

<https://doi.org/10.26565/1992-4259-2026-34-08>

УДК: 911.3:502.5]:622.34(477)

**T. S. KOPTIEVA**, PhD (Earth Sciences), Assoc. Prof.,  
Associate Professor of the Department of Socio-Economic Disciplines and Geography,  
e-mail: [koptevatania36@hnpu.edu.ua](mailto:koptevatania36@hnpu.edu.ua) ORCID ID: <https://orcid.org/0000-0001-9405-16744>  
*H. S. Skovoroda Kharkiv National Pedagogical University*  
29, Alchevskykh, Str., Kharkiv, 61000, Ukraine

## **GEOECOLOGICAL FEATURES OF THE FORMATION AND DEVELOPMENT OF MINING LANDSCAPE-TECHNICAL SYSTEMS OF UKRAINE**

**Purpose.** To analyze the patterns of formation, structure, and functioning of mining landscape-technical systems of Ukraine, to identify their typological features, and to substantiate directions for their optimization and rational use under current geoecological challenges.

**Methods.** Historical-geographical approach, landscape-geomorphological analysis, cartographic modeling using GIS technologies (Google Earth), generalization method, and anthropogenic-landscape forecasting method.

**Results:** The mining territories of Ukraine represent complex landscape-technical systems formed as a result of long-term interaction between natural conditions and technogenic processes. These systems extend beyond the boundaries of mining and land allotments, encompassing extensive adjacent areas transformed by mining activities, including post-mining landscapes. It has been found that the dominant elements of these territories are geo-mining technical systems, whose structure includes natural, technological, and information blocks, while their functioning is associated with the movement of mineral matter and intensive geodynamic processes. It has been established that mining landscapes are formed under the influence of both open-pit and underground mining methods, which determines their morphological diversity (quarry-dump, subsidence-related, lake-wasteland, etc.). It has been proven that the Kryvyi Rih Landscape-Technical System (KLTS) serves as a unique testing ground for the formation of technogenic landscapes, where a wide range of their types is concentrated. It has been determined that anthropogenic landscapes occupy significant areas, forming a complex altitudinal-landscape structure with accumulative, denudation-accumulative, and denudation levels. It has been revealed that the intensive development of mining activities has led to substantial transformations of relief, the hydrological network, microclimate, soil cover, and vegetation of the region. The features of the Donetsk and Pre-Carpathian landscape-technical systems have been analyzed; they are characterized by a high level of anthropogenic pressure, significant disturbances of geosystems, activation of exogenous processes, and the formation of technogenic landforms. It has been established that within the Donbas region there is intensive soil and water pollution, disruption of the hydrogeological regime, and the emergence of hazardous geodynamic phenomena. The Pre-Carpathian region is characterized by slow processes of natural restoration of vegetation and soils, accompanied by significant mosaicity of the landscape structure. It has been identified that the formation of mining landscapes is accompanied by the development of negative natural-anthropogenic processes (erosion, karst, subsidence, flooding, pollution), which determine the current geoecological state of the territories. It has been substantiated that the optimization of mining territories should be based on a systemic approach, taking into account structural, functional, and dynamic characteristics of geosystems, and should include land reclamation, the development of geoecological monitoring, and rational environmental management.

**Conclusions:** The mining landscape-technical systems of Ukraine are complex natural-anthropogenic formations, whose functioning is determined by the interaction of natural factors and technogenic processes. They are characterized by significant transformation of natural components, the formation of specific morphological structures, and active migration of matter. The current state of these systems is associated with the development of geoecological problems, which necessitates the implementation of comprehensive optimization measures, including reclamation, monitoring, and rational resource use. The identified patterns of formation and development of mining landscapes should serve as a basis for further research and practical measures aimed at stabilizing and restoring disturbed territories.

**KEYWORDS:** *mining landscapes, landscape-technical system, geo-mining technical system, technogenic landscape, anthropogenic transformation, reclamation, geoecological optimization*

---

© Koptieva, T. S., 2026



[This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0](https://creativecommons.org/licenses/by/4.0/)

**Як цитувати:** Коптієва Т. С. Geocological features of the formation and development of mining landscape-technical systems of Ukraine. *Вісник Харківського національного університету імені В. Н. Каразіна. Серія «Екологія»*. 2026. Вип. 34. С.110-124. <https://doi.org/10.26565/1992-4259-2026-34-08>

**In cites:** Koptieva, T. S. (2026). Geocological features of the formation and development of mining landscape-technical systems of Ukraine. *Visnyk of V.N. Karazin Kharkiv National University. Series Ecology*, (34), 110-124. <https://doi.org/10.26565/1992-4259-2026-34-08>

## Introduction

Mining-industrial territories correspond to mining and land allotments; however, the concept of a “mining-industrial territory” is considerably broader and includes anthropogenically transformed areas that have emerged beyond these allotments and remain under the influence of the mining industry. Post-industrial territories that emerged after the completion of mineral extraction and beneficiation possess a specific status. Within these territories, remnants of historical objects (mines, excavations, buildings, etc.) have been preserved, while transformed landforms have developed at the industrial sites and waste storage facilities, accompanied by activated processes of landscape self-restoration. The primary objective of this constructive-geographical study is to analyze the landscape structure of mining-industrial territories, identify their comprehensive characteristics, and substantiate proposals for their further rational use. This involves the application of various methodological approaches: geocological, geocadastral, historical-geographical, and medical-geographical.

Although the formation of mining-industrial landscapes is conditioned by human activity, they develop within specific physical-geographical conditions and in close interaction with existing natural landscapes. Consequently, an important feature of their study is the consideration of both natural and socio-historical factors. At present, mining-industrial territories constitute complex landscape-technical structures formed under the influence of various anthropogenic impacts, including mining-industrial, residential, transport, hydraulic-engineering, and others. The dominant subtype within mining-industrial territories is represented by geo-mining technical systems. Geo-mining technical systems belong to autonomous geotechnical systems in which a forced movement of the system-forming flow of mineral matter occurs [19]. In the conceptual scheme of geo-mining technical systems, the following

principal elements may be distinguished: the extraction component (mineral extraction equipment), the servicing component (drainage systems and waste-rock development systems), and the accompanying component (quarry-dump complexes). The functioning of geo-mining technical systems is primarily determined by the specifics of their formation and development. A characteristic feature of mining-industrial geo-mining technical systems is their particular structure, whose main elements include the natural (landscape), technological (design, extraction, and processing), and informational blocks. A distinctive feature of the technological extraction element of geo-mining technical systems is the presence of several units, namely: quarry and dumping units (for open-pit mining operations) and mine units (for underground mining operations). The structural elements of geo-mining technical systems are distinguished by the peculiarities of both the technological process and their functioning.

In Ukraine, both anthropogenic and mining-industrial landscapes, particularly those of southern Ukraine, were first studied by Yu. I. Hlushchenko, who investigated the anthropogenic-natural geocomplexes of the Kerch Peninsula and characterized mining-industrial developments. The views of V. I. Vernadsky, A. E. Fersman, and V. H. Bondarchuk concerning the scale and significance of industrial activity in the life of planet Earth are widely recognized. Taking into account their development features, landscape structure, and impact on the natural environment, industrial landscapes are subdivided into industrial proper and mining-industrial landscapes.

Mining-industrial landscapes of Ukraine have been investigated by such researchers as H. I. Denysyk, V. L. Kazakov, H. M. Zadorozhnia, S. M. Smetana, and others. S. M. Smetana developed a taxonomic classification of technogenic landscapes. V. L. Kazakov focused on theoretical issues of anthropogenic landscape

science, carried out a classification of technogenic, particularly mining-industrial, landscapes, and proposed mechanisms for their rational use. H. I. Denysyk and H. M. Zadorozhnia developed a taxonomic system of mining-industrial landscapes and identified derivative processes and phenomena within them.

Among the studies devoted to industrial landscapes, the works of L. M. Tiutiunyk deserve special attention. Based on field research, these works provided the first characterization of the industrial landscapes of the Kryvyi Rih

### Object and Methods of Research

The object of the study is the mining-industrial landscape-technical systems of Ukraine in terms of their geocological condition and development. In selecting the terminological framework of mining-industrial landscapes, the method of terminological analysis was applied. The principle of historicism was employed to analyze the development and formation of mining-industrial landscape-technical systems within the territory of Ukraine.

In the analysis of mining-industrial landscape-technical systems, the methods of observation and diagnostics were used. The observation method made it possible to obtain primary information in the form of a body of empirical knowledge. The diagnostic method was applied to identify the principal properties and characteristics of the investigated mining-industrial landscape-technical systems. The method of landscape-geomorphological analysis enabled

Landscape-Technical System, proposed classification schemes, partially investigated their geochemical properties, and compiled corresponding cartographic schemes.

Numerous scholars have also investigated anthropogenic types of localities directly associated with mining-industrial landscapes, including V. H. Bondarchuk, Ye. A. Ivanov, H. I. Denysyk, A. V. Hudzevych, and I. M. Voina. Their scientific works present a wide variety of anthropogenic landforms (negative and positive) formed during the extraction of mineral resources.

the study of contemporary landforms and revealed the dependence of the spatial distribution of mining-industrial landscape-technical systems on terrain features. Based on the conducted research, the territories were mapped using Google Earth. In certain cases, fragments of specific types of mining-industrial landscapes (quarry-dump types) were also demonstrated, including the quarries of PJSC “Inhulets Mining and Processing Plant” and PJSC “Southern Mining and Processing Plant.” By applying the method of generalization, conclusions of a theoretical, methodological, and practical nature were substantiated. The method of anthropogenic-landscape forecasting made it possible to develop approaches for improving the structure of mining-industrial landscape-technical systems, preventing their destruction, enhancing their qualitative characteristics, and predicting future changes within particular regions.

### Results and Discussion

Industrial landscapes in Ukraine have formed around large industrial enterprises of the processing industry or within industrial regions. In particular, they are concentrated in Donbas, Kryvbas, the Industrial Prydniprovia region, the Lviv–Volyn Basin, and others. Areas dominated by industrial landscapes are characterized by the most active formation and rapid accumulation of technomass, the presence of a two-tier (surface and subsurface) structure of unique landscape complexes, the complete anthropogenization of geocomponents and landscape complexes, as well as clearly defined temporal and spatial boundaries of industrial landscapes, which in most cases makes it possible to distinguish industrial landscapes from other anthropogenic ones [13].

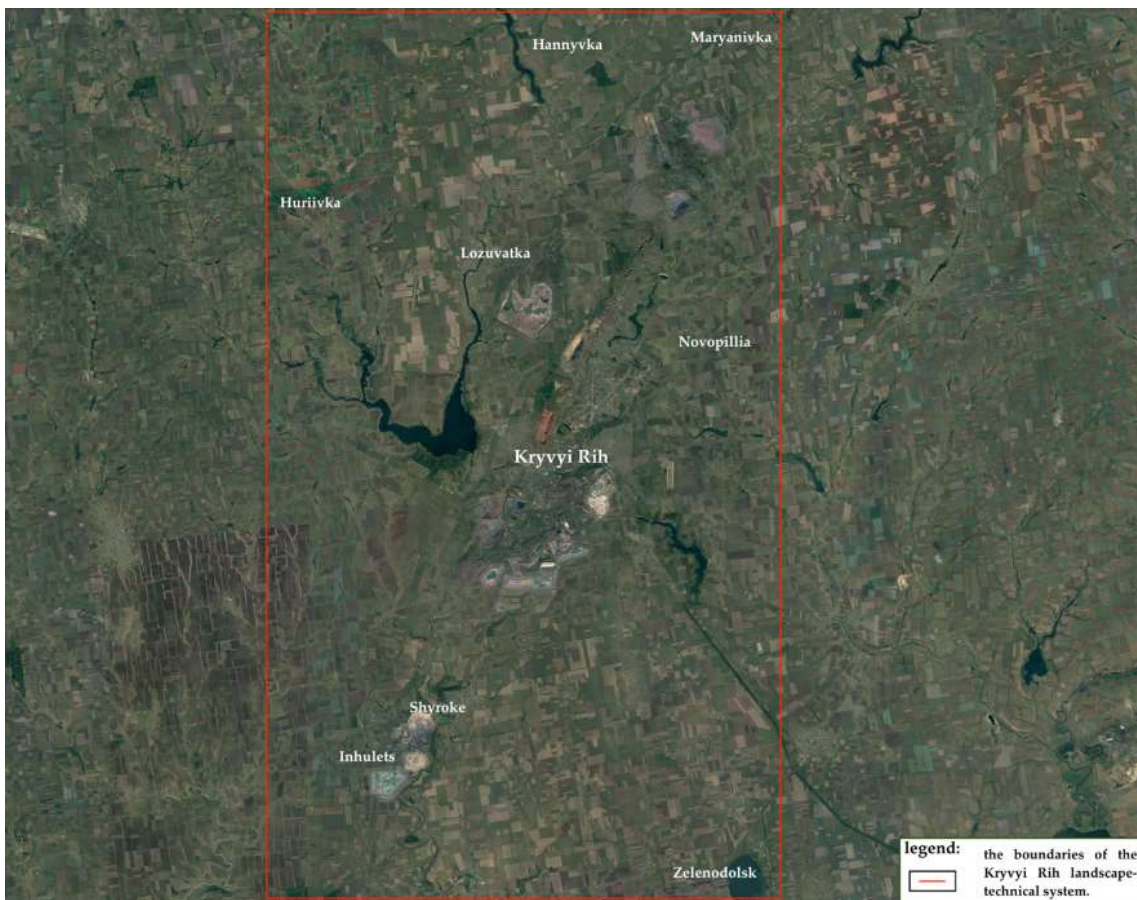
The mining industry in the Kryvyi Rih region has been functioning for approximately one and a half centuries; however, even within this relatively short period, it has transformed natural landscapes into anthropogenic ones, which currently dominate the landscape structure of the region.

*The Kryvyi Rih Landscape-Technical System* (hereinafter referred to as the KRLTS) originated within the territory of Kryvyi Rih in Dnipropetrovsk Oblast. Its development is based on the Kryvyi Rih iron ore basin. The extraction of mineral resources, primarily iron ores, in this territory was accompanied by significant transformation of natural landscapes and the formation of anthropogenic landscapes. Their area increases annually, mainly due to the

expansion of mining-industrial landscapes. At present, iron ore extraction is concentrated at the following mining and processing plants: Central, Northern, Southern, and Inhulets Mining and Processing Plants, which belong to LLC “Metinvest Holding,” as well as the Novokryvoriizkyi Mining and Processing Plant, which belongs to PJSC “ArcelorMittal Kryvyi Rih.” In terms of the concentration of mines, quarries, and mining and processing plants, this macroregion has no equivalent in global practice. It was precisely on the basis of the mining-industrial enterprises of the Kryvbas basin that the KRLTS was formed [8].

The spatial configuration of the KRLTS has undergone significant changes, and its established boundaries are not absolute but rather conditional. A clear tendency toward boundary transformation can be observed due to the active development of technogenesis. In the mid-1970s, the boundaries of the KRLTS almost completely coincided with those of the Inhulets-

Saksahan valley-gully physical-geographical district of the steppe spurs of the Dniro Upland within the Dniester–Dnipro northern-steppe province. However, by the late 1980s, mining-industrial construction had begun in the eastern part of the Middle Inhulets inclined physical-geographical district. Consequently, from the 1990s to 2010, the boundaries of the Kryvbas quarries were altered, and new territories were allocated for waste dumping. Administratively, the KRLTS encompasses the territories of two districts – Kryvyi Rih and Shyrokye – as well as parts of the adjacent Apostolove, Pyatykhatky, and Sofiiivka districts of Dnipropetrovsk Oblast, in addition to small territories within the Vysohopillia district of Kherson Oblast and the Kazanka district of Mykolaiv Oblast. At present, according to its territorial configuration, the KRLTS extends 96 km from north to south and 62 km from west to east, covering an area of 4.1 thousand km<sup>2</sup>, which constitutes 0.67% of the territory of Ukraine (Fig. 1).



**Fig. 1** – Current boundaries of the Kryvyi Rih landscape-technical system (prepared using GIS technology Google Earth)

Mining-industrial landscapes are widespread throughout the territory of the Kryvyi Rih region, which is stipulated by the specific spatial occurrence of iron ore deposits within the Kryvyi Rih iron ore basin. Over time, anthropogenic landscapes – predominantly mining-industrial ones – have emerged and continue to develop, currently occupying nearly 40 thousand hectares and playing a significant role in the functioning of the contemporary Kryvyi Rih Landscape-Technical System (KRLTS). At the same time, the heterogeneity of natural conditions, together with the presence of quarries and waste dumps, determines the specific features of the region's altitudinal and landscape structure.

The surface landforms of the KRLTS were formed on the basis of the Ukrainian Shield and its geological formations. The leading element of the morphostructural relief consists of forest-loamy upland and lowland watershed plateaus complicated by various types of morphosculpture, including fluvial, karst, suffosion, gravitational, and aeolian forms. The relief is represented predominantly by meso- and microforms. Due to the activity of temporary watercourses, erosion, material transportation, and accumulation, a fluvial relief developed. During the formation of the mining-industrial complex, fluvial processes immediately begin to exert an active influence on the lithogenic base, transforming and stabilizing it.

Within the KRLTS, anthropogenic saline and freshwater reservoirs accumulate approximately 500 million m<sup>3</sup> of water. Among them, sludge storage facilities contain up to 200 million m<sup>3</sup> of mine and quarry waters with an average mineralization of 5–8 g/dm<sup>3</sup>. Every year, more than 40 million m<sup>3</sup> of mine water from depths of up to 1,500 m reaches the surface from the aquifers of all geological structures within this territory. At the same time, the estimated flooded areas caused by water filtration from sludge storage facilities within Kryvbas amount to 230–270 km<sup>2</sup>. The hydrological network of the KRLTS has been completely transformed. The microclimate has undergone significant changes not only within Kryvbas itself but also in adjacent regions. In landscapes affected by technogenic activity within the KRLTS, natural soils have been replaced by soil mixtures and technogenic substrates, while the vegetation cover has been transformed into phytocenoses dominated by synanthropic and ruderal (weed) associations with impoverished taxonomic composition.

As a result of iron ore extraction and industrial waste disposal along the iron ore deposits of

the Kryvyi Rih geological structure, the northern steppe landscapes and the riverbeds of the Saksahan and Inhulets rivers were completely destroyed. In their place, anthropogenic landscapes – predominantly residential and industrial – have emerged and continue to develop actively, becoming the dominant background landscapes within the KRLTS. Contemporary natural landscapes of the KRLTS have formed under the influence of landscape-forming factors, including lithogenic, hydrogeological, soil, and vegetation factors [18].

The structure of the mining-industrial landscapes of the KRLTS is formed by the following locality types: quarry-dump types (dump-mono-basin, plateau-shaped multi-tier dump, ridge-shaped multi-tier dump, quarry-dump-lake, quarry-dump-terrace, quarry-lake-terrace, and quarry-terrace types), as well as mine-collapse, mine-subsidence, and lake-wasteland locality types.

Mining-industrial landscapes of the Kryvyi Rih region have mainly been studied within the framework of altitudinal stages, altitudinal-landscape levels, and locality types. As a result, three altitudinal-landscape levels have been distinguished: accumulative, denudation-accumulative, and denudational. These are characteristic of almost all quarry-dump complexes within the KRLTS. The most widespread locality types in this territory are quarry-terrace and plateau-shaped multi-tier dump types. The altitudinal differentiation of each of these types is also heterogeneous. In particular, microzones – areas characterized by different rates of denudation-accumulative processes – are clearly distinguished within them. It is important to note the upper denudational, middle accumulative-denudational, and lower accumulative microzones. Altitudinal tiers can also be observed within these microzones [5].

Having passed through various stages and phases of development, relatively stable biocenoses dominated by steppe zonal flora have formed within the quarry-dump locality types of the KRLTS. These include *Festuca rupicola* Heuff, *Koeleria cristata* (L.), *Poa stifolia* (L.), *Elytrigia repens* (L.), *Agropiron pectinatum* (Bieb.), *Lotus ukrainicus* (Klok.), *Astragalus dasyanthus* (Pall.), *Coronilla varia* (L.), *Melilotus albus* (Medik.), *Xeranthemum annuum* (L.), *Galium verum* (L.), and others, totaling more than 100 species. In addition, territories adjacent to waste dumps (ravines and fallow lands) characterized by chernozem substrates contain such species as *Stipa lessingiana* (Trin.), *Gagea ucrainianica* (Klok.), *Thymus marschallianus* (Willd.), *Adonis vernalis* (L.),

*Salvia officinalis* (L.), and others. On old waste dumps with rocky substrates (Precambrian crystalline rocks, including granites, amphibolites, gneisses, quartzites, shales, etc.) and mixed substrates (combinations of Precambrian crystalline rocks and Cenozoic sedimentary rocks), the following species are widespread: *Zygophyllum fabago* (L.), *Crambe tataria* Sebeok, *Crambe pontica* (Stev. ex Rupr.), *Alyssum minutum* (Schlecht. ex DC.), *Gypsophila paniculata* (L.), *Dryopteris filix-mas* (L.) Schott, and others. In general, all local landscape-technical systems of Kryvbas are characterized by an incomplete cycle of vegetation cover and landscape formation. The overwhelming majority of plants on waste dumps are anemochorous (up to 60%) and barochorous (up to 20%), while only certain old spoil heaps exhibit a significant degree of vegetation closure and function as centers of ecological information for adjacent systems [7].

Kryvbas is the most unique region of Ukraine in terms of both the diversity and territorial structure of mining-industrial landscapes. Within the relatively small territory of the Kryvyi Rih region (4.1 thousand km<sup>2</sup>), highly diverse groups of technogenic landscapes have formed. The region represents a landscape unique area where almost all varieties of technogenic

landscapes of Ukraine are combined. It has been estimated that within the city of Kryvyi Rih, which constitutes the residential-industrial core of the region, the most widespread technogenic landscapes are residential (34.1%), industrial (31.9%), and transport (15.0%) types. Currently, seven quarries operate within the territory of Kryvbas: Quarry No. 1 of the Northern Mining and Processing Plant, Quarry No. 2 of the Northern Mining and Processing Plant, Quarry No. 3 of the Northern Mining and Processing Plant, the Southern Mining and Processing Plant Quarry, the Hleivutka Quarry belonging to the Central Mining and Processing Plant, the Pershotravnevyi Quarry belonging to the Northern Mining and Processing Plant, the Hannivka Quarry belonging to the Northern Mining and Processing Plant, and the Inhulets Quarry belonging to the Inhulets Mining and Processing Plant.

The KRLTS holds several records within the mining industry:

- The deepest iron ore quarry in Europe – the quarry of PJSC “Inhulets Mining and Processing Plant” is one of the most powerful and deepest quarries in Europe, reaching a depth of 426 m. The quarry contains substantial iron ore reserves amounting to approximately 38 million tons of ore (Fig. 2).



**Fig. 2** – The quarry of PJSC “Inhulets Mining and Processing Plant”  
(prepared using GIS technology Google Earth)

- The quarry of PJSC “Southern Mining and Processing Plant” is one of the largest quarries in the world and serves as one of the principal sites for iron ore extraction in Ukraine, as well as a major attraction of industrial tourism. Its depth is approximately 400 m, its length reaches 3 km, and its width is 2.6 km. The quarry has a rounded shape and, in terms of productivity and depth, is surpassed only by the Inhulets Mining and Processing Plant quarry (Fig. 3).

- The deepest iron ore mine in the world, located within the KRLTS, is the Kryvorizka Mine (formerly known as the Rodina Mine). The designed production capacity of the mine amounts to 2.6 million tons of high-grade ore and is ensured through the development of the 1240–1315 m horizons. The iron content in the ore massif at the operating horizons of 1165 m and 1240 m reaches 58.6%. The shaft of the Kryvorizka Mine extends to a depth of 1,580 m.



**Fig. 3** – The quarry of PJSC “Pivdennyi Mining and Processing Plant” (prepared using GIS technology Google Earth).

The Donetsk Landscape-Technical System, where all major grades of coal are represented, constitutes the principal coal-bearing region of Ukraine in terms of both reserves and extraction volumes. Within the Carboniferous strata, approximately 300 coal seams have been identified, two-thirds of which have a thickness of 0.30–0.45 m, while only 130 seams exceed 0.45 m in thickness. Geologically, Donbas is divided into two coal-bearing regions: the Southwestern and the Northeastern. The former is associated with the Kalmius–Torets depression, whereas the latter corresponds to the Bakhmut Basin.

Within the Donetsk Carboniferous sequence, two maxima of coal accumulation are distinguished: in the Lower Carboniferous, the

Upper Visean and Lower Serpukhovian deposits, and in the Middle Carboniferous, two stratigraphic stages. The principal reserves of Donetsk coal are of Middle Carboniferous age. Lower Carboniferous coal-bearing deposits of industrial significance extend along the southern margin of the Donetsk depression for approximately 300 km and have a width ranging from 15 to 40 km. Middle Carboniferous coal-bearing deposits are distributed throughout the entire territory of the depression and are most clearly expressed within the depression itself and on its southwestern slope. Along the depression, the coal-bearing capacity gradually decreases and completely disappears toward the northeastern direction.

According to the scheme of economic regionalization, two principal economic subregions were formed within the territory of Donetsk Oblast: the Central Industrial Subregion and the Southern (Azov) Industrial-Agricultural Subregion. In turn, the Donetsk–Sloviansk polycomponent zone is located within Donetsk, Luhansk, and partially Dnipropetrovsk oblasts and is associated with the Hercynides of the Donetsk folded structure and the deposits of the Dnipro–Donetsk Depression. This zone is conventionally divided into two macroregions: the Donetsk and the Sloviansk–Artemivsk macroregions. In general, a significant number of deposits of complex-forming mineral resources are densely concentrated within the zone, while some of them (hard coal and rock salt) are characterized by basin-type distribution. The combination of various types of fuel-energy, mining-chemical, technological, non-metallic raw materials for metallurgy, and construction materials caused the formation of a complex of extraction, beneficiation, and processing enterprises of fuel-energy, metallurgical, chemical, and construction specialization within this territory. As a result, three industrial agglomerations and eleven industrial hubs were formed within Donbas [8].

The territories of Donetsk and Luhansk oblasts of Ukraine are located within the steppe climatic zone, and these lands contain the largest proportion of steppe natural and semi-natural landscapes in Ukraine. Within Donetsk and Luhansk oblasts, the area of steppe landscapes amounts to 314,499 and 596,210 hectares respectively, constituting 8% and 19% of the total area of the oblasts. Natural territories of the region are represented by steppe ecosystems: the central part of Donetsk Oblast and the southern part of Luhansk Oblast are occupied by the rocky steppes of the Donetsk Ridge, the northern part of Luhansk Oblast is represented by chalk flora communities also belonging to the steppe type, while the southern part of Donetsk Oblast consists of the flat chernozem steppes of the Azov region.

Intensive exploitation of mineral deposits, their further beneficiation, and processing negatively affect the lithosphere and contribute to the activation of exogenous geological processes, changes in the physicomachanical properties and composition of soils, and pollution of groundwater and surface waters of Donbas. Within a relatively short period, natural waters, soils, vegetation, and other components of the natural environment are destroyed under the influence of mining technogenesis. The mechanism of these processes is primarily determined by the migration of toxic

metal compounds together with natural waters. In particular, lead is widespread in the soils of Donetsk Oblast due to the presence of its sources, including motor vehicles, metallurgical and coke-chemical industries, coal-fired boiler plants, and others. The average lead content in urban soils (96.8 mg/kg) is almost three times higher than in rural areas (35.4 mg/kg). The average zinc content in urban soils (228.1 mg/kg) exceeds by more than three times its concentration in rural soils (60.8 mg/kg). The manganese content in urban soils of the region (2296 mg/kg) is approximately twice as high as in rural areas (1274 mg/kg), where manganese concentrations do not exceed current hygienic standards [7].

The development of the extractive industry has been accompanied by the alienation of large areas of agricultural land in Donbas, which, after temporary use, were transformed into technogenic wastelands. Significant losses of land resources also occurred because safety zones were established around each waste rock dump, within which atmospheric air became polluted and soils salinized and waterlogged. Large areas are occupied by sites of concentrated solid waste from processing enterprises, including ash dumps, tailings storage facilities, and slag disposal sites. Their substrates contain substantial amounts of toxic elements contaminating the atmosphere, soils, groundwater, and surface waters. The most prolonged and intensive impact on natural landscapes and the formation of mining-industrial landscapes occurs during open-pit extraction of mineral resources. In such cases, mixed rock horizons are exposed and transferred to waste dumps. In addition, the morphological components of natural landscapes, from tracts to locality systems, undergo restructuring. Significant territories of Donetsk Oblast have experienced such destruction of natural landscape structure, where numerous deposits of different types of mineral raw materials are exploited by open-pit methods.

By the beginning of the armed conflict in Donbas, up to 14 billion tons of coal and waste rock had been extracted, while the volume of created mine workings exceeded 9 billion m<sup>3</sup>, and the total area of fragmented disturbed territory reached 15 thousand km<sup>2</sup>. The mine complex of Donbas represents a stable source of emissions amounting to up to 6 billion m<sup>3</sup>/year of explosive and toxic gases (methane, radon, etc.), whose migration pathways are significantly altered under military impacts on mine drainage and ventilation regimes. In general, industrial coal extraction caused irreversible disturbances of the

geodynamic and hydrodynamic equilibrium of the region and significantly increased the sensitivity of the geological system to military factors.

Technogenic disturbances of natural conditions within this territory are primarily caused by mining operations conducted at nearly 900 mines across 180 coal seams. In total, approximately 2,250 seam workings are counted within the coal-bearing geological structures, which significantly reduced their geomechanical stability during flooding and background seismic events. The created natural-technogenic geosystem of the region – “technogenic objects – environment” – encompassed approximately 4,000 potentially hazardous facilities, more than 300 mines and quarries, and 2.5 thousand so-called “kopanky” (unlicensed shallow pits), as well as up to 1,300 spoil heaps, among which more than 300 are burning and constitute permanent sources of pollution by toxic elements and compounds affecting the near-surface atmosphere, adjacent landscapes, and groundwater. At the same time, under conditions of reduced mine drainage (almost by half) and increasing flooded areas, the risk of accelerated burning of spoil heaps and their explosion with destructive effects on adjacent residential and industrial facilities significantly increases. Critical ecological impacts on the hydrogeomechanical conditions of the geological system (filtration compression, mechanical and chemical suffusion, etc.) and disturbances of surface and underground hydrosphere regimes were caused by the annual inflow into mine workings of up to 760 million m<sup>3</sup> (24.5 m<sup>3</sup>/s) of contaminated mineralized mine waters containing up to 2.5 million tons/year of water-soluble salts. During the expansion of coal mining operations and disturbances of the geological system, including regional aquitards and the spatial development of technogenic fracturing accompanied by riverbed disruption (more than 600 cases), the volume of local groundwater runoff resources increased up to fivefold.

Considering the severe impact of hazardous exogenous processes (landslides, karst, abrasion, flooding, etc.) on Donetsk Oblast, the entire territory has been classified as a first-category hazard area. The length of the coastline affected by abrasion amounts to approximately 50.7 km. The total area of rocks susceptible to leaching constitutes 3,102 km<sup>2</sup>. The area of open karst distribution reaches 52 km<sup>2</sup>, with 371 manifestations accounting for 11.7% of the affected territory. The dissolution of carbonate and sulfate rocks occurs at different rates. Karst processes are most widespread and develop most rapidly in gypsum-

bearing and salt-bearing deposits. These areas are located on the slopes of the Bakhmut, Mokra and Sukha Plotva, Kazennyi Torets rivers, and the Horilyi Pin stream. Human activity (mines, brine extraction industries, quarries, large water intakes, and leakage from urban communications) significantly accelerates karst processes by increasing the velocity of groundwater movement within fissure-karst aquifers. Surface areas where karst-forming processes are most widespread are located in Sloviansk, Kramatorsk, Soledar, Bakhmut, and Mariupol [9].

The vegetation of the Donetsk Landscape-Technical System is represented by such species as *Astragalus sareptanus* A. Beck, *Bulbocodium versicolor*, *Centaurea pseudoleucolepis* Kleopow, *Hyssopus cretaceus* Dubjan, *Neottia nidus-avis*, *Adonis vernalis* L. Spach, *Onosma tanaitica* Klokov, *Achillea glaberrima* Klokov, *Matthiola fragrans* Bunge, *Elytrigia stipifolia* (Czern. ex Nevski) Nevski, *Lycopodiella inundata* (L.) Holub, and others.

The Donetsk Landscape-Technical System also contains numerous mining facilities known not only in Ukraine but throughout Europe:

- PJSC “Pokrovske Mine Administration” is the largest coal mine in Ukraine, with a projected production capacity of 2.1 million tons per year. Industrial coal reserves exceed 200 million tons.

**The Pre-Carpathian Landscape-Technical System** is located within the territories of Lviv and Ivano-Frankivsk oblasts. Spatially, it is associated with the Pre-Carpathian Foredeep. According to geological regionalization, this zone incorporates several major territorial concentrations of mineral deposits: the Pre-Carpathian oil and gas region, the Pre-Carpathian sulfur-bearing basin, the Pre-Carpathian potassium-bearing basin, the Dniester gypsum-bearing district, and others. It is characterized by a clustered pattern of territorial distribution of mineral deposits. In particular, the Boryslav–Stebnyk and Dolyna–Kalush macroclusters, as well as the Yavoriv, Rozdil, Mykolaiv–Pustomyty, Nadvirna, Bilche–Volynsia, and Saryi Sambir clusters, are distinguished.

The Pre-Carpathian Landscape-Technical System is characterized by three historical-geographical periods of mineral resource exploitation: the pre-industrial period, the artisanal period (before 1772), and two industrial periods – the manufactory period (until 1939) and the industrial period (until 1991). In the course of research on the Pre-Carpathian Landscape-Technical System, particular attention has been devoted to the natural conditions of soil substrate formation and

vegetation self-restoration on ozokerite mining waste dumps. It was established that these formation processes proceed slowly within the waste dumps. The principal limiting factor for phytocenosis formation on extraction dumps is excessive salinization of the soil substrate. The first species to restore vegetation on the dumps is sea buckthorn (*Hippophae rhamnoides*), which occurs in the form of dense thickets and isolated small clusters. In addition to sea buckthorn, black poplar (*Populus nigra*), silver birch (*Betula pendula*), aspen (*Populus tremula*), Norway maple (*Acer platanoides*), and European ash (*Fraxinus excelsior*) occur within this territory. Flooded and poorly drained depressions provide natural conditions for the development of hydrophilic and hygrophilous vegetation, whereas mesophilous and xerophilous vegetation dominates on the tops of waste dumps. The mosaic character of the natural conditions of the dumps has resulted in differences in vegetation species composition. The greatest species diversity is characteristic of phytocenoses in flooded areas. Poor vegetation composition is typical of steep slopes affected by sheet erosion and saline areas of newly formed spoil deposits [13, p. 140].

Regarding the natural-economic systems of the Pre-Carpathian sulfur-bearing basin, the development of geosystems and the degree of their anthropogenic transformation under conditions of liquidation of sulfur industry enterprises possess specific features. In particular, this includes the ecological condition of mining-industrial geosystems under the flooding of sulfur quarries and the creation of reservoirs and recreational zones on their basis. The territory of the Pre-Carpathian Landscape-Technical System is characterized by centers of hazardous exogenous processes, including landslides, erosion, karst, abrasion, and others.

Reclamation is particularly necessary within burning coal waste dumps (especially the dump of PJSC “Lviv Coal Company”), zones of intensive land subsidence, karst sinkholes, flooded areas, and ozokerite mining dumps. Special attention should also be devoted to the regularities of geosystem functioning and development within areas of underground sulfur smelting (mining districts “Pisotskyi” and “Borysy”). The degree of anthropogenic transformation of soil and vegetation cover is relatively high. Within the mining district “Yavoriv Reservoir,” geosystems with a moderate level of transformation of embryozems predominate. Soil formation on external dumps, tailings storage facilities, the internal part of hydraulic dumps, and the southern sections of the quarry occurs almost without human

intervention. Areas of strong anthropogenic influence on soil mixtures have been identified in zones of ongoing industrial use, construction sand extraction, and accumulation of solid household waste. Strongly transformed vegetation communities dominate, accounting for 38.7% of the total area of the site. Significant transformational changes associated with sulfur extraction and post-mining activities have occurred in the majority of geosystems within the Pre-Carpathian mining-industrial landscape-technical system. Severe vegetation damage is observed within the shoreline zones of reservoirs and areas undergoing reclamation works. Vegetation cover remains almost unrestored within industrial sites and areas of illegal construction sand extraction. Within sulfur deposits, only 5–6% of disturbed territories have been reclaimed. These are mainly dumps formed from Quaternary loess-like loams. On most dumps composed of Neogene clays, reclamation activities are not conducted. Soil formation, as well as the further functioning conditions of young embryozems and technosols, exhibit a number of features differing from natural analogues. Depending on the age of the dumps and the nature of overburden rocks, pedogenesis affects the upper substrate layers (3–20 cm). Soil mixtures are characterized by low thickness and weak differentiation of the vertical profile. They are marked by the formation of simple vegetation communities as a result of spontaneous overgrowth and reclamation, accumulation of primary organic matter, development of organogenic horizons, and related processes [13].

Post-mining geosystems within the Pre-Carpathian sulfur-bearing basin are gradually overgrown by woody vegetation (*Pinus sylvestris*, *Hippophae rhamnoides*, *Salix caprea*, *Robinia pseudoacacia*, *Populus tremula*, *Betula pendula*) and herbaceous species, indicating the potential for independent natural restoration of soil and vegetation cover. However, the processes of self-restoration of disturbed lands proceed too slowly.

The vegetation of the Pre-Carpathian Landscape-Technical System is mainly represented by such species as *Blechnum spicant*, *Pyrola rotundifolia*, *Moneses uniflora*, and others. The European type of geographical elements includes *Streptopus amplexifolius*, *Symphytum cordatum*, *Primula elatior*, *Mercurialis perennis*, and others. Among the representatives of the European geoelement, numerous endemic species are also present, including *Festuca carpatica*, *Festuca porcii*, *Cardamine opizii*, *Sedum carpaticum*, *Viola*

*declinata, Leucanthemum rotundifolium, Muscari ponicum*, and others.

In general, the specific features of landscape structure within mining-industrial landscape-technical systems are determined both by the peculiarities of natural conditions (tectonics, geological structure, hydrological conditions, etc.) and by technological aspects (production schemes, duration and intensity of industrial processes, etc.) related to mineral resource exploitation [22]. The contemporary structure of geosystems within areas of mineral extraction and beneficiation is determined by the extraction method (open-pit or underground), the mining system applied, the intensity and duration of exploitation of mining-industrial facilities, as well as the conservation or liquidation of mining enterprises [19]. It is precisely the transformation of geosystem genesis during mineral resource development that distinguishes mining-industrial geosystems from adjacent territories. The formation of these geosystems is conditioned by the development of natural-anthropogenic processes and phenomena, including land subsidence, landslides, erosion, karst collapses, flooding, pollution, and others. The principal role in the manifestation and functioning of these geosystems is played by the correlation and dominant direction of migration flows, predominantly destructive ones [23].

Optimization of mining-industrial territories represents a complex of controlled managerial measures implemented both during mineral extraction and beneficiation to ensure more efficient use, and after the completion of mineral resource exploitation to guarantee environmental safety

The functioning of mining-industrial landscape-technical systems exerts a significant influence on the formation of diverse landscape types belonging to the mining-industrial class. Mining-industrial landscapes should be understood as anthropogenic complexes formed as a result of the interaction between a geo-mining technical system and the environment, functioning through the use of both natural energy and the energy determined by mining technologies, and characterized by active migration of mineral and biogenic matter.

In the course of anthropogenic transformation of landscape structure under the influence of mining equipment, a complex of geoecological problems is formed. Disturbance of the lithogenic base of the territory causes the development of

and the performance of other economic functions. The selection of optimization measures primarily depends on the complexity of landscape structure, the intensity of natural-anthropogenic processes, the degree of anthropogenic transformation and pollution of geosystems, the level of ecological hazard, and the amount of funding available for such measures [20]. Optimization measures for mining-industrial territories involve substantiating implementation pathways, identifying natural and socio-economic constraints, determining specific forms of environmental management, and analyzing the consequences of human activity. These measures should combine technologically advanced, economically efficient, and long-term rational exploitation of mineral deposits with the use of other natural resources, protection of geosystems from excessive anthropogenic pressure, regulation of natural-anthropogenic processes, and preservation of valuable historical-cultural and protected natural sites [21].

The outcomes of optimization of mining-industrial territories include improvement of the ecological condition of mining-industrial geosystems; regulation of the intensity of hazardous natural-anthropogenic processes; reclamation of waste dumps, settling ponds, industrial sites, and related areas; creation of optimal conditions for the revitalization of anthropogenically transformed geosystems; substantiation and implementation of geoecological monitoring systems; improvement of land-use structure and establishment of protected natural areas; as well as museification and revalorization of historical mining heritage sites.

## Conclusions

depressive landforms, which are particularly pronounced within quarry sections of mining-industrial territories. The condition of atmospheric air is closely associated with industrial emissions from enterprises and the functioning of industrial complexes. Surface waters undergo substantial changes in water-level regimes and loss of hydrochemical properties. Due to drainage activities within mining-industrial territories, groundwater levels significantly decline, while both quantitative and qualitative characteristics deteriorate. The soil geocomponent experiences losses of fertility and is restored only partially through reclamation measures. Significant transformations also affect vegetation cover, manifested in the replacement of natural vegetation by ruderal-wasteland communities of patchy character.

An essential task for addressing the further optimization of the mining-industrial landscape-technical systems analyzed in this study is the identification of patterns of their dynamics and development. The identified dynamic tendencies of mining-industrial landscapes should form the basis of a structural-dynamic landscape analysis of the prerequisites for rationalizing their use, while systems of measures aimed at improving the geoecological condition of the region should be formulated with consideration of the obtained analytical results.

Restoration of the landscape structure of territories disturbed by mining-industrial activities should be completed through reclamation works. The final stage of reclamation is the biological stage, which is directed toward restoring the natural landscape structure of the territory.

In implementing optimization approaches, it is advisable to apply the following principles: optimization measures should be carried out exclusively on the basis of a systemic approach encompassing structural, functional, and dynamic aspects; optimization of the territorial structure should account for landscape-ecological principles of territorial optimization; the structural

aspect enables consideration of mining-industrial territories as complex landscape-technical structures resulting from anthropogenic impacts; the functional aspect involves the investigation and mandatory consideration, when selecting directions for territorial optimization, of the components of mining-industrial landscape-technical systems – waste dumps, quarries, mine structures, and the corresponding diverse mining-industrial landscapes formed on their basis; the dynamic aspect takes into account the historical characteristics of territories and their contemporary transformations.

The identified tendencies of dynamic changes in mining-industrial landscapes should serve as prerequisites for selecting directions of environmental management optimization within these territories. The criterion for territorial optimization should be the correspondence between the selected reclamation methods and the landscape structure of the territory. Of particular importance is the establishment of an ecological-landscape geoinformation monitoring system for the purpose of generalization and further optimization of territories on the basis of scientifically substantiated approaches.

### Conflict of Interest

The author declare no conflict of interest regarding the publication of this manuscript. Furthermore, the author has fully adhered to ethical norms, including avoiding plagiarism, data falsification, and duplicate publication.

**Authors Contribution:** all authors have contributed equally to this work

### AI Statement

The work does not use artificial intelligence resources.

### References

1. Baranovskiy, V. A. (2001). Ecological geography and ecological cartography. Kyiv: Fitosociocenter, 252 p. (in Ukrainian)
2. Gavrylenko, O. P. (2006). Some aspects of implementing the geoecological approach to rational regional nature management. *Ecology and Rational Nature Use: Collection of Scientific Works of Sumy State Pedagogical University named after A. S. Makarenko*, 3–8. (in Ukrainian)
3. Gutsuliak, V. M. (2015). Landscape ecology. Kharkiv: V. N. Karazin Kharkiv National University, 284 p. (in Ukrainian)
4. Denysyk, H. I., & Kopteva, T. S. (2021). Kryvyi Rih landscape-technical system: development, current state, and optimization paths. *Physical Geography and Geomorphology*, 105–107, 25–29. <https://doi.org/10.17721/phgg.2021.1-3.03> (in English)
5. Denysyk, H. I., & Zadorozhnia, H. M. (2013). Derivative processes and phenomena in technogenic landscapes. Vinnytsia: Edelveis i K, (in Ukrainian)
6. Ivanov, Ye. A. (2012). Anthropogenization of landscapes: approaches, diagnostics, modeling. *Scientific Bulletin of Chernivtsi University. Geography Series*, 612–613, 54–59. (in Ukrainian)
7. Ivanov, Ye. A. (2009). Geocadastral studies of mining territories. Lviv: Ivan Franko National University of Lviv Publishing Center, (in Ukrainian)

8. Ivanov, Ye. A. (2007). Landscapes of mining territories. Lviv: Ivan Franko National University of Lviv Publishing Center. (in Ukrainian)
9. Kiselov, Yu. O. (1999). Justification of geo-geomorphological analysis in studying landscapes of eastern Ukraine. In *Landscape as an integrating concept of the XXI century* (pp. 128–130). Kyiv. (in Ukrainian)
10. Kozynska, I. P. (2009). Methods of studying mining landscapes. *Scientific Notes of Vinnytsia State Pedagogical University. Geography Series*, 18, 94–98. (in Ukrainian)
11. Koptieva, T. S. (2021). Mining landscapes of Kryvyi Rih landscape-technical system. *Man and Environment. Problems of Neocology*, 35, 18–26. <https://doi.org/10.26565/1992-4224-2021-35-02>
12. Kulikovska, O. Ye. (2005). Modern aspects of monitoring anthropogenic landscapes of the Kryvyi Rih Basin. In *Theoretical, regional, and applied directions of anthropogenic geography and landscape studies* (pp. 214). Kryvyi Rih. (in Ukrainian)
13. Landscape studies: state, problems, prospects. (2014). Proceedings of the International Scientific Conference (24–27 September 2014). Lviv: Ivan Franko National University Publishing Center. (in Ukrainian)
14. Koptieva, T., & Denysyk, B. (2021). Quarry and dump landscape systems of Kryvorizhzhia. *SGEM 2020 Conference Proceedings*, 665–670. <https://doi.org/10.5593/sgem2020/5.1/s20.082>
15. Denysyk, H. I., Kazakov, V. P., & Yarkov, S. V. (2012). Syngeneses of vegetation cover in technogenic landscapes. *Vinnytsia: Edelweis i K*, (in Ukrainian)
16. Cherevatskyi, D., & Soldak, M. (2024). Three-dimensional brownfields: the tragedy of the mining communities. *Journal of European Economy*, 22, 556–570. <https://doi.org/10.35774/jee2023.04.556>
17. Orange, H. (2012). Cornish mining landscapes: public perceptions of industrial archaeology in a post-industrial society. Doctoral thesis, University College London.
18. Kopteva, T. S. (2025). Surface quarry-dump layer of mining landscapes of the Kryvyi Rih landscape-technical system. *Landscape Studies*, 7(1), 95–105. <https://doi.org/10.31652/2786-5665-2025-7-95-105>
19. Denysyk, H. I., & Kozynska, I. P. (2015). Industrial landscapes of uranium mining regions in Ukraine. Uman: Vizavi, (in Ukrainian)
20. Kravchenko, O. V., & Yevsieieva, O. V. (2020). Mining geoecology and geotechnologies: conceptualization and evaluation elements. *Visnyk of Dnipro University. Series: Geology, Geography*, 28(2), 112–120.
21. Sinha, N., Deb, D., & Pathak, K. (2017). Development of a mining landscape and assessment of its soil erosion potential using GIS. *Engineering Geology*, 216, 1–12.: [https://doi.org/10.1016/S0013-7952\(16\)30493-8](https://doi.org/10.1016/S0013-7952(16)30493-8)
22. Pawlik, M., & Rudolph, T. (2024). Concept for long-term geo-monitoring of the post-mining environment using the example of the Prosper-Haniel mine. *E3S Web of Conferences*, 526, 01009. <https://doi.org/10.1051/e3sconf/202452601009>
23. Kumar, A., Singh, R. K., & others. (2023). A brief review paper on mining subsidence and its geo-environmental impact. *Materials Today Proceedings*. <https://doi.org/10.1016/j.matpr.2023.04.183>

The article was received by the editors 08.04.2026  
The article is recommended for printing 19.05.2026

The article was revised 10.05.2026  
This article published 30.05.2026

**Т. С. КОПТЄВА**, PhD (Науки про Землю),  
доцент кафедри суспільно-економічних дисциплін і географії  
e-mail: [koptevatania36@hnpu.edu.ua](mailto:koptevatania36@hnpu.edu.ua) ORCID ID: <https://orcid.org/0000-0001-9405-1674>  
*Харківський національний педагогічний університет імені Г.С.Сковороди,*  
вул. Алчевських, 29, Харків, 61000, Україна

## **ГЕОЕКОЛОГІЧНІ ОСОБЛИВОСТІ ФОРМУВАННЯ ТА РОЗВИТКУ ГІРНИЧОПРО- МИСЛОВИХ ЛАНДШАФТНО-ТЕХНІЧНИХ СИСТЕМ УКРАЇНИ**

**Мета.** Аналіз закономірностей формування, структури та функціонування гірничопромислових ландшафтно-технічних систем України, виокремлення їх типологічних особливостей і обґрунтування напрямів оптимізації та раціонального використання в умовах сучасних геоекологічних викликів.

**Методи.** Спостереження, ландшафтно-геоморфологічний аналіз, картографічне моделювання із використанням ГІС-технологій (Google Earth), метод антропогенно-ландшафтного прогнозу.

**Результати:** Гірничопромислові території України є складними ландшафтно-технічними системами, сформованими внаслідок тривалої взаємодії природних умов і техногенних процесів. Вони

охоплюють не лише межі гірничих і земельних відводів, але й значні прилеглі території, трансформовані під впливом гірничодобувної діяльності, включаючи постмайнінгові ландшафти. Домінуючими елементами цих територій є геогірничотехнічні системи, структура яких представлена природним, технологічним та інформаційним блоками, а функціонування пов'язане з переміщенням мінеральної речовини та інтенсивними геодинамічними процесами. Встановлено, що гірничопромислові ландшафти формуються під впливом відкритого та підземного способів видобування, що визначає їх морфологічну різноманітність (кар'єрно-відвальні, шахтно-просадочні, озерно-пустирні та ін.). Криворізька ландшафтно-технічна система (КЛТС) є унікальним полігоном формування техногенних ландшафтів, де зосереджено широкий спектр їх типів. Встановлено, що антропогенні ландшафти займають значні площі, формуючи складну висотно-ландшафтну структуру з акумулятивними, денудаційно-акумулятивними та денудаційними рівнями. Виявлено, що інтенсивний розвиток гірничодобувної діяльності спричинив суттєві зміни рельєфу, гідрологічної мережі, мікроклімату, ґрунтового покриву та рослинності регіону. Особливості Донецької та Прикарпатської ландшафтно-технічних систем характеризуються високим рівнем антропогенного навантаження, значними порушеннями геосистем, активізацією екзогенних процесів та формуванням техногенних форм рельєфу. В межах Донбасу спостерігається інтенсивне забруднення ґрунтів і вод, порушення гідрогеологічного режиму та формування небезпечних геодинамічних явищ. Для Прикарпатського регіону характерні процеси повільного самовідновлення рослинності та ґрунтів, що супроводжуються значною мозаїчністю ландшафтно-технічної структури. Формування гірничопромислових ландшафтів супроводжується розвитком негативних природно-антропогенних процесів (ерозія, карст, просідання, підтоплення, забруднення), які визначають сучасний геоecологічний стан територій. Обґрунтовано, що оптимізація гірничопромислових територій має базуватися на системному підході з урахуванням структурних, функціональних і динамічних характеристик геосистем, а також передбачати рекультивацию порушених земель, розвиток геоecологічного моніторингу та раціональне природокористування.

**Висновки.** Гірничопромислові ландшафтно-технічні системи України є складними природно-антропогенними утвореннями, функціонування яких визначається взаємодією природних чинників і техногенних процесів; характеризуються значною трансформацією природних компонентів, формуванням специфічних морфологічних структур і активною міграцією речовини. Сучасний стан цих систем супроводжується розвитком геоecологічних проблем, що потребує впровадження комплексних заходів оптимізації, зокрема рекультивациі, моніторингу та раціонального використання ресурсів. Виявлені закономірності формування і розвитку гірничопромислових ландшафтів мають стати основою для подальших досліджень і практичних заходів щодо стабілізації та відновлення порушених територій.

**КЛЮЧОВІ СЛОВА:** *гірничопромислові ландшафти, ландшафтно-технічна система, геогірничотехнічна система, техногенний ландшафт, антропогенна трансформація, рекультивациія, геоecологічна оптимізація*

### Конфлікт інтересів

Авторка повідомляє про відсутність конфлікту інтересів. Крім того, авторка дотримувалася етичних норм, включаючи плагіат, фальсифікацію даних та подвійну публікацію.

### Декларація про використання ШІ

В роботі не використано ресурс штучного інтелекту.

### Список використаної літератури

1. Барановський В. А. Екологічна географія і екологічна картографія. Київ: Фітосоціоцентр, 2001. 252 с.
2. Гавриленко О. П. Деякі аспекти реалізації геоecологічного підходу до раціоналізації регіонального природокористування. *Екологія і раціональне природокористування: Збірник наукових праць Сумського державного педагогічного університету ім. А.С.Макаренка*. 2006. С. 3–8.
3. Гуцуляк В. М. Ландшафтна екологія. Х. : ХНУ імені В. Н. Каразіна, 2015.– 284 с.
4. Денисик Г. І., Коптева Т. С. Криворізька ландшафтно-технічна система: розвиток, сучасний стан, шляхи оптимізації. *Фізична географія та геоморфологія*. 2021. № 105–107. С. 25–29. <https://doi.org/10.17721/phgg.2021.1-3.03>
5. Денисик Г. І. Задорожня Г.М. Похідні процеси та явища в ландшафтах зон техногенезу. Вінниця : ПП «Едельвейс і К», 2013. 220 с.
6. Іванов Є. А. Антропогенізація ландшафтів: підходи, діагностування, моделювання. *Наук. вісн. Чернівець. ун-ту*. Вип. 612–613 : Геогр. Чернівці, 2012. С. 54–59.
7. Іванов Є. А. Геокадастрові дослідження гірничопромислових територій : монографія. Львів : ВЦ ЛНУ ім. І. Франка, 2009. 372 с.

8. Іванов Є. А. Ландшафти гірничопромислових територій : монографія. Львів: ВЦ ЛНУ ім. І. Франка, 2007. 334 с.
9. Кисельов Ю. О. Обґрунтування еколого-геоморфологічного аналізу при вивченні ландшафтів сходу України. Ландшафт як інтегруюча концепція XXI століття. Збірник наукових праць. Київ, 1999. С.128–130.
10. Козинська І. П. Методи досліджень гірничопромислових ландшафтів. *Наукові записки ВДПУ. Серія: Географія*. Вінниця, 2009. Вип. 18. С. 94–98.
11. Koptieva T. S. Mining landscapes of Kryvyi Rih landscape technical system. *Людина та довкілля. Проблемнеокології*. 2021. Вип. 35. С. 18–26. DOI: <https://doi.org/10.26565/1992-4224-2021-35-02>
12. Куліковська О. Є. Сучасні аспекти моніторингу антропогенних ландшафтів Криворізького басейну. Теоретичні, регіональні, прикладні напрямки розвитку антропогенної географії та ландшафтознавства: Матеріали II міжнародної наукової конференції. Кривий Ріг: Видавничий дім, 2005. 214 с.
13. Ландшафтознавство: стан, проблеми, перспективи: Матеріали міжнародної наукової конференції присвяченої 70-річчю заснування кафедри фізичної географії, 60-річчю діяльності Львівської школи ландшафтознавства, 110-річчю з дня народження професора К. І. Геренчука і 80-річчю з дня народження професора Г. П. Міллера (24-27 вересня 2014 р.). Львів : Видавничий центр ЛНУ ім. Івана Франка, 2014. 198 с.
14. Koptieva T., Denysyk B. Quarry and dump landscape systems of Kryvorizhzhia. *Surveying, Geology and Mining, Ecology and Management – SGEM 2020 : XX-th International Multidisciplinary Scientific GeoConference*. Albena, 2021. Рр. 665–670. DOI: <https://doi.org/10.5593/sgem2020/5.1/s20.082>
15. Денисик Г. І., Казаков В. П., Ярков С. В. Сингенез рослинного покриву у ландшафтах зон техно-генезу: монографія. Вінниця: ПП «Едельвейс і К», 2012. 240 с.
16. Cherevatskyi, Danylo & Soldak, Myroslava. (2024). Three-dimensional brownfields: the tragedy of the mining communities. *Journal of European Economy*. Vol. 22.. 556-570. <https://doi.org/10.35774/jee2023.04.556>
17. Orange, H; (2012) Cornish mining landscapes: public perceptions of industrial archaeology in a post-industrial society. Doctoral thesis , UCL (University College London).
18. Коптєва Т. С. *Поверхневий кар'єрно-відвальний ярус гірничопромислових ландшафтів Криворізької ландшафтно-технічної системи. Ландшафтознавство*. 2025. 7(1). С. 95–105. DOI : <https://doi.org/10.31652/2786-5665-2025-7-95-105>
19. Денисик, Г. І., Козинська, І. П. Промислові ландшафти регіону видобутку уранових руд в Україні: монографія. Умань, Візаві, 2015, 282.
20. Kravchenko, O. V., & Yevsieieva, O. V. (2020). Mining geocology and geotechnologies: Conceptualization and evaluation elements. *Visnyk of Dnipro University. Series: Geology, Geography*, 28(2), 112–120. <https://geology-dnu.dp.ua/index.php/GG/article/download/941/766>
21. Sinha, N., Deb, D., & Pathak, K. (2017). *Development of a mining landscape and assessment of its soil erosion potential using GIS. Engineering Geology*, 216, 1–12. [https://doi.org/10.1016/S0013-7952\(16\)30493-8](https://doi.org/10.1016/S0013-7952(16)30493-8)
22. Pawlik, M., & Rudolph, T. (2024). *Concept for long-term geo-monitoring of the post-mining environment using the example of the Prosper-Haniel mine. E3S Web of Conferences*, 526, 01009. <https://doi.org/10.1051/e3sconf/202452601009>
23. Kumar, A., Singh, R. K., & others. (2023). *A brief review paper on mining subsidence and its geo-environmental impact. Materials Today Proceedings*. <https://doi.org/10.1016/j.matpr.2023.04.183>

Стаття надійшла до редакції 08.04.2026  
Стаття рекомендована до друку 19.05.2026

Переглянуто 10.05.2026  
Опубліковано 30.05.2026