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Analysis of Rural Areas of Ukraine on the Basis of ESA WorldCover 2020

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Abstract. At present, GIS technologies penetrate various spheres of socio-economic life of humankind. In this paper, based on GIS technologies, the main classes of the land cover of Ukraine were analysed with further in-depth study in terms of regions and rural and urban areas. The results of this study are based on ESA WorldCover data; according to them, 32% of Ukraine's territory can be attributed to urban areas, while 68% – to rural areas. In general, the analysis showed that Ukraine is characterised by a high degree of land using, so the land that was cultivated in 2020 accounted for 55.5% of its area. 70% of rural areas comprise cultivated areas, 30% – in urban areas. The leaders among the oblasts with the largest share of cultivated lands are Zaporizhzhia (76%), Kirovohrad (76%), Mykolaiv (77%). An inherent feature of Ukraine's land structure is a considerable share of land (15.3%) under meadows, hayfields, and pastures, which are vital in restoration and preservation and as an essential element of regional ecosystems. 66% of the territories of this class are concentrated in rural areas, on urban areas – 34%. Most of them are in Luhansk (26%), Lviv (24%) and Volyn (22%) oblasts. The level of forest cover in Ukraine is 23.3%, with 17.7% being forests and the other 6% – protective forest belts, orchards, and arboretums. Rural areas account for 64% of forested areas. The most forested areas are Zakarpattia (68%), Ivano-Frankivsk (54%) and Zhytomyr (45%), while the least forested are Kherson (4%), Zaporizhzhia (5%) and Mykolaiv (6%). In general, 71% of forested areas are rural and 29% are urban. In Ukraine, the share of surface waters covering the geographical area is 2.4%, of which 71% is in rural territories and 29% – in urban territories. Cherkasy (5%), Zaporizhzhia (6%), and Kherson (8%) oblasts are the top three oblasts in terms of surface water supply with 64%, 63% and 82% in rural areas, respectively (Fig. 8). In turn, the oblasts with the smallest share of open water areas are Zhytomyr (0.5%), Luhansk (0.4%) and Zakarpattia (0.3%) oblasts, with 77%, 33%, and 46%, respectively

Keywords: rural territories, GIS technologies, land cover, cultivated land, forested area

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INTRODUCTION

At the turn of the 21st century, the era of exclusively military space is over, and today a significant part of spacecraft is working for the benefit of socio-economic development of society. Information from spacecraft is particularly useful to support environmental, social, and economic issues. Satellite information, as a source of data for geographic information technologies, allows overcoming the problem of subjectivity or the so-called "anthropogenic factor". The "anthropogenic factor" is manifested in the limited ability of people to visit and describe all parts of the Earth's surface and describe them qualitatively. In addition, regarding the pace of development of statistical analysis methods, the analytical product improves every year as a result of processing information from spacecraft and processed using geographic information systems and technologies. Such a product includes classified images of the Earth's surface.

The availability of reliable initial data on the current state of landscapes, features and trends of their changes depending on social conditions is a necessary condition for economical and balanced nature management. To justify effective conservation measures, it is important to know the dynamics and pace of changes that have occurred in the use of landscapes and what they have caused, how profoundly modern landscapes have changed compared to their natural state and why, what are the regional features of landscape use. The basis for solving these problems is the analysis of spatial differences in land use at the level of rural and urban areas.

The consequences of intensive land use, which has recently become a global problem, are manifested in deforestation, increasing arable land, ploughing, depletion of water and land resources to provide the world's growing population with natural resources, energy, and food. Irrational use of nature causes disruption of ecosystems, leads to considerable loss of biodiversity, and disrupts the resilience of geosystems, their ability to self-regulate. In addition, changes in land use cause an impact on regional climatic conditions due to changes in water and energy balances, disruption of the hydrological cycle. In addition to pollution of natural components, there are also habitats of species.

Modern types of land use dictate the needs of developing scientific bases, methods of territorial organisation of land tenure, strengthening the protection of land resources and soil cover, in view of entrepreneurial potential of rural or urban areas. Analysis and assessment of anthropogenic transformation of geosystems is an integral part of the measures of systemic rational land management and sound environmental policy. Deterioration of natural ecosystems is associated with increasing anthropisation of the environment and the natural environment.

The purpose of this study was to geographically separate the rural areas of Ukraine and further analyse their land cover. To achieve this purpose, it was necessary to perform the following tasks: 1) to analyse modern methodological approaches to the classification of land cover; 2) to analyse the land cover of Ukraine (forested areas, cultivated lands, pastures and hayfields, surface waters) with the separation of rural areas; 3) to analyse the land cover at the level of regions of Ukraine with the separation of rural areas.

LITERATURE REVIEW

One of the manifestations of human activity is significant changes in land cover (increase in built-up areas, areas under agriculture, decrease in forest area, etc.). These changes have become one of today's global challenges, as these changes are in most cases unplanned and manifest themselves in the form of ecosystem degradation, drinking water shortages, etc., and in turn have a negative impact on food security around the world. Many scientists from different countries of the world were engaged in the scientific analysis of changes in the earth's cover. Information on the state and change of the Earth's cover is currently in demand in many areas of human activity, especially in rural/urban and regional planning (Hashem & Balakrishnan, 2015; Liou *et al.,* 2017; Lyzhnyk & Svidzinskaya, 2014), monitoring the condition of the environment and assessing the anthropogenic impact on it (Mutanga *et al.,* 2014; Nguyen *et al.,* 2016; Nguyen & Liou, 2019b), forecasting and monitoring the consequences of disasters caused by natural and anthropogenic factors (Maxwell *et al.,* 2018; Talukdar *et al.,* 2020), satellite crop monitoring and assessment of the soil condition and its type (Braun & Hochschild, 2017; Chen *et al.,* 2019; Lyzhnyk & Svidzinskaya, 2014), etc. The reasons for the widespread implementation of land monitoring in various spheres of human activity are primarily due to the development of remote sensing hardware in the form of such spacecraft as Landsat, SPOT, Sentinel, IRS, ASTER, MODIS. In addition, a powerful stimulus for the development of this area is the implementation of statistical methods in classification of the Earth's surface in the form of machine learning algorithms (Maxwell *et al.,* 2018; Mutanga *et al.,* 2014). Methods of machine learning are divided into two branches: controlled (with a teacher) and uncontrolled (without a teacher) (Halder *et al.,* 2011; Talukdar *et al.,* 2020). Methods of controlled classification include machine learning based on reference vectors (SVM) (Wu *et al.,* 2019), random forest (RF) (Xu *et al.,* 2019), spectral angle mapping (SAM), fuzzy adaptive mapping with resonance theory (Fuzzy ARTMAP), Mahalanobis distance (MD), radial basis function RBF), decision tree (DT), multilayer perception (MLP), naive Bayesian classifier (MLC) and fuzzy logic, while unsupervised classification methods include cluster affinity

propagation algorithm (AP), fuzzy C-means algorithms, K-means algorithm , ISODATA (iterative self-organising data), etc (Chen *et al.,* 2019; Halder *et al.,* 2011).

The use of the above methodological apparatus in the study and analysis of the earth's land cover was carried out by scientific teams from many scientific centres around the world, the main achievements of which will be presented in the future. M. Z. Hoque et al. (2022) assessed the dynamics of LULC change and associated ecosystem service values (ESVs) of coastal Bangladesh during 1999-2019 by analysing historical Landsat LULC images and economic valuation techniques, respectively. Findings revealed a high prevalence of rural settlement-based Tree Outside Forest (TOF) land sprawl over agricultural land. As a result, the analysis revealed an increase in built-up, forest, water bodies, and saltpan/aquaculture areas and a decrease in agricultural and bare land areas. A suite of annual land cover and land cover change products has been released by a team of American scientists for the United States. An independently collected land cover reference sample dataset was produced by analysts interpreting Landsat data, high-resolution aerial photographs, and other ancillary data to assess the accuracy of these products (Stehman *et al.,* 2021). Such studies have enabled other teams to improve the accuracy of national classification models and, in general, to have more confidence in satellite imagery. An important study in the development of GIS technologies in the direction of predicting future changes in the earth's cover was done by a team of Brazilian scientists who analysed the future changes in land use and land cover of the advancement of agriculture in the native vegetation areas of the Cerrado/Atlantic forest ecotone in the Prata River basin in 2033, 2050, 2080, and 2100. The modelled future scenarios of LULC indicated the advancement of crop agriculture and decreases in wetlands (banhado), savannahs, riparian forests, seasonal semideciduous forests and wet grasslands (da Cunha *et al.,* 2021).

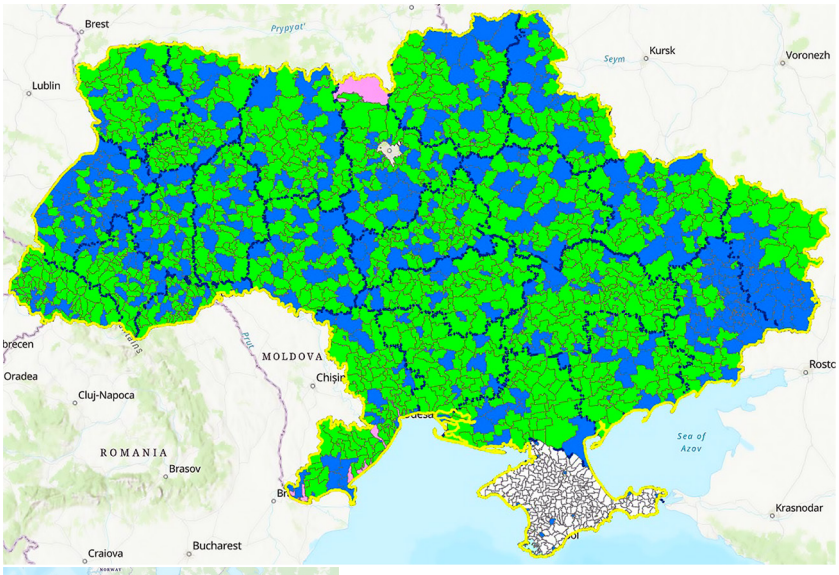
C.M. Viana et al. (2019) intended to apply a long-term LULC analysis in a rural region based on a Landsat time series of 21 years (1995 to 2015). The team selected training samples from the open LULC source data and applied the K-means clustering technique to refine the range of spectral signatures for each LULC class. The results revealed that the proposed method was efficient in classifying a long-term satellite time-series with the accuracy of 76%, providing insights into the main LULC changes that occurred over the years under investigation. The verification of the classification of the earth's cover showed the low accuracy. Therefore, Chinese scientists S. Xu et al. (2019) tried to increase it by combining two models based on images with high spatial resolution. As a result, the combination of SVM and RF classifiers using the C5.0 algorithm is a quick and effective way to improve rural cover classification (Talukdar & Pal, 2018; Talukdar *et al.,* 2020).

MATERIALS AND METHODS

Research area. Ukraine is an independent, democratic country located in Eastern Europe, in the southwestern part of the Eastern European Plain. The area of Ukraine is 603,548 km^2. As of January 1, 2021, the population was 41,588,354 people, according to the State Statistics Service. The largest country in terms of area, the territory of which lies entirely in Europe. The territory of Ukraine lies between 44" and 52" N and 22" and 40" E. The distance between the extreme northern and southern points is 893 km, and between the extreme western and eastern – 1,316 km. Ukraine is a unitary state, which includes 27 regions: 24 oblasts, 1 autonomous republic (AR Crimea) and 2 cities with special status: Kyiv and Sevastopol. These territorial units differ on three grounds: 1) by geographical features they are divided into regions (Crimea, oblasts, districts, cities-regions Kyiv and Sevastopol) and settlements (cities, towns, villages); 2) by their status – on: administrative-territorial units (oblasts, districts), self-governing territorial units – territorial communities (urban, settlement, rural); 3) by place in the system of administrative-territorial organisation of Ukraine – to territorial units of primary level (urban, settlement and rural territorial communities), middle level (districts) and higher level (Autonomous Republic of Crimea, oblasts, cities of Kyiv and Sevastopol) (Constitution of Ukraine, 1996; State Statistics Service of Ukraine).

Another territorial and administrative division in Ukraine is the territorial community – residents united by permanent residence within a village, town, city, which are independent administrative-territorial units, or voluntary association of residents of several villages, towns, cities, which have a single administrative centre (according to the Law of Ukraine "On Local Self-Government"). According to Article 140 of the Constitution of Ukraine, a territorial community is defined as residents of a village, settlement, city, or a voluntary association of residents of several villages into a rural community (Constitution of Ukraine, 1996). As of 2021, there are 1,469 communities in Ukraine formed by uniting villages, settlements, and cities. Territorial community, the administrative centre of which is the city, is an urban territorial community, the centre of which is defined as an urban-type settlement – settlement, the centre of which is determined by the village – rural. For the sake of this study, urban areas will include the territories of urban territorial communities, while rural areas will include the territories of rural and settlement territorial communities (Fig. 1).

a)



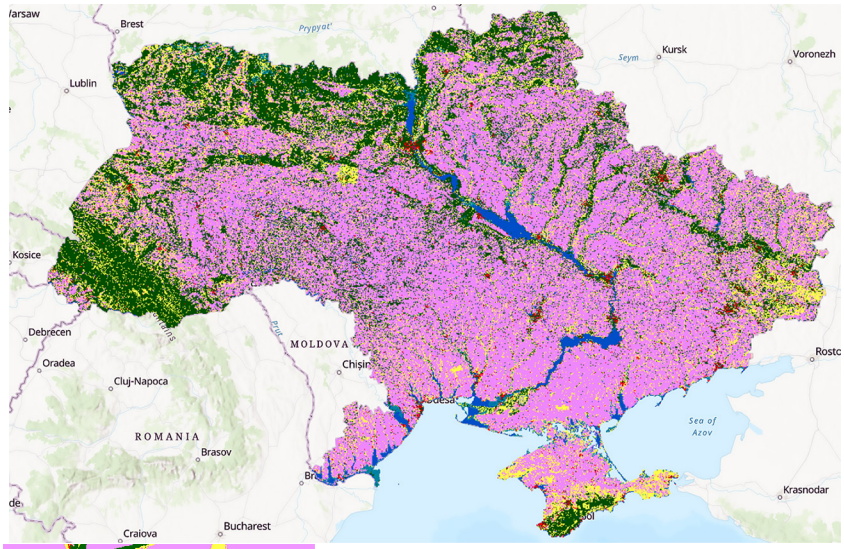
b)

------ State border of Ukraine;
------ Regional (oblast) borders;
------ Territorial community borders;
------ Rural and settlement TC*;
------ Urban TC*;
------ State (gov.) and other territories;
*TC – territorial community

Figure 1. *Geographical position (b) of Ukraine and its administrative-territorial division (a)*

Data sources. In this work, to study the earth's surface of Ukraine at the level of territorial communities, we used the product of the European Space Agency (ESA) WorldCover 2020 with global coverage with a resolution of 10 m. The classification method was based on spectral images from the Sentinel-1 and Sentinel-2 spacecraft (Fig. 2).

a)



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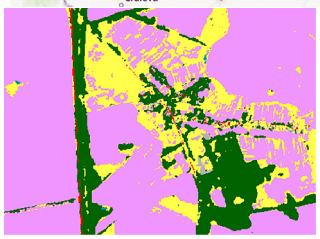

On the picture presented classified territories of Velyka Horbasha village, Chernyakhiv territorial community, Zhytomyr oblast

Forested areas – green;
Shrubs – yellow
Meadows, hayfields – lime
Cultivated land – pink
Built-up land – red
In more detail – Table 1

Figure 2. *Results of the European Space Agency's ESA WorldCover 2020 Earth Cover Classification for Ukraine (a) and for small village (b)*

ESA WorldCover's global product was created based on the developments of GlobCover and CCI Land Cover from the European Space Agency (Table 1). The algorithm used to create the ESA WorldCover product was based on the analysis of the dynamic annual map of multispectral images Sentinel-2, and radar data with synthetic aperture (SAR) of the C-band spacecraft Sentinel-1 (Arino *et al.,* 2008; Buchhorn *et al.,* 2020; Camp-Valls *et al.,* 2011). The WorldCover product prototype was statistically tested using an independent test data set. The verification was in line with the recommendations for the CEOS (Earth Observation Satellite Committee) verification (Phase 3). The results of the inspection showed that the overall accuracy of the WorldCover product is 74.4±0.1% for 2020. In terms of soil types, wood cover and snow/ice, classes of agricultural land, water bodies and bare/sparse vegetation were highly accurate, while classes of shrubs, grasses and mosses/lichens were mapped with less accuracy.

***Table 1**. Characteristics of earth cover classes according to the methodology of the European Space Agency ESA WorldCover 2020*

Code	Name	Feature
10	Forested areas	This class of land cover includes any geographical area in which there are forested areas with a cover of at least 10%. Areas planted with trees, such as protective forest belts, parks, and orchards, are included in this class
20	Shrubs	This class includes any geographical area dominated by natural shrubs with a cover of 10% or more. Shrubs are defined as woody perennials with stable and woody stems and without any defined main stem less than 5 m tall
30	Meadows, hayfields, pastures	This class includes any area dominated by natural herbaceous plants (plants without a stable stem or shoots above the ground and without a clear solid structure) meadows, prairies, steppes, savannas, pastures with a coverage of 10% or more, regardless of the type of human and/or animal activity
40	Cultivated lands	Land cover covered with cultivated annual crops. Greenhouses are considered built up
50	Built-up land	Land cover, which houses, roads, railways, and other anthropogenic objects. Houses include both residential and industrial buildings. Asphalt and concrete roads are included in this class
60	Rarefied vegetation	Land cover with open ground, sand, or stones, never has more than 10% of vegetation cover at any time of the year
70	Snow and ice	This class includes any geographical area that is permanently covered by snow or glaciers
80	Permanent reservoirs	This class includes any geographical area covered by water bodies for most of the year: lakes, reservoirs, and rivers. There can be both fresh and salt water. In some cases, water can freeze for part of the year, but not less than 9 months per calendar year
90	Grassy wetlands	Land cover dominated by natural grassy vegetation (10% or more cover), which is constantly or regularly flooded with fresh or salt water
95	Mangrove thickets	Taxonomically diverse, salt-resistant trees and other plant species thrive in tidal protected tropical coastal areas, islands, and estuaries
100	Moss and lichen	Land covered with lichens and/or mosses. Lichens are complex organisms formed because of a symbiotic association of fungi and algae

***Source**: Arino et al., 2008*

RESULTS AND DISCUSSION

The product of the classification of the Earth's cover of our planet is the observed physical cover of the Earth, divided into classes based on a certain method. Today we can distinguish two main methods of monitoring the state and dynamics of changes in land cover: field surveys and analysis of remote sensing. The first method is exceptionally reliable but requires large investments for scaling (coverage of territories at the regional, national, and global levels). The basis for the second method is the processing of information from remote Earth sensing using ground, aviation, or space survey. The method of remote sensing analysis has several features: 1) global scale; 2) a deep time series of observations allows tracking changes over time (Landsat products have been available since 1972); 3) enables operational monitoring of any geographical area; 4) low quality compared to field surveys.

In this work, we used the results of the ESA WorldCover product to analyse the state and structure of the earth's cover in Ukraine. The results of such an analysis prove the high reliability of the coincidence of official data and the results obtained (Table 2). Thus, the total area of the country obtained as a result of processing the ESA WorldCover product differs by 0.6% from the official data. A similar analysis conducted at the oblast level also shows a prominent level of coincidence in all oblasts except Mykolaiv (-2.4%), Kherson (-6.3%) and the ARC (-5.5%). Such significant deviations require more in-depth study.

***Table 2**. Land cover of Ukraine according to the results of processing the product ESA WorldCover, thousand hectares*

Type of land cove / Admin. unit	Forested areas	Shrubs	Meadows	Cultivated lands	Built-up land	Rarefied vegetation	Permanent reservoirs	Grassy wetlands	In total	Official Square (Rahman *et al.*, 2012)	Deviation
Vinnytsia	593	0.0	234	1736	25	11	29	11	2,640	2,651	-0.4
Volyn	840	0.1	438	659	11	13	15	38	2,015	2,014	0.0
Dnipropetrovsk	365	0.1	400	2,171	60	33	127	34	3,191	3,191	0.0
Donetsk	377	0.0	453	1,671	72	29	29	19	2,650	2,652	-0.1
Zhytomyr	1,338	0.0	560	981	19	33	14	38	2,984	2,983	0.0
Zakarpattia	871	0.2	240	141	15	4	4	1	1,276	1,278	-0.1
Zaporizhzhia	143	0.0	269	2,060	41	15	159	32	2,718	2,718	0.0
Ivano-Frankivsk	747	0.0	271	346	14	7	8	1	1,393	1,390	0.2
Kyiv	894	0.0	341	1,318	38	31	118	72	2,813	2,813	0.0
Kirovohrad	282	0.0	194	1,874	18	12	65	12	2,458	2,459	0.0
Luhansk	505	0.0	703	1,353	36	38	11	22	2,669	2,668	0.0
Lviv	903	0.0	519	708	27	8	11	6	2,182	2,183	0.0
Mykolaiv	140	0.1	301	1,838	37	12	48	26	2,402	2,460	-2.4
Odesa	290	0.1	441	2,236	62	29	169	109	3,335	3,331	0.1
Poltava	451	0.0	340	1,861	23	16	104	77	2,872	2,875	-0.1
Rivne	870	0.2	400	618	16	25	10	66	2,005	2,005	0.0
Sumy	672	0.0	375	1,285	15	10	13	15	2,384	2,383	0.0
Ternopil	295	0.0	135	922	14	7	8	3	1,383	1,382	0.1
Kharkiv	601	0.0	420	1,998	35	23	38	28	3,143	3,142	0.1
Kherson	105	0.0	319	1,850	34	39	217	100	2,666	2,846	-6.3
Khmelnytskyi	437	0.0	227	1,338	17	10	24	11	2,063	2,065	-0.1
Cherkasy	492	0.0	142	1,284	20	12	112	33	2,094	2,090	0.2
Chernivtsi	333	0.0	123	325	12	5	11	1	809	810	0.0
Chernihiv	1,034	0.0	545	1,487	13	16	23	70	3,189	3,187	0.1
ARC	300	0.0	777	1,201	64	48	39	47	2,477	2,620	-5.5
Ukraine	**13,977**	**1.1**	**9,194**	**33,272**	**767**	**493**	**1,414**	**872**	**59,991**	**60,355**	**-0.6**

Analysis of the land cover of Ukraine shows that over half of the country's surface (33,272 thousand hectares) is cultivated land (Fig. 3), i.e., land that is subject to tillage operations. At the same time, according to the official data of the State Statistics Service of Ukraine (SSSU), the area of cultivated land is 27,046.2 thousand hectares (Pyvovar & Pyvoar, 2021), i.e., the difference is 23%. This discrepancy is primarily due to the method of collecting information from agricultural enterprises and rural households of the SSSU. But cultivated land cannot be called agricultural, as part of the agricultural land belongs to the class of meadows and hayfields. 23.3% of the territory of Ukraine is forested areas, while according to official data of the SSSU this figure is 17.7%. The difference of 6% or 3,621 thousand hectares is because the forested areas according to ESA WorldCover include both forests and areas planted with trees (protective forest belts, parks, and orchards).

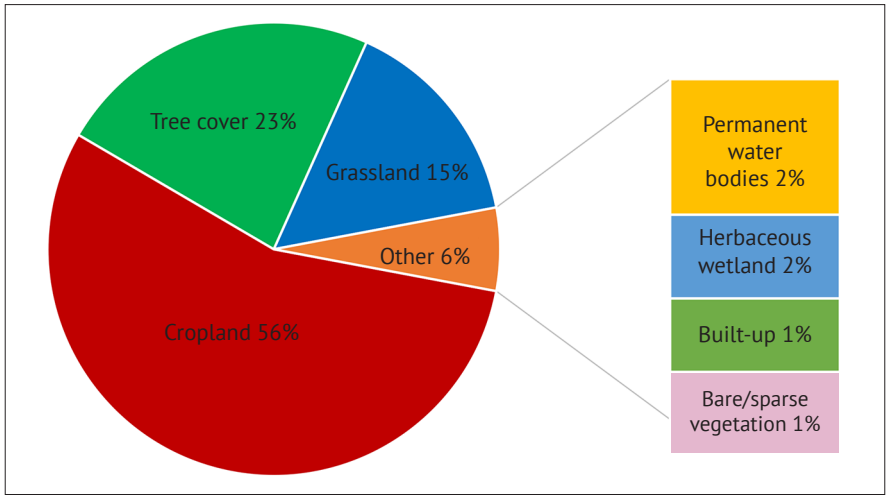

***Figure 3**. The structure of the land cover of Ukraine according to the product ESA WorldCover, 2020*

Rural areas are a multifunctional socio-spatial entity that functions as a synergistic unity of human, natural and economic potentials with their inherent characteristics: open natural space prevails over buildings, traditional rural way of life and primary processing of resources into goods or services to meet their own needs and ensure development (Pyvovar & Pyvovar, 2021). To divide rural and urban areas, we used the classification of territorial communities of Ukraine into urban, settlement and rural. At the same time, urban and rural communities are the basis of rural areas, and urban communities, respectively, urban areas. As a result of combining ESA WorldCover land cover data and landfills of territorial communities of Ukraine, we structured the territories of oblasts into rural and urban areas (Figure 4).

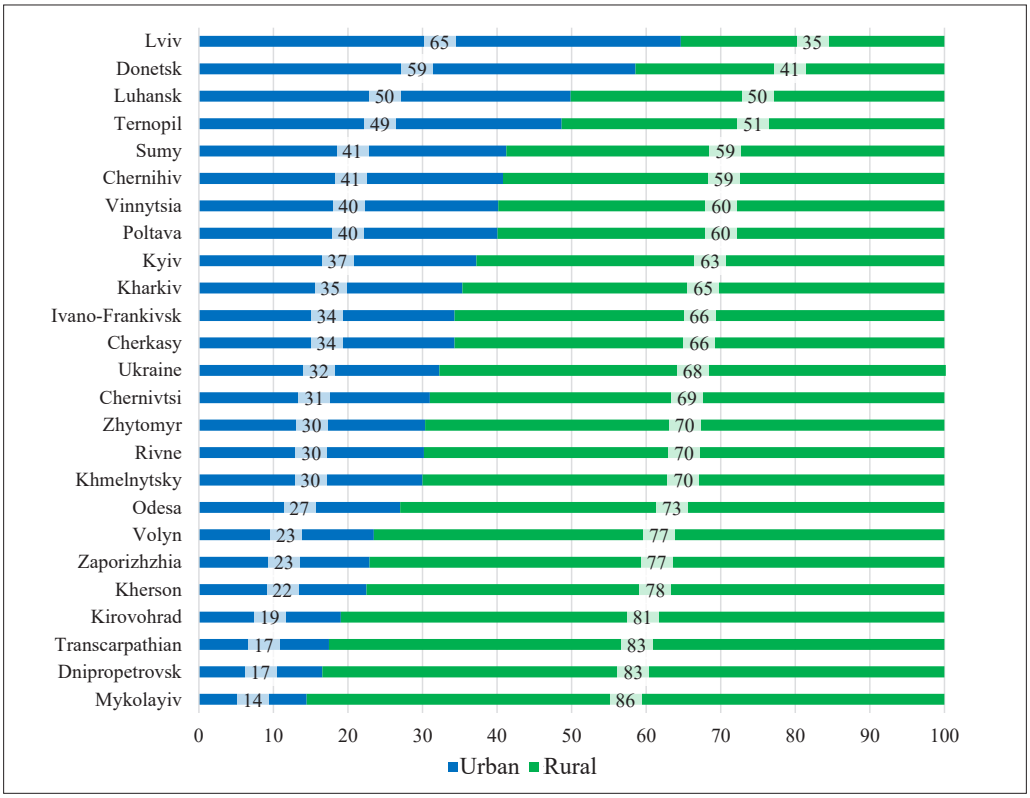

***Figure 4**. The structure of the territories of Ukraine at the regional level according to the product ESA WorldCover, 2020*

According to Figure 4, 32% of the surface of Ukraine can be attributed to urban, respectively 68% – to rural. The largest share of rural territories is represented in such oblasts as Mykolaiv (86%), Dnipropetrovsk (83%) and Zakarpattia (83%). The oblasts with the highest proportion of urban areas are Lviv (65%), Donetsk (59%) and

Luhansk (50%). Geographical features and location of oblasts are not factors that affect the distribution structure of rural and urban areas.

Forested areas are parts of the land cover where the share of tree cover is not less than 10%. Such areas include forests, protective forest belts, agricultural orchards, forest parks. According to ESA WorldCover data, 23.3% of Ukraine's territory is covered by forested areas. According to official data from the SSSU, the same figure is 17.7% (Fig. 5) (Shubravska & Prokopenko, 2016). The difference of 6% or 3621 thousand hectares are forest belts, orchards, parks, and other forested areas. Forests in Ukraine are concentrated in Polissia and the Ukrainian Carpathians (Fig. 6).

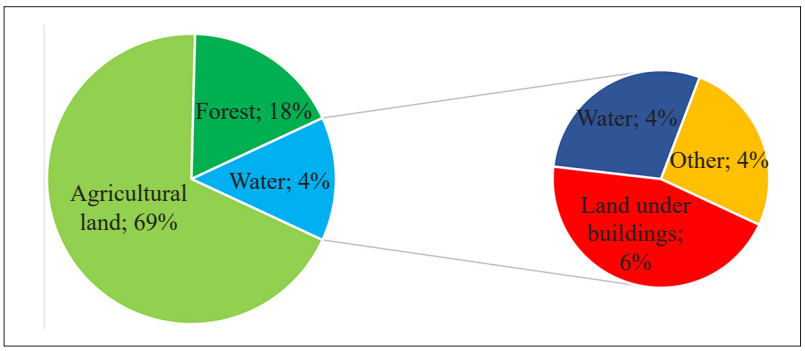

Figure 5. *The structure of the land cover of Ukraine according to the official data from the SSSU*
Source: *(Shubravska & Prokopenko, 2016)*

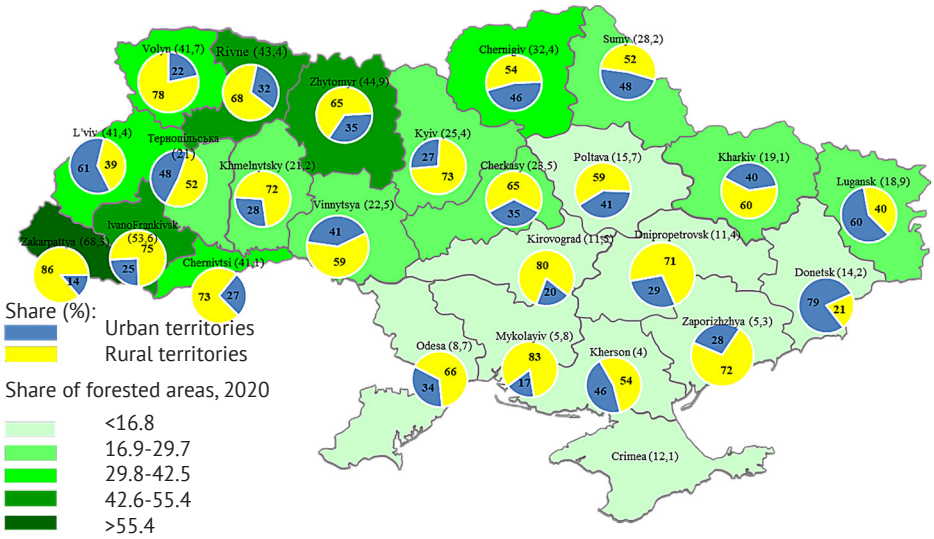

Figure 6. *Structure and distribution of forested areas of Ukraine at the regional level according to the product ESA WorldCover, 2020*

The most forested areas are Zakarpattia (68%), Ivano-Frankivsk (54%) and Zhytomyr (45%) oblasts, while the least forested are Kherson (4%), Zaporizhzhia (5%) and Mykolaiv (6%) oblasts. In general, 71% of forested areas are rural and 29% are urban. The oblasts with the largest share of forested areas in rural areas are Zakarpattia (86%), Mykolaiv (83%), Kirovohrad oblast (80%), and the smallest – Ternopil (43%), Luhansk (40%), Lviv (39%).

15% of the territory of Ukraine is covered with meadows, hayfields, and pastures – a class of land cover, which includes areas with vegetation of 10% or more, regardless of the type of human and/or animal activity. Meadows – a plot of soil in conditions of sufficient or excessive moisture, covered with perennial herbaceous plants, mainly cereals and sedges. It is usually used as pasture for livestock and as hayfields. All meadows are characterised by the presence of grass and turf. Hayfields (hayfields) are also called agricultural lands, the vegetation of which is constantly used for hay production. This is one of the main types of fodder base for livestock in the post-vegetation period and in general during stall keeping. Pastures – land covered with vegetation used by animals (livestock, poultry) as forage. 66% of the territories of this class fall on rural areas, respectively on urban areas – 34%. This class of territories is a vital part of the functioning and restoration of territorial ecosystems. Most of them are concentrated in Luhansk (26%), Lviv (24%) and Volyn (22%) oblasts, while the least in Cherkasy (7%), Kirovohrad (8%) and Vinnytsia (9%) oblasts (Fig. 7).

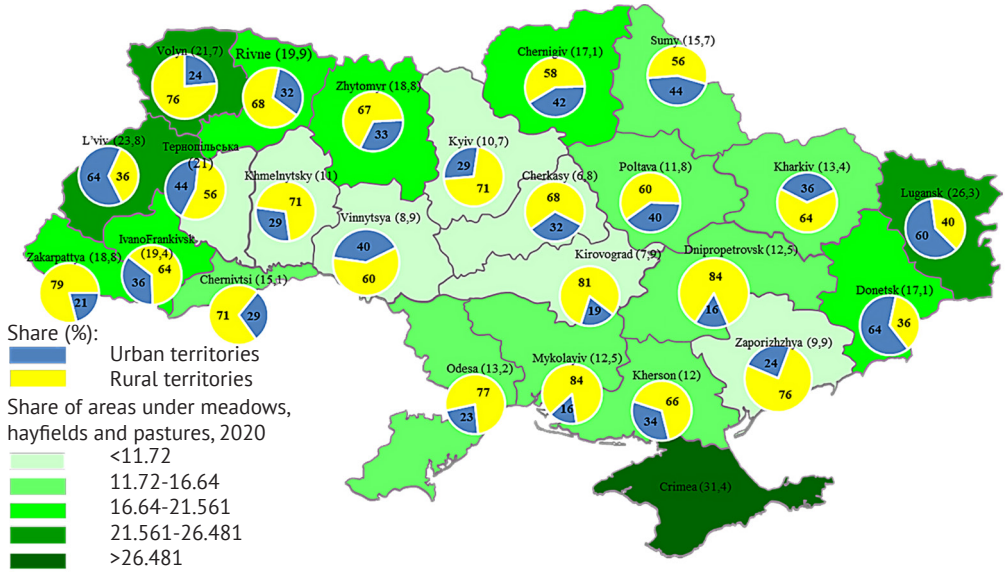

***Figure 7**. Structure and distribution of the territories of Ukraine under meadows, hayfields and pastures at the regional level according to the ESA WorldCover product, 2020*

Cultivated land – land that is systematically cultivated and used for growing crops. However, according to the ESA WorldCover methodology, indoor land (greenhouses, hotbeds, and insulated nurseries) does not fall into this category. Given the small share of closed land (greenhouses), cultivated land can be compared with the level of ploughing. In total, 55% of Ukraine's territory is cultivated, while according to the Food and Agriculture Organisation (FAO), the level of ploughing in Ukraine is 53.9%. For comparison, in Poland this figure is 36.5%, in Germany 34.1%, in the United States – 17.5% (Nguyen & Liou, 2019a). According to ESA WorldCover, 70% of rural areas are cultivated and 30% in urban areas. The leaders among the oblasts with the largest share of cultivated lands are Zaporizhzhia (76%), Kirovohrad (76%), Mykolaiv (77%). Therewith, in rural areas, ploughing is 80%, 81% and 87%, respectively (Figure 8). Respectively, the lowest share of cultivated lands was in Rivne (31%), Ivano-Frankivsk (25%) and Zakarpattia (11%) oblasts with the corresponding level of ploughing of rural areas 72%, 49% and 70%.

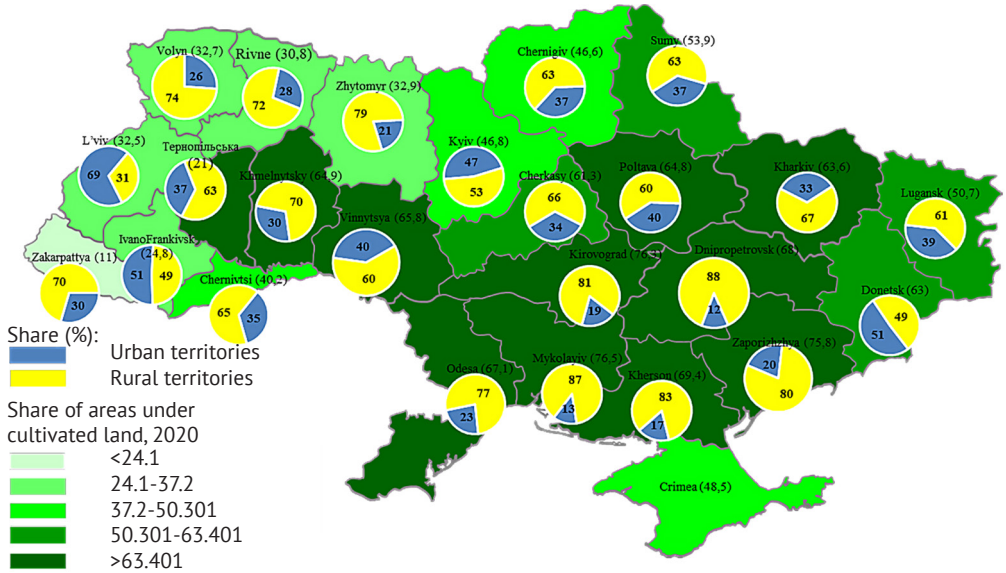

***Figure 8**. Structure and distribution of territories of Ukraine under cultivated lands at the regional level according to the ESA WorldCover product, 2020*

Permanent reservoirs are parts of the land cover with inland waters that are permanently or temporarily (not less than 9 months during the year) and have the form of various water bodies (streams, reservoirs). According to the analysis of ESA WorldCover data in Ukraine, about 2.3% of the territories are under open water, of which 71% are in rural territories and 29% in urban territories. The leading oblasts in terms of surface

water supply were Cherkasy (5%), Zaporizhzhia (6%) and Kherson (8%) with the respective shares of 64%, 63% and 82% in rural areas (Fig. 8). In turn, the oblasts with the smallest share of open water areas are Zhytomyr (0.5%), Luhansk (0.4%) and Zakarpattia (0.3%) oblasts with the respective shares of rural areas at 77%, 33% and 46 % (Fig. 9).

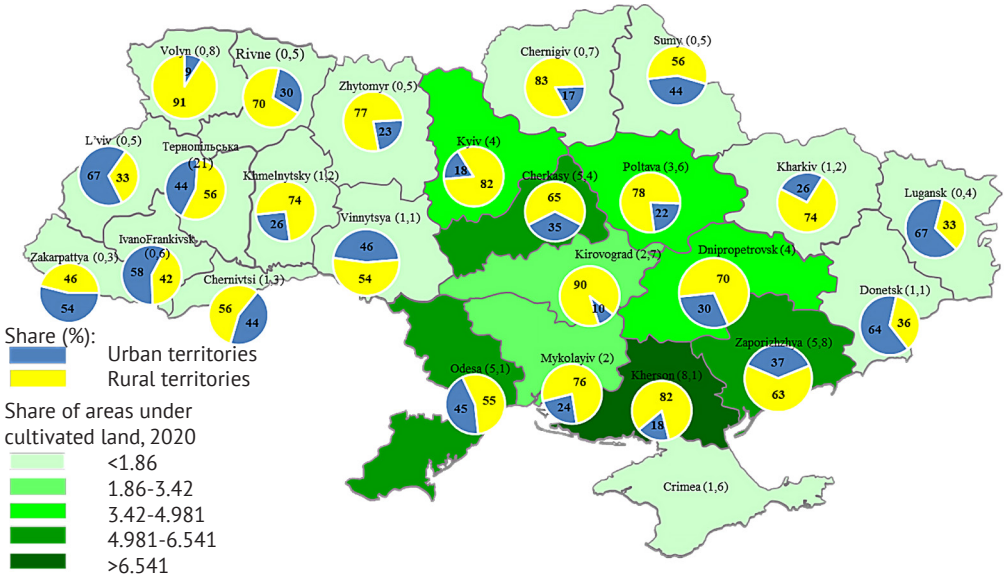

***Figure 9**. Structure and distribution of territories of Ukraine under open waters at the regional level according to the product ESA WorldCover, 2020*

The use of the product ESA WorldCover, 2020 for the analysis of land cover classes of Ukraine has shown high recognition results at two types of levels: national and regional, rural, and urban. However, some minor discrepancies were noted, namely the fact that some recognition results, especially for small plots (less than 1 hectare), do not correspond to real data. Furthermore, some fallow lands were incorrectly classified as wetlands. Some of the forested areas in certain areas have been classified as swamps or meadows, which we believe is due to fluctuations in humidity. The class of human infrastructure facilities (settlements, industrial facilities) is still difficult to classify. Also, high heterogeneity, a combination of small artificial (buildings, roads) and semi-natural objects (homesteads, lawns, wastelands) in many cases is not classified correctly.

In recent years, several scientific papers have appeared on the analysis and use of terrestrial classification products (Lyalko *et al.,* 2006; Lyzhnyk & Svidzinskaya, 2014). A significant amount of European research focuses on the analysis of coverage, which is the basis for land management in the European Union. The publications focus on the issues of land cover classification algorithms and data verification methods (Zibtsev *et al.,* 2015). Similar works were carried out for the territory of Ukraine to improve the quality and accuracy of data. Based on the use of this data, several new data processing methods using machine leaning methods have been created (Kusul *et al.,* 2015). At the same time, the question of further application of classification data for the development of regional policy based on the concept of sustainable development is still open.

CONCLUSIONS

The classification of land cover based on satellite imagery is vital in decision-making in business and in regional and national governance. Businesses receive up-to-date information on the state of the natural object – the object of production, while state and regional authorities can use this information for strategic development planning, development of support programs, etc. In general, 68% of Ukraine's territory is rural, with 64% of forested areas, 70% of cultivated lands, 71% of open water areas and 66% of meadows, pastures, and hayfields. The analysis shows that Ukraine is characterised by a high degree of land development. Thus, in 2020, 55.5% of their total area was cultivated. A characteristic feature of Ukraine's land structure is a significant share of land (15.3%) under meadows, hayfields, and pastures, which play a significant role in restoration and preservation of groups and are an essential element in the functioning of regional ecosystems. Forested areas by their purpose and location can perform several important functions, the most important being water protection, preservation, sanitation, recreation, and meeting the needs of society in wood. The level of afforestation in Ukraine is 23.3%, with 17.7% of the territory being forests and the other 6% being protective forest belts, orchards, and arboretums. At the same time, the level of afforestation in Ukraine is one of the lowest among the EU countries, where it is 38%. In Ukraine, the share of surface waters covering the geographical area is 2.4% and the distribution of these waters between oblasts is uneven. Thus, the leading oblasts in terms of surface water supply in 2020 were Cherkasy (5%), Zaporizhzhia (6%) and Kherson (8%). In the same period, the lowest level of surface water supply was found in Zhytomyr (0.5%), Luhansk (0.4%) and Zakarpattia (0.3%) oblasts.

REFERENCES

[1] Arino, O., Bicheron, P., Achard, F., Latham, J., Witt, R., & Weber, J.L. (2008). GlobCover the most detailed portrait of Earth. *ESA Bulletin*, 136, 25-31.

[2] Braun, A., & Hochschild, V.A. (2017). SAR-based index for landscape changes in African savannas. *Remote Sensing*, 9, article number 359. doi: 10.3390/rs9040359.

[3] Buchhorn, M., Lesiv, M., Tsendbazar, N.-E., Herold, M., Bertels, L., & Smets, B. (2020). Copernicus global land cover layers—collection 2. *Remote Sensings*, 12(6), article number 1044.

[4] Camps-Valls, G., Benediktsson, J.A., Bruzzone, L., & Chanussot, J. (2011). Introduction to the issue on advances in remote sensing image processing. *IEEE Journal of Selected Topics in Signal Processing*, 5, 365-369.

[5] Chen, Z., Wang, L., Wei, A., Gao, J., Lu, Y., & Zhou, J. (2019). Land-use change from arable lands to orchards reduced soil erosion and increased nutrient loss in a small catchment. *Science of the Total Environment*, 648, 1097-1104.

[6] Constitution of Ukraine (1996, June). Retrieved from https://zakon.rada.gov.ua/laws/show/~93~254%D0%BA/96-%D0%B2%D1%80#n4603.

[7] da Cunha, E.R., Santos, C.A.G., da Silva, R.M., Bacani, V.M., & Pott, A. (2021). Future scenarios based on a CA-Markov land use and land cover simulation model for a tropical humid basin in the Cerrado/Atlantic forest ecotone of Brazil. *Land Use Policy*, 101, article number 105141.

[8] Halder, A., Ghosh, A., & Ghosh, S. (2011). Supervised and unsupervised landuse map generation from remotely sensed images using ant-based systems. *Applied Soft Computing*, 11, 5770-5781.

[9] Hashem, N., & Balakrishnan, P. (2015). Change analysis of land use/land cover and modelling urban growth in Greater Doha, Qatar. *Annals of GIS,* 21, 233-247.

[10] Hoque, M.Z., Islam, I., Ahmed, M., Hasan, S.S., & Prodhan, F.A. (2022). Spatio-temporal changes of land use land cover and ecosystem service values in coastal Bangladesh. *The Egyptian Journal of Remote Sensing and Space Science*, 25(1), 173-180.

[11] Kussul, N.M., Shelestov, A.Yu., Skakun, S.V., Basarab, R.M., Yaylimov, B.Ya., Lavrenyuk, M.S., Kolotiy, A.V., & Yashchuk, D.Yu. (2015). Retrospective regional map of the earth's cover for Ukraine: Methodology of construction and analysis of results. *Space Science and Technology*, 21(3), 31-39.

[12] Liou, Y.A., Nguyen, A.K., & Li, M.H. (2017). Assessing spatiotemporal eco-environmental vulnerability by Landsat data. *Ecological Indicators*, 80, 52-65.

[13] Lyalko, V.I., Shportyuk, Z.M., Sakhatskyi, O.L., & Sybirtseva, O.M. (2006). Land cover classification in Ukrainian Carpathians using the MERIS Terrestrial Chlorophyl Index and red edge position from ENVISAT MERIS data. *Space Science and Technology*, 12, 10-14.

[14] Lyzhnyk, G.L., & Svidzinskaya, D.V. (2014). Analysis of the modern structure of land use based on decoding remote sensing data (on the example of Murovanokurilovetsky district of Vinnytsia region). *Journal of Cartography*, 10, 90-97.

[15] Maxwell, A.E., Warner, T.A., & Fang, F. (2018). Implementation of machine-learning classification in remote sensing: An applied review. *International Journal of Remote Sensing*, 39, 2784-2817.

[16] Mutanga, O., Odindi, J., & Abdel-Rahman, E.M. (2014). Land-use/cover classification in a heterogeneous coastal landscape using Rapid Eye imagery: Evaluating the performance of random forest and support vector machines classifiers. *International Journal of Remote Sensing*, 35, 3440-3458.

[17] Nguyen, A.K., Liou, Y.A., Li, M.H., & Tran, T.A. (2016). Zoning eco-environmental vulnerability for environmental management and protection. *Ecological Indicators*, 69, 100-117.

[18] Nguyen, K.A., & Liou, Y.A. (2019a). Global mapping of eco-environmental vulnerability from human and nature disturbances. *Science of the Total Environment*, 664, 995-1004.

[19] Nguyen, K.A., & Liou, Y.A. (2019b). Mapping global eco-environment vulnerability due to human and nature disturbances. *MethodsX*, 6, 862-875.

[20] Pyvovar, P.V., & Pyvovar, A.M. (2021). Formation of the definition of "rural areas" as an economic category. *Agrosvit*, 11, 21-33. doi: 10.32702/2306-6792.2021.11.21.

[21] Rahman, A., Kumar, S., Fazal, S., & Siddiqui, M.A. (2012). Assessment of land use/land cover change in the North-West District of Delhi using remote sensing and GIS techniques. *Journal of the Indian Society of Remote Sensing*, 40, 689-697.

[22] Shubravska, O.V., & Prokopenko, K.O. (2016). Agriculture of Ukraine: State and resource development opportunities. *The Economy of Agro-Industrial Complex*, 11, 19-25.

[23] Official webcite of State Statistics Service of Ukraine (n.d.). Retrieved from http://www.ukrstat.gov.ua/.

[24] Stehman, S.V., Pengra, B.W., Horton, J.A., & Wellington, D.F. (2021). Validation of the US geological survey's land change monitoring, assessment and projection (LCMAP) collection 1.0 annual land cover products 1985-2017. *Remote Sensing of Environment*, 265, article number 112646.

[25] Talukdar, S., & Pal, S. (2018). Wetland habitat vulnerability of lower Punarbhaba river basin of the uplifted Barind region of Indo-Bangladesh. *Geocarto International*, 35(8), 857-886.

[26] Talukdar, S., Singha, P., Mahato, S., Praveen, B., & Rahman, A. (2020). Dynamics of ecosystem services (ESs) in response to land use land cover (LU/LC) changes in the lower Gangetic plain of India. *Ecological Indicators*, 112, article number 106121.
[27] Viana, C.M., Girão, I., & Rocha, J. (2019). Long-term satellite image time-series for land use/land cover change detection using refined open source data in a rural region. *Remote Sensing*, 11(9), article number 1104.
[28] Wu, L., Zhu, X., Lawes, R., Dunkerley, D., & Zhang, H. (2019). Comparison of machine learning algorithms for classification of LiDAR points for characterisation of canola canopy structure. *International Journal of Remote Sensing*, 40, 5973-5991.
[29] Xu, S., Zhao, Q., Yin, K., Zhang, F., Liu, D., & Yang, G. (2019). Combining random forest and support vector machines for object-based rural-land-cover classification using high spatial resolution imagery. *Journal of Applied Remote Sensing*, 13(1), article number 014521.
[30] Zibtsev, S.V., Mironyuk, V.V., & Gilitukha, D.V. (2015). Dynamics of the forest cover of the Chornobyl Exclusion Zone according to the global map of high-resolution forest ecosystems. *Forestry and Horticulture*, 6. Retrieved from http://nbuv.gov.ua/UJRN/licgoc_2015_6_4.

Аналіз сільських територій України на основі продукту ESA WorldCover 2020

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Анотація. На сьогодні ГІС технології проникають в різні сфери соціально-економічного буття людства. В цій статті на основі ГІС технологій було проаналізовано основні класи земного покриву України з подальшим поглибленим вивченням в розрізі областей та сільських і міських територій. Відповідно до результатів цього дослідження на основі даних ESA WorldCover, 32 % територій України можна віднести до міських, відповідно 68 % – до сільських. В загалом, проведений аналіз демонструє що Україна характеризується високим ступенем освоєння земельного фонду, так на землі, які піддавались культивації у 2020 році припадало 55,5 % його площі. Сільські території на 70 % складаються з культивованих, міські території – 30 %. Лідерами серед областей із найбільшою часткою культивованих угідь є Запорізька (76 %), Кіровоградська (76 %), Миколаївська (77 %) при цьому на сільських територіях розорень становить 80 %, 81 % та 87 % відповідно. Характерною рисою структури земель України є суттєва частка земель (15,3 %) під луками, сіножатями та пасовищами, що виконують важливу роль як у процесі відновлення та збереження гуртів так і як важливий елемент функціонування регіональних екосистем. 66 % територій цього класу припадає на сільські території, відповідно на міські – 34 %. Найбільше їх зосереджено у Луганській (26 %), Львівській (24 %) та Волинській (22 %) областях. Рівень залісненості території України становить 23,3 %, причому 17,7 % територій це ліси, а інші 6 % – захисні лісосмуги, фруктові сади та дендропарки. На сільські території припадає 64 % заліснених територій. До найбільш заліснених територій відносяться Закарпатська (68 %), Івано-Франківська (54 %) та Житомирська (45 %), тоді як найменш залісненні Херсонська (4 %), Запорізька (5 %) та Миколаївська (6 %). В загалом 71 % заліснених територій припадає на сільські території та відповідно 29% – на міські. В Україні частка поверхневих вод, що покривають географічну територію становить 2.4 %, з яких 71 % припадає на сільські території, відповідно 29 % – на міські. Областями-лідерами по забезпеченню поверхневими водами були Черкаська (5 %), Запорізька (6 %) та Херсонська (8 %) з відповідними частками, що припадають на сільські території 64 %, 63 % та 82 % (Рис. 8.). В свою чергу до областей із найменшою часткою територій під відкритими водами відносяться Житомирська (0.5 %), Луганська (0.4 %) та Закарпатська (0.3 %) області з відповідними частками, що припадають на сільські території 77 %, 33 % та 46 %

Ключові слова: сільська місцевість, ГІС-технології, земний покрив, культивовані землі, заліснені території