of arable land is now at risk. Soil contamination with heavy metals, explosives, and other toxic elements has become a new and serious challenge for the environment and public health [4].

The experience of other countries in restoring territories after military conflicts is a valuable source for developing effective land decontamination and restoration strategies in Ukraine. Countries such as France, Germany, the United Kingdom, and Spain have faced similar environmental consequences after major wars, and their restoration strategies can be adapted to Ukrainian conditions [5].

After World War I, France faced severe soil contamination in large areas, particularly in the east, where the most intense battles took place. A classification system was developed to assess the level of damage. Some areas were declared unsuitable for agriculture for decades, and special reforestation and soil rehabilitation programs were implemented. Methods such as bioremediation and the application of natural organic fertilizers were used to reduce the concentration of toxic substances [5].

After World War II, Germany faced widespread pollution due to infrastructure destruction and heavy bombing. The problem of contamination with heavy metals, especially cadmium and lead, required a comprehensive approach. Germany developed detailed land reclamation and decontamination plans, including the use of special phytoremediation crops that helped cleanse the soil of toxic elements. The method of phytoremediation - using specific plants to remove pollutants - was actively employed [6].

Significant soil contamination was also recorded in Spain during the Civil War of 1939 and in the United States after military training exercises in 2011. In both cases, the use of weapons and combat activities led to serious environmental consequences, particularly soil and water pollution. Given the scale and intensity of hostilities in Ukraine since the Russian invasion in February 2022, as well as the use of various weapons, including those banned by international treaties, Ukraine may face an extremely high level of contamination. The ongoing military operations cover vast territories, posing a serious threat to the country's ecosystem. The use of chemical, biological, and radioactive substances could have long-term and devastating effects on soil fertility, which will impact agriculture and public health in these regions [7, 8, 9].

By studying the experience of foreign countries, Ukraine has the opportunity to adapt various restoration models to its unique conditions. For example, France developed a classification system after World War I, dividing territories based on their level of damage. "Green zones" were quickly restored, while "red zones" remained unsuitable for agricultural use and required long-term decontamination [10].

A similar system could be implemented in Ukraine, particularly in regions that have suffered the most destruction, such as Kharkiv, Kherson, Mykolaiv, and Sumy oblasts [5, 9].

Additionally, to restore contaminated soils in Ukraine, bioremediation and phytoremediation methods could be applied, as they have proven effective in other countries. These methods use natural processes to cleanse soils of toxic substances, including heavy metals and explosives. Another crucial component of restoration is the reclamation of degraded lands, making them suitable for future use.

Adapting international experience will allow Ukraine to develop a comprehensive land-use recovery strategy that considers environmental, social, and economic factors. This also includes granting protected status to some areas, ensuring their effective management. By considering all these aspects, Ukraine has the opportunity not only to restore its economy after the war but also to lay the foundation for sustainable development in the future.

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Sivaiev D., *PhD student*
Odesa I. I. Mechnikov National University

FORECASTING ANNUAL ENVIRONMENTAL RISKS OF MAXIMUM RUNOFF OF THE RIVERS IN UKRAINIAN POLISSIA

Climate change has heightened the need for effective hydrological risk management, with the EU Floods Directive offering a framework for forecasting and mitigating flooding risks. This study focuses on the rivers of Ukrainian Polissia, particularly the Pripyat River basin, where climate change is altering hydrological regimes, leading to earlier and more frequent snowmelt-rainfall floods. The research emphasizes the use of predictive monitoring and forecasting models, such as the "Prypiat" system, to assess maximum runoff and flood risks, contributing to better flood preparedness and environmental safety in the region.

Key words: climate change, hydrological risks, flood forecasting, Ukrainian Polissia, EU Floods Directive

Climate change necessitates the implementation of effective mechanisms for managing hydrological risks. A key direction of adaptation is the implementation of the EU Floods Directive [1], which provides for the introduction of modern approaches to forecasting, prevention, and mitigation of natural disaster consequences. The adaptation of Ukrainian legislation to EU standards will contribute to the improvement of the water bodies monitoring system, enabling the effective assessment of potential threats, the prevention of critical situations, and the assurance of environmental safety.

Given these challenges, predictive monitoring of water resources during periods of maximum runoff becomes especially important. Its results will enable timely planning of measures to protect territories and infrastructure from flooding, as well as contribute to the efficient use of water resources in the context of climate change.

The object of the study is the rivers of Ukrainian Polissia (within the right-bank area of the Pripyat River and small right tributaries of the Dnipro River).

The Pripyat River basin, which serves as the main water artery of this region, is located within the forest and forest-steppe zones of Ukraine. Its right-bank tributaries, as well as the small right tributaries of the Dnipro, cover significant areas of the Volyn, Rivne, Zhytomyr, Khmelnytskyi, and Ternopil regions.

The hydrological regime of the rivers in Ukrainian Polissia is undergoing significant changes under the influence of climate change, which is manifested in fluctuations in the periodicity and intensity of water runoff. In particular, changes in temperature regimes, an increase in the amount and intensity of precipitation, as well as shifts in snow cover distribution, lead to substantial alterations in runoff formation. This is reflected in fluctuations in the intensity of spring and autumn runoff, as well as an increase in the frequency of catastrophic snowmelt-rainfall floods [2].

The aim of this study is to forecast annual environmental risks associated with the maximum snowmelt-rainfall runoff of the rivers in Ukrainian Polissia. The research focuses on assessing the impact of climate change on the region's hydrological regime, particularly on the periodicity and intensity of spring floods and high-water events.

Description of Major Floods in the Pripyat River Basin. Flood peaks in the basin generally occur in the second or third decade of March. The decline in water levels and discharge during floods happens gradually and over an extended period, especially in the lower reaches of the rivers. This recession can be complicated by rainfall-induced floods, which slow down the reduction in water flow and extend the duration of the flood recession, in some years lasting until late June or early July.

At the Ukrainian Hydrometeorological Institute of the State Emergency Service of Ukraine and the National Academy of Sciences of Ukraine (UHMI), an analysis was conducted on past flooding events in the Pripyat River basin from 1994 to 2017. The study focused on flood events caused by river waters. Out of 154 recorded flooding events in the Pripyat River basin, 99 were attributed to water levels exceeding the channel-floodplain corridor thresholds. Additionally, between 1994 and 2017, two incidents were recorded where water levels surpassed protective structures, and three cases involved the failure of protective structures. All past flooding events in the Pripyat River basin had negative consequences for public health and the economy.

Research Findings. The analysis of long-term observations (up to 2024) indicates a trend toward an earlier onset of spring flooding in the rivers of Ukrainian Polissia. In recent years, under conditions of unstable winter temperature regimes, low snow reserves, and uneven snow accumulation, floods caused by snowmelt-rainfall waters have begun forming earlier, almost during winter periods. Such early floods were observed in the years 2002, 2007, 2008, 2011, 2015, 2016, and 2019–2024.

The melting of snow due to increased temperatures leads to the formation of peak snowmelt-rainfall runoff in rivers. However, due to the reduction of snow cover and its rapid melting, floods are becoming less extensive and less widespread. Along with climate warming, the likelihood of catastrophic mixed floods is increasing. This hydrological regime of rivers may result in higher economic losses from extreme floods. The runoff hydrographs exhibit a complex multi-peak pattern, making it challenging to distinguish the specific spring runoff wave (as observed in 2004, 2008, 2014, and 2016). In recent years, this spring runoff wave has been either insignificant or almost absent in some rivers.

According to the Ukrainian Hydrometeorological Center of the State Emergency Service of Ukraine (https://meteo.gov.ua), the hydrometeorological conditions in the basin of the rivers of Ukrainian Polissia during the winter of 2025 were unfavorable for the formation of spring runoff. The anomalously warm winter led to the absence of a stable snow cover, insignificant soil freezing, and insufficient soil moisture in many regions. This may result in low water levels in rivers during the spring runoff period.

The forecasting of annual hydrological risks associated with the maximum runoff of the rivers of Ukrainian Polissia is carried out using the method of territorial long-term forecasts of spring flood characteristics [3].

For this purpose, regional dependencies of the modular coefficients of runoff layers and maximum water discharge are used, based on the total moisture reserves in the snow cover and spring precipitation. A preliminary assessment of water availability is conducted using discriminant analysis, which considers a complex of hydrometeorological factors. The forecast values of runoff are determined based on regional dependencies, which are built upon the long-term average values of maximum water discharge and runoff layers.

For the automation of the forecasting process, a computer-based system "Prypiat" has been developed and implemented in the operational activities of the hydrometeorological service based on a mathematical model for long-term forecasting of peak water discharge during spring floods. This system enables the issuance of long-term forecasts of peak water discharge and a preliminary probabilistic prognostic assessment of flood hazards, allowing for an early evaluation of flood probability.

For this purpose, cartographic representations of the characteristics of maximum snowmelt and rain-induced runoff are used in the form of modular coefficients of runoff depth or peak water discharge (Fig. 1a). In addition to maps of the forecasted values of modular coefficients, a scheme is also provided that illustrates the probability of exceeding the forecasted values over a multi-year period (in percentage) for any given area (Fig. 1b), regardless of the level of its hydrometeorological study.

(a) (б)

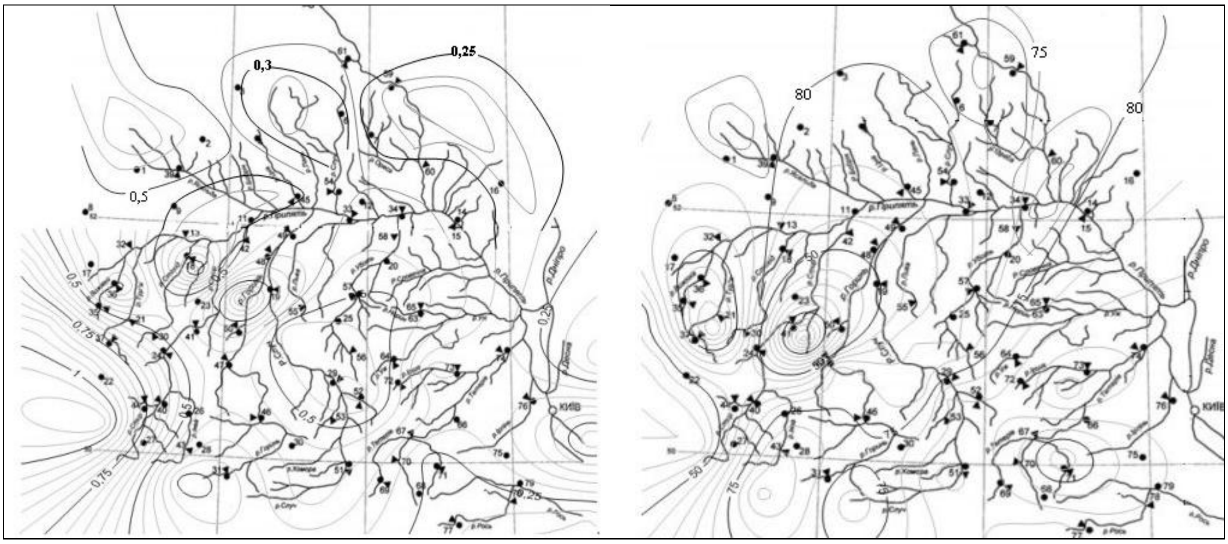

Fig. 1. Distribution of forecasted maximum modular coefficients (a) and probability of exceedance (P%) (b) of maximum spring flood discharge values across the territory of the Ukrainian Polissia.

For example, at P = 20%, a flood will occur once every 5 years, while at P = 1%, it will occur once every 100 years, and so on. According to the requirements of the EU Flood Directive, the characteristics of maximum discharge should be determined for a probability of P = 0.2% (once every 200-500 years), P = 1% (once every 100 years), and P = 10% (once every 10 years).

Conclusions. The proposed methodology is an effective tool for preventing the negative consequences associated with the formation of maximum snowmelt-rainfall runoff in the rivers of the Ukrainian Polissya. The predictive cartographic monitoring of maximum discharge values confirmed its potential for effective management of hydrological risks and environmental protection, particularly during emergency situations.

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Skorokhod D., *PhD student*
Odesa I.I. Mechnikov National University

SPATIAL AND TEMPORAL DYNAMICS OF WATER BALANCE COMPONENTS IN THE PIVDENNYI BUH RIVER BASIN UNDER CLIMATE CHANGE CONDITIONS

This study focuses on the Pivdennyi Buh River basin, where climate change has altered the dynamics of spring floods. Long-term observations from 1945 to 2020 reveal a decrease in snow cover water reserves and a shift in the timing of peak snow storage and spring runoff, leading to weaker spring floods. The research emphasizes the importance of understanding the temporal and spatial variations in water balance elements for better management of water resources and addressing the effects of climate change on hydrological systems.

Key words: climate change, spring floods, water balance, Pivdennyi Buh River, hydrometeorology

The spatial and temporal distribution of water storage is crucial for studying flooding, as well as for addressing water supply issues and the rational use of water resources. Contemporary climate change, which has been most pronounced in recent decades, significantly affects hydrometeorological factors and the conditions of annual runoff formation, particularly the high-water phase of river hydrological discharge water during spring floods.

The object of this study is the Pivdennyi Buh River basin, which is characterized by annual snow accumulation and snowmelt, leading to spring floods of varying intensity (spring runoff from 35% to 60% of the annual total). The occurrence of winter thaws, particularly in recent decades, has led to snow redistribution across catchment areas, winter replenishment of soil moisture reserves, and a decrease in the depth of soil frost penetration. As a result, the spring flood wave may be weakly expressed.

The aim of this study is to determine the magnitude and temporal variability of the elements of the water balance of the Pivdennyi Buh River catchment during the period of spring flood formation.

Water balance studies are one of the main sections of hydrology and are a means of solving important theoretical and practical hydrological problems. The results of water balance studies serve as the basis for quantitative assessment of water resources and their changes under the influence of human activity and climate change.

The research is based on observations of hydrometeorological and agrometeorological characteristics of the spring flood, including water discharge, air temperature, precipitation, snow cover water storage, soil frost penetration depth, and soil moisture index.

The climate of Ukraine, like that of the entire globe, has warmed throughout the instrumental observation period, and the dynamics of this change largely correspond to global climate changes [1]. Climate models tested for the territory of Ukraine indicate a further increase in warming during the 21st century. Unlike air temperature trends, precipitation patterns exhibit significant interannual fluctuations and high spatial variability. Redistribution of precipitation is observed both seasonally and across the plains of Ukraine [2].

This study examined temperature conditions during the winter-spring season. Chronological graphs of mean monthly air temperatures in February and March over long-term observation periods indicate a trend toward rising temperatures in these months (with a significant correlation coefficient of r = 0.33-0.37). This undoubtedly affects snow accumulation conditions in river catchments and, in warm winters, contributes to the formation of winter floods.

Chronological graphs and differential integral curves, constructed from long-term observation data (1945-2020) on maximum snow storage at individual snow survey points, demonstrate a decrease in snow cover of water reserves over the past two decades. This is one of the reasons for the reduction in river runoff during the spring flood period.

The temporal variability of the dates of maximum snow storage (1945-2020) tends to shift to earlier dates, particularly in recent years. Accordingly, the onset of the spring flood has also changed, shifting to earlier, nearly winter months.

Long-term time series of precipitation observations during the spring flood period, as well as snow storage trends, exhibit a cyclic pattern with a general tendency toward reduction: a decline in precipitation during the snowmelt period has been observed since the early 1980s, and a decrease in precipitation during the flood recession phase has been noted since the 1990s.

Studies of long-term time series of maximum soil frost penetration depths (as of 2020), presented as chronological graphs, show a cyclic character (with r = 0.41-0.57). Since the mid-1960s, we have observed frost penetration depths increase, but since the late 1980s, there has been a significant decrease trend.

Chronological graphs of runoff characteristics of the spring flood in the Pivdennyi Buh River basin show a downward trend in both runoff layers and peak water discharge, with significant correlation coefficients (r = 0.50-0.71). Differential integral curves indicate the cyclic nature of variations in spring flood runoff: an increase until the 1940s, stabilization by the 1980s, followed by a sharp decline to the present day [2, 3].

Conclusion. Thus, the spatial and temporal dynamics of the hydrometeorological components of the water balance of the Pivdennyi Buh River catchment will allow for a more thorough solution to the balance in the future under climate change.

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Svyrydenko A. O., *student*
V. N. Karazin Kharkiv National University, Kharkiv, Ukraine,
Koval I. M., *DrSc (Agriculture), Professor*

HYDROTHERMAL COEFFICIENTS AS IMPORTANT INDICATORS OF CLIMATE CHANGE

The research presents an analysis of hydrothermal coefficients based on data from the Rivne and Poltava weather stations.
Key words: climate change, forest zone, forest-steppe zone.

Climate is changing rapidly, so it is important to assess the likely impacts of climate change on vulnerable ecosystems around the world. Forests contain the world's largest terrestrial carbon pool and are a major sink that reduces the accumulation of carbon dioxide in the atmosphere. Climate change is likely to lead to significant changes in the structure and function of ecosystems [1, 4].

Changes in temperature and precipitation and the rate of these changes are among the most important factors in climate change. It makes sense to analyze temperature and precipitation simultaneously. Parameters that have a mathematical coefficient/ratio of precipitation (or humidity values) and temperature are known as aridity indices and are used as a measure of aridity. Thus, aridity indices are important not only as indicators of plant growth, but can also be considered as important indicators of climate change [2, 3, 5].

The purpose of the study is to compare changes in hydrothermal coefficients for the cities of Rivne (forest zone) and Poltava (forest-steppe zone) for 1974-1998 and 1999-2023.

The Hydrothermal coefficient O_1 reflects the hydrological conditions from October of the previous year to August of the current year, i.e. it characterizes both the period of moisture accumulation in the soil, which occurs in the autumn of the previous year and in winter, and the conditions of the growing season [5]. In the Rivne, the O_1 hydrothermal coefficient in the second period increased by 11% compared to the first one, and in Poltava – by 13%. The De Martonne Aridity Index and Hydrothermal coefficient of Selyaninov, which characterize the hydrological conditions of the growing season, showed an increase in aridity for both cities in the second period compared to the first one.

Aridity conditions in the forest zone (Rivne) and in the forest-steppe zone (Poltava) during 1974-2023 changed differently. These changes for the Hydrothermal index ranged from 2 to 18%. At the same time, for the forest zone, the hydrothermal indices reflecting the hydrological conditions of the growing season were higher in Rivne than in Poltava and changed at a faster rate. Thus, for Rivne, the De Martonne Aridity Index decreased by 6%, and for Poltava – by 4%, and for the Hydrothermal coefficient of Selyaninov – by 18% and 13%, respectively (Table 1).

Table 1.

Hydrothermal coefficients according to data from Rivne and Poltava weather stations

Hydrothermal index	Rivne (forest zone)		Poltava (forest-steppe zone)	
	1974-1998	1999-2023	1974-1998	1999-2023
Hydrothermal coefficient O_1	1.30±0.06	1.55±0.09	1.44±0.11	1.66±0.07
The De Martonne Aridity Index	34.41±2.06	33.04±1.30	32.73±1.71	30.36±1.55
Hydrothermal coefficient of Selyaninov	1.59±0.12	1.30±0.07	1.13±0.08	1.02±0.07

Thus, aridity increases during the growing season in both natural zones (forest and forest-steppe), and this process is happening more rapidly in the forest zone.

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Tertytskyi Ie. P., *PhD student*
V. N. Karazin Kharkiv National University

NAVIGATING AMBIGUITIES OF BLUE AND GREEN INFRASTRUCTURE IN ECOSYSTEM SERVICES

Blue infrastructure (BI), encompassing water bodies such as rivers, lakes, and artificial water systems, plays a crucial role in urban areas by providing essential ecosystem services, including flood regulation and water purification. However, integrating BI into urban planning is complicated by inconsistent definitions and approaches, particularly due to the ambiguous boundary between blue and green infrastructure. This paper explores these challenges and emphasizes the need for clearer distinctions between these infrastructures, alongside improved management strategies for sustainable urban water resource management. It discusses the varying definitions of BI across different geographic and cultural contexts, as well as its integration with green and gray infrastructure.

Keywords: Blue infrastructure, green infrastructure, ecosystem services, urban water bodies, sustainable development, climate adaptation.

Since the pace of urbanization remains consistently high, according to UN forecasts, by 2050, nearly 70% of the world's population will live in cities. Urbanized settlements around the world are facing serious challenges caused by climate change, water security issues, air pollution, and deteriorating public health [1].

In scientific literature, the network of green (land) and blue (water) spaces is often referred to as "ecological infrastructure» - a strategically planned network of natural and semi-natural areas, such as parks, street trees, green roofs, and urban water streams, which provide various ecosystem services within the city [2]. However, to understand the contribution of blue infrastructure (BI) and its objects in providing ecosystem services, it is necessary to define the term BI, as it varies depending on geographic and cultural contexts, as well as specific scientific approaches.

As the research suggests, there are various approaches in the scientific publications to defining blue infrastructure. Some researchers, particularly Polish and British, integrate BI with green infrastructure, proposing the concept of blue-green infrastructure, where water bodies are considered a part of green spaces. At the same time, other scholars, such as those from the USA and China [3], define BI separately, emphasizing its role in reducing temperature and improving the urban environment. Some researchers also integrate BI with gray infrastructure, particularly for managing stormwater and reducing peak water flows [4].

In Ukraine, green and blue-green infrastructure are actively studied, although these concepts are often not distinguished, especially with a focus on regulating rainfall through green infrastructure. There are studies on blue infrastructure separately (water bodies and artificial hydro- structures) [5], but its role is defined as integrating it into urban planning, particularly through the creation of elements for managing water resources and adapting to climate change.

The main ecosystem services provided by blue infrastructure, include: regulation of the water cycle (drainage, storage, and water purification), flood risk reduction, water quality improvement, and biodiversity support. In addition, blue infrastructure contributes to the improvement of the microclimate, reduction of temperature, and creation of recreational spaces, positively effecting the quality of life of residents. The choice of these specific ecosystem services is due to their significant role in ensuring sustainable water resource management, which is critically important for urban environments [6].

Therefore, we will distinguished blue infrastructure will as a separate category, including only water bodies that are of significant importance for water resource management within the urban environment. Such blue infrastructure objects include rivers, lakes, ponds, canals, streams, reservoirs, wetlands, and other water bodies, as well as permeable surfaces and artificial systems for collecting and storing rainwater, which play an essential role in sustainable water management in cities.

Components of blue infrastructure in the example of Uzhhorod city, Ukraine. In Uzhhorod, water bodies such as the Uzh River, the diversion canal (for main water supply), and several artificial lakes are the main elements of blue infrastructure, performing ecological functions such as regulating water flow, supporting biodiversity, and improving air quality. Secondary objects include artificial water bodies located in Bozdosh Park, which are prone to marsh formation, as well as mineral water springs, which include both natural springs and artificial wells, with only one being actively integrated into the water supply network.

The main problems of blue infrastructure in Uzhhorod include the drying up of lakes and the river during dry periods, leading to the formation of islands, flooding, and overflow during rain floods, as well as restrictions on recreation due to health risks at water bodies.

Threats and challenges to water resources. The ecosystem services provided by water bodies, such as water purification, flood regulation, and biodiversity support, are directly dependent on the health of aquatic ecosystems. However, assessing their effectiveness is complex due to inconsistencies in measuring these services and the lack of standardized criteria [7].

The assessment of ecosystem services of water bodies involves the use of various approaches, such as ecological, economic, and social analysis. Key methods include assessing biodiversity, the functional properties of aquatic ecosystems (such as water purification or flood regulation), and determining the economic value of services provided by water bodies through contingent valuation methods or cost-based assessments. Additionally, it is important to consider social aspects, particularly the accessibility of water bodies for recreation and their role in supporting local well-being.

Anthropogenic factors, such as pollution and changes in land use, significantly degrade these services, requiring the development of new approaches to managing blue infrastructure [8]. Furthermore, issues in conceptualizing blue infrastructure complicate its integration with other elements of urban planning, reducing its effectiveness in urban ecosystems.

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Viktorova N. V., *student*
V. N. Karazin Kharkiv National University
***Maksymenko N. V.**, DrSc (Geography), Professor*
***Cherkashyna N. I.**, English Language Supervisor*

BIOINDICATORS AS A METHOD OF ASSESSING THE ECOLOGICAL STATE OF ENVIRONMENTAL COMPONENTS

The article discusses the principle of bioindicators, their classification, and their application to air, water, and soil monitoring. Particular attention is paid to practical application in environmental research, as well as the advantages over traditional methods of environmental pollution assessment.

Key words: bioindication, bioindicators, environmental monitoring, environmental assessment, environmental research.

Modern technological developments are causing environmental problems to become more acute: air, water and soil pollution, climate change and biodiversity loss. Solving these problems is not a task for one day or even one month. In addition, most of them require effective methods of environmental monitoring, but the "second" and "third" world do not have the capacity to countries conduct complex and expensive instrumental environmental monitoring. For such cases, there are more affordable ways to assess the environmental situation - bioindication.

Bioindication is a method based on the use of living organisms that are sensitive to environmental changes, allowing to determine the level of pollution and its impact on ecosystems [1].

Bioindicators are organisms or groups of organisms that respond to environmental changes in a certain way, which allows to assess the level of pollution or other environmental characteristics of an area [2]. They can be classified according to various criteria, such as their organization (individual, population, or ecosystem), the type of response to pollution, and their habitat.

The use of bioindicators provides reliable data on the state of ecosystems, as they respond to the complex impact of various pollution factors, not just to individual substances [3].

Bioindication is based on the study of changes in biological systems under the influence of external factors. The main mechanisms of bioindicators include physiological changes (color changes, such as needles of coniferous trees, changes in the shape and structure of tissues in plants), for animals these are behavioral changes in feeding, reproduction, and migration. One of the important factors is population changes, such as the disappearance of some species and the increase in the population of others.

As an example, lichens are widespread in many regions of the world and are one of the most effective indicators of air pollution. They do not have a root system and absorb nutrients directly from the air, which makes them sensitive to harmful substances such as sulfur and nitrogen oxides and heavy metals [6].

With this feature, lichens are widely used to assess air quality. They are sensitive to the concentration of sulfur dioxide contained in industrial emissions. In areas with high levels of pollution, the number of lichens is significantly reduced [5].

In addition to lichens, air quality can be assessed by the condition of coniferous trees. Their needles accumulate pollutants, and changes in their color and shape can determine the level of pollution [7].

Aquatic bioindicators include microorganisms, algae, mollusks, fish, and amphibians. Some of them, such as trout, can only live in clean water, while others, such as crucian carp, can survive even in heavily polluted waters [8].

An important indicator of water quality is the presence of biofilms, which are specific microorganisms that develop in water bodies with high levels of organic pollution. The massive reproduction of blue-green algae indicates the saturation of the reservoir with nutrients and a decrease in water productivity, which is a consequence of excessive phosphate and nitrate intake [9].

Soil bioindicators include earthworms, nematodes, soil bacteria, and fungi. A high number of worms indicates good soil aeration and the absence of toxic chemicals [10].

Microscopic fungi and bacteria play an important role in the decomposition of organic matter and the formation of humus. Their presence and diversity are indicators of a healthy soil environment [11].

Bioindication has advantage of thean integrated approach, as organisms do not react to one component of pollution, but to all of them at once, which can give an overall picture of the ecosystem. This also help method can to detect some problems at an early stage and take action. Sensitive organisms can signal changes long before serious consequences occur [12], which will significantly speed up the process of environmental restoration. As mentioned earlier, the method does not require sophisticated laboratory equipment, which makes it accessible to most countries of the world.

Bioindication is a valuable method of environmental monitoring that allows detecting pollution, assessing its impact on ecosystems, and developing effective measures for their preservation. The use of bioindicators in research contributes to the development of environmental science and the implementation of more effective environmental protection strategies [14].

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Yanitskyi D. R., *student*
Oles Honchar Dnipro National University
***Masiuk O. M.**, PhD (Biology), Associate Professor*

RARE PLANTS OF KRASNOKUTSK FOREST

The report analyzes four cases of detecting rare plants (three species listed in the Red Book of Ukraine and one classified as regionally rare for Dnipropetrovsk region) in an area under significant anthropogenic impact in Zhovti Vody, Dnipropetrovsk region, where uranium ore mining and sulfuric acid production facilities are operating. The study aims to assess the plants' resistance to elevated radiation and chemical pollution, as well as to identify adaptive mechanisms that could be used in the development of biodiversity conservation measures.

Keywords: Rare species, Red Book of Ukraine, biodiversity conservation.

The intensification of economic activities causes habitat fragmentation, ecosystem degradation, and the loss of fertile soils and essential ecosystem services that support life. Although biodiversity conservation is a global challenge, regional conservation is crucial due to the heterogeneity of ecotopes. The loss of even a single species can trigger a cascade effect throughout the ecosystem. The detection of rare plants in specific ecotopes indicates the presence of local refugia that preserve populations even under high anthropogenic pressure, which is important for nature conservation measures and the reclamation of disturbed areas.

The Krasnokutskyi Forest in Zhovti Vody (Dnipropetrovsk region) is an example of a forest stand undergoing secondary succession following human interference. The region containing the study site was actively used for the extraction and processing of iron–uranium–scandium ores from the Zhovtorychensky deposit between 1951 and 1989. In the vicinity of the study site, there is a hydrometallurgical plant with its reserved tailings storage facility, a sulfuric acid plant, and a municipal waste disposal site, all of which cause radiation and chemical contamination of soils, water, and air. In addition, the city hosts the Eastern Mining and Beneficiation Plant with four tailings storage facilities, while the production of sulfuric acid and the waste disposal site create further environmental stress [1]. Overall, these industrial facilities exert a significant anthropogenic impact that negatively affects the ecosystem of Zhovti Vody, making the Krasnokutskyi Forest a valuable case study for the conservation of species populations under high pollution levels.

During the geobotanical survey of the Krasnokutskyi Forest conducted from March to October 2024, three plant species listed in the Red Book of Ukraine and one considered regionally rare for the Dnipropetrovsk region were discovered. These include: (*Tulipa quercetorum*), (*Ornithogalum boucheanum*), (*Astragalus dasyanthus*) and (*Scilla bifolia*).

Tulipa quercetorum is an Eastern European species of the *Liliaceae* family, occurring in Ukraine at the eastern edge of its range, predominantly in the Left Bank Forest-steppe and in isolated areas of the Right Bank Forest-steppe [2]. Its natural habitats include floodplain groves, barracks forests, and shrublands; the species is a typical representative of the *Querco-Fagetea class.* Its conservation status is "vulnerable" according to the Red

Book of Ukraine [3]. It was found in small populations in plots dominated by *Quercus robur*, *Acer platanoides*, and *Acer campestre*.

Ornithogalum boucheanum is a Mediterranean species of the *Hyacinthaceae* family with a range spanning southern Central Europe, the Balkans, western Minor Asia, and regions north of the Black Sea [5]. The species is listed in the Red Book of Ukraine as "not evaluated." It grows in barracks and floodplain forests, forest edges, shrublands, gullies, wet meadows, and ruderal sites on various soil types. In the steppe region of Ukraine, its typical associations are classified as *Tilio-Acerion* [3]. It was observed as a moderately abundant group in plots dominated by *Acer campestre* and *Fraxinus excelsio*r [4].

Astragalus dasyanthus is a species of the *Fabaceae* family widespread in Eastern and Southern Europe, the Balkans, and the Transcaucasus; in Ukraine, it is found in the Forest-steppe and Steppe. In steppe populations, the number of individuals was low, but in the absence of grazing pressure, the populations tended to thicken. The species is classified as "vulnerable" according to the Red Book of Ukraine [3]. It was detected in small but numerous groups in plots where *Quercus robur* dominated the arboreal vegetation.

Scilla bifolia is a species of the *Asparagaceae* family that originates from Europe and Western Russia to Syria (via Turkey). The species is included in the list of regionally rare plants of the Dnipropetrovsk region [5]. It is found in deciduous forests, forest edges, and shrublands, particularly in the forest steppe of both the Right and Left Banks, extending to Sumy. Large populations of the species were observed in plots dominated by *Quercus robur*, *Acer platanoides*, and *Acer campestre*.

The analysis of the Krasnokutskyi Forest (Zhovti Vody, Dnipropetrovsk region) demonstrated that even under high radiation and chemical stress, local biodiversity hotspots persist. The detection of rare species (*Tulipa quercetorum, Ornithogalum boucheanum, Scilla bifolia, Astragalus dasyanthu*s) is of both scientific and practical significance, as it enhances our understanding of their resilience to adverse conditions and the adaptive strategies they employ. The presence of these species in the study area indicates the existence of natural refugia that can be utilized for the conservation of populations and the maintenance of ecological balance. These results may serve as a basis for effective conservation measures, reclamation, and nature protection actions in industrial landscapes at both regional and global levels.

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Yanul V., *PhD student*
Institute of Ecology of the Carpathians NAS of Ukraine

SPIDER SPECIES OF HIGH CONSERVATION VALUE IN OLD-GROWTH SYCAMORE AND BEECH FORESTS OF THE VODODILNO-VERKHOVYNA MOUNTAIN RANGE (UKRAINIAN CARPATHIANS)

This study explores the ecological features of three rare spider species regularly detected in pitfall traps set up in old-growth ecosystems of the Vododilno-Verkhovyna Mountain Range, Ukraine.
Key words: spiders, rare species, Carpathian endemics, old-growth forest

Introduction. Spiders (order Araneae) represent a highly diverse group of arthropods found in nearly all terrestrial ecosystems. To date, over 52,000 spider species have been documented worldwide, and the discovery of new species continues to expand (World Spider Catalog, 2025). Ecosystems of old-growth forests represent well-preserved, highly organized environments which provide a wide range of crucial niches for diverse invertebrate fauna, including spiders. Nevertheless, known data on the species composition of spiders in the Vododilno-Verkhovyna Mountain Range, in particular, old-growth stands, is rather scattered (Yanul, 2023a, b).

The present study aims to describe the ecological features of three rare spider species, which have been regularly detected by pitfall traps study in old-growth ecosystems.

Methods. The current study was held in the Lviv region, near the southwestern vicinities of Vill. Verkhne Husne, alongside the north-eastern slope of Pykui Mountain (1406 m, highest peak of Lviv region). The survey scheme includes 18 ground pitfall traps (p.t.), installed on two studying plots (Plot 1 and Plot 2). Each study Plot is divided into two subplots of 9 traps, a subplot under a natural tree recovery gap and a subplot under a tree canopy. As a conservative filler in traps, a 10% CH_3COOH solution has been used. More details on plots (P) and subplots (SP) are described below:

P1. Natural sycamore and beech old-growth forest. Many beech and sycamore tree individuals at the site are above 100 years old. Geographical coordinates: 48.841263 N, 22.997723 E Altitude: 1090 m. SP1. (9 ground p.t. underneath tree canopy). Period of trap group exposure: 24.05. – 24.10.2023 and 16.06. - 21.09.2024. SP2. (9 ground p.t. underneath recovery gap). Period of trap group exposure: 24.05. – 24.10.2023 and 16.06. - 21.09.2024.

P2. Representing similar age and tree composition as Plot 1, but situated at a lower altitude (890 m). Geographical coordinates: 48.862934 N, 23.002509 E. SP1. (9 ground p.t. underneath tree canopy). Period of traps exposing: 25.05. – 29.10.2023; 26.04. – 13.08.2024. SP2. (9 ground p.t. underneath recovery gap). Period of trap group exposure: 8.07. - 29.10.2023.

The Stecker-Bergman method (1977) was employed to assess the rarity and dominance of species within the overall spider communities.

Results.

Family Agelenidae C. L. Koch, 1837

Coelotes pickardi carpathensis Ovtchinnikov, 1999

Conservation status: Near Threatened, Endemic (Gajdoš et al, 2014).

Total individuals counted: 88.

Remarks. This species is a Carpathian endemic, currently known only from the Ukrainian Carpathians. Its biological characteristics remain largely unknown. In the pitfall studies conducted, its presence within the spider community of Plot 1 ranges from rare (R) to dominant (D). Notably, it is absent from Plot 2, where it is replaced by the broadly European *Coelotes terrestris* (Wider, 1834), which, according to our findings, also inhabit the foothills of the Vododilno-Verkhovyna range.

Family Linyphiidae Blackwall, 1859

Centromerus silvicola (Kulczyński, 1887)

Conservation status: Vulnerable (Gajdoš et al, 2014)

Total individuals counted: 2.

Remarks: This species is considered relatively rare in Central Europe, typically found in the moss and leaf litter of damp woodlands, especially in low mountain ranges (Nentwig et al., 2025). Its presence in spider communities is infrequent, with confirmed observations in Plot 1 Subplot 2 and Plot 2 Subplot 1. At the studied locations, *Centromerus silvicola* was observed to co-occur with the more prevalent *C. sellarius* (Simon, 1884).

Pallidophantes milleri (Starega, 1972)

Conservation status: Vulnerable, Endemic (Gajdoš et al, 2014).

Total individuals counted: 62.

Remarks: This species is a Carpathian endemic, present in Ukraine, Poland, Romania, and Slovakia (Nentwig et al., 2025). In our studies, its rarity varies from a singleton in Plot 2 to being one of the dominant species in Plot 1. *P. milleri* prefers forests situated above 1,000 meters, extending up to the timberline. A greater number of individuals was recorded during the first year of our studies.

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Yefremova A. A., *student*
V. N. Karazin Kharkiv National University
Rychak N. L., *PhD (Geography), Associate Professor*

QUALITY STANDARDS OF DRINKING WATER IN UKRAINE AND POLAND

A comparative analysis of regulatory documents regarding water quality requirements for drinking purposes in Ukraine and Poland was conducted. Approximately 250 indicators of various groups were independently examined: organoleptic, physicochemical, microbiological, and specific. Similarities and differences were identified. The most significant differences were found in the quantitative values of physicochemical indicators.

Keywords: environmental standards, drinking water, quantitative water quality indicators

Water is one of the most valuable natural resources, affecting public health, ecosystem conditions, and economic development stability. The quality of water resources plays a crucial role in ensuring ecological security and sustainable national development. Therefore, the harmonization of environmental water quality standards between countries is of particular importance.

The aim of this study is to determine the compliance level of Ukrainian environmental standards with international norms and to identify possible ways for their improvement, considering Poland's experience. Descriptions of national standards, rules, and regulations regarding drinking water requirements for both countries are provided in Table 1.

Table 1

Description of national regulatory documents on drinking water quality

Country	***Standart***	***Description***
Ukraine	DSanPiN 2.2.4-171-10	Hygienic requirements for drinking water. Defines safe levels of contaminants, prevents diseases, and protects public health.
	DSTU 7525:2014	Establishes drinking water quality requirements and control methods, covering both centralized and non-centralized water supply systems.
Poland	PN-EN 15975-2:2013-12	Guidelines for crisis and risk management. Ensures risk management to improve water supply systems.
	PN-EN ISO 14189:2016-10	Defines the method for quantitative analysis of *Clostridium perfringens* in drinking water using membrane filtration. Applies to water without solid particles.
	PN-EN ISO 17994:2014-04	Evaluates the relative performance of two quantitative methods for determining microorganisms according to ISO/TR 13843.

The document analysis showed that Ukraine regulates both centralized and non-centralized water supply systems, whereas Poland focuses mainly on centralized water supply systems under crisis and risk conditions. Although microorganism analysis is relevant for all water types, Poland emphasizes specific microorganism detection methods such as *Clostridium perfringens* analysis via membrane filtration and efficiency assessment of various microbiological determination methods.

Ukrainian national standards aim to ensure water safety and public health by establishing hygienic requirements and quality control measures for different water supply types. Meanwhile, EU country standards focus more on crisis risk management and specialized microbiological contamination detection methods, improving the accuracy and efficiency of water quality control in various conditions.

When comparing the organoleptic drinking water quality standards of Ukraine and Poland, we found significant differences in turbidity standards. (Table 2).

Table 2

Standards for organoleptic indicators of drinking water quality [1,2]

Ukraine				Poland			
№	Indicator	Units of measurement	Drinking water standart	№	Indicator	Units of measurement	Drinking water standart
1	Smell: at t 20 ℃ at t 60 ℃	points	≤ 2 ≤ 2	1	Smell	points	0-5
2	Color	Degrees or Pt/l (1 degree = 1 mg Pt/L)	≤ 20-35[7]	2	Color	(Platinum-Cobalt scale) mg*Pt/L	15
3	Turbidity	Nephelometric unit (1 NTU = 0,58 mg/L)	≤1,0-3,5[7]	3	Turbidity	Nephelometric unit (1 NTU = 0,33 mg/L)	≤1,0

In Ukraine, the maximum turbidity level is allowed to reach 3.5, whereas in Poland, it cannot exceed 1. Poland has stricter color standards. The measurement units indicate that Ukraine employs measurement approaches similar to European standards. Regarding odor regulation, both countries have identical norms, but Poland does not differentiate odor assessment by temperature.

An analysis of physicochemical drinking water quality indicators revealed that Poland enforces stricter control over manganese, iron, mercury, and chloroform content (Table 3).

Table 3

Standards for drinking water quality based on physicochemical indicators [1,3]

№	Indicator	Units of measurement	Drinking water standart	
			Ukraine	**Poland**
1	Manganese	mg/L	≤0,05-0,5	≤0,05
2	Ammonium	mg/L	≤0,05-2,6	≤0,5
3	Nitrates	mg/L	≤50	≤50
4	Nitrites	mg/L	≤0,5	≤0,5
5	Total iron	mg/L	≤0,2-1,0	≤0,200
6	Chlorides	mg/L	≤250-300	≤250
7	Fluorides	mg/L	≤ 1,5	≤ 1,5

8	Arsenic	mg/L	≤ 0,01	≤ 0,01
9	Cadmium	mg/L	≤ 0,001	≤ 0,005
10	Copper	mg/L	≤ 1	≤ 2
11	Mercury	mg/L	≤ 0,0005	≤ 0,001
12	Chloroform	mg/L	-	≤ 0,03

The nitrate, nitrite, and fluoride content standards are identical in both countries. Ukraine enforces stricter standards for cadmium and copper. Poland has stricter iron content limits compared to Ukraine.

As a result of this study and an analysis of regulatory documents, standards, and sanitary-hygienic recommendations, both differences and similarities in approaches to drinking water quality requirements have been identified.

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