6th International Congress on Engineering and Life Science

PROCEEDINGS

GİRNE ÜNİVERSİTESİ 2013 1978 UNIVERSITY OF KYRENIA

INTERNATIONAL CONGRESS ON ENGINEERING AND LIFE SCIENCE

ICELIS

2-4 SEPTEMBER 2025

KYRENIA-TRNC

2-4 September 2025

Kyrenia - Turkish Republic of Northern Cyprus

https://icelis.net

POSTER PRESENTATION

Monitoring of Soil and Land Resources Using Remote Sensing Methods: Example of the Myrhorod District of the Poltava Region, Ukraine

Dmytro SOPOV[1*], Victor SIDORENKO[1], Oksana MALASHCHUK[1], Viacheslav FOMENKO[1], Nadiia SOPOVA[2]

[1]*Odesa State Agrarian University, Faculty of Geodesy, Land Management and Agricultural Engineering, Department of Geodesy, Land Management and Land Cadastre, Odesa, Ukraine*

[2]*State Biotechnological University, Faculty of Forestry, Woodworking Technologies and Land Management, Department of Land Resources Management, Geodesy and Cadastre, Kharkiv, Ukraine*

[*]**Correspondence:** lnu.sopov@gmail.com

Abstract

Rational use and protection of soil and land resources are key factors in ensuring food security, enhancing agricultural productivity, and preserving the environment. Due to the intensive agricultural activity that covers a significant part of the territory of the Myrhorod District in Poltava Region, there is a pressing need for systematic monitoring of land conditions. Such monitoring is essential for timely detection of negative changes and for making informed management decisions regarding soil conservation and restoration. This study substantiates the feasibility of using modern remote sensing (RS) methods for collecting, processing, and analyzing information about the condition of soil cover. The use of high- and medium-resolution satellite imagery, calculation of vegetation indices (such as NDVI and SAVI), and integration of these data into geographic information systems (GIS) allow for spatially detailed and up-to-date information on land use structure, vegetation cover, and potential signs of land degradation. The results of the analysis made it possible to identify key trends in land use changes, to localize areas affected by erosion, salinization, compaction, or reduced fertility. This, in turn, provides a basis for developing practical recommendations to improve agricultural production, implement soil protection technologies, and plan land use more effectively. The application of RS methods combined with GIS analysis enhances the quality of monitoring while reducing time and resource costs compared to traditional survey methods. The results presented are of practical relevance for local authorities, land management services, agricultural enterprises, and environmental organizations involved in the management and protection of land resources.

Keywords: Soil and Land Resources, Remote Sensing of the Earth, GIS Technologies, Rational Land Use, Satellite Images.

1. Introduction

Monitoring, in a broad sense, refers to a systematic and continuous observation of phenomena and processes occurring in the environment under the influence of natural and anthropogenic factors. The primary objectives of environmental monitoring include the study of properties, assessment of the current state, effective management of environmental components and processes, as well as forecasting potential changes.

Soil cover and land resources are among the key elements of the natural environment subject to monitoring, alongside water, air, vegetation, and other components. In light of increasing anthropogenic pressures and the impacts of climate change, the need for comprehensive research on soil conditions and the implementation of sustainable land use practices is becoming increasingly urgent (Lischenko et al., 2022).

Modern approaches to soil and land resource monitoring rely on an integrated application of ground-based (field) and remote sensing methods. These complementary techniques enable the acquisition of both general and detailed information: while satellite imagery provides a synoptic overview of soil degradation and erosion processes across large areas, field surveys offer in-depth insights into the condition of soils, the intensity of erosion, and the underlying causes of its development at specific sites.

2. Materials and Methods

Remote sensing-based monitoring of soil and land resources can be implemented at multiple spatial scales, including global, national, regional (e.g., oblast level), local (e.g., administrative district), and site-specific (e.g., individual farms). In this study, particular attention is given to the Myrhorod district of Poltava region, which serves as a representative area characterized by intensive agricultural land use and, therefore, presents a relevant case for both scientific analysis and practical applications.

Satellite-based monitoring of soil and land resources may be conducted using both direct and indirect methods. Direct remote sensing approaches involve the identification and analysis of soil types, humus content, and surface properties. Indirect methods, by contrast, infer soil characteristics from related indicators such as vegetation condition, soil moisture levels, or pollution intensity.

Given that soil and land conditions are shaped by a variety of negative natural and anthropogenic processes, these processes also become essential targets for Earth observation. Among such processes are forest and peat fires, heatwaves, erosion, salinization, flooding, waterlogging, and shoreline abrasion. Their spatial manifestations and dynamics can be effectively detected and analyzed through the integration of multispectral and temporal satellite imagery.

3. Results

Remote sensing (RS) is a powerful tool for analyzing land use over large areas, including administrative districts. In the Myrhorod district of Poltava region, relevant issues related to soil cover and land use that can be studied using remote sensing methods include erosion processes, the negative impact of climate change on soil moisture levels, frequent ignition of peatlands, and a reduction in forested areas (Mohylnyi et al., 2023).

As shown in the satellite image (Figure 1), among the various types of land use in the Myrhorod district, agricultural lands predominate, with arable land occupying the largest share. Significant forested areas are also present in the northern part of the district (Hadiyah territorial community) and along rivers, along with numerous water bodies formed by rivers, lakes, wetlands, and ponds.

Agricultural lands in the satellite image appear as a grid of squares, rectangles, and trapezoids, with field sizes generally ranging from 60 to 100 hectares. This geometric pattern is the result of irrigation systems and the orthogonal layout of irrigation infrastructure and roads. In some areas, this regularity is disrupted by river valleys and erosional landforms.

Figure 1. A fragment of the territory of Myrhorod district, Poltava region. Sentinel-2_L2A_True_color satellite image dated August 21, 2024 *(generated by the authors using Copernicus Browser)*.

It is worth noting that in the Poltava region, active efforts are being made to restore irrigation systems. In recent years, the staff of the Kremenchug Interdistrict Water Management Administration have reactivated five major pumping stations, an inter-farm pipeline network, and 11 kilometers of the main canal within the Hradizh irrigation system, which had been out of operation since 2004.

Fields with irrigated and non-irrigated vegetation crops appear differently on satellite imagery. Non-irrigated fields typically display a more homogeneous, textureless tone, sometimes with a striped pattern. In contrast, irrigated fields often exhibit a mottled texture due to uneven water distribution. The characteristics of this mottled pattern can be used to assess the quality and technical condition of the irrigation system.

Remote sensing (RS) serves as an effective tool for monitoring soil and land resources at the level of individual agricultural enterprises and territorial communities. Analysis of satellite imagery allows for the identification and measurement of crop and pasture areas, assessment of crop condition using vegetation indices, and detection of zones requiring the application of fertilizers or agrochemicals (Carneiro et al., 2023).

An important task in maintaining soil fertility is adherence to crop rotation practices, which can also be monitored using satellite imagery. Figure 2 presents satellite images of a selected agricultural area near the village of Myrne over a four-year period (captured in late spring to early summer), where the rotation of crops in the fields is clearly visible. Winter crops appear in dark green, spring plantings and young shoots in light green, while unplanted fields or those without visible sprouts are shown in dark gray. Sentinel-2 imagery provides high spatial resolution and captures data in multiple spectral bands, allowing for detailed differentiation of vegetation types based on their spectral signatures. This enables the tracking of crop rotations and fallow periods over time, thus supporting systematic monitoring (Lischenko et al., 2022). By comparing images from different years, it is possible to detect deviations from planned crop rotations, such as repeated cultivation of the same crop on the same field across multiple seasons.

Figure. 2. Sentinel-2_L2A_True_color satellite images of agricultural lands near the village of Myrne, Velykosorochynska rural community, Myrhorod district, Poltava region.

The use of remote sensing (satellite imagery) can enhance the understanding of surface characteristics by capturing spectral reflectance signatures related to soil properties. These properties can be analyzed using composites (combinations of spectral bands) and vegetation indices such as NDVI, NDWI, and others. Vegetation indices (VIs) represent specific combinations of reflectance values from different spectral channels. They are selected based on empirical knowledge and calculated using reference spectral reflectance curves of various crops and soils. Numerical values of VIs are used to characterize and assess the biophysical parameters of vegetation cover.

Adequate soil moisture is a key factor for achieving high crop yields (Carneiro et al., 2023). For winter crop plantings, assessing the condition of the snow cover is particularly important and can be detected using the Normalized Difference Snow Index (NDSI). This index allows for distinguishing between cloud cover and snow cover because snow absorbs shortwave infrared radiation but reflects visible light, whereas clouds generally reflect both wavelengths.

Figure 3 shows satellite images of the same area in the Myrhorod district taken during different winter months. Snow cover is depicted in bright blue on the images. However, the authors were unable to find any images for January 2023, likely due to high cloud cover during that period, which prevented obtaining cloud-free quality images. It is worth noting that with climate change, winters are becoming less snowy, which negatively affects soil moisture accumulation and reduces protection of winter crops from low temperatures.

20.12.2023 08.02.2023 23.02.2023

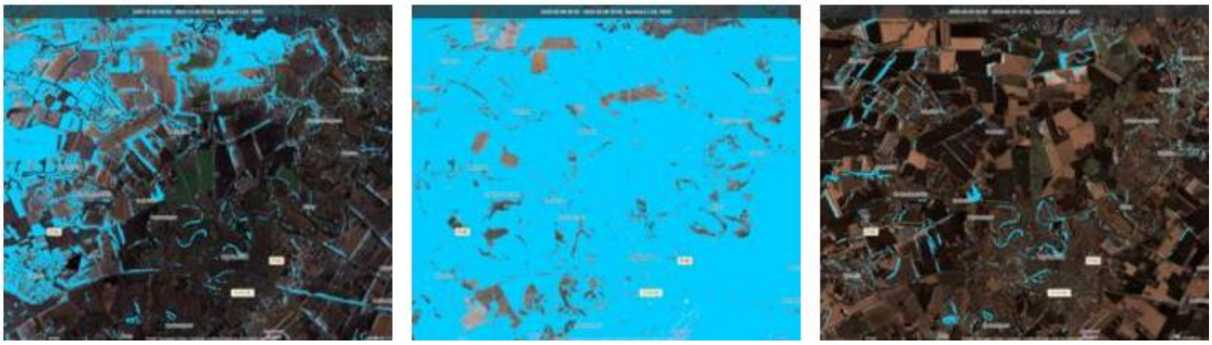

Figure 3. Sentinel-2_L2A satellite images of a fragment of the Myrhorod district territory displayed using the NDSI index. Snow cover is highlighted in bright blue *(generated by the authors using Copernicus Browser)*.

One of the most common and informative indiDces for assessing vegetation condition and land use is the Normalized Difference Vegetation Index (NDVI), which represents the normalized difference of reflectance values in the red and near-infrared regions of the electromagnetic spectrum. This index characterizes plant health and the environmental conditions in which plants develop. It is calculated using the formula: $NDVI = (NIR - RED) / (NIR + RED)$.

The NDVI index ranges from -1 to +1. Very low values (from -1.0 to 0.1) correspond to bare areas, rocky surfaces, sand, or snow. Moderate values (from 0.1 to 0.2) represent areas with sparse vegetation, such as dry steppes and meadows. The next range, from 0.2 to 0.5, indicates areas with moderate vegetation cover (for example, cultivated fields in early growth stages or shrubs). High NDVI values (from 0.6 to 0.8) correspond to healthy vegetation typical of temperate zones (such as healthy forests and meadows during peak growing seasons). Values from 0.8 to 1.0 characterize areas with very dense and healthy vegetation, for example, tropical forests. NDVI is also considered an indicator of drought stress. Its values can be used to detect plant stress caused by diseases and pests. Figure 4 shows a Sentinel-2A image from May 23, 2024, displayed using the NDVI index. Areas with healthy vegetation and significant biomass are highlighted in saturated green. The concentration of vegetation is clearly visible in the forested valleys of the three largest rivers, as well as on agricultural lands with winter crops.

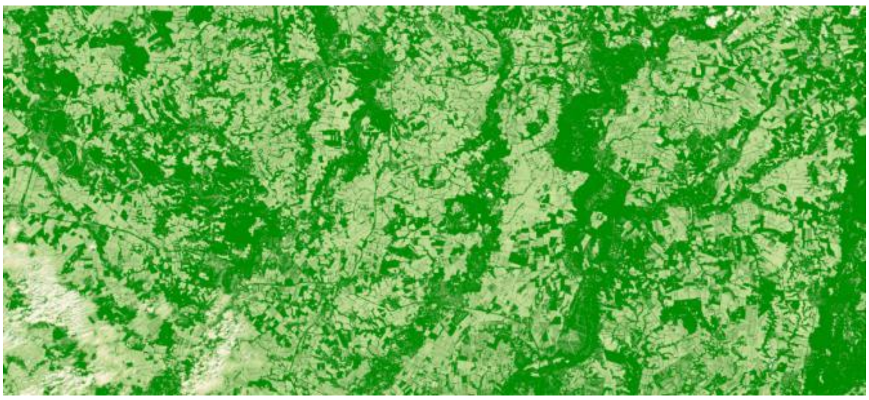

Figure 4. Sentinel-2A satellite image from May 23, 2024, displayed using the NDVI index for the majority of Myrhorod district *(image downloaded by the authors from Copernicus Browser)*.

Since the climate of the Poltava region is characterized by rising average temperatures, it was important to determine how the NDVI index changed in 2024 compared to the same period in 2019. To do this, maps displaying fields based on the NDVI index were created in QGIS using satellite images: one for 2024 (Figure 5) and one for 2019 (Figure 6). The difference between the layers NDVI_24 and NDVI_19 was then calculated using the raster calculator (Figure 7).

Based on the obtained results, it is evident that in many areas of the district (highlighted in shades of red), vegetation conditions have deteriorated due to a decrease in soil moisture levels (Carneiro et al., 2023).

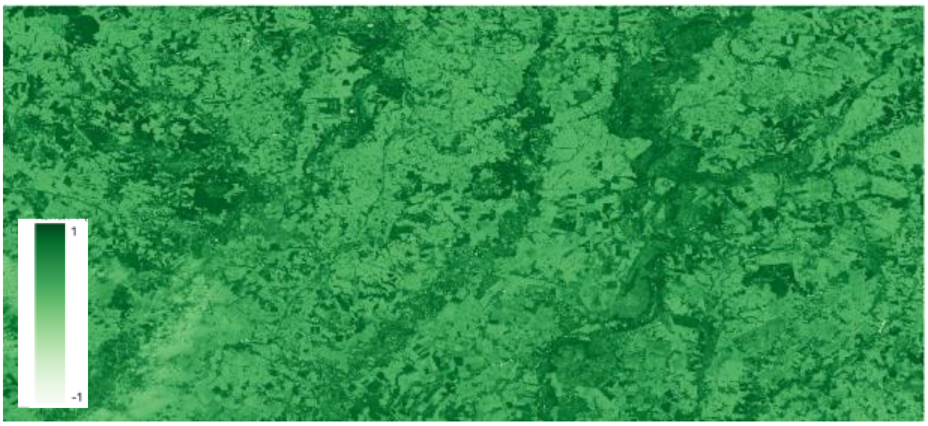

Figure 5. NDVI index for the study area as of May 23, 2024 *(analysis of the Sentinel-2A image was performed by the authors using QGIS)*.

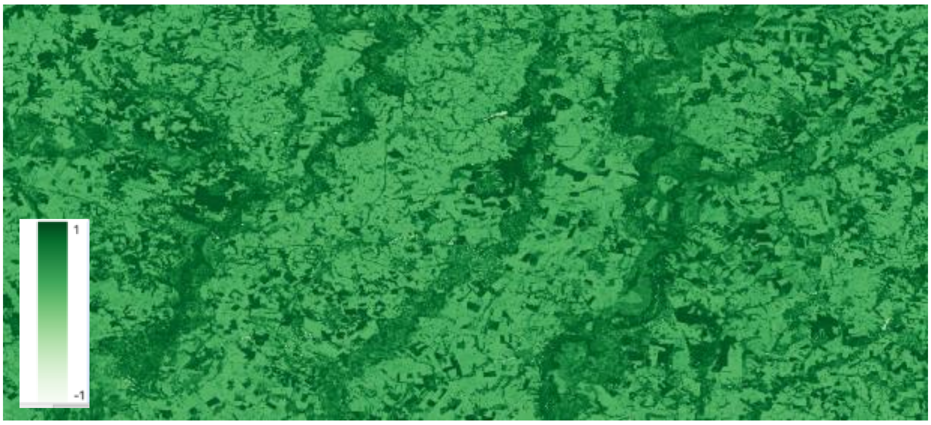

Figure 6. NDVI index for the study area as of May 20, 2019*(analysis of the Sentinel-2A image was performed by the authors using QGIS)*.

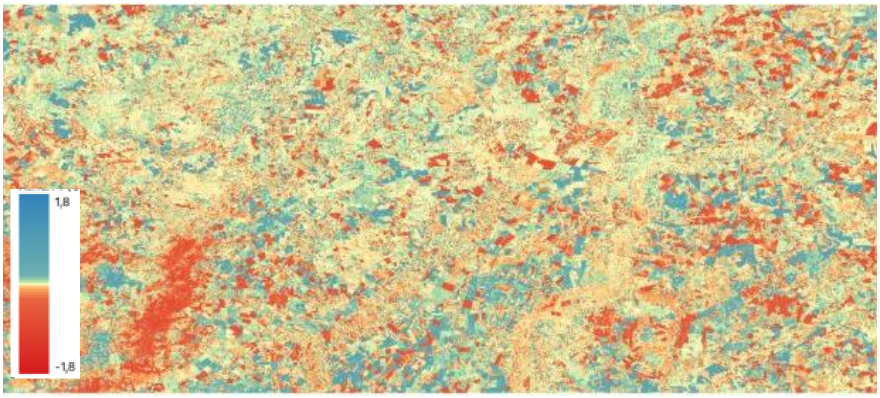

Figure 7. NDVI for 2024 compared to NDVI for 2019 (layer difference). *Image analysis was performed by the author in QGIS.*

The agricultural composite B11-B08-B02 is a specific combination of three spectral bands derived from satellite imagery, used to analyze vegetation and soil conditions in agriculture (Kumar et al., 2022). Each of these bands carries important information about the reflectance of light from objects on the Earth's surface. Analyzing images using this band combination helps identify healthy plants, stressed vegetation, and dead or senescent biomass. The agricultural composite allows for monitoring vegetation development throughout the growing season and assessing the potential yield of crops. Since pests and diseases alter the spectral characteristics of plants, this composite can also be used to detect plant health issues at early stages (Deng et al., 2022).

As previously mentioned, soil degradation in the form of erosion and loss of organic matter is a characteristic issue in the Myrhorod district, particularly in its northern part, where the greatest elevation differences are observed. Water and wind erosion affect soil stability, ecosystem functioning, and carbon and water cycles. Erosional processes are most prevalent on slopes, which are prone to the washing away of the fertile topsoil layer. Two main types of water erosion are distinguished: sheet erosion, where the slope is more or less uniformly affected and water erodes the soil evenly – especially during heavy rains; and linear erosion, which occurs along well-defined lines such as gullies, ravines, and river valleys, creating deep cuts in the terrain (Romanciuc, 2018).

As a result of topsoil erosion, the spectral characteristics of the soil surface change, since the removal of upper genetic horizons leads to a decrease in humus and iron compound content. On satellite imagery, such surfaces appear lighter compared to areas unaffected by water erosion (Figure 8). The consequences of water erosion are well known: terrain dissection, reduction in arable land area, and complications in agricultural practices, among others. The best time to detect erosion is during the growing season when the contrast between eroded and non-eroded areas is most noticeable.

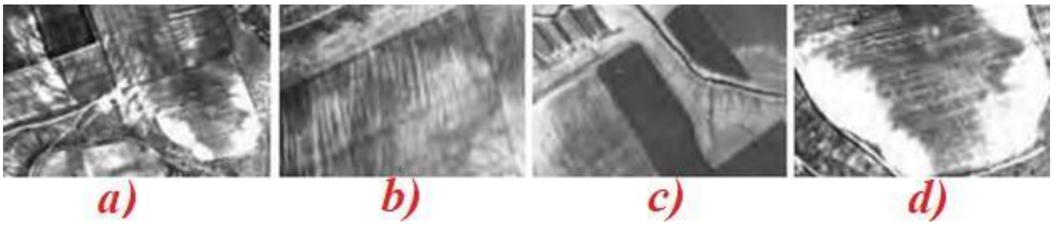

Figure 8. Images of soil cover erosion degradation based on remote sensing data: a) signs of slope erosion degradation; b) micro-gully erosion; c) gully erosion; d) sheet erosion.

Significant damage to agricultural lands can be caused by such erosion landforms as gullies and ravines. The use of remote sensing methods for identifying gullies and ravines should begin with an analysis of the terrain to determine which areas are most prone to erosion and, consequently, to the formation of these features. On satellite images, ravine networks are distinguished by their elongated, winding, tree-like shapes (Demattê et al., 2018). These dendritic patterns typically form on slopes composed of soft rocks. A sharp contrast in color and tone is often observed between the bottom of a gully or ravine and its slopes. The bottoms tend to appear darker due to the accumulation of organic matter and moisture. Unlike ravines, whose bottoms and slopes are often covered with woody vegetation, gully bottoms are frequently bare or sparsely vegetated. When identifying gullies and ravines on satellite images, it is important to consider seasonal variations. Imagery from late spring, autumn, and early summer is preferred due to the minimal influence of vegetation cover and atmospheric phenomena such as snow (Wang et al., 2021).

Figure 9 presents a high-resolution image showing the gully and ravine network located south of Butovycheske village in the Myrhorod district. The images were captured by the Sentinel-2 L2A satellite in May 2024, a period when the influence of green vegetation and atmospheric conditions is minimal. The image resolution is 8192*6386 pixels. An additional image was obtained using the Google Earth application (Figure 10).

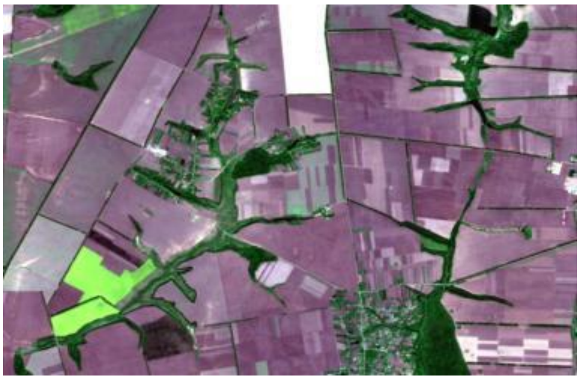

Figure 9. Satellite image of a fragment of the Myrhorod district captured by Sentinel-2 L2A on May 8, 2024, showing the area south of Butovycheske village. Area: 55.59 km² *(LandViewer platform)*.

Figure 10. Gullies and ravines between the villages of Velykyi Pereviz and Pelahiyivka in the Myrhorod district. High-resolution image from Google Earth, 2023 *(captured by the authors)*.

The identification of ravines and, especially, gullies requires high-resolution satellite imagery, as well as viewing in various band combinations to detect water bodies, which may blend with vegetation in natural color imagery (Wang et al., 2021). For instance, on the satellite image (Figure 11) displayed in natural colors, the gully-ravine network between the villages of Velykyi Pereviz and Pelahiyivka in the Myrhorod district can be seen. For comparison, the same image is shown using the NDWI (Normalized Difference Water Index) map (Figure 12). This index is the most suitable for mapping water bodies, which appear blue in the image (NDWI values greater than 0.5 indicate water). The index helps to identify the distribution of microrelief depressions characterized by increased moisture and typically associated with groundwater recharge areas. Using the NDWI during the analysis of the gully-ravine network makes it possible to distinguish between erosion forms and water bodies. It should be noted that the interpretation of satellite images must be confirmed by ground data obtained during field surveys (Gao, 1996).

Figure. 11. Gully-beam network in the villages of Velykyi Pereviz and Pelageyivka. Sentinel-2_L2A_True_color satellite image from September 25, 2024.

Figure. 12. Gully-beam network in the villages of Velykyi Pereviz and Pelageyivka. Sentinel-2_L2A_NDVI satellite image from September 25, 2024.

The quality of soil and land resources is negatively affected by forest and peat fires. The frequency of these phenomena is increasing as the climate changes. Particularly favorable conditions for fires arise when there is a dry summer and windy weather.

The territory of Myrhorod district contains extensive peatland areas where fires occasionally occur. According to data from the Main Department of the State Emergency Service of Ukraine in the Poltava region, three large-scale peat fires were recorded in the Myrhorod district in September 2024 alone: in the villages of Hyryavi Iskivtsi (Lokhvytska urban community), Bodakva (Zavodska urban community), and Maltsi (Myrhorod urban community).

Extinguishing peat fires is a complex process because peat can burn several meters underground, making the fire invisible, and after some time, it can resurface again. Peat fires have a significant and long-lasting negative impact on the quality of soil and land resources. During the fire, organic matter, which is the primary source of nutrients for plants, is burned away. The combustion products of peat acidify the soil, adversely affecting microorganisms whose activity is essential for enhancing soil fertility. High temperatures during the fire destroy soil structure, which worsens aeration and water permeability. Additionally, heavy metals that contaminate the soil and groundwater are released (Trokhymenko et al., 2023). This is far from an exhaustive list of peat fire consequences, which also include air pollution, harmful effects of combustion products on humans and animals, changes to the hydrological regime and ecosystems, soil erosion, and increased flood risks. The restoration of peatlands after fires is a very lengthy process that can take decades. Even after the fire is extinguished, the soil remains vulnerable to further degradation (Romanciuc, 2018).

Fires are best analyzed and mapped on satellite images using the shortwave infrared (SWIR) composite. Minerals and organic materials heated during a fire exhibit characteristic spectral features in this range, which allows burned areas to be clearly distinguished on the images and, in some cases, active flames to be detected. Another option for analyzing fire effects is the use of false color composites. This method enhances the contrast between different surface types, facilitating visual interpretation of the images. Recently burned lands appear in shades of brown, while areas with ongoing fires are shown in red hues (Demattê et al., 2018).

The images below show the burn scar from a peat fire near the village of Petrivtsi in the Myrhorod district, which lasted from August 28 to August 31, 2024. Satellite images of the same burned peatland are presented in different spectral band combinations – True Color, SWIR, False Color, and a custom setting Custom_script_12-11-8A (Figures 13, 14, 15, 16). As a result of this fire, surface peat deposits were destroyed over an area of 1 hectare.

Remote sensing technology helps to determine where a fire started (which is especially important for establishing the cause of ignition), the direction in which it is spreading, the area affected by the fire, the nearest populated areas that may be threatened, and the territories where restoration efforts (such as planting vegetation, applying fertilizers, etc.) should ultimately be carried out.

Figure 13. Image of the peat fire near the village of Petrivtsi, Myrhorod district, dated September 15, 2024. Sentinel-2_L2A_True color satellite image *(captured by the authors)*.

Figure 14. Image of the peat fire near the village of Petrivtsi, Myrhorod district, dated September 15, 2024. Sentinel-2_L2A_SWIR satellite image *(captured by the authors)*.

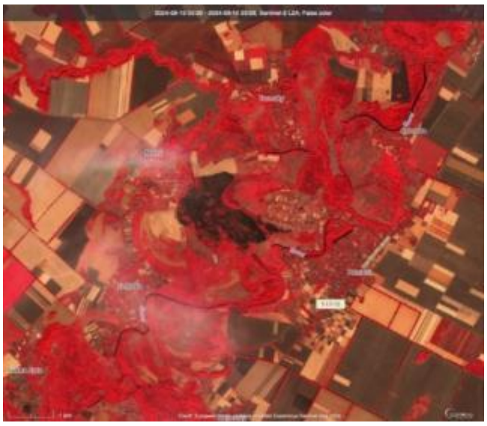

Figure 15. Image of the peat fire near the village of Petrivtsi, Myrhorod district, dated September 15, 2024. Sentinel-2_L2A_False color satellite image *(captured by the authors)*.

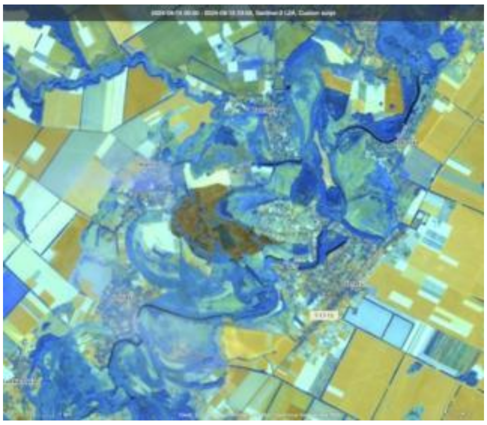

Figure 16. Image of the peat fire near the village of Petrivtsi, Myrhorod district, dated September 15, 2024. Sentinel-2_L2A_Custom_script_12-11-8A satellite image *(captured by the authors)*.

The next two figures demonstrate the beginning of a peat fire near the village of Bodakva (Figure 17) and the burn scar formed as a result of this fire 16 days later (Figure 18).

In 2024, forest fires in the Poltava region became more frequent compared to the previous year. Artificial coniferous plantations on sandy soils are especially vulnerable to fires because pine trees burn more easily than deciduous trees. Unlike fires in mixed forests, where mostly the undergrowth of grass and shrubs burns, fires in pine forests often take on a crown fire character. Remote sensing technology helps to detect fire hotspots, assess the scale of fires (measuring the burned area is sufficient to calculate losses), monitor fire dynamics, and evaluate the impacts of fires on vegetation and the entire ecosystem.

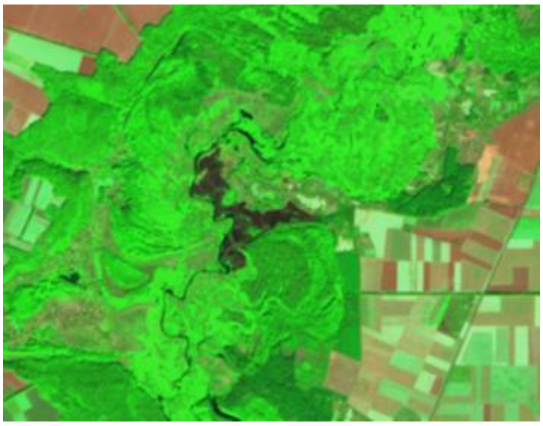

Figure 17. Sentinel-2_L1C_SWIR satellite image dated September 9, 2024, of the area where the peat fire ignition began near the village of Bodakva, Myrhorod district. Data source: Copernicus Open Access Hub *(captured by the authors)*.

Figure 18. Sentinel-2_L1C_SWIR satellite image dated September 25, 2024, of the burn scar area from the peat fire near the village of Bodakva, Myrhorod district. Data source: Copernicus Open Access Hub *(captured by the authors)*.

4. Conclusion

The conducted study of the soil and land resources of the Myrhorod district in Poltava region using remote sensing methods demonstrated the high effectiveness of satellite data for monitoring the following issues: land use dynamics, vegetation condition, detection of vegetation stress during the growing season, soil moisture assessment, evaluation of soil and land resource status, erosion degradation, development of peat fires, and their consequences.

At the same time, it was established that remote sensing has certain limitations related to cloud cover, atmospheric conditions, and the spatial resolution of images. Therefore, to obtain more detailed information about the state of soil and land resources, it is necessary to combine remote sensing data with the results of ground-based research.

References

Carneiro, F. M., De Brito Filho, A. L., Ferreira, F. M., De Freitas Seben, G., Junior, Brandão, Z. N., Da Silva, R. P., & Shiratsuchi, L. S. (2023). Soil and satellite remote sensing variables importance using machine learning to predict cotton yield. *Smart Agricultural Technology*, *5*, 100292. https://doi.org/10.1016/j.atech.2023.100292

Demattê, J. A. M., Fongaro, C. T., Rizzo, R., & Safanelli, J. L. (2018). Geospatial Soil Sensing System (GEOS3): A powerful data mining procedure to retrieve soil spectral reflectance from satellite images. *Remote Sensing of Environment*, *212*, 161-175. https://doi.org/10.1016/j.rse.2018.04.047

Deng, X., Wang, Y., & Song, M. (2022). Development geography for exploring solutions to promote regional development. *Geography and Sustainability*, *4*(1), 49-57. https://doi.org/10.1016/j.geosus.2022.12.003

Gao, B. (1996). NDWI – A normalized difference water index for remote sensing of vegetation liquid water from space. *Remote Sensing of Environment*, *58*(3), 257-266. https://doi.org/10.1016/s0034-4257(96)00067-3

Kumar, S., Meena, R. S., Sheoran, S., Jangir, C. K., Jhariya, M. K., Banerjee, A., & Raj, A. (2022). Remote sensing for agriculture and resource management. In M. K. Jhariya, R. S. Meena, A. Banerjee & S. N. Meena (Eds.), *Natural resources conservation and advances for sustainability* (pp. 91-135). Elsevier. https://doi.org/10.1016/B978-0-12-822976-7.00012-0

Lischenko, L., Shevchuk, R., & Filipovich, V. (2022). The technique for satellite monitoring of peatlands in order to determinate their fire hazard and combustion risks. *Ukrainian Journal of Remote Sensing*, *9*(1), 16-25. https://doi.org/10.36023/ujrs.2022.9.1.210

Mohylnyi, S., Khainus, D., Sopova, N., Sopov, D., & Makieiev, D. (2023). *Use of geodesic methods and GIS technologies in monitoring of poly protective forest strips*. International Conference of Young Professionals “GeoTerrace-2023”. Lviv. https://doi.org/10.3997/2214-4609.2023510074

Romanciuc, I. (2018). Investigation the influence of soil’s moisture regime on their degradation using the remote sensing and ground field verification. *Ukrainian Journal of Remote Sensing*, *17*, 26-30. https://doi.org/10.36023/ujrs.2018.17.126

Trokhymenko, G., Litvak, S., Litvak, O., Andreeva, A., Rabich, O., Chumak, L., Nalysko, M., Troshyn, M., Komarysta, B., & Sopov, D. (2023). Assessment of iron and heavy metals accumulation in the soils of the combat zone. *Eastern-European Journal of Enterprise Technologies*, *5*(10 (125)), 6-16. https://doi.org/10.15587/1729-4061.2023.289289

Wang, B., Zhang, Z., Wang, X., Zhao, X., Yi, L., & Hu, S. (2021). The suitability of remote sensing images at different resolutions for mapping of gullies in the Black Soil region, northeast China. *Remote Sensing*, *13*(12), 2367. https://doi.org/10.3390/rs13122367