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ANALYSIS OF LAND USE IN THE SEASIDE REGIONS OF UKRAINE IN 2017—2022 BASED ON SATELLITE INFORMATION

Introduction. *Land is recognized as a primary national asset under the special protection of the state, as mandated by Ukrainian law. It serves as the foremost natural resource, a vital foundation for human life and activity, and underpins the establishment and development of all sectors of the national economy. Therefore, an effectively organized, sustainable economy is unattainable without the rational utilization and protection of land resources.*

Problem Statement. *Research on land use in Ukraine's coastal regions has become especially relevant. Since parts of these areas have been under occupation since 2014, understanding the spatial-temporal variability of land use in these regions presents significant challenges for Ukraine.*

Purpose. *To analyze land use in the coastal regions of Ukraine using satellite data to assess spatio-temporal changes.*

Materials and Methods. *This research utilized land use/land cover (LULC) mapping based on satellite data from Sentinel-2, analyzed through deep learning models using artificial neural networks.*

Results. *The spatial distribution of land use in Ukraine's coastal regions in 2022 was thoroughly analyzed. Additionally, the spatio-temporal variability of land use from 2017 to 2022 was assessed, revealing distinctive patterns in the spatial distribution of various land cover classes. The findings show that the innovative approaches to LULC mapping and the resulting data can be effectively applied to land resource management in Ukraine.*

Conclusions. *The LULC mapping approach demonstrates significant potential for interdisciplinary research and applied work in natural resource management and territorial planning at both the national and regional levels. Moreover, these innovative LULC mapping methods present a robust tool for identifying and understanding the scale of natural, anthropogenic, and military-induced emergencies.*

Keywords: land use, land cover, natural assets, land resource management, remote sensing of the Earth, satellite data, deep learning, convolutional neural networks.

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Land represents a primary national asset under special state protection, as per Article 14 of the Constitution of Ukraine [1]. As an irreplaceable and invaluable resource, land forms the backbone of any society. It is the main natural resource, a fundamental basis for human existence and activity, and underpins the development of all sectors within the national economy. Land also serves as the primary means of production in agriculture and forestry, making the organization of its rational use and protection crucial for effective economic development. Society faces a significant challenge in managing land use: first, to halt soil degradation and restore its productivity; second, to enhance production efficiency through rational land tenure and land use practices, while integrating land as a form of capital within economic circulation [2, 3].

Ukraine possesses substantial natural resources, including land, water, forest, mineral, and raw materials. It ranks among the world's richest countries in soil quality and land bioproductivity. The high natural productivity of the soil makes Ukraine's land fund one of the nation's most vital resources for economic development and wealth creation. Currently, however, Ukraine's natural resource potential is not fully optimized. Its investment returns and contributions to accelerated socio-economic development remain unsatisfactory. The country has developed an unbalanced structure for environmental and socio-economic management that is largely inefficient and poses environmental risks [4].

The importance of land resources as an economic asset cannot be overstated. According to researchers [5, 6], land resources contribute to more than 40% of Ukraine's productive capacity. The prominent role of Ukraine's land fund serves as both a key factor of production and a foundational element for economic growth [4]. This significance is particularly evident at the regional level, where both environmental and social factors are critical [7—9].

In a broad context, land use in coastal areas encompasses the geospatial development of the "blue economy" — a relatively recent global paradigm focused on sustainable ocean and coastal management [10]. The concept of geospatial economic development initially emerged within terrestrial regions and has since extended to encompass marine environments [11]. Methodological transformations in coastal land use, spurred by environmental and social challenges [12, 13], now increasingly incorporate resilience factors [14, 15], an emphasis amplified by the impacts of the Russian war against Ukraine [16].

An advanced data management system underpins decision-making for sustainable land use, especially regarding blue economy considerations [17, 18]. The core of this system is Earth remote sensing, which provides crucial data to coastal science, facilitating informed decisions on the sustainable development of marine and coastal zones [19].

The European Union has introduced legislative measures and international projects to protect the environment, monitor natural resources, and promote blue economy initiatives in Europe, including the Azov-Black Sea region. Incorporating EU environmental directives into Ukrainian legislation lays an essential foundation for sustainable development and environmental improvement, particularly within Ukraine's coastal zones. The Black Sea and Sea of Azov, with their sea basins and socio-economic systems, represent a globally significant "natural laboratory" for fundamental science, sustainable development policy, and blue economy advancements [20].

The relevance of this topic is further underscored by Ukraine's approval of the Concept of the National Target Program for the Use and Protection of Land, issued by the Cabinet of Ministers of Ukraine on January 19, 2022 [21]. The Program's primary goal is to implement Ukraine's state policy for sustainable land use, establish environmentally safe conditions for population settlement and economic activities, and safeguard land against degradation, pollution, and depletion. It also emphasizes soil fertility restoration, landscape and biodiversity preservation, and the maintenance of soil cover functions within a market economy and in the face of global climate change. Key aspects of the Program's implementation include developing automated information-analytical systems and leveraging Earth remote sensing data. This will ensure accurate information on the condition of land resources, enhance monitoring efforts, and support the development of scientific and methodological bases for land resource management [21].

Today, research utilizing Earth remote sensing data, particularly satellite measurements, has gained significant traction among scientists across various scientific disciplines. This popularity stems from satellite capabilities to cover vast areas with high spatial resolution, transcending state boundaries, economic zones, and other geopolitical delineations [22].

This paper aims to analyze land use in Ukraine's coastal regions based on satellite measurement data. In our view, studies on land use in Ukraine's coastal zones are particularly timely, given that portions of this territory have been under occupation since 2014. The spatial-temporal variability of land use in these regions presents an ongoing challenge for Ukraine. It is important to note that research on the Sea of Azov-Black Sea region, utilizing satellite data, is regularly conducted by marine science experts. In this field, a considerable number of methods, methodologies, and programs have been developed for numerical and simulation modeling of hydrophysical and dynamic processes in the marine environment. Nevertheless, these advancements continue to be refined, as exemplified in the methods described in [23]. Likewise, various methods and computational modeling programs are applied in contemporary land use studies based on satellite data. However, achieving greater experimental accuracy requires rigorous verification, particularly when testing models on actual field sites.

This paper presents an analysis of land use dynamics in the seaside regions of Ukraine using satellite measurement data spanning from 2017 to 2022. The research covers the Odesa, Mykolaiv, Kherson, Zaporizhzhia, and Donetsk Oblasts, as well as the Autonomous Republic of Crimea, treated as an independent administrative unit.

The study relies on land use/land cover (LULC) mapping using data from the Sentinel-2 satellite and employing a Deep Learning (DL) model. The European Space Agency's Sentinel satellites have provided the foundation for high-resolution global LULC mapping, with detail down to 10 meters [24]. The objective of LULC mapping is to characterize the Earth's surface through categorical classes of natural or anthropogenic origin — such as forests, shrubs, grasslands, wetlands, croplands, urban areas, and water bodies. Deep artificial neural networks, specifically Deep Learning (DL) models, have shown promising potential in LULC mapping due to their high performance in computer modeling, particularly with Convolutional Neural Networks (CNNs) for classifying remote sensing images. Achieving high performance in DL models, however, requires training on large, intelligent datasets. Intelligent data incorporates all preprocessing methods that enhance data value and reliability, along with high-quality expert annotations that increase accuracy [25].

To analyze land use in the seaside regions of Ukraine from 2017 to 2022, relevant maps were generated using the ArcGIS Living Atlas of the World [26]. This tool offers a global Land Use/Land Cover (LULC) map based on ESA Sentinel-2 satellite imagery with a spatial resolution of 10 meters. The map was developed collaboratively by Environmental Systems Research Institute (Esri), Impact Observatory, and Microsoft. Annually, Impact Observatory generates land classifications with an AI-powered Deep Learning model, trained using billions of image pixels labeled by the National Geographic Society (NGS). Global LULC maps are created by applying this model to the Sentinel-2 Level-2A image collection on the Microsoft Planetary Computer, which processes over 400,000 Earth observations annually. The algorithm provides LULC predictions across nine categories [27], divided as follows [28]:

1. **Water** — Areas predominantly observed with water year-round, such as rivers, ponds, lakes, oceans, and flooded salt marshes.

2. **Trees** — Dense, tall (~4.5 meters or higher) vegetation, including forests, dense savanna vegetation, plantations, wetlands, and mangroves.

3. **Flooded Vegetation** — Vegetated areas with frequent water mixing; seasonally flooded regions with mixed grass/shrub/trees/bare land, including flooded mangroves, surface vegetation, rice paddies, and other irrigated croplands.

4. **Crops** — Man-planted agricultural crops such as corn, wheat, and soybeans.

5. **Built Area** — Artificial structures, major roadways, and rail networks, such as buildings, dense urban areas, asphalted surfaces, and parking structures.

6. **Bare Ground** — Rock or soil areas with sparse vegetation year-round, including sands, deserts, dry salt marshes, and lakebeds.

7. **Snow/Ice** — Uniform areas of permanent snow or ice, typically in mountainous regions or high latitudes, covering glaciers and snow fields.

8. **Clouds** — Regions with no land cover information due to persistent cloud cover.

9. **Rangeland** — Open areas with uniform grass and minimal tall vegetation, including natural grasslands, fields with sparse forest cover, open savannas, and pastures.

The classification process is structured as follows [28]:

The maps utilize version 003 of the global Sentinel-2 LULC data product, created through an AI-driven Deep Learning model trained on over five billion manually labeled pixels from Sentinel-2 images, covering more than 20,000 locations across the world's major biomes. This foundational Deep Learning model employs six-band Sentinel-2 Level-2A surface reflectance data, including visible blue, green, red, near-infrared, and two short-wave infrared bands. To construct the final map, the model processes multiple measurements across different dates throughout the year, combining these results into an annual representative map. The initial Sentinel-2 Level-2A data was accessed via the Microsoft Planetary Computer, with scalability provided by Microsoft Azure Batch.

Given the vast volume of generated graphical material, presenting it fully here is beyond this paper's scope. Instead, we focus on summarizing key findings based on LULC mapping derived from satellite data using the Deep Learning model. Fig. 1 displays a 2022 land use map generated from Sentinel-2 satellite data, illustrating land use across Ukraine's coastal regions. The choice of 2022 for detailed analysis reflects the significant occupation of Ukraine's seaside regions due to Russian aggression that year. Therefore, we have analyzed land use in 2022 in detail and explored the spatio-temporal dynamics of land use for the 2017—2022 period.

The legend to Fig. 1 contains 7 of the 9 classes listed above. This is due to the fact that in the research area (Fig. 1) such classes as: clouds and snow/ice were not constantly observed throughout the year.

Let us consider in more detail land use in seaside regions in 2022 based on satellite measurements. The diagrams of land use in seaside regions in 2022 (Fig. 2) are built based on available information [29] and Fig. 1.

Odesa Oblast. Figure 2, *a* illustrates that a significant portion (78%) of Odesa Oblast is dedicated to agricultural use. Rangelands account for 8% of the region's territory, primarily located in the Danube Delta within the Izmail District, with additional areas in the Bolgrad District, the Dniester Estuary's coastal zone, the Lower Dniester National Nature Park, the Kuialnyk Estuary, and along the northern Black Sea coastline near the Village of Chornomorske in Odesa District. Tall, dense vegetation is concentrated primarily in the northern Podilskyi District. Built-up areas correspond to urban settlements, with the City of Odesa representing the largest built-up area in the region. Water bodies constitute 3% of the regional territory, encompassing estuaries, bays, lakes, and a 12-mile territorial waters zone in the Black Sea. Areas with flooded vegetation are mainly found in the Danube Delta, Izmail District. In 2022, no bare ground areas were observed in the region.

Mykolaiv Oblast. Figure 2, *b* shows that agricultural land comprises the highest percentage

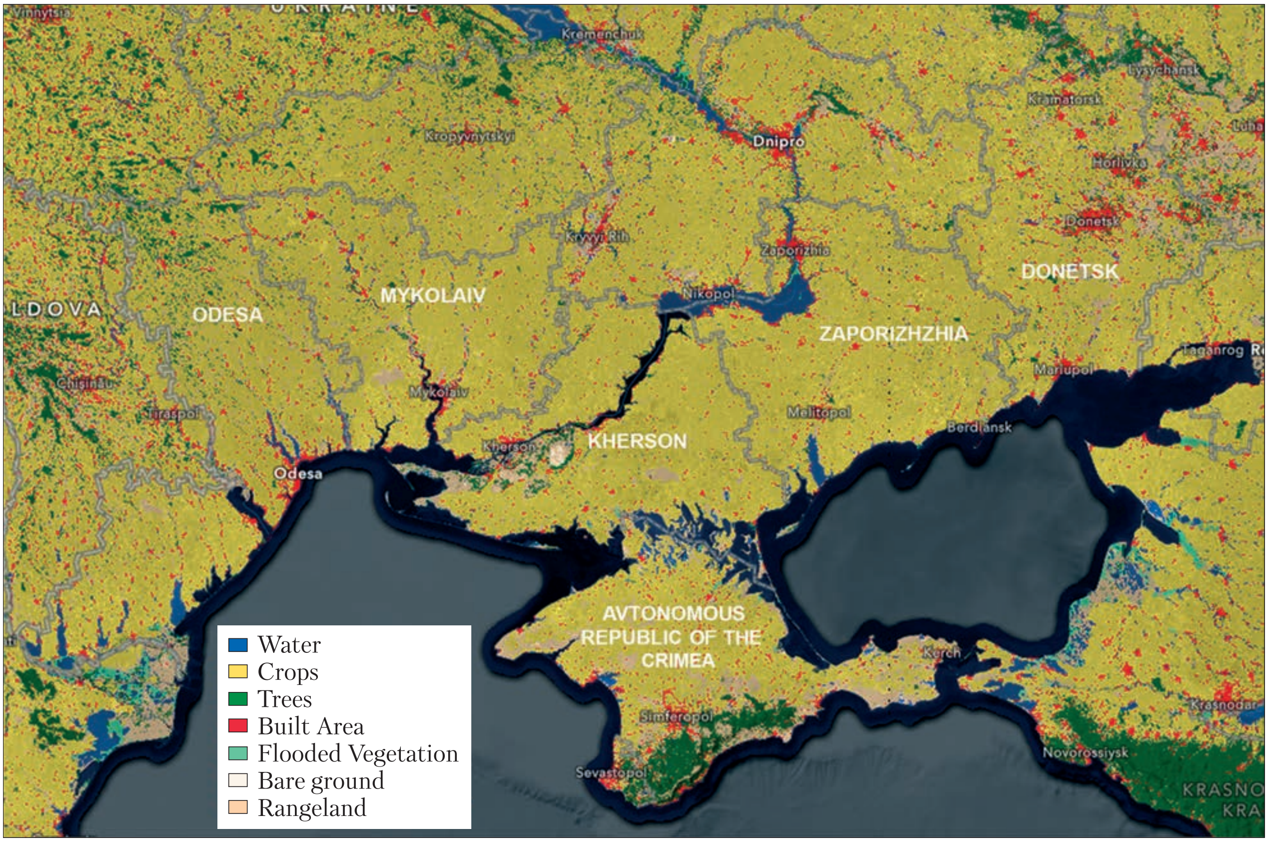


Fig. 1. Land use map in 2022 based on satellite data (ESA satellite: Sentinel-2)
Source: based on [29].

(87%) of land use among Ukraine's seaside regions. Rangelands are the second most prevalent, covering 6% of the region's total area, and are concentrated along major rivers such as the Southern Bug and Berezan in the Mykolaiv District. Built-up areas are centered around urban settlements, with the city of Mykolaiv containing the most extensive built-up area. Dense vegetation (Tree class) is observed along the Southern Bug River and near Pervomaisk and Voznesensk cities. Water bodies make up just 1% of the region's territory, including the Dnieper-Bug Estuary, Berezan Estuary, Southern Bug, Berezan, Ingul Rivers, and the Tashlytsky Reservoir near Yuzhnoukrainsk. Flooded vegetation primarily appears in the Biloberezhzhia Sviatoslava (Sviatoslav's Ivory Coast) National Nature Park within Mykolaiv District, with additional smaller areas along the Southern Bug and Ingul Rivers.

Kherson Oblast. Figure 2, *c* indicates that agricultural land occupies the largest portion (79%) of Kherson Oblast. Rangelands are prominent in the Dnipro River Delta, the Askania-Nova Biosphere Reserve, Dzharylhach National Nature Park, and along the Sivash Lake coast. Water bodies constitute 4% of the region's area, dominated by the Dnipro River. Flooded vegetation appears in the Dnipro River Delta and is also present in small patches near the Sivash Lake and the Tendrivska Bay. Dense vegetation clusters are primarily in the Dnipro River Delta and around the Oleshky Sands National Nature Park. Built-up areas are concentrated in urban centers, with Kherson and Nova Kakhovka being the largest. Areas with bare

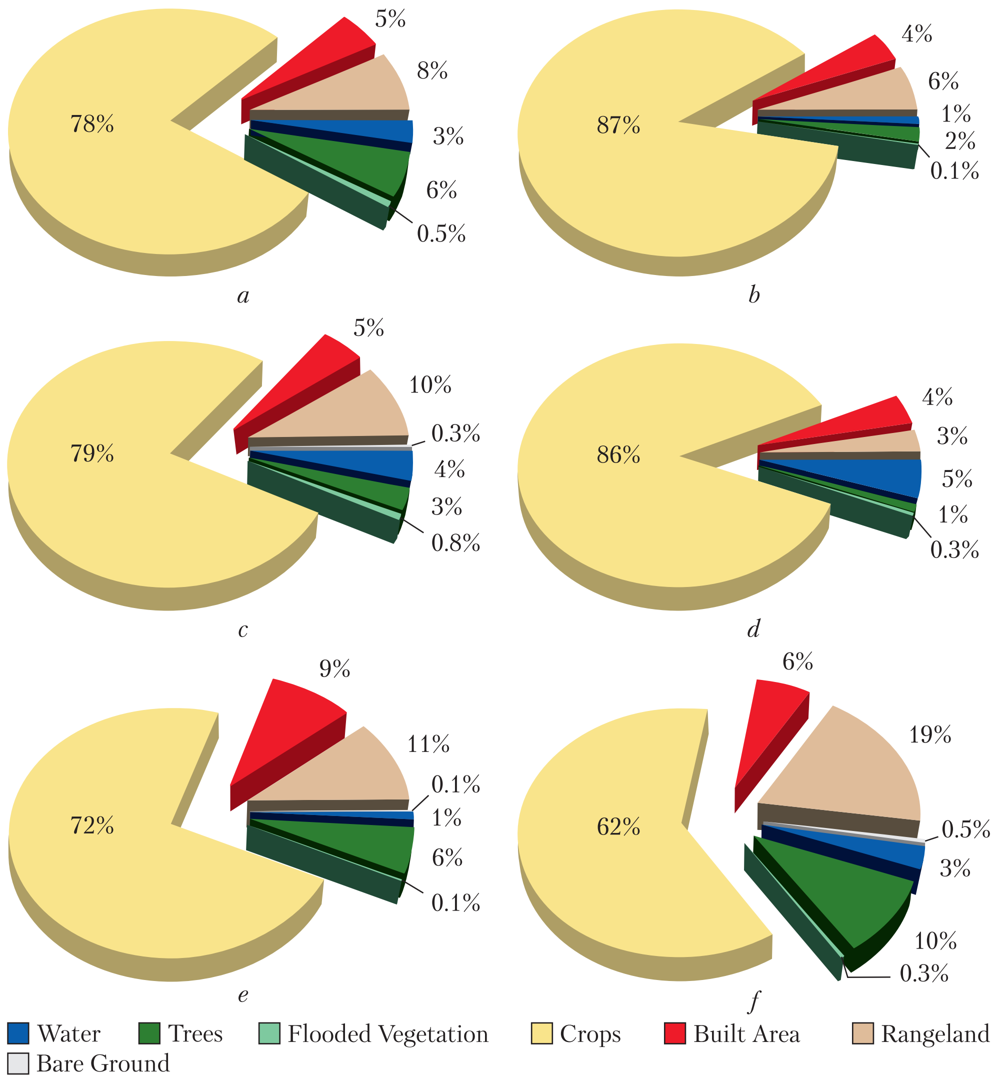


Fig. 2. Diagrams of land use in 2022 based on satellite information in the regions of Ukraine: *a* — Odesa Oblast; *b* — Mykolaiv Oblast; *c* — Kherson Oblast; *d* — Zaporizhzhia Oblast; *e* — Donetsk Oblast; *f* — Autonomous Republic of Crimea

Source: built by the authors based on [29].

ground are primarily located within Oleshky Sands National Nature Park.

Zaporizhzhia Oblast. In terms of agricultural land use, Zaporizhzhia ranks second among Ukraine's seaside regions, with 86% of its land dedicated to agriculture (Fig. 2, *d*). Water bodies occupy the largest share of territory among the seaside regions, covering 5% of the area. Major water bodies in 2022 included the Kakhovka Reservoir and the Molochnyi Estuary, located in the southern part of the Melitopol District. Built-up areas correspond to the locations of larger urban settlements, with Zaporizhzhia, Melitopol, Berdyansk, and Tokmak being notable urban centers. The region's area covered by trees is the smallest among the seaside regions studied, constituting only 1% of the territory, mainly around Zaporizhzhia and extending south, with smaller pockets near Melitopol and Energodar. Flooded vegetation areas are concentrated near the southern Kakhovka Reservoir, close to the village of Kushugum, and the central reservoir area near Energodar in the Vasylivka District. Rangelands account for only 3% of the total area, the smallest among the seaside regions, with minor clusters along the Sea of Azov coast near Berdyansk and Primorsk, as well as in the vicinity of Melitopol, Energodar, and Zaporizhzhia.

Donetsk Oblast. Figure 2, *d* shows that 72% of Donetsk Oblast's territory is used for agriculture, with a spatial distribution extending evenly across the region except for the western area, where rangelands are concentrated. Built-up areas cover the largest share among the seaside regions, constituting 9% of the territory, densely distributed throughout the region. Notable urban areas include Donetsk, Mariupol, Horlivka, Kostiantynivka, Kramatorsk, Slovyansk, and Lyman. Dense vegetation covers 6% of the land, primarily located in the Holy Mountains National Nature Park within the Kramatorsk and Bakhmut Districts, as well as near Donetsk and extending eastward in the Horlivka District. Water bodies are minor, comprising reservoirs and small rivers, covering just 1% of the territory. Flooded vegetation areas are mainly found in the southwestern part of Holy Mountains National Nature Park. Bare ground areas (0.1%) are minimal and not visually prominent.

Autonomous Republic of Crimea. Figure 2, *f* illustrates that Crimea has the lowest percentage of agricultural land use (62%) among Ukraine's seaside regions. These lands are distributed evenly across the peninsula except in the southern and southeastern areas and parts of the northern and southern Kerch District. Dense vegetation areas, covering 10% of the land, are concentrated mainly in the southern and southeastern parts of the peninsula. This is the highest percentage of densely vegetated land use among the seaside regions of Ukraine.

Rangelands occupy 19% of the Crimean Peninsula, primarily in the northern and southern parts of the Kerch District, the western Yevpatoriya District, the Yalta District, the southern Feodosia District, and central Bilohirsk District. This percentage is also the highest for rangelands among the seaside regions. Built-up areas consist of scattered urban zones, with Simferopol, Sevastopol, Feodosia, Yevpatoria, and Kerch as the primary urban centers. Water bodies cover 3% of the peninsula, mainly consisting of salt lakes and bays, such as Sivash and Sasyk-Sivash. Areas with flooded vegetation are found near the Sivash Lake, especially in the southern part of the Dzhankoy District.

Sparse areas with bare ground are scattered across the peninsula, with visible cells in the northern and southern Kerch District.

To provide a comparative overview, a histogram of relative land use for each class by region in Ukraine is presented in Fig. 3, illustrating each region's proportion of land use within its corresponding category relative to the total in Ukraine.

From Fig. 3, *a* generalized overview of land use in the respective classes across Ukraine can be derived, allowing for a quantitative assessment of each region's land use status.

- **Water Bodies:** The Zaporizhzhia Oblast boasts the largest area of water bodies, while Mykolaiv Oblast holds the smallest.
- **Vegetation Density:** The Autonomous Republic of Crimea has the most extensive areas of high-density vegetation, with the Zaporizhzhia Oblast showing the least.
- **Flooded Vegetation:** Odesa and Kherson Oblasts emerge as the leaders in areas of flooded vegetation, while other seaside regions collectively account for only 3.3% of Ukraine's territories in this category.
- **Agricultural Land Use:** The highest agricultural land use is found in the Odesa Oblast, contrasting with the Autonomous Republic of Crimea, which has the least.
- **Built Areas:** Donetsk Oblast has the largest built area, while Odesa and the Autonomous Republic of Crimea exhibit similar levels of built-up land despite the latter's smaller overall territory by 7.2 thousand km^2. The Kherson Oblast has the least built area.

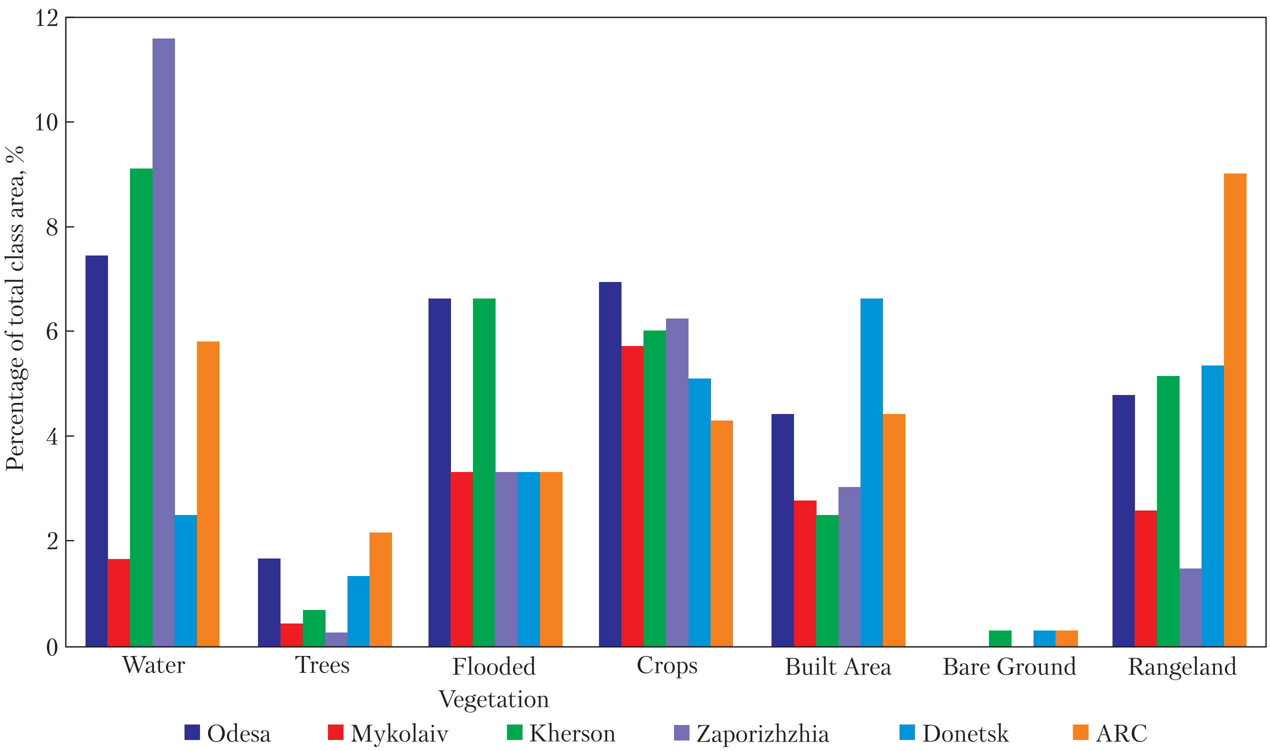


Fig. 3. Histogram of relative indicators of the distribution of land use in the seaside regions according to their general use throughout the territory of Ukraine based on satellite information in 2022

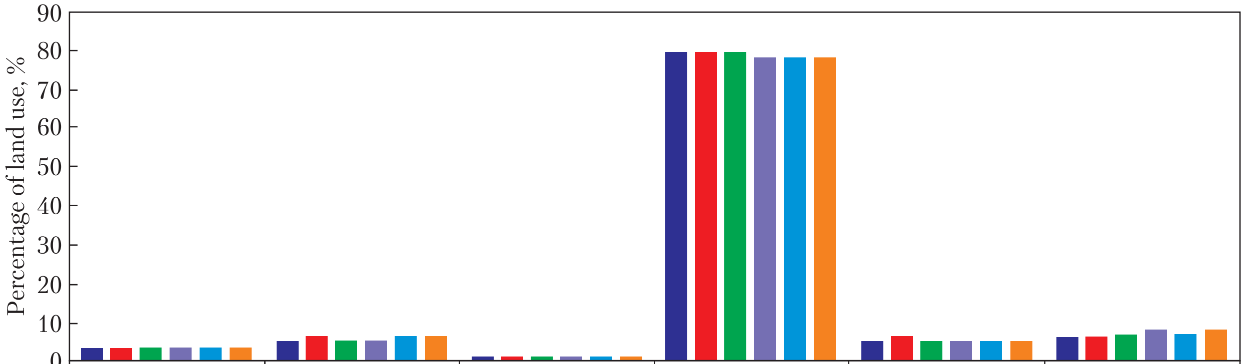
Source: calculated and built by the authors based on data [29].

- **Bare Ground:** Kherson and Donetsk Oblasts, along with the Autonomous Republic of Crimea, share similar values in the distribution of bare ground areas. Other seaside regions did not report land plots of this class.
- **Rangelands:** The Autonomous Republic of Crimea holds the largest rangeland area, while the Zaporizhzhia Oblast has the smallest.

The variability of land use for the period from 2017 to 2022 is depicted in Figs. 4—9.

Odesa Oblast. Figure 4 presents a histogram that compares land use indicators in the Odesa Oblast, based on satellite data across different classes from 2017 to 2022.

As shown in Fig. 4, the water areas of water bodies remained unchanged throughout the studied period. The accumulation of high-density vegetation increased by 1% in the northern part of the region when comparing 2020 and 2021. The indicators of variability in areas with flooded vegetation generally characterize the dynamics of changes in this class near the Danube Delta and in minor cells from 2017 to 2021, particularly north of the Dniester Estuary in the Bilhorod-Dnistrovskyi and Odesa Districts. In 2022, these minor cells were no longer observed. The area of agricultural land decreased in the second half of the studied period, starting in 2020, a trend that was observed throughout the region. Conversely, there has been an increase in the area of rangelands since 2020. This can be attributed to the fact that part of the crop class was included in the rangelands class, indicating that agricultural crops were not planted in these territories during the relevant years. The area designated as built remained relatively stable throughout the studied period, with the exception of 2018, when the relative indicators for this class increased by 1%. Visually



	Water, %	Trees, %	Flooded Vegetation, %	Crops, %	Built Area, %	Rangeland, %
2017	3	5	0.70	79	5	6
2018	3	6	0.80	79	6	6
2019	3	5	0.60	79	5	7
2020	3	5	0.50	78	5	8
2021	3	6	0.70	78	5	7
2022	3	6	0.50	78	5	8

Land cover classes

Fig. 4. Dynamics of land use in the Odesa Oblast based on satellite information in the period from 2017 to 2022
Source: built by the authors based on data [29].

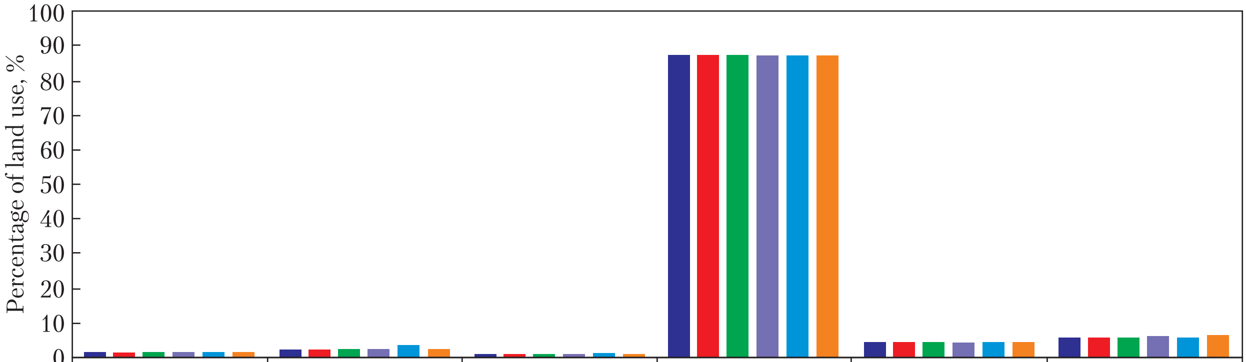
separate cells of the built-up area were not observed this year, apart from a minor increase in the territories of small villages in the region. This increase in indicators may be attributed to the quality of primary information processing. Throughout 2017 and from 2019 to 2022, these indicators did not change. Areas with bare ground were not observed in the region during the studied period.

Mykolaiv Oblast. Figure 5 shows a histogram of the variability of land use in the region during the period from 2017 to 2022, based on satellite information.

The variability of the water areas of water bodies in the region remained unchanged throughout the studied period (Fig. 5). Areas of high-density vegetation, as well as areas with flooded vegetation, also remained stable during this time. Only in 2021 did the relative indicators of these classes increase by 1% and 0.1%, respectively. The territories designated for agricultural crops and built areas showed no changes during the entire period. However, the relative indicators for the territory of rangelands indicate growth starting from 2020. This variability from 2019 to 2022 is generally attributed to fluctuations in the area of this class of land along major rivers, such as the Southern Bug and Berezan, as well as within the territory of the Biloberezhzhia Sviatoslava (Sviatoslav' National Nature Park).

Kherson Oblast. The histogram presented in Fig. 6 illustrates the variability of land use in the region during the period from 2017 to 2022 based on satellite information.

As illustrated in Fig. 6, the water areas of water bodies and areas of high-density vegetation in the region remained unchanged throughout the studied period. The relative indicators indicate variability in areas with flooded vegetation during this



	Water, %	Trees, %	Flooded Vegetation, %	Crops, %	Built Area, %	Rangeland, %
2017	1	2	0.10	87	4	5
2018	1	2	0.10	87	4	5
2019	1	2	0.10	87	4	5
2020	1	2	0.10	87	4	6
2021	1	3	0.20	87	4	5
2022	1	2	0.10	87	4	6

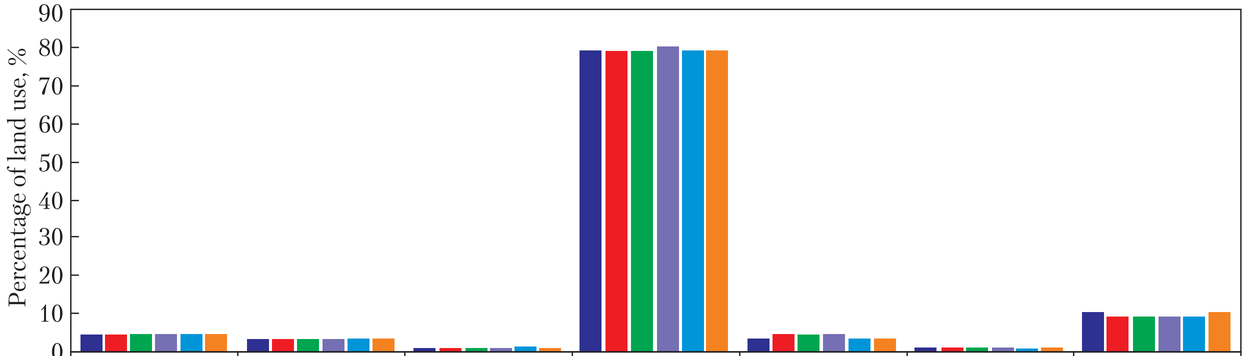
Land cover classes

Fig. 5. Dynamics of land use in the Mykolaiv Oblast based on satellite information in the period from 2017 to 2022
Source: built by the authors based on data [29].

time. This variability is attributed to the increase and decrease of territories along the coast of the Dnipro River, from the city of Nova Kakhovka to the Dniprovska Gulf, as well as small areas along the coast of the Tendrivska Bay and the Sivash Lake. The areas designated for agricultural land remained consistent throughout the period, with the exception of 2020. The increase in the territory of this class of land in 2020 can be visually traced across the region. According to the relative indicators, the built area decreased in 2021 and 2022, years marked by occupation and hostilities in the region. Our visual analysis of satellite-based maps from 2020 to 2022 indicated a trend toward a reduction in the territories of small towns and cities, which nearly vanished from the map by 2022. The variability of areas with bare ground during the studied period was characterized by fluctuations in the territory of this class of land use within the Oleshky Sands National Nature Park and along the coast of the Sivash Lake. The increase in the area of rangelands in 2022 can be explained by the expansion of land use in the Dnipro River Delta, the Askania-Nova National Biosphere Reserve, the Dzharylhach National Nature Park, and along the coast of the Sivash Lake.

Zaporizhzhia Oblast. Figure 7 presents a histogram of the variability of land use in the region during the period from 2017 to 2022, based on satellite information.

As shown in Fig. 7, the water areas of water bodies in the region increased in 2021. A visual analysis of land use maps created from satellite information revealed a general increase in the territory of water bodies in the Kakhovka Reservoir and the Molochnyi Estuary. The variability of high-density vegetation in the region remained unchanged



	Water, %	Trees, %	Flooded Vegetation, %	Crops, %	Built Area, %	Bare Ground, %	Rangeland, %
2017	4	3	0.70	79	3	0.40	10
2018	4	3	0.80	79	4	0.30	9
2019	4	3	0.70	79	4	0.40	9
2020	4	3	0.60	80	4	0.40	9
2021	4	3	0.90	79	3	0.20	9
2022	4	3	0.80	79	3	0.30	10

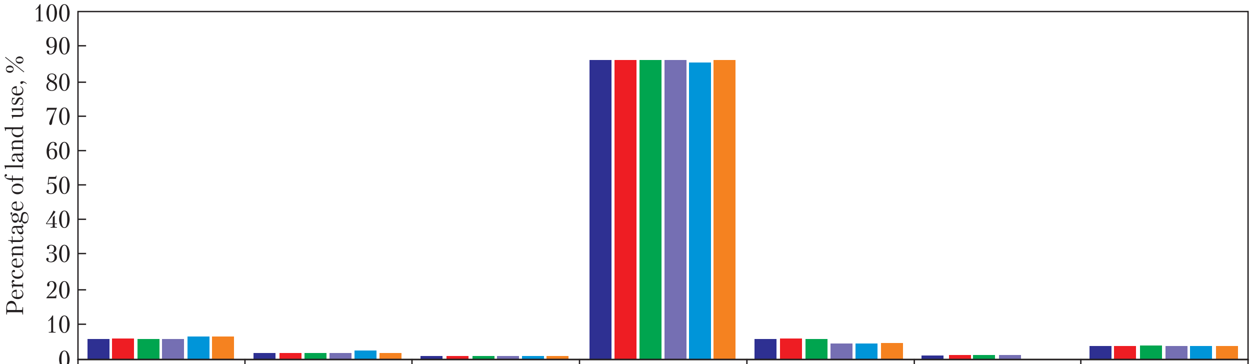
Land cover classes

Fig. 6. Dynamics of land use in the Kherson Oblast based on satellite information in the period from 2017 to 2022
Source: built by the authors based on data [29].

overall, with only 2021 showing an increase in the relative indicators for these areas. This increase can be traced near the city of Zaporizhzhia and extends southward throughout the region. Additionally, an increase is observed south and north of the city of Melitopol and along the coast of the Kakhovka Reservoir within the region. The area designated for flooded vegetation remained unchanged throughout the studied period. Agricultural land areas remained consistent except for 2021, when a decrease in the territory of this class became visually apparent between the cities of Melitopol and Tokmak. The built area declined in the second half of the studied period, starting from 2020. Our visual analysis of satellite-based maps from 2019 to 2022 indicated a trend of decreasing territories of small towns and cities during 2020, 2021, and 2022. The variability of areas with bare ground from 2017 to 2020 was characterized by fluctuations in this class of land use along the coast of the Molochnyi Estuary. However, in 2021 and 2022, no areas corresponding to this land use class were identified. The territories of rangelands in the region remained unchanged throughout the studied period.

Donetsk Oblast. Figure 8 presents a histogram reflecting the variability of land use in the region during the period from 2017 to 2022, based on satellite information.

The relative indicators of the variability of water areas in the region indicate that their territory remained unchanged during the studied period (Fig. 8). Areas of high-density vegetation were consistent during the periods of 2018—2020 and 2022. A significant increase in areas of dense vegetation was observed in 2021. The results of the visual analysis of land use maps for this class from 2020 to 2022 suggest that the increase in high-



	Water, %	Trees, %	Flooded Vegetation, %	Crops, %	Built Area, %	Bare Ground, %	Rangeland, %
2017	5	1	0.30	86	5	0.10	3
2018	5	1	0.30	86	5	0.10	3
2019	5	1	0.30	86	5	0.20	3
2020	5	1	0.30	86	4	0.10	3
2021	6	2	0.30	85	4	0.00	3
2022	6	1	0.30	86	4	0.00	3

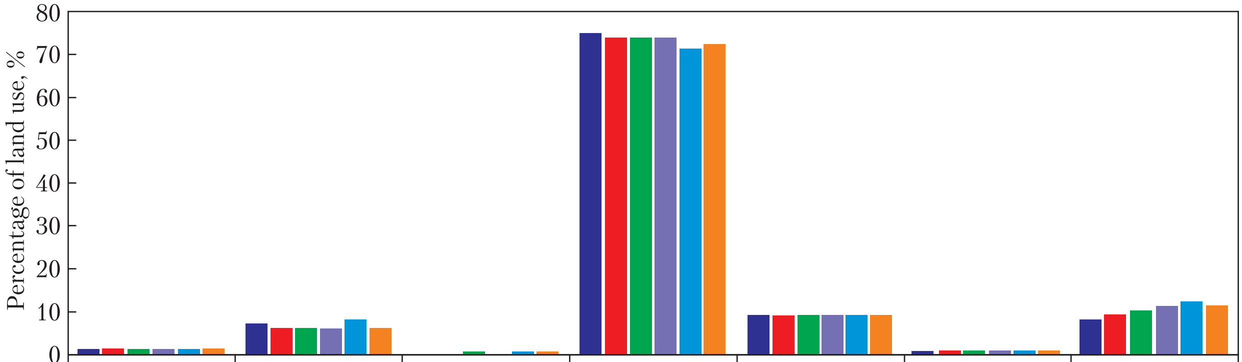
Land cover classes

Fig. 7. Dynamics of land use in the Zaporizhzhia Oblast based on satellite information in the period from 2017 to 2022
Source: built by the authors based on data [29].

density vegetation in the region in 2021 was primarily concentrated near the cities of Donetsk, Horlivka, and Bakhmut in the central part of the region. Areas with flooded vegetation were not observed in 2017, 2018, or 2020. In 2019, 2021, and 2022, the areas designated for this class remained unchanged. The main concentration of this land use class was located in the southwestern part of the Holy Mountains National Nature Park, along with small areas on the Bilosarayska Kosa in the Taganrog Bay, southwest of the city of Mariupol. The relative indicators for the variability of agricultural land use show a significant decrease in territory in 2021 and 2022 compared to the period from 2017 to 2020. This reduction is evident throughout the central and western parts of the region. The areas of built environments and those with bare ground remained unchanged during the studied period. The territories of rangelands in the region exhibited a growing trend from 2017 to 2022, with a significant increase in concentration in the central and western parts of the region.

Autonomous Republic of Crimea. Figure 9 presents a histogram of land use variability on the peninsula for the corresponding class during the period from 2017 to 2022, based on satellite information.

As seen in Fig. 9, the water areas of water bodies in the region increased in 2021 and 2022. A visual analysis of land use maps constructed using satellite information indicated an overall increase in the territory of water bodies, primarily due to the expansion of water areas in lakes and bays, particularly the Sivash and the Sasyk-Sivash Lakes. The area of high-density vegetation remained unchanged during the periods of 2017—2019 and 2022, with a reduction observed in 2020 and 2021. Visual analysis of the maps for the region, created



	Water, %	Trees, %	Flooded Vegetation, %	Crops, %	Built Area, %	Bare Ground, %	Rangeland, %
2017	1	7	0.00	75	9	0.10	8
2018	1	6	0.00	74	9	0.10	9
2019	1	6	0.10	74	9	0.10	10
2020	1	6	0.00	74	9	0.10	11
2021	1	8	0.10	71	9	0.10	12
2022	1	6	0.10	72	9	0.10	11

Land cover classes

Fig. 8. Dynamics of land use in the Donetsk Oblast based on satellite information in the period from 2017 to 2022
Source: built by the authors based on data [29].

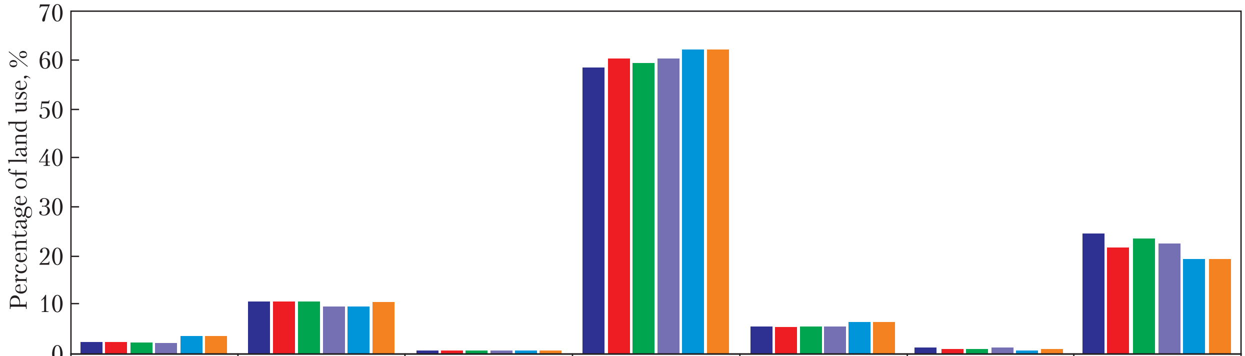
from satellite information between 2019 and 2022, revealed a decrease in high-density vegetation concentration in the southern and southeastern parts of the peninsula.

An increase in areas with flooded vegetation was noted in 2021 and 2022, driven by a rise in concentration along the coast of the Sivash Lake in the southeastern part of the peninsula. Throughout the studied period, agricultural land showed a tendency to increase uniformly across the central, western, and northern parts of the peninsula, as well as in the central area of the Kerch District of the Autonomous Republic of Crimea. The built area also increased in 2021 and 2022 compared to the period from 2017 to 2020, with growth observed primarily in the southern part of the peninsula, particularly extending southward from the city of Simferopol.

Conversely, areas with bare ground and rangelands exhibited a decline in land use. In the case of bare ground, a reduction was observed along the shores of the Sivash Lake in the southern part of the peninsula and the Black Sea in the southern and eastern regions of the Kerch District. Similarly, the decrease in rangelands was noticeable throughout the western, southern, and northern parts of the peninsula, as well as in the territory of the Kerch District.

In summary, the analysis indicates that the information obtained through land use and land cover (LULC) mapping based on satellite data (Sentinel-2) using a Deep Learning model can effectively inform land resource management processes in Ukraine. The process of land resource management encompasses generally accepted components essential for effective governance (Fig. 10), namely:

In our case, the object of management is the land areas of the seaside regions of Ukraine. By emp-



	Water, %	Trees, %	Flooded Vegetation, %	Crops, %	Built Area, %	Bare Ground, %	Rangeland, %
2017	2	10	0.10	58	5	0.80	24
2018	2	10	0.20	60	5	0.60	21
2019	2	10	0.10	59	5	0.60	23
2020	2	9	0.10	60	5	0.80	22
2021	3	9	0.30	62	6	0.30	19
2022	3	10	0.30	62	6	0.50	19

Land cover classes

Fig. 9. Dynamics of land use in the Autonomous Republic of Crimea based on satellite information in the period from 2017 to 2022

Source: built by the authors based on data [29].

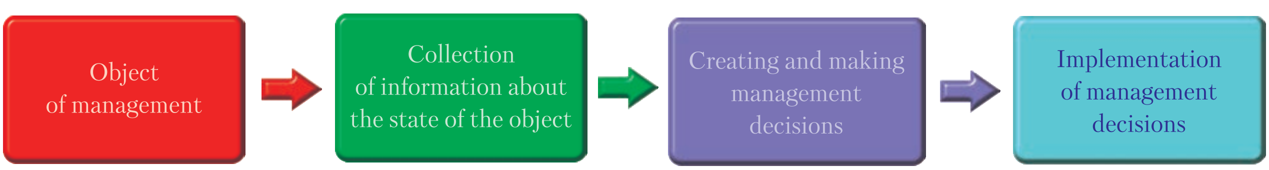


Fig. 10. Scheme of the land resource management process

Source: built by the authors.

loying a management tool such as LULC mapping, detailed information about the status of the management object can be obtained. This information allows for a qualitative and quantitative description of its current state, which is essential for developing and implementing effective management decisions.

Based on the analysis of the research results, several conclusions can be drawn. The method described in this paper enabled a quantitative characterization of the spatial-temporal variability of land use in seaside regions, utilizing satellite information. The findings suggest the feasibility of applying land use/land cover (LULC) mapping based on satellite data (specifically from the Sentinel-2 satellite) using a Deep Learning model at various scales, including national and regional levels, for studying the spatial distribution and spatio-temporal variability of land use. This approach can also be effectively applied to analyze smaller local areas, such as neighborhoods within large cities.

However, it is important to note that for the study of local natural areas — such as sandy beaches or park areas — using LULC maps may currently be impractical, as the information tends to be subject to significant errors on such smaller scales. Therefore, it is necessary to continue refining the LULC mapping method based on satellite data and the Deep Learning model, along with validating its results. We believe that developing alternative methods for processing satellite information for the research of small local areas is essential.

In general, LULC mapping based on satellite data using the Deep Learning model holds substantial potential for research across various scientific fields, as well as for practical applications in nature management and territorial planning at both national and regional levels. Moreover, innovative approaches to LULC mapping can serve as a powerful tool for identifying the scale of emergency situations, whether natural, anthropogenic, or military in nature.

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АНАЛІЗ ВИКОРИСТАННЯ ЗЕМЕЛЬ ПРИМОРСЬКИХ РЕГІОНІВ УКРАЇНИ У ПЕРІОД 2017—2022 рр. НА ОСНОВІ СУПУТНИКОВОЇ ІНФОРМАЦІЇ

Вступ. Відомо, що земля є основним національним багатством та перебуває під особливою охороною держави згідно законодавства України. Вона є основним природним ресурсом, матеріальною умовою життя й діяльності людей, основою для розміщення і розвитку низки галузей народного господарства. Тому ефективний розвиток економіки неможливий без організації раціонального використання й охорони землі.

Проблематика. Сьогодні є актуальним дослідження використання земель у приморських регіонах України, адже частина їх знаходиться під окупацією з 2014 року і дослідження просторово-часової мінливості використання земель на цих територіях є проблемним для України.

Мета. Аналіз використання земель приморських регіонів України за даними супутникових вимірювань.

Матеріали й методи. Дослідження виконано на основі інформації картографування використання землі / земельного покриву (LULC) за супутниковими даними (супутник: Sentinel-2) із застосуванням глибоких штучних нейронних мереж або моделі Глибокого Навчання (DL).

Результати. Проведено детальний аналіз просторового розподілу використання земель приморських регіонів України у 2022 році. Досліджено просторово-часову мінливість використання земель приморських регіонів України у періоді 2017—2022 рр. Виявлено особливості у просторовому розподілі відповідних класів земельного покриву на територіях приморських регіонів України. Визначено, що інноваційні підходи картографування LULC та отримані на їхній основі дані, можна використовувати в управлінні земельними ресурсами України.

Висновки. Метод картографування LULC має значний потенціал для досліджень у різних галузях науки, зокрема й для виконання прикладних завдань у сфері природокористування, планування територій на національному та регіональному рівнях. Крім того, інноваційні підходи картографування LULC можна використовувати як потужний інструмент для виявлення масштабів дії надзвичайних ситуацій природного, техногенного, антропогенного, воєнного характеру.

Ключові слова: використання землі, земельний покрив, природні активи, управління земельними ресурсами, дистанційне зондування Землі, супутникові дані, глибоке навчання, згорткові нейронні мережі.