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GEOINFORMATION MAPPING OF THE SOIL COVER AND LAND ADJACENT TO THE BURSHTYN TPP, AND RECOMMENDATIONS FOR THEIR ENVIRONMENTALLY BALANCED USE

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Abstract. *Today, an important task for Ukraine is to assess the condition of land damaged and contaminated by military operations and to restore it.*

The use of geographic information systems and comprehensive analytical methods has repeatedly proven its effectiveness. In this study, GIS technologies are used to map the condition of land around the Burshtyn Thermal Power Plant in order to study the anthropogenic load on it.

Based on remote sensing data, namely satellite images, analytical cartographic sources and scientific publications, thematic maps have been constructed, namely a soil map, three maps of soil contamination with heavy metals (copper, lead, cobalt), and a land map. These maps were developed in the QGIS environment and designed in accordance with standards.

Within the zone of influence of the Burshtyn TPP, various types of soils have been identified that react differently to anthropogenic load. Analysis of the spatial distribution of heavy metals has made it possible to clearly identify areas of pollutant accumulation. This will allow for the formation of environmentally safe land use.

The results of the study can be used for environmental zoning planning, degraded land management, and the development of sustainable development programmes after the Burshtyn TPP ceases operations.

Keywords: *Burshtyn TPP, ecology, land condition, soils, GIS technologies, cartography, anthropogenic load.*

Problem statement

In the current conditions of full-scale war, the task of comprehensively assessing the condition of land affected by military operations and ensuring the environmental safety of the population is particularly relevant.

The detonation of ammunition leads to toxic substances entering the soil, which results in a reduction or complete loss of fertility, degradation of the soil cover, the inability to use such territories for agricultural purposes, in particular for grazing livestock, and limits their further economic development. In addition, it negatively affects the state of aquatic ecosystems and the atmosphere and leads to changes in the landscape.

The destruction of industrial and civil facilities is also a negative factor for the environment due to the release of hazardous substances into the environment. The paper analyses changes in the region's environmental situation following the shutdown of the Burshtyn TPP after its destruction. A comparison and analysis of the relationship between soil contamination caused by the operation of the TPP and military actions is planned to be carried out in further studies.

Analysis of recent studies and publications

One of the facilities destroyed as a result of military operations is the Burshtyn TPP, which was the largest power plant in western Ukraine before the full-scale war began. Until 2022, the Burshtyn TPP supplied energy to three regions of western Ukraine (Zakarpattia, Ivano-Frankivsk and Lviv) and also exported electricity to Hungary and Slovakia.

According to data from the Main Statistical Office of Ivano-Frankivsk Oblast, in 2022, emissions of harmful substances into the air from stationary sources amounted to 152,3 tonnes, which is 11.6% less than in 2021. The share of emissions from TPP accounted for 87.8% of all stationary sources in the region [1].

Carbon dioxide emissions (the main greenhouse gas associated with climate change) reached 10.1 million tonnes in 2022, which is 15.8% lower than in the previous year [1].

Another pressing issue remains the pollution of water bodies in the region. The main causes of pollution are industrial and domestic wastewater, but in recent years there has been a decrease in the volume of discharges into water bodies, which is associated with a reduction in water consumption by enterprises [1].

A positive development is the reduction in logging compared to 2021. In 2022, logging was carried out on an area of 18.9 thousand hectares, and the total volume of timber harvested was 589 thousand m^3. Reforestation measures were carried out on 1.7 thousand hectares, of which 720 hectares were planted with new crops, and 989 hectares underwent natural regeneration [1].

One of the main positive effects for the ecology of Ivano-Frankivsk and the neighbouring Lviv and Ternopil regions, which fall within the zone of influence of the Burshtyn TPP, was the elimination of direct emissions. Thus, after the TPP was shut down, the level of air pollution within a 5 km radius decreased by more than 70% (according to observations in Burshtyn and Demyaniv) [2].

However, it is important to understand that previously accumulated pollutants remain in the soil and on the surface of structures, and during the dry season they can re-enter the atmosphere in the form of dust. Thus, it is clear that the shutdown of the plant does not mean a complete cessation of the circulation of toxicants, and the natural self-purification of soils is a very slow process that can take decades without special remediation measures.

The purpose of the study

To date, the shutdown of the Burshtyn TPP has created favourable conditions for the ecological stabilisation of the region, but new challenges are emerging due to the slow pace of recovery [3].

One of the key tasks is the reclamation of degraded land, strengthening laboratory control over soil conditions in residential areas, eco-zoning and restricting hazardous areas for agricultural use.

Thus, there is a need to create a soil map, a map of the surrounding area around the Burshtyn TPP, and a map of the condition of the land (e.g., soil contamination with heavy metals). The results obtained can then be used to develop restoration measures. Thus, mapping the land adjacent to the Burshtyn TPP is the main task of our research.

Materials and methods of the study

For spatial analysis of the state of the land, we used geoinformation technologies, the results of well-known scientific studies, satellite images, and analytical cartographic materials. The task was to create a multi-layered cartographic models within a 30-kilometre zone around the Burshtyn TPP (70650 hectare) to further determine the level of anthropogenic pressure on land resources and the characteristics of land use structure.

The main tool used to build the maps was QGIS software, which allowed us to work with raster layers, perform vectorisation of boundaries, classification of territories, and formation of thematic layers. The classification of land based on satellite images was performed visually by the author and using the public cadastral map (Kadastr live). All images were pre-processed, digitised, and adapted for integration into the GIS environment.

Each map is designed in accordance with the requirements: it contains a legend, symbols and a scale. The final images are saved in PNG format for presentations and PDF format for printing.

Research results and discussion

To assess the condition of the land adjacent to the Burshtyn TPP, a thematic soil map was created by digitising and deciphering the materials of the dissertation research by M.M. Prykhodko [4] (Fig. 1).

At least six main soil types were identified in the 30-kilometre zone, which differ in their physical and chemical characteristics and, accordingly, in their sensitivity to anthropogenic stress.

Based on the results of the analysis, three groups of soil cover were identified in the area under consideration:

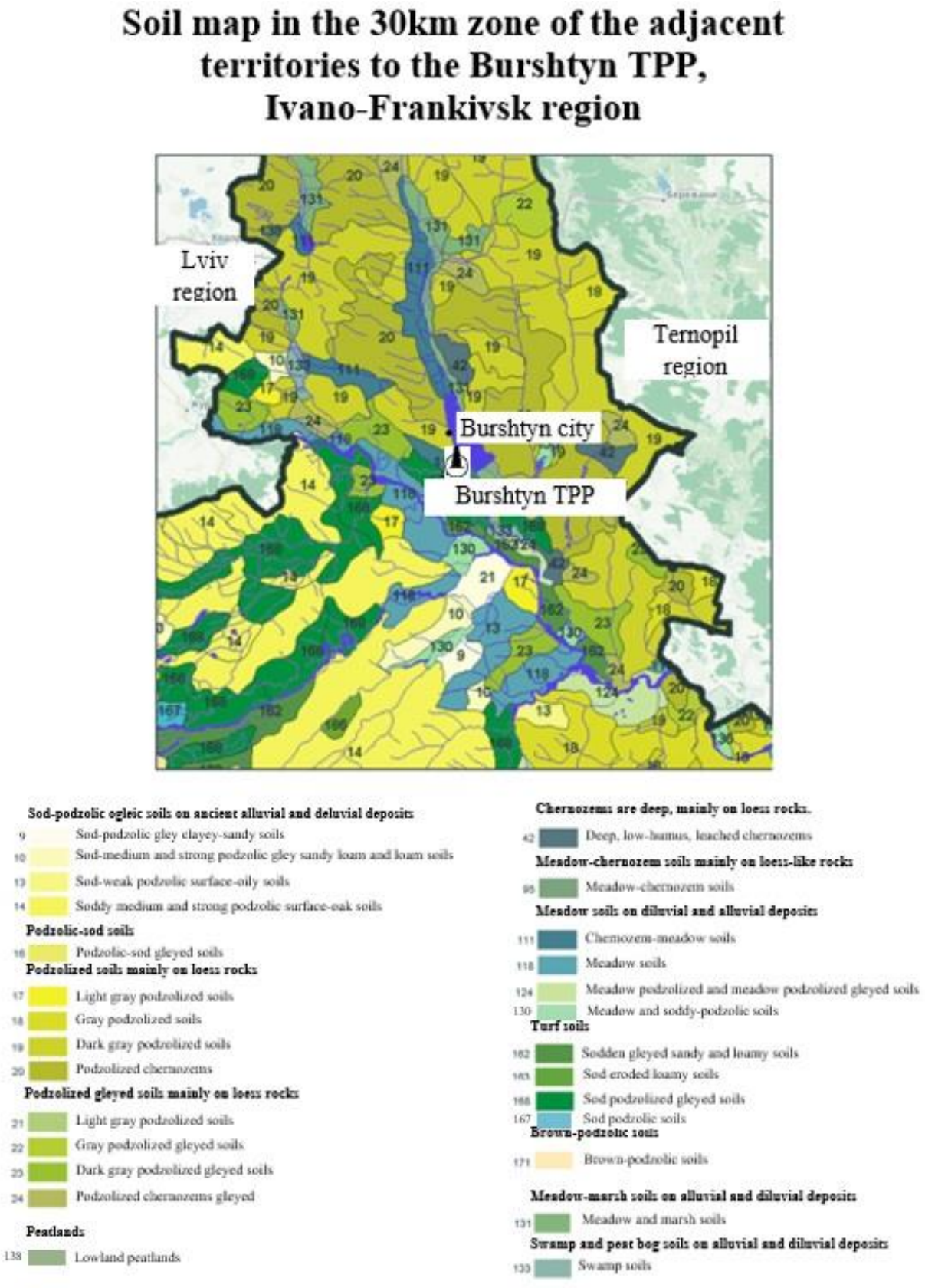

Fig. 1. Soil map in the 30-km zone from the Burshtyn TPP according to [4]

1. Sod-podzolic sandy loam soils (over 42% of the territory, ≈ 29673 hectare). These prevail in the central and northern parts of the zone and are characterised by low

humus content (0.9–1.5%) and high acidity (pH 4.8–5.5), which makes the soils extremely vulnerable to heavy metal accumulation.

2. Grey and dark grey podzolic soils (about 29% of the territory, ≈ 20490 hectare). They are widespread on forested slopes and in the southern part of the territory (near the Dniester River). They have a higher humus content, moderate acidity (pH 5.6–6.5) and good moisture capacity, which allows these soils to better accumulate ionic forms of metals, reducing their mobility.

3. Peaty soils and peat bogs (about 12% of the territory, ≈ 8480 hectare). They are mainly found in depressions and river floodplains. They are characterised by excessive moisture and significant sorption capacity, as well as high mobility of soluble compounds. Under conditions of changing hydrological regime, they can become secondary sources of pollution, which can lead to additional environmental hazards [4-7].

Thus, based on spatial analysis, the territory is divided into the following ecological zones:

- high-risk zone – areas with light, acidic soils open to atmospheric influences;
- stable buffer zone – forest and meadow soils with high regenerative capacity;
- retention and secondary migration zone – podzolic soils and peat bogs in low-lying areas.

The long-term operation of the Burshtyn TPP suggests the accumulation of heavy metals in the soil [8]. Therefore, it was decided to map soil contamination in a 30-kilometre zone.

The study looked at lead (Pb), copper (Cu) and cobalt (Co), as these are the most common in the ash from the brown coal used at the TPP.

When creating thematic averaged maps, digital data from scientific studies [4] adapted in the QGIS environment were used, which formed the basis for analytical modelling.

Fig. 2 shows a map of copper soil contamination. An area of increased contamination is observed within a radius of 1.5–2 km from the TPP. Maximum concentrations are recorded in soils with low buffering capacity and high acidity. The

Cu level exceeds the maximum permissible concentrations by 1.3–1.5 times, which primarily affects arable land and pastures, as they lack protective vegetation cover. Even at a distance of 4–5 km from the TPP, the copper concentration remains at the upper limit of the norm.

Fig. 3 shows the average distribution of lead, the level of contamination of which is relatively stable without exceeding the regulatory indicators. Concentrations range from 13 to 18 mg/kg, which is below the MPC (30 mg/kg), but indicates a gradual accumulation in the upper soil layer. The highest levels were recorded in open areas.

The cobalt distribution map (Fig. 4) shows a uniform Co content without local anomalies. Its concentrations average 13 mg/kg and do not exceed the MPC (50 mg/kg). This confirms that even in the zone of direct impact of the TPP, cobalt accumulation is background in nature and is mainly associated with the geochemical characteristics of the soil.

Thus, it can be concluded that lead and copper have the most significant impact on the condition of the land, and therefore there is a need for constant monitoring and regulation of land use.

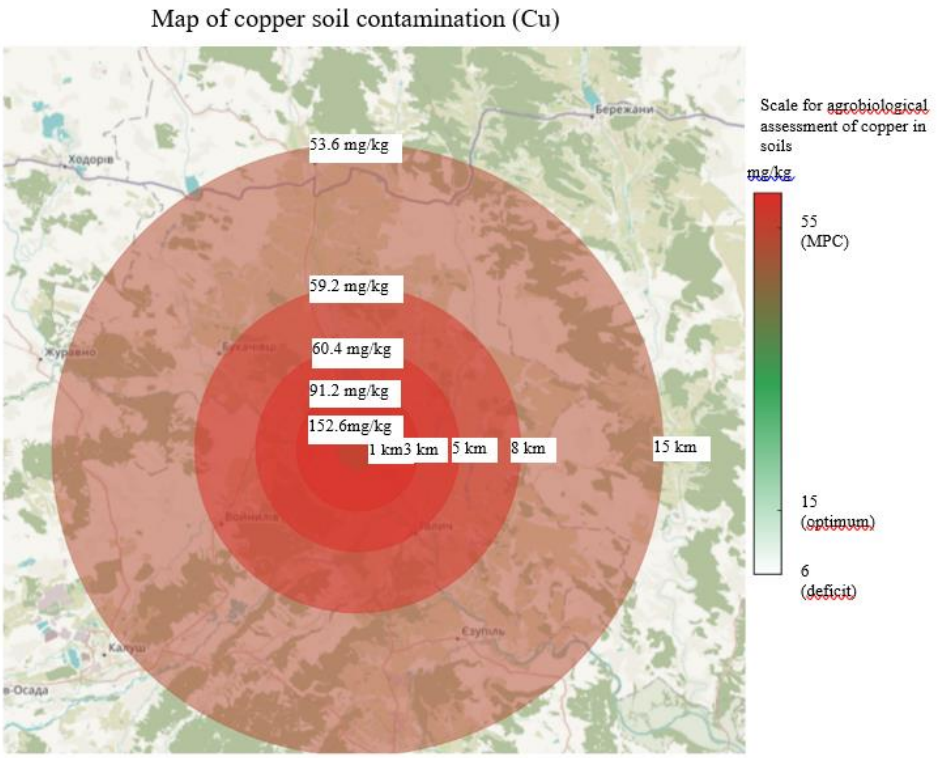

Fig. 2. Map of copper contamination within 15 km of the Burshtyn TPP according to data [4]

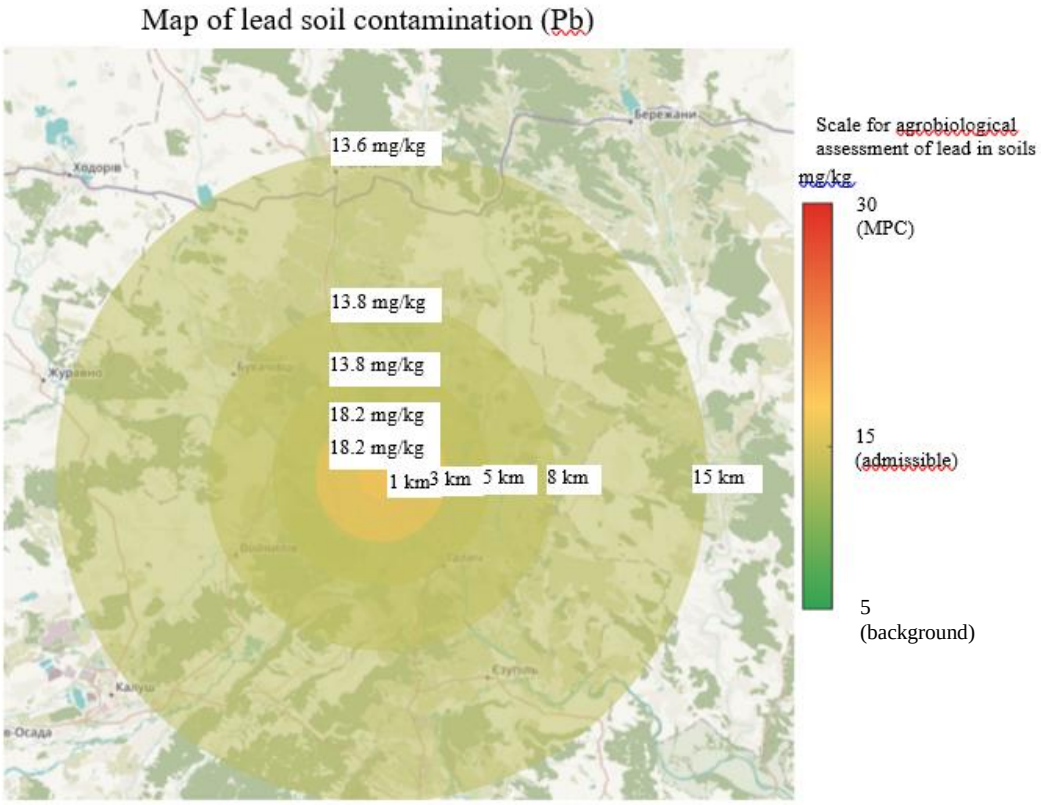

Fig. 3. Map of lead pollution within a 15 km zone from the Burshtyn TPP according to data from [4]

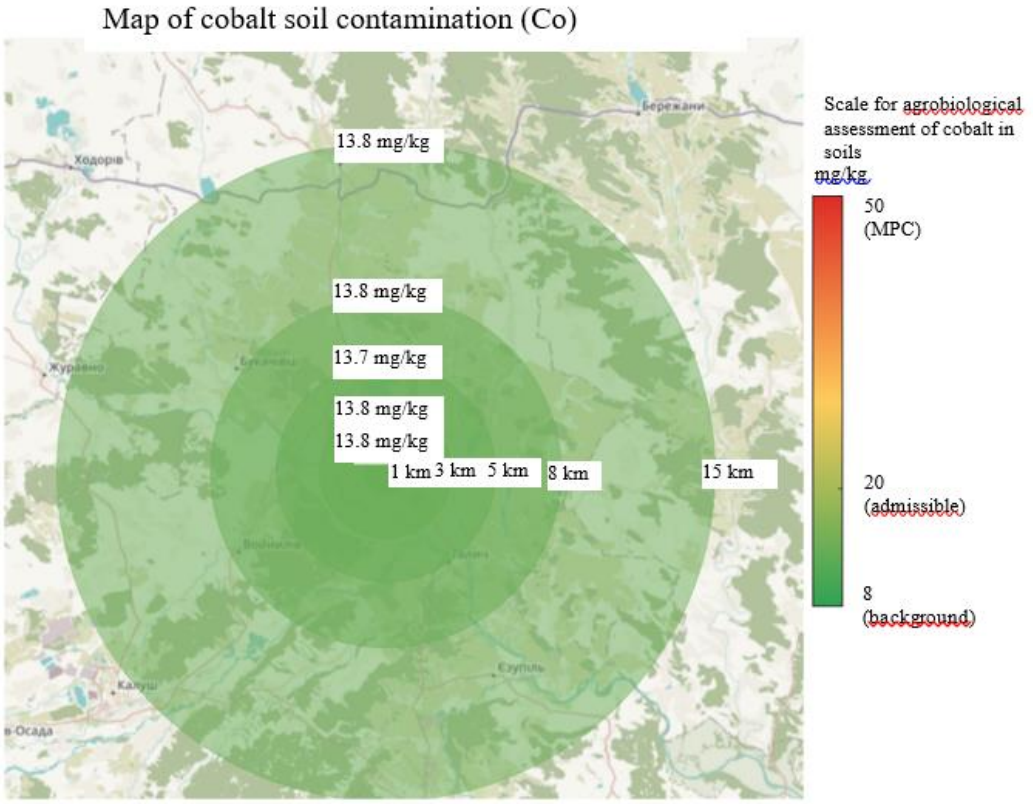

Fig. 4. Map of cobalt pollution within 15 km of the Burshtyn TPP according to data from [4]

The landscape also has a significant impact on the migration of pollutants. Watershed plains and open lands (arable land, pastures) are most vulnerable to the accumulation and spread of pollution. On the other hand, sloping and forested areas retain their barrier function, trapping dust particles and partially preventing pollutants from entering the soil environment [9].

Based on satellite images for 02.05.2025, authors compiled a land use map for a 10-kilometre zone (Fig. 5). A Sentinel-2 satellite image (L2A, atmospherically corrected) was used, displayed in natural colours (True Colour), with visualisation at a scale corresponding to an altitude of 3 km.

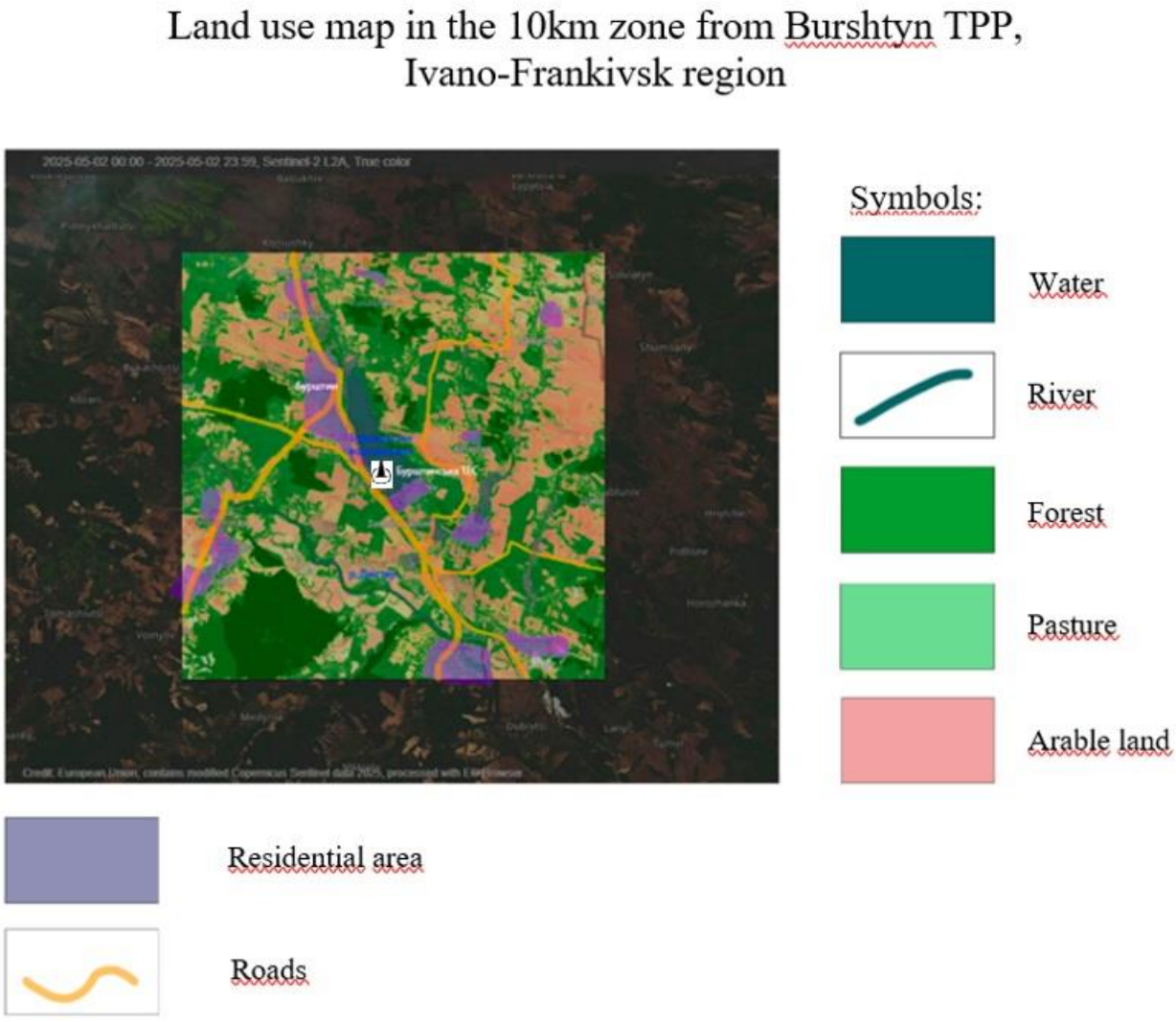

Fig. 5. Map of land use in the area affected by the Burshtyn TPP, created on the basis of satellite images

Based on the analysis of maps showing the content of lead, copper and cobalt in combination with the land use map, three concentric risk zones can be identified:

1) critical zone (0–2 km) – the city of Burshtyn, its southern outskirts and the villages of Demyaniv and Novy Martyniv. Here, there are persistent exceedances of the MPC for lead, disturbed soil structure and degraded land.

2) zone of ecological stress (2–5 km) – covers parts of the villages of Zadnistrianske, Kukilnyky, and Ozeryany. Soil concentrations of metals have risen to critical levels, especially in river floodplains and hayfields.

3) Moderate impact zone (5–10 km) – there are trends towards the accumulation of pollutants, but mainly within background levels.

This zoning confirms the model of gravitational dispersion of pollutants, according to which the largest amount of toxicants settles in close proximity to the source, especially in conditions of high humidity, air inversions and south-westerly winds.

In total, more than 12 villages are at varying degrees of risk, and some of them are already experiencing a decline in quality of life.

As a result of the study, some recommendations can be made to reduce the threats: introduce local environmental safety plans; create an "eco-passport" for the community territory; conduct an inventory of soils with MPC exceedances; develop mechanisms for compensation measures for owners of degraded land.

Conclusions and prospects

The results of spatial analysis of land show significant differences in the level of anthropogenic impact within a 30-kilometre zone around the Burshtyn TPP, but they are not completely lost for economic use. Significant areas still have the potential for environmentally balanced use, provided that competent zoning and nature-oriented solutions are applied. Land reuse is possible with the coordinated cooperation of local authorities, scientists and the community, systematic environmental monitoring and the implementation of a local strategy for restoration and adaptive land use.

Thus, the integration of data from scientific sources, cartographic materials and satellite images has provided a comprehensive spatial visualisation and provides a basis

for the practical application of the research results in regional natural resource management.

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ГЕОІНФОРМАЦІЙНЕ КАРТОГРАФУВАННЯ СТАНУ ҐРУНТОВОГО ПОКРИВУ Й ЗЕМЕЛЬ, ПРИЛЕГЛИХ ДО БУРШТИНСЬКОЇ ТЕС, ТА РЕКОМЕНДАЦІЇ ЩОДО ЇХ ЕКОЛОГІЧНО ЗБАЛАНСОВАНОГО ВИКОРИСТАННЯ

Анотація. *На сьогоднішній день важливим завданням для України є оцінка стану земель, що зазнають руйнувань і забруднень від бойових дій та їх відновлення.*

Використання геоінформаційних систем та комплексних аналітичних методів неодноразово довело свою ефективність. В даному дослідженні ГІС-

технології використовуються для картографування стану земель навколо Бурштинської ТЕС з метою вивчення техногенного навантаження на них.

На основі даних дистанційного зондування Землі, а саме супутникових знімків, аналітичних картографічних джерел і наукових публікацій побудовано тематичні картосхеми, а саме картосхема ґрунтів, три картосхеми забруднення ґрунтів важкими металами (мідь, свинець, кобальт), картосхема угідь. Вказані картосхеми розроблені у середовищі QGIS та оформлені відповідно до стандартів.

У межах зони впливу Бурштинської ТЕС встановлено наявність відмінних типів ґрунтів, які по-різному реагують на техногенне навантаження. Аналіз просторового розподілу важких металів дозволив чітко визначити зони накопичення забруднювачів. Це дозволить сформувати екологічно безпечне землекористування.

Результати дослідження можуть бути використані для планування екологічного зонування, управління деградованими землями та розробки програм сталого розвитку після припинення діяльності Бурштинської ТЕС.

Ключові слова: *Бурштинська ТЕС, екологія, стан земель, ґрунти, ГІС-технології, картографування, техногенне навантаження.*