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Degradation of Land Cover in the De-Occupied Territories of Ukraine

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Abstract

The land cover trend analysis helps to identify trends in land cover change, such as changes in the area and structure of natural ecosystems or in anthropogenic impacts on the environment. Such analysis will provide insight into the causes of the dynamics of natural ecosystems and help develop strategies for their conservation and restoration. An analysis of changes in cover in the de-occupied territories is necessary to assess the impact of anthropogenic factors on land use, that is important for making decisions on the rational use of natural resources, especially in the post-war period. The object of the research is the land cover of the Kharkiv region and its changes. The purpose and objectives of the research are to identify negative trends in the land cover of the Kharkiv region as a result of hostilities, using satellite data and open source statistics.

KEY WORDS: *degradation, Kharkiv region, land cover changes, de-occupied territories, agriculture, nature, war.*

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1. Introduction

The North-Eastern region of Ukraine has a strong mining and processing industry and significant agricultural potential. The intensive economic activity is causing significant land cover transformation, which leads to mostly negative consequences for natural ecosystems and the region's economy. Analyzing land cover change trends on the example of the Kharkiv region is an urgent task to understand the dynamics of changes and identify their causes. The analysis of land cover trends is of scientific importance in identifying land cover trends, which will contribute to understanding the causes of changes in natural ecosystems and developing strategies for their conservation and restoration. In addition, the analysis of land cover changes can be important for assessing the impact of anthropogenic and natural factors on land use, which is key in making decisions on the rational use of natural resources, especially in the post-war period.

The fires are a serious threat to people, nature and the economy of Ukraine. The use of geoinformation technologies allows for comprehensive analysis and monitoring of the fire situation, identifying hot spots and the most

vulnerable areas, predicting risks and effectively managing resources during firefighting. Given the increase in the number of fire incidents due to military operations, the using of geoinformation analysis is extremely important for preventing and fighting fires in Ukraine.

The object of the research is the land cover of the Kharkiv region and its changes.

The purpose and objectives of the research are to identify negative trends in the land cover of the Kharkiv region as a result of hostilities, using satellite data and open source statistics. The main objectives of the study are: to analyze statistical data on changes in the land cover of the Kharkiv region for the period 2015-2022; to analyze the state of land cover based on remote sensing materials; to identify trends in the change of certain land covers that have the largest share among all the covers of the Kharkiv region; to assess the impact of hostilities on the state of the Izyum forest and the air as a result of numerous forest fires using satellite data.

2. Method of Investigation

The main methods of our research are the analysis of remote sensing materials, in particular, Sentinal-2 and Sentinal-5P satellite images. To obtain detailed information on land cover changes for the period 2015-2022, we used the web sources Land Cover 2022 [1], Worldcover 2021 Map [2], Global Land Cover 2015 [3].

The mathematical and statistical method was used to process statistical information and obtain index images as a result of processing satellite images and obtaining thematic rasters.

The electronic resource Firms [4] was used to analyze fires. The resource analyses data from the MODIS imaging systems on the Terra, Aqua satellites and Viirs, that are available from the Suomi NPP and NOAA-20 satellites. The MODIS instruments on board Terra and Aqua EOS satellites continuously collect data, providing global coverage every 1-2 days. The MODIS instruments have a swath of 2330 km and have been available since November 2000 (for Terra) and July 2002 (for Aqua) to the present. For MODIS, a pixel is approximately 1 km, and for VIIRS, it is approximately 375 m. Each hotspot of detected active fire represents the center of the pixel that contains one or more fires and other thermal anomalies (e.g. volcanoes). The center point of the pixel doesn't necessarily represent the coordinates of the actual fire. The fire detection is performed by an algorithm that uses the powerful mid-infrared radiation from the fire. NASA's MODIS algorithm inspects each pixel of the MODIS band and assigns each pixel one of the following classes: missing data, clouds, water, non-fire, fire, or unknown. For the pixels classified as thermal anomalies, latitude and longitude data are provided.

The research used data from the MODIS hyperspectral imaging system. The attribute table provides the following information about each fire: latitude, longitude, channel brightness temperature (in Kelvin), time of data acquisition, satellite, confidence level, data type, fire radiation power, daytime or nighttime fire. For further geoinformation analysis, statistical information for the state of Ukraine for 2022 on all types of fires recorded by the MODIS imaging system in csv format was downloaded from the Firms website. The table was loaded into QGIS by adding a text layer, after which the layer was exported to a shapefile.

3. Investigation Results

The results of the analysis of land cover changes conducted using the Global Land Cover service [3] and statistical data of the Kharkiv region [5] are presented in the graphs (Fig. 1, 2). Land cover trends reflect the interaction of various factors, such as climate change, human activity, development, pollution, and warfare. The knowledge and consideration of these trends is key to developing strategies for biodiversity conservation, provision of environmental services and sustainable economic development.

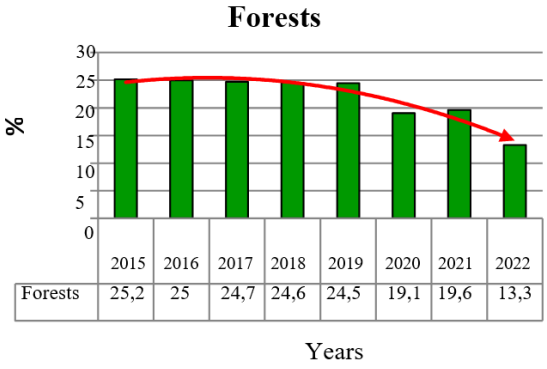

Fig. 1. Graph and polynomial trend line of forest cover change for 2015-2022.

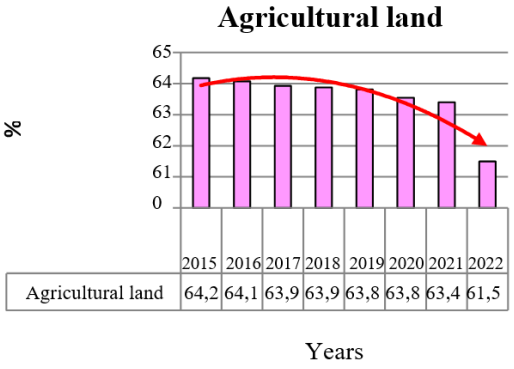

Fig. 2. Graph and polynomial trend line of changes in agricultural land cover in 2015-2022.

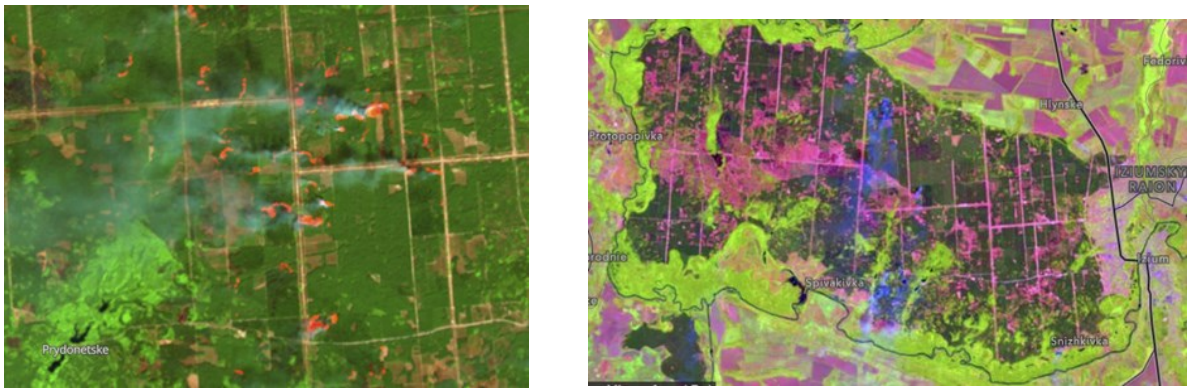

Fig. 3. Sentinal-2 satellite images of 06.05.2022 of forest fires in the Izium forest, Kharkiv region, caused by military operations in the spring of 2022 in natural colors and SWIR combination.

The forests cover a significant area of the Kharkiv region (over 20%) and play an important role in the industrial sector of export production. Following the extremely strong impact of the hostilities in 2022, the forest cover of the Kharkiv region has become a focus of special attention. The Izyum forest in Kharkiv region was severely affected by the military events, suffering extensive damage from fires caused by the fighting. The significant areas of the forest have burned out,

especially after the summer fires of 2022, as can be seen on satellite imagery (Fig. 3). In addition, the danger from forest fires is the release of CO2, a greenhouse gas equivalent that exacerbates climate change. Another dangerous gas is NO2 - nitrogen dioxide caused by the burning of fossil fuels and biomass.

The Fig. 4 shows a fragment of the Sentinal-5P satellite image, that examines the state of the atmosphere. As a result of the fire, the concentration of nitrogen dioxide in the atmosphere over the forest area is maximum. The image shows the increased concentration in shades of green to brown. The damage caused to the air as a result of emergencies and hostilities during martial law in 2022 was calculated to be in the total amount of UAH 9277642,200 thousand [2].

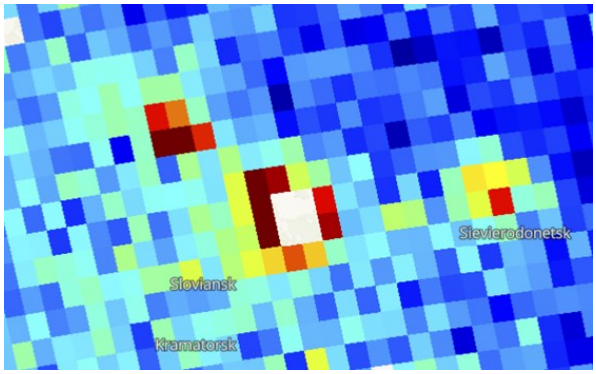

Fig. 4. Increased content of nitrogen dioxide in the atmosphere on the territory of the Izyum forest as of 03.05.2023 according to the Sentinal-5P satellite data.

The results of the analysis of land cover change in Kharkiv region show an extraordinary level of economic development of the region's land. The general trend since 2015 has been a decrease in forests and agricultural land, with a significant reduction in 2022, which is the result of hostilities and their consequences. The military operations lead to a number of mechanical, physical and chemical impacts on the land cover. The vegetation destruction, soil disturbance, and desertification are common consequences of military and technological pressure. In particular, land cover degradation due to military operations has become a major trend in land cover change. The hostilities in the Kharkiv region have severely damaged all natural resources: land areas have been contaminated and polluted with various wastes, the air has been polluted by explosions and fires, water bodies, forest resources and biota have fallen victim to enemy equipment, pollution and deliberate destruction. As a result of the armed aggression of the russian federation against Ukraine, the significant damage has been done to land resources. According to the National Scientific Centre "A.N. Sokolovsky Institute of Soil Science and Agrochemistry", the greatest impact on agricultural land and soil cover is caused by enemy aircraft and artillery (80% of the surveyed areas) [6]. The air, soil, and water pollution can cause significant reductions in yields, food contamination, and threats to human health. During the war, more than 20,000 facilities were damaged or destroyed in the region, 31% of which were in Kharkiv. Of the total number of protected areas in the temporarily occupied territory and in the combat zone, there were 84 protected areas covering an area of 35.1 thousand hectares (46.8% of the total area) in Izium, Kupiansk, Kharkiv, and Chuhuiv districts of Kharkiv region [5].

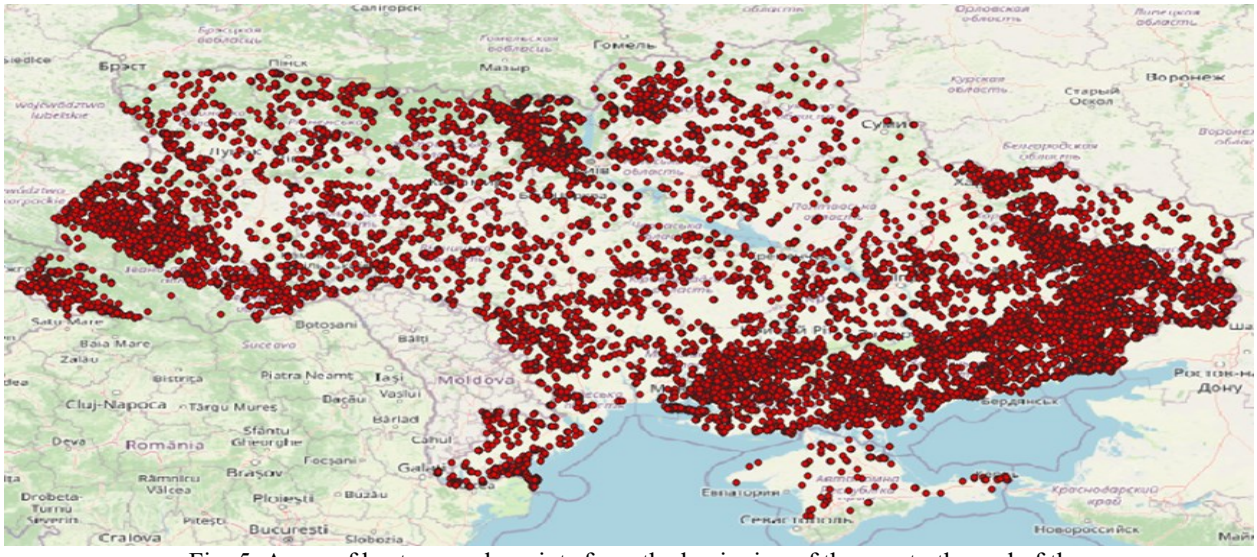

Fig. 5. Array of heat anomaly points from the beginning of the war to the end of the year.

For a more detailed study of land cover changes related to military activities, including the destruction of the humus horizon, soil contamination with metal fragments and explosive residues, and soil contamination with heavy metals, field research and the use of high-resolution aerial or space imagery are needed.

The general statistical information on the fire situation was obtained in QGIS, based on the Firms resource, and displayed through the basic statistics option for 2022: the total number of recorded thermal anomalies was 15327; the initial temperature in Kelvin (K) was converted to °C and contained the following critical values: min 26.85 °C, max 180.65 °C. The next step in the data processing was to select and save the sample of the number of fires for the period from the beginning of the war on 24 February 2022 to the end of the year. There were 14992 such anomalies. Among them, the anomalies with low level of confidence were removed, which are those that are less than 15 K (according to the Firms resource). They mainly include pixels with sun glare. The created sample from the attribute table of all anomaly values above 15 K contains 14709 values of thermal anomalies of high confidence (Fig. 5).

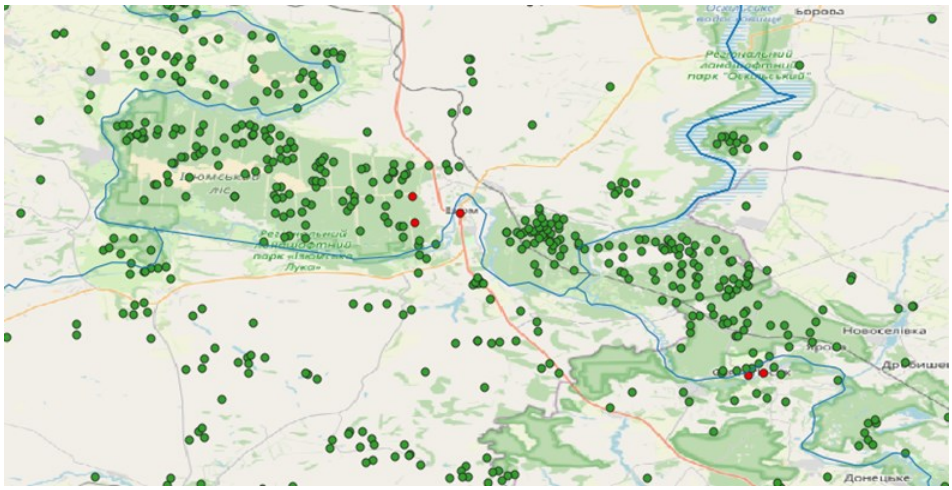

Fig. 6. Map's fragment of classification of thermal anomalies by type (Izium forest area).

Further analysis of the point array involves determining the number of heat anomalies by type. We classify all the anomalies by type and colour the points accordingly: thermal anomalies caused by vegetation burning - green; 2 - thermal anomalies caused by static ground sources - red. Vegetation fires predominate on the territory of the Izyum forest, and, accordingly, most of them are green (Fig. 6).

Fig. 7. Heat map of the fire situation from the beginning of the war to the end of 2022.

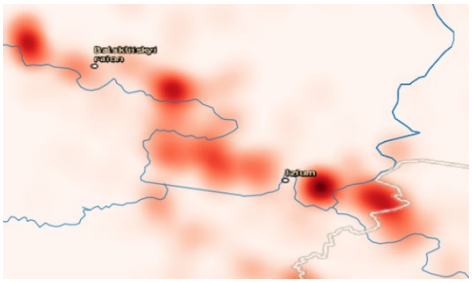

Fig. 8. Fragment of the heat map for the territory of the Izyum forest in Kharkiv region.

To identify the hottest spots in Ukraine, the heat map was created (Fig. 6). The input data is the brightness temperature of the pixels, that are classified into three gradations with uniform distribution: 27.0 - 78.0 (14163 values, the largest number); 78.1 - 129.0 (528 values); 129.1 - 181 (18 values). The heat map shows the 18 hottest points with their temperature values in °C (Fig. 7, 8).

4. Conclusions

Thus, the following actions and measures can be recommended to overcome the consequences of the hostilities and restore economic activity:

- to conduct demining the territories of the region's nature reserves and forests;
- to conduct a comprehensive study on the assessment of the degree of contamination of territories and soils;
- to establish the necessary measures to clean up the territory and restore its suitability for agriculture;
- to establish control over the quality of air, soil and water;
- to introduce support from the state and local authorities.

The GIS analysis from the beginning of the war to the end of 2022 revealed 14709 thermal anomalies of high reliability, including maximum value of 180.65 °C and minimum of 26.85 °C. The highest temperatures were recorded at 18 locations between 22.03.2022 and 31.07.2022. Among these 18 outbreaks, the largest number occurred in two months - August/September. The heat map shows the foci and spread of fires across Ukraine, that corresponds to active hostilities during this period.

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