Фізична географія та геоморфологія (2021) **1-3 (105-107)** 25-29
https://doi.org/10.17721/phgg.2021.1-3.03

Kryvyi Rih landscape technical system: development, current state and ways of optimization

Tetiana S. Koptieva, Hryhoriy I. Denysyk

Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, 32, Ostrozkyi str., Vinnytsia, 21000, Ukraine

Abstract

Peculiarities of formation and current state of one of the most powerful in Ukraine and Europe Kryvyi Rih landscape technical system are considered. It is noted that continuous and active development of the mining industry within Kryvyi Rih iron ore basin during 150 years has led to the formation of a unique structure of the landscape technical system. Its formation took place unevenly in space and time, which made it possible to identify and justify three stages of development: artisanal, initial industrial and active industrial one. It is shown that the new natural conditions and landscape structure of this system formed during the long industrial development stand out against the background of steppe landscapes and require new approaches to their optimization and further rational use.

Keywords

Kryvyi Rih iron ore basin, Kryvyi Rih landscape technical system, mining landscapes, state of development, structure, directions of optimization, rational use

Received: 3 April 2021 / Accepted: 30 July 2021

Криворізька ландшафтно-технічна система: розвиток, сучасний стан, шляхи оптимізації

Тетяна С. Коптєва, Григорій І. Денисик

Вінницький державний педагогічний університет імені Михайла Коцюбинського, вул. Острозького, 32, Вінниця, 21000, Україна

Реферат

Розглянуто особливості формування та сучасний стан однієї із найпотужніших в Україні та Європі Криворізької ландшафтно-технічної системи. Зазначено, що безперервний, упродовж 150 років, та активний розвиток гірничодобувної промисловості у межах Криворізького залізорудного басейну призвів до формування своєрідної за структурою ландшафтно-технічної системи. Її формування проходило нерівномірно у просторі та часі, що дало можливість виділити і обґрунтувати три етапи розвитку: кустарних розробок (IVст. до н.е. – XVII ст.), початкового промислового освоєння (XVIII – перша половина XX ст.), активного промислового освоєння (друга половина XX ст. – початок XXI ст.). Показано, що сформовані упродовж тривалого промислового розвитку нові природні умови і ландшафтна структура Криворізької ландшафтно-технічної системи виокремлюються на фоні степових ландшафтів і потребують нових підходів до їх оптимізації та подальшого раціонального використання.

Ключові слова

Криворізький залізорудний басейн Криворізька ландшафтно-технічна система, гірничопромислові ландшафти, стан розвитку, структура, напрями оптимізації, раціональне використання

Надійшла до редакції: 2 квітня 2021 / Прийнята: 30 липня 2021

1. Introduction

In Ukraine Kryvyi Rih landscape technical system was formed, which covers almost the entire territory of Kryvyi Rih in Dnipropetrovsk region. The basis of its development is one of the most powerful iron ore basins in Europe, whose industrial reserves of iron ore alone amount to more than 18 billion tons. Kryvyi Rih landscape technical system has been formed for almost 150 years. The extraction of minerals, mainly iron ore, was accompanied by a complete transformation of natural landscapes and the formation on their basis of peculiar, still poorly studied anthropogenic landscapes. At the beginning of the 21st century anthropogenic landscapes of Kryvyi Rih are a unique combination of residential (urban) and industrial (mining) landscapes, which are significantly distinguished against the background of field landscapes of the steppe zone of Ukraine. The structure of industrial landscapes of Kryvyi Rih is dominated by mining. They not only occupy large areas, but also form the ecological situation of Kryvyi Rih and adjacent territories and are the source of a number of adverse processes that often threaten the normal functioning of people. All together it intensifies the processes of cognition of the development of Kryvyi Rih landscape technical system, its current state and the development of ways of further rational use.

2. Materials and methods

Scientists, especially geologists and geographers, have been studying the nature and landscapes of Kryvyi Rih, including iron ore within it for a long time. Detailed knowledge of the Kryvyi Rih basin of iron ore began in the second half of the 19th century. P. Kulshin (1825-1839), M. Barbot-de-Marne (1866–1867), Strippelman (1872), S. Gartung (1872–1873), G. Fedoseeva (1874), L. Semechkin (1874), S. Kontkevich (1878 –1887), V. Domger (1875), P. Pyatnitskyi (1881) (Marinich & Shishchenko, 2006). Interesting results that gave a more complete picture of Kryvyi Rih iron ore basin belong to V. Zuev and O. Pol (1876).

In the middle of the 20th century V. Bondarchuk and T. Klevtsov (Bondarchuk, 1949) considered the territory of the basin in terms of industrially changed landscapes for the first time.

Active landscape studies of the territory of Kryvyi Rih began in the 21st century. V. Kazakov studied the geomorphological features of quarries, dumps and dips of Kryvbas (Kazakov, 2001).

H. Denysyk and H. Zadorozhnia found derivative processes and phenomena in the landscapes of zones of technogenesis (Denysyk & Zadorozhnia, 2013). L. Bulava singled out the development of landscape-forming processes in mining landscapes (Bulava, 1990). M. Smetana and S. Yarkov studied the structure of anthropogenic plant groups, determined their species composition, development successions and features of altitude differentiation (Denysyk *et al.*, 2012). General features development of the geological environment of Kryvbas was considered by I. Paranko (2005).

The purpose of the study is to identify and justify the stages of development of Kryvyi Rih landscape technical system, to characterize its modern natural conditions and the dominant mining landscapes and to identify ways of further rational use of nature.

During the study of Kryvyi Rih landscape technical system the following research methods were used: literary method to analyze a number of scientific works on this issue; historical method, which is used to characterize the formation and development of this system; cartographic analysis of cartographic materials; spatial analysis method to characterize geological – geomorphological, climatic, hydrological features and floristic diversity of the study area; and forecasting method to describe development of ways to optimize Kryvyi Rih landscape technical system.

The data we used on the diversity of mining landscapes was primarily the classification made by H. I. Denysyk and H. M. Zadorozhnia (2013). This classification is functional and genetic, because the diversity of industrial landscapes is determined by a certain type of human use of the natural environment, and this in turn allows to distinguish the type, subtype and kind of landscapes and thus to determine the origin of landscapes. Therefore, when obtaining the classification data, we can testify that mining landscapes are a complex geosystem and in the future mining landscapes will grow by type of use.

3. Results and discussion

Kryvyi Rih landscape technical system was formed unstable in space-time dimensions. This makes it possible in the process of its development to distinguish three stages:

– *handicrafts* (4th century BC – 17th century). In the Neolithic and Eneolithic, fine-grained quartzite was mined within the territory of modern Kryvyi Rih, which was used as a substitute for flint. During the Bronze Age, stone tools were used to make tools, weapons, and to be used for housing.

The development of iron ores in Kryvbas was started by Scythian tribes, who smelted iron and made weapons (until the middle of the first millennium AD). During the times of Kievan Rus, Kryvyi Rih was a "Wild Steppe". After the Tatar-Mongol invasion, the territory was occupied by nomads, who were mainly engaged in cattle breeding and agriculture;

– *initial industrial development* (18th – first half of the 20th century.) The emergence of capitalist relations in Western Europe stimulated the development of industry in Ukraine. After V. Zuev discovered the "iron slate" in Kryvyi Rih, O. Pol in 1876 began the industrial development of iron ore in Kryvyi Rih, in particular, the Saksagan ore field. The open method of development of useful raw materials from under insignificant thickness of overburden – to 9 m prevailed. Dumps were low, but wide, with a slope angle of 6–8°. The depth of the quarries did not exceed 40 m. However, after the purchase of 21 thousand hectares of land for mines, their number increased significantly in 1895-1897 (Denysyk & Zadoroznia, 2013). The use of the underground method of iron ore mining began in 1898. At the same time, the area of mining increased - from 800 hectares in 1934 to 2700 hectares in the middle of the twentieth century. The depth of the quarries reached 90 m, the height of the dumps from 12 to 25 m (Denysyk *et al.*, 2012; Kazakov, 2001; Paranko, 2005). In 1935, the first failure funnels were formed above the underground workings.

– *active industrial development* (second half of the 20th - early 21st century.) During the 50-70 years of the 20th century. Mining and processing plants were built in Kryvyi Rih, which gradually grew into powerful mining complexes, which are the basis of modern Kryvyi Rih landscape and technical system. Along with the technical development of mining facilities, the morphometric parameters of quarries and dumps are also increasing.

At the beginning of the 21st century within Kryvyi Rih Landscape Technical System (KLTS) the average depth of quarries is over 400 m (Pivdennyi HZK (mining and processing plant) quarry), the height of dumps and dams is up to 100 m (dumps of Hannivskyi quarry, tailings Voykivske, Mykolaivske), depth of mines is up to 1400 m (mine 'Rodina', 'Jubileina') (Kazakov, 2001). According to V. Palienko's estimates, the total area occupied by quarries in Kryvbas is 33.34 km, dumps are 60.0 km, tailings are 52.74 km, subsidence zones over minefields – 34.71 km (Palienko *et al.*, 2006). In general, Kryvyi Rih landscape technical system stretches 96 km from north to south, 62 km from west to east, and covers an area of 4.1 thousand km, which is 0.67% of the territory of Ukraine (Fig. 1).

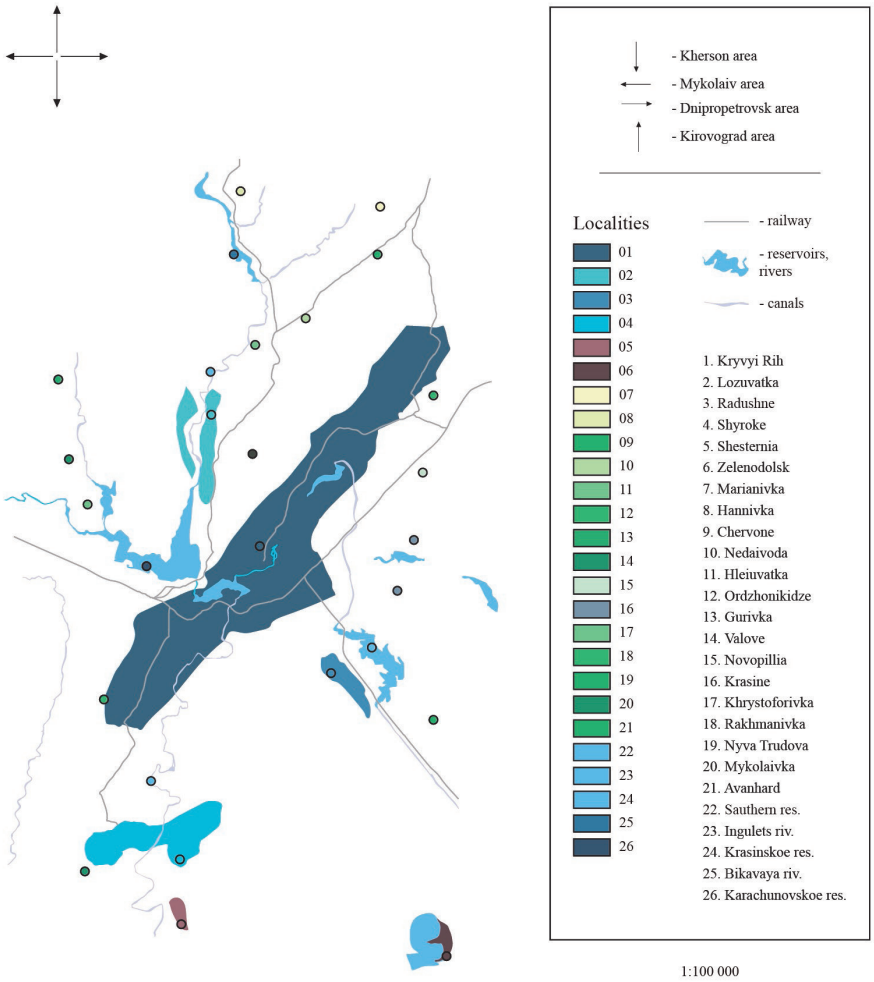

Fig. 1. Boundaries of Kryvyi Rih landscape technical system.
Рис. 1. Межі Криворізької ландшафтно – технічної системи.

Administratively, KLTS covers the entire territory of two districts: Kryvyi Rih and Shyroke, parts of the adjacent Apostolove, Piatykhatky and Sofiivka districts of Dnipropetrovsk region, as well as small areas of Vysokopillia district of Kherson and Kazan districts of Mykolaiv regions.

Due to the peculiar spatial location, the natural conditions of KLTS are heterogeneous. Kryvbas is located in the central part of the Ukrainian Crystal Shield, in the geological structure of which two structural tiers are distinguished: the crystalline basement is composed of metamorphosed volcanic-sedimentary and granitoid formations of the Precambrian and sedimentary cover, the section of which is represented by sediments. On the basis of the Ukrainian Shield and its rocks, the surface forms of the KLTS territory were formed. Here the main element of the morpho-structural relief is loess-loamy upland and lowland watershed plateaus (200–250 m.a.s.l.), which are complicated by various morpho sculpture-fluvial, karst, suffusion, gravitational and aeolian. The relief is mainly represented by meso and microforms.

The KLTS lies within the Atlantic-continental European insufficiently humid, warm temperate climatic region. According to the meteorological station of Kryvyi Rih, the average annual air temperature in the central part of Kryvyi Rih is +8.5°C (in the north of the region – +7.9°C, in the south – +9.0°C). The average air temperature in July is +22.2°C, in January – -5.1°C.

Annual precipitation in the northern and central regions of KLTS is 425–450 mm, in the southern part – 400–425 mm. An "island of heat" has formed over the residential and industrial landscape of Kryvyi Rih. It is warmer here, in particular in the cold period of the year by 1.8°C, more precipitation, fog, reduced doses of solar radiation, sometimes smog.

The surface waters of KLTS form 8 small rivers, except Ingulets, belonging to the Dnieper basin: Ingulets (with tributaries – Saksagan, Zelena, Zhovta, Bokova) (with tributary Bokovenka), Verbova (a tributary of the Visun River, which, in turn, flows into in the river Ingulets), as well as Kamyanka, which is a tributary of the river Bazavluk. Their riverbeds are either canalized or occupied by ponds. In addition, 9 reservoirs with a total area of 9340 ha have been created within KLTS only to provide water to public utilities. There are 25 agricultural reservoirs.

The soil cover of Kryvyi Rih landscape technical system is dominated by ordinary low-humus chernozems – 67.5% of the territory. Common chernozems (NW regions), chernozems of southern low-capacity low-humus (20.3% of the area) in the southern part of KLTS, as well as meadow-chernozem, meadow saline and others are also widespread.

Vegetation of KLTS represents more than 1260 species of higher plants. The indigenous type of vegetation is the steppes, which are dominated by perennial herbaceous plants, including turf grasses: feather grass, fireweed, celery, rye, heathers and others. The settlement of steppe animals has been preserved only in protected areas, as well as in exclusion zones between anthropogenic landscapes.

During the 150-year operation of KLTS, the natural landscapes of its territory have undergone radical changes. The largest changes were as a result of iron ore mining and storage of industrial waste. In particular, the northern steppe landscapes, Saksagan and Ingulets rivers were completely destroyed along the iron ore deposits of Kryvyi Rih structure. Instead, anthropogenic, mostly residential and industrial landscapes have been formed and are actively developing, which are now the background within the KLTS. The structure of industrial landscapes is dominated by mining landscapes, which occupy more than 40 thousand hectares of Kryvyi Rih landscape technical system. Significant diversity of mining landscapes within KLTS is reflected in the scheme of their classification, compiled in conjunction with H. M. Zadorozhnia (Fig. 2).

The diversity of KLTS mining landscapes and their structure require a separate study. Here we only note that on the territory of KLTS there is one of the largest in Europe iron ore quarry of the Southern Mining and Processing Plant, the area of which is 570 ha, length is 3000 m, width is 2650 m, depth in a closed loop is 360 meters with uphill part, which is 425 meters. The largest tailings pond was created by the Northern Mining and Processing Plant: it has been in operation since 1963. The total area is 1750 hectares. If we take into account the depth (up to 450 m) of numerous quarries and the height (more than 200 m) of dumps, then on the area of 40 thousand hectares of Kryvyi Rih landscape technical system instead of plain (absolute heights up to 200 m) steppe landscapes formed "lowland" mining landscapes. These anthropogenic structures, which are not typical for steppe plains, require non-standard approaches to their optimization and further rational use. So far, two prevail: reclamation - partial backfilling of quarries and leveling of their sides and slopes of dumps with subsequent planting of woody vegetation and weeds (this is one of the most costly methods) and leaving the used areas for self-restoration. It turned out to be not enough. Detailed landscape studies (Bulava, 1990; Denysyk *et al.*, 2012; Denysyk & Zadoroznia, 2013; Kazakov, 2001; Paranko, 2005) have been conducted over the past 20 years and our field surveys within the "low-mountain" mining landscapes of KLTS, provide an opportunity to recommend a number of other approaches to their optimization and further rational use. Including:

– revitalization (return of life). Widely used in Western Europe, where revitalization is seen as the reconstruction of post-property geosystems, changing their functioning use. In particular, in Poland, the Eziorko recreational zone was created at the Hrybuw Commune at the site of underground sulfur smelting. Within KLTS, recreational areas are formed spontaneously on the basis of quarries filled with groundwater;

– creation of a regional system of integrated monitoring of KLTS territory, the main task of which should be a comprehensive study of the geological and landscape environment, which will create the preconditions for the formation of a single geographic information space;

– bequest of separate geological objects (sections, rocks), original surface and underground forms, reservoirs in quarries, plant groups with their subsequent inclusion in the regional ecological network;

– development of the tourism sector, in the structure of which to consider opportunities for the development of scientific and extreme tourism.

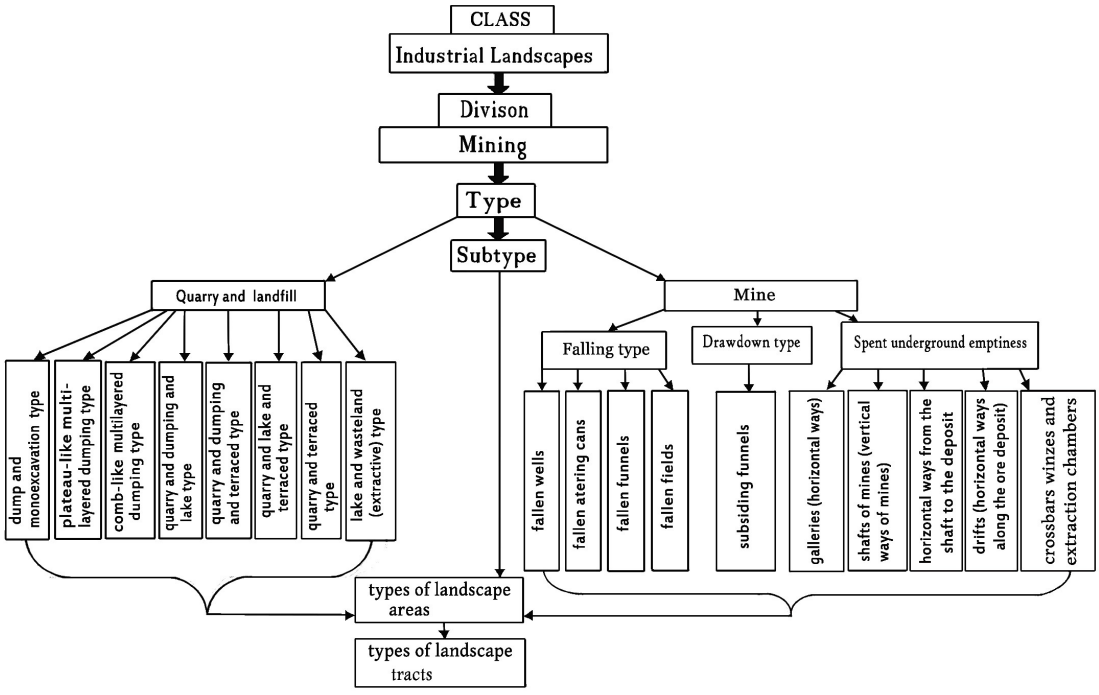

Fig. 2. Taxonomic system of mining landscapes of KLTS (Denysyk & Zadorozhnia, 2013)
Рис. 2. Таксономічна система гірничопромислових ландшафтів КЛТС (Денисик Г., Задорожня Г., 2013).

4. Conclusion

The study of technogenesis zones in order to optimize their functioning and minimize the impact of adverse processes on the environment is relevant. In this aspect, Kryvyi Rih landscape technical system is unique not only within Ukraine, but also in Europe. At the beginning of the 21st century powerful human and industrial potential is concentrated here, and rich natural resources, in particular iron ore reserves, make it possible to actively develop KLTS in the future. Within Kryvyi Rih landscape technical system, peculiar natural conditions and landscapes peculiar only to it are formed. The processes and phenomena of the geological-geomorphological group, which are often leading in modern relief formation, are developing most actively. Activation of hydrological processes leads to the formation of unique hydrological landscapes, man-made aquifers. Climatic processes develop locally, but significantly affect the mesoclimate of Kryvbas. New soil-biological processes lead to the formation of the original biotic diversity, which is clearly distinguished against the background of typical steppe. All together it has led to the formation of unique by structure and dynamics "low-mountain" mining landscapes within KLTS, which have no analogues. These landscapes need new approaches to their cognition and rational use in the future. Among the new optimization measures are the creation of a regional system of integrated monitoring of the territory of KLTS, revitalization, the formation of a system of protected areas with their subsequent inclusion in the regional eco-network, the development of tourism with priority of scientific and extreme tourism.

ORCID iD

Tetiana S. Koptieva https://orcid.org/0000-0001-9405-1674
Hryhoriy I. Denysyk https://orcid.org/0000-0002-0941-9217

References

Bondarchuk, V. G. (1949). *Osnovy geomorfolohii* [*Fundamentals of geomorphology*]. Moskva: Uchpedgiz (in Russian).

Bulava, L. N. (1990). *Fizyko-geograficheskii ocherk Krivorozhskoho hornopromyshlennoho raiona* [*Physical and geographical sketch of the Kryvyi Rih mining district*]. KGPI (in Russian).

Denysyk, G. I., Kazakov, V. P., & Yarkov, S. V. (2012). *Synhenez roslynnoho pokryvu u landshaftakh zon tekhnohenezu* [*Syngenesis of vegetation cover in landscapes of technogenesis zones: monograph*]. Vinnytsia: PE "Edelweiss and K"(in Ukrainian).

Denysyk, G. I., & Zadorozhnia, G. M. (2013). *Pokhidni protsesy ta iavushcha v landshaftakh zon tekhnohenezu* [*Derived processes and phenomena in landscapes of zones of technogenesis: monograph*]. Vinnytsia: Regional Printing House Vinnytsia (in Ukrainian).

Kryvyi Rih State Pedagogical University (2017). *Zahalnyi opys klimatychnykh umov Kryvorizhzhia* [*General description of climatic conditions of Kryvyi Rih*]. Retrieved from: https://kdpu.edu.ua/pryroda-kryvorizhzhia/fizyko-heohrafichna-kharakterystyka/klimat.html (20.11.2020) (in Ukrainian).

Kazakov, V. L. (2001). Geomorfolohichna struktura karieriv i ikh klasyfikatsiia [Geomorphological structure of quarries and their classification]. *Actual problems of geology, geography, ecology*, 3, 31 – 36 (in Ukrainian).

Marinich, O. M., & Shishchenko, P. G. (2006). *Fizychna geografiia Ukrainy* [*Physical geography of Ukraine*]. Kyiv: TV "Knowledge" (in Ukrainian).

Palienko, V. P., Barshchevsky, N. E., Spitsa, R. A., & Zhilkin S. V. (2006). Izmeneniia reliefa na teritorii Ukrainy na rubezhe tysiachiletii [Terrain change in Ukraine at the turn of the millennium]. *Changes in the natural environment at the turn of the millennium*, 41 – 51 (in Ukrainian).

Paranko, I. S., (2005). Kryvyi Rih potentsiina zona vynyrnennia tekhnohennopryrodnykh i tekhnohennykh nadzvychainykh sytuatsii [Kryvyi Rih is a potential zone of occurrence of technogenic and man-caused emergencies]. *Geological and Mineralogical Bulletin*, 1, 5 (in Ukrainian).

Rudko, G. I., Ivanov, E. A., & Kovalchuk, I. P. (2019). *Hirnychopromyslovi heosystemy Zakhidnoho rehionu Ukrainy: monohrafiia* [*Mining geosystems of the Western region of Ukraine: monograph*]. Chernivtsi: Bookrek.