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Dynamics of forest stands changes on the territory of Skole Beskydy National Nature Park

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Abstract. The relevance of the study is determined by the issue of assessing the condition and utilization of forest cover within the territory of the Skole Beskydy National Nature Park, as well as the necessity to develop effective methods for monitoring and conserving forest ecosystems. The purpose of the study was to investigate the dynamics of forest cover changes within the Skole Beskydy National Nature Park, as well as to assess the losses of forest resources in this area and recommend the obtained series of images to enhance the forest management system. The research was conducted using a comprehensive approach combining various methods of studying forest cover changes and their comparison. The basis for applying remote sensing technologies was the use of specific multispectral satellite images combined with attribute information on forest land geospatial data. The most progressive methods of studying changes in forest plantations based on remote sensing data using geographic information systems have been demonstrated. Satellite images were obtained from the Landsat 8 satellite data set through the United States Geological Survey data portal. The normalized burn ratio and normalized difference vegetation index are calculated and compared. An analysis was also carried out using the Global Forest Watch online resource. As a result of the study, changes in forest cover were identified, an assessment of the changes was provided, and a map reflecting forest changes that occurred in the Skole Beskydy National Nature Park from 2000 to 2020 was developed. According to the results of the analysis, a low level of losses of forest plantations due to natural factors, including losses from fires, was established. The main part of forest losses is caused by anthropogenic factors. The practical significance of the results lies in the possibility of using the obtained series of images within public control and improving the forest management system

Keywords: satellite images; satellite; vegetation index; forest loss; forest gain; tree cover

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Introduction

In the modern world, the urgent problem of deforestation and logging of forest areas underscores the importance of systematic monitoring of forest ecosystems for their preservation. The application of satellite imagery significantly enhances the efficiency of landscape monitoring and serves a wide range of practical and scientific purposes. The use of geographic information systems (GIS) for data analysis and processing allows for the effective management and monitoring of forest areas. This approach is particularly crucial for open forest territories, as traditional on-site data collection methods are time-consuming and require significant financial and labour resources. Satellite monitoring of forest areas provides the opportunity to detect, track, and assess the dynamics of changes in forest ecosystem cover over extensive areas.

To enhance the effectiveness of monitoring changes in forest plantations, a comprehensive approach that combines various research methods is crucial. One such method is the utilization of the Global Forest Watch (GFW) map of global forest changes. In their study, O. Yakovenko (2023) examined the distribution characteristics of forest vegetation on forest “islands” in the Chernihiv Polissia Region and the dynamics of their area over the past 20 years using the GFW online resource. The research demonstrated the high effectiveness of the GFW online resource in studying the dynamics of forest resource changes. By incorporating additional research methods into the analysis of forest cover changes, a more comprehensive and coherent result could be achieved, allowing for the comparison of data obtained through different methods.

Among Ukrainian researchers involved in studies of forest cover change using Earth remote sensing data, notable works include those by O.H. Chaskovskyy & H.H. Hrynyk (2020) and O. Barabash *et al.* (2021). In the study by O.H. Chaskovskyy & H.H. Hrynyk (2020), the GFW map and Sentinel-2 satellite data were utilized to assess forest loss in the Ukrainian Carpathians. The results confirmed the validity of employing various research methods for data comparison and detecting changes in forest cover caused by both logging and natural factors. In the research conducted by O. Barabash *et al.* (2021), the calculation of the normalised difference vegetation index (NDVI) using Landsat 5 and 8 satellite data was applied to track vegetation changes in the Chernobyl exclusion zone. An information system for analysing temporal vegetation changes over decades was developed in the article. The results of NDVI determinations based on Landsat 5 and Landsat 8 satellite image series for the summer periods of 2000, 2010, and 2020 in the Chernobyl exclusion zone were analysed. The research demonstrated that these methods are sufficiently effective for analysing the dynamics of vegetation status over time and allow for identifying overall positive-negative trends in vegetation cover change in the studied area.

Effective development of Earth remote sensing methods has also been facilitated by E. Lossou *et al.* (2019), C. Shang *et al.* (2020) and M.J. Faruque *et al.* (2022). In the study by C. Shang *et al.* (2020), effective forest mapping by attributes using remote sensing data was demonstrated. M.J. Faruque *et al.* (2022) assessed the dynamics of land use and land cover changes for the years 1990, 2000, 2010, and 2020. The analysis revealed a decrease in agricultural lands and an increase in aquaculture. Researchers E. Lossou *et al.* (2019) used optical remote sensing and spatial analysis methods to assess the condition of forest estates. The results of the study showed that forest reserves in the region, which were among the richest in terms of species diversity in high-altitude forests, had undergone significant degradation. The scientists concluded that the use of remote sensing and GIS to detect, quantitatively assess and explain changes in land cover types is effective. The high relevance and promising development prospects of earth remote sensing methods in forest studies were demonstrated by researchers E. Abad-Segura *et al.* (2020).

The Skole Beskydy National Nature Park (Skole Beskydy NNP) was established with the aim of preserving, restoring and sustainably using landscapes in the western part of the Ukrainian Carpathians, which contain typical and unique natural complexes of significant ecological, aesthetic, scientific, educational, recreational and health value (Decree of the President of Ukraine No. 157/99, 1999). Therefore, it is important to conduct scientific research on natural complexes and their changes under conditions of recreational use. The purpose of the study was to monitor the changes in the forest plantations within the Skole Beskydy NNP, to assess the forest loss in the area and to recommend the obtained images for the improvement of the forest management system.

Materials and Methods

The study was carried out as follows: obtaining and processing satellite data; performing segmentation and classification of the obtained images; calculating the NDVI and the normalized burn ratio (NBR); conducting an analysis of forest cover change using the online resource GFW; comparing data from different time periods based on NDVI calculations and GFW data; identifying changes in forest cover within the Skole Beskydy NNP during 2017-2022; assessing changes in forest cover within the Skole Beskydy NNP; based on the analysis results, recommending the obtained images for the possibility of responding to changes in forest cover. In order to obtain an up-to-date and dynamic analysis of forest cover changes, the study period from 2017 to 2022 was chosen.

The United States Geological Survey (USGS) website was used to obtain satellite images. The USGS Earth Explorer data portal was used to access a range of geospatial data. The Earth Explorer browser was used to download images from open archives, allowing the selection of images based on criteria such as scanner type, months of the year during the growing season, day or night capture, and maximum allowable cloud cover. This browser allows the selection of images for a specific area in vector format

(Longhenry *et al.*, 2011). The study used satellite imagery from the Landsat 8-9 satellite.

NDVI and NBR measurements were used to monitor disturbed areas. The NDVI is a standardised vegetation index based on satellite imagery that reflects green biomass. Green biomass absorbs electromagnetic waves in the visible red spectrum and reflects them in the near infrared spectrum. Chlorophyll absorbs solar radiation in the red spectrum (0.62-0.75 μm), while the reflection of energy by leaf cell structure occurs in the near infrared (0.75-1.3 μm). High photosynthetic activity results in low reflectance coefficients in the red spectrum and high coefficients in the near infrared. Comparing these values allows vegetation to be distinguished from other natural objects. The index is sensitive to changes in soil and atmospheric background, except in situations with limited vegetation.

The values of the NDVI range from -1.0 to 1.0. Negative values often indicate the presence of clouds, water bodies, or snow, while values close to zero indicate rocky terrain or bare soil. Very low NDVI values (0.1 and below) may indicate the presence of barren rocky areas, sand, or snow. Moderate values (from 0.2 to 0.3) suggest the presence of shrubs and grasslands, while high values (from 0.6 to 0.8) are characteristic of forests in temperate and tropical regions (Reszka & Fuentes, 2015). The formula for calculating the NDVI is as follows:

$$NDVI = \frac{(NIR-Red)}{(NIR+Red)}, \quad (1)$$

where *NIR(B*5*)* is 760-900 nm, near-infrared spectral range; *Red(B*4*)* is 630-690 nm, visible red spectral range. NBR is used to detect areas affected by fire. The NBR formula includes indicators obtained from signals at wavelengths corresponding to both the near-infrared and shortwave infrared spectral ranges. Healthy vegetation is characterized by high reflectance in the near-infrared spectrum, while areas recently burned by fire are well distinguished in the shortwave infrared spectrum. During the calculation of this index, a raster image obtained using channels of the near-infrared and shortwave infrared spectral ranges is used. NBR values range from +1 to -1. Low NBR values (less than -0.66) indicate significant vegetation damage by fires. Values (-0.66 to -0.1) indicate moderate vegetation damage by fires. Values (-0.1 to 0.1) indicate areas with no vegetation. Values (0.1 to 0.3) correspond to areas with vegetation recovery. Values above 0.3 indicate the presence of vegetation (Alcaras *et al.*, 2022). The formula for the NBR index is:

$$NBR = \frac{(NIR-SWIR2)}{(NIR+SWIR2)}, \quad (2)$$

where *NIR(B*5*)* is near-infrared spectral range; *SWIR*2 is shortwave infrared spectral range, mid-infrared zone. The QGIS GIS platform was used. QGIS is a free cross-platform GIS. One of the most advanced directions in GIS development is the combination of GIS technologies and remote sensing data processing (Manson *et al.*, 2015). To analyse long-term changes in forest cover, the GFW Interactive world forest map (n.d.) was also used. GFW is an open-source web application designed for monitoring forest resources almost in real-time. The project is an initiative of the World Resources Institute in collaboration with the University of Maryland, Vizzuality, Google, Esri, U.S. Agency for International Development, and others. GFW provides the latest data, tools, and technologies for effective forest monitoring worldwide. The data in GFW are already classified and ready to use (Portillo-Quintero *et al.*, 2021). The platform allowed setting necessary criteria for information search and provided a detailed overview of the forest status in the selected area.

The tree cover loss indicator shows the annual loss of tree canopy, defined as the replacement of vegetation at stand level above 5 metres within the selected area. The indicator of tree cover gain is determined as woody vegetation taller than 5 metres, which can take the form of natural forests, woodlands or tree plantations within the canopy density range (Myronyuk & Bilous, 2017).

Results and Discussion

To analyse the overall condition and trends in forest cover dynamics, remote sensing technologies are often applied. Remote sensing data obtained from satellites can be used for monitoring and mapping land use and vegetation cover. Observing changes is most commonly done by using multispectral satellite images acquired at different times, based on which analysis and forecasting are conducted. The use of specific multispectral satellite images, combined with attribute information on the geospatial data of forested areas, forms the basis for remote sensing technology applications. The result of land monitoring is a cartographic image showing changes in land cover. The detected changes, recorded in different time satellite images, allow for an assessment of these changes. The images undergo digital processing and visual analysis. GIS based on remote sensing data allows for calculating areas and comparing changes over a selected period.

The study of forest cover in the Skole Beskydy NNP was carried out using remote sensing. The online platform of the USGS Earth Explorer data portal allows instant visualisation of satellite data from different satellites and data collections. The search function was used to identify the location of the study area, and the polygon tool was used to create a polygon layer around the study area. Based on the search results, one image was selected from each of the years 2017, 2018, 2019, 2021 and 2022 within the July and August. The selected image is from August 4, 2017 (Fig. 1). The selected satellite images were downloaded in the fourth (*B*4), fifth (*B*5), and seventh (*B*7) channels in tag image file format for further analysis. Satellite imagery was obtained from Landsat 8-9 OLi/TIRS Collection Level 1 data. In conducting geospatial analysis, open-source QGIS desktop GIS software was used to process prepared cartographic materials (Chaskovskyy *et al.*, 2021).

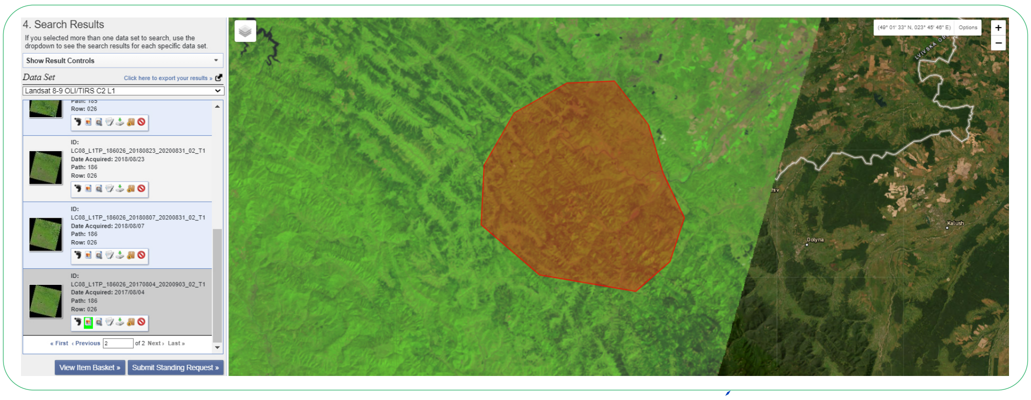

Figure 1. Satellite image dated August 4, 2017

Source: made by the authors

To determine changes in vegetation cover over a specific period, it was necessary to calculate the NDVI values in QGIS. The "Raster Calculator" tool was used to calculate the NDVI (Fig. 2). Subsequently, based on the basic OpenStreetMap Standard map, a vector layer outlining the territory of the Skole Beskydy NPP was created in shapefile format (Fig. 3).

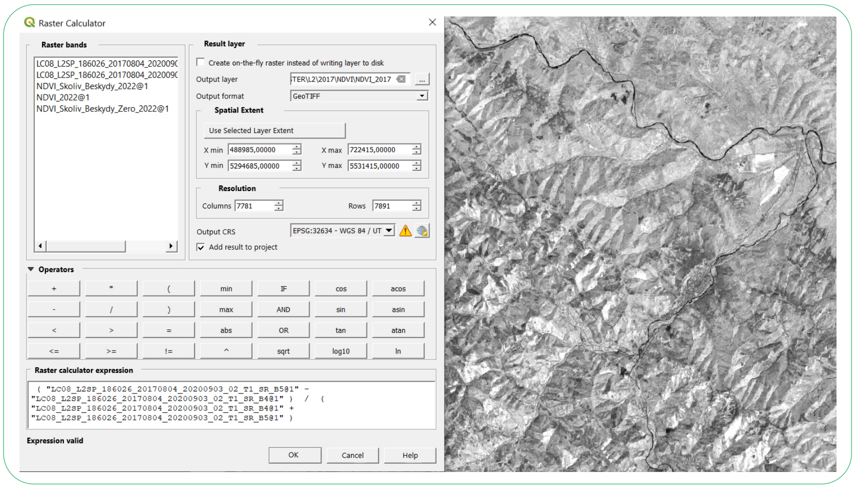

Figure 2. Calculation of the NDVI

Source: made by the authors

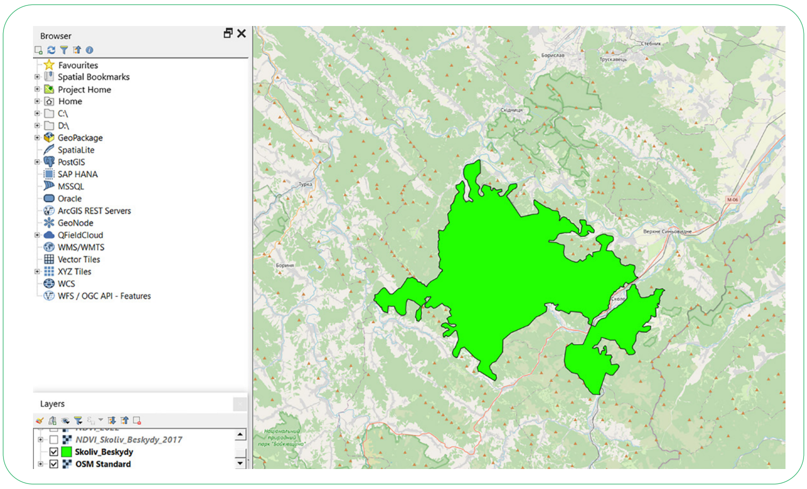

Figure 3. Vector layer of the Skole Beskydy NNP

Source: made by the authors

To conduct the analysis of satellite images within the territory of the Skole Beskydy NNP, a raster image was extracted based on the mask layer. The layer style was set for NDVI values ranging from < 0.2 to 0.9. Upon completing the settings, a ready raster layer within the Skole Beskydy NNP boundaries with the calculated NDVI was obtained (Fig. 4).

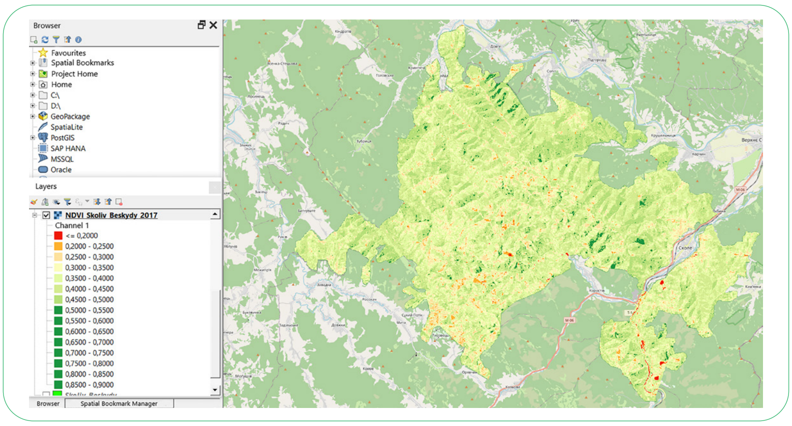

Figure 4. Raster layer of the Skole Beskydy NNP with the NDVI dated August 4, 2017
Source: made by the authors

The same actions were then repeated with the remaining satellite images. Ready raster layers were obtained for the period 2017-2022. On the maps, areas marked in red, corresponding to values < 0.2, indicate places with absent forest cover and areas dominated by shrubs and grasslands (0.2-0.3). The next step involved calculating the NBR index. Recently, the vegetation index NBR has gained special significance due to the increasing frequency of extreme weather events leading to fires and destruction of forest stands. NBR is widely used in forestry to detect fires, analyse fire intensity, and monitor vegetation surviving after a catastrophe. It reflects the spectral brightness curve of the index.

Detecting forest logging presents challenges in cases where logging occupies a small area or is selective. All disturbances to the forest cover (associated with both logging activities and natural factors) generally have similar spectral decoding characteristics. Partial or complete disturbance (removal) of forest cover results in a decrease in the reflection coefficient in the *NIR* zone of the spectrum, due to a decrease in chlorophyll content. At the same time, the reflection coefficient increases in the *SWIR* zone, attributed to the emergence of open soil areas. Additionally, logging sites experience an increase in the reflection coefficient in the visible range (in the red channel), as open soil reflects more solar radiation than tree canopies.

The images obtained from the Earth Explorer resource were downloaded into QGIS, and using the Raster Calculator tool, the NBR index was computed. Subsequently, similar to the process with the NDVI, the calculated raster images for the NBR index were cropped using the mask layer. The resulting layer with the calculated NBR index from August 23, 2018, is presented (Fig. 5). A comparison of the indicators of vegetation absence using the NDVI and NBR is shown in Figure 6.

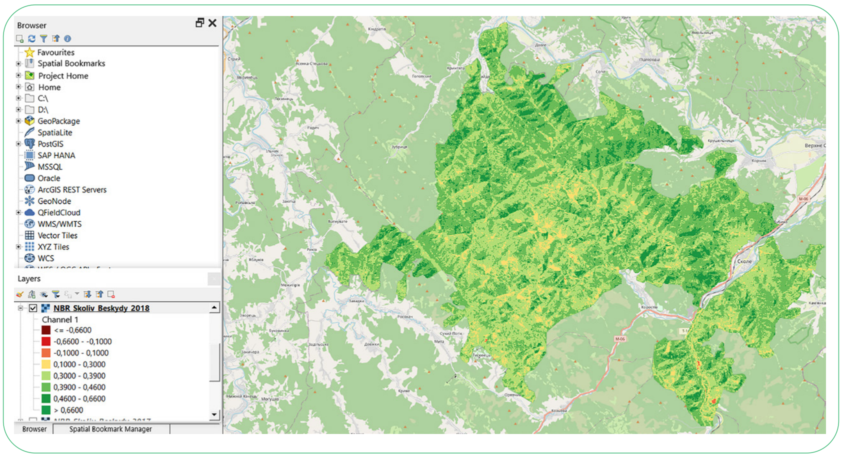

Figure 5. Raster layer of the Skole Beskydy NNP with the NBR index dated August 23, 2018
Source: made by the authors

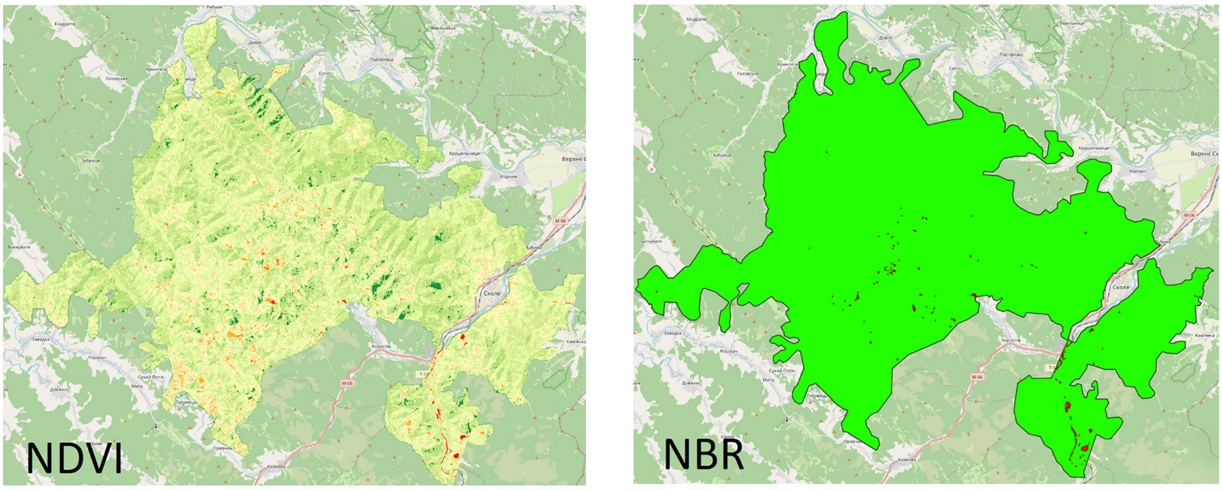

Figure 6. Comparison of vegetation absence using NDVI and NBR indices dated August 4, 2017
Source: made by the authors

Visual analysis of the comparison between the results of analysis using NDVI and NBR indices showed a similarity in the areas with absent forest cover. Figure 7 depicts the result of the statistical report within the period of 2017-2022.

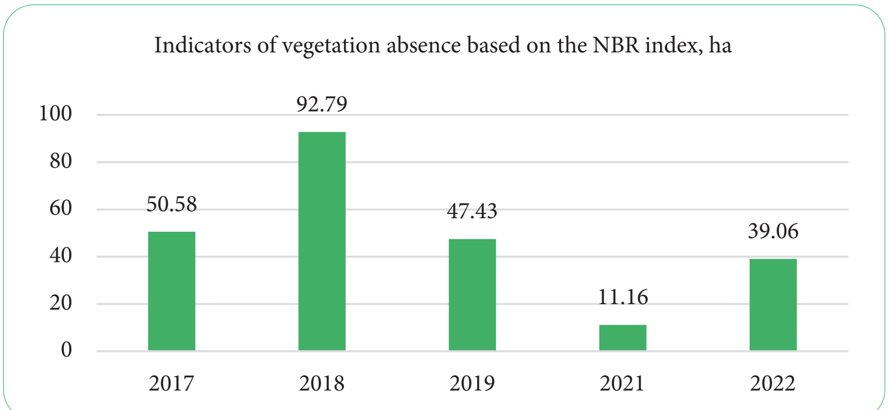

Figure 7. Diagram of areas with absent vegetation cover based on the calculation of the NBR index results
Source: made by the authors

Also, for the analysis of changes in forest cover, GFW was used. The data obtained on the GFW website are widely used in global forest research by leading scientists and represent significant progress in monitoring forest resources. With GFW, the following data can be obtained: the area of forests in the selected area; the area of forest loss, their dynamics over the years, and their spatial representation on the map (for some regions and reasons); the area of new plantations and their representation on the map; tracking of forest fires and their consequences; forest composition by species; the ability to view protected areas with clear boundaries; tree biomass density; key climate indicators (e.g., carbon dioxide emissions from forest loss) and others. This resource contains both forest loss and forest gain maps for the years 2001 to 2022. On the website, users can select or download a file with the area of interest for analysis and map presentation. Users can also specify the years in which these losses or gains occurred. Forest loss includes changes in both natural and planted forests and is not necessarily caused by humans. All these indicators are dynamic and have been tracked since 2000 and updated almost in real-time. A similar analysis has been conducted for the area of Skole Beskydy NNP protected landscape area. Maps displaying forest loss during the observation period from 2017 to 2022 were utilized in the study. Moreover, maps with a canopy cover exceeding 30% were chosen for comparison. Figure 8 displays the occurrence of forest loss during the year 2017 in Skole Beskydy NNP. According to the analysis, the forest loss in 2017 is approximately 55 hectares. Based on the research results, a map of total forest loss for the period 2017-2022 has been created (Fig. 9).

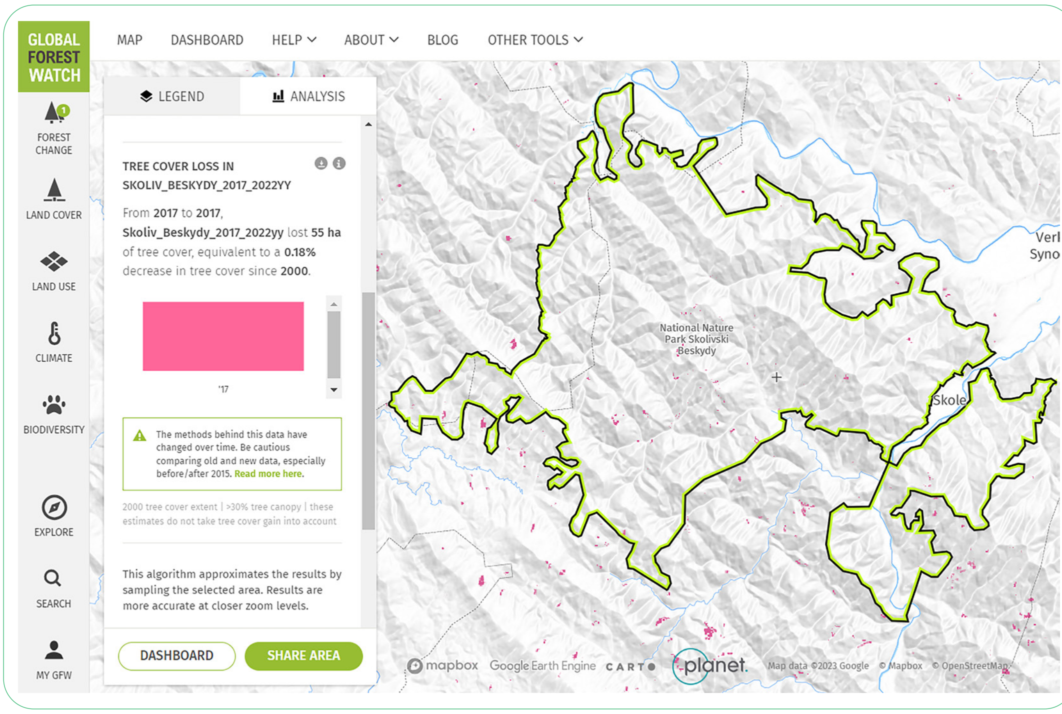

Figure 8. Map of forest loss in the Skole Beskydy NNP in 2017

Source: made by the authors

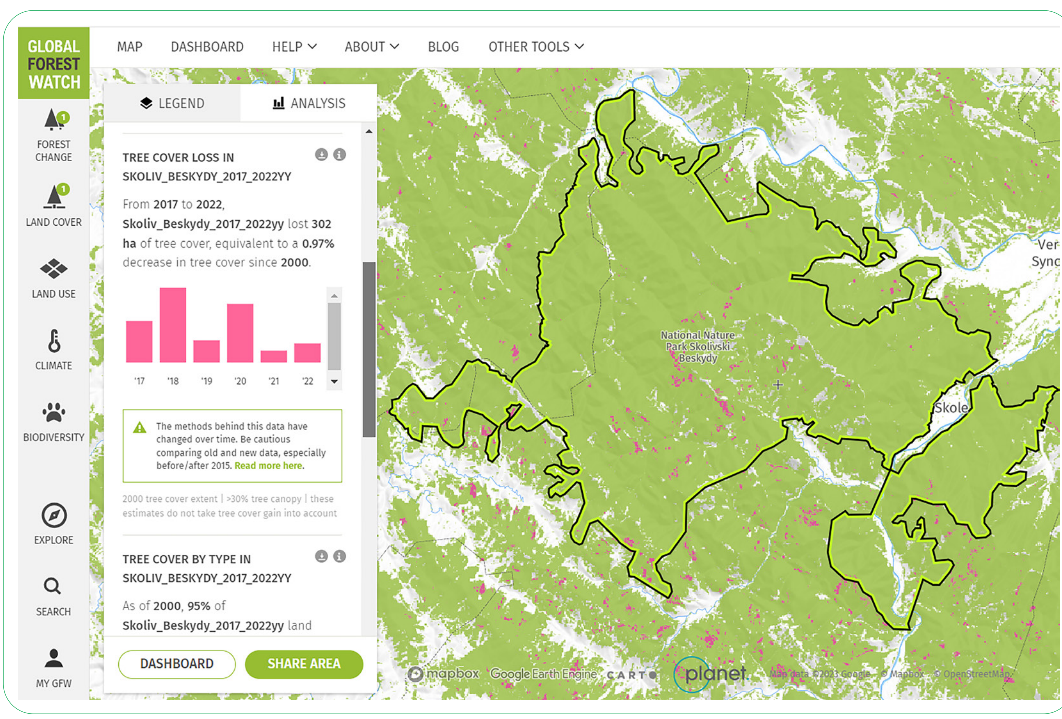

Figure 9. Map of cumulative forest loss in the Skole Beskydy NNP with representation of existing forest cover in the period from 2017 to 2022

Source: made by the authors

From 2017 to 2022, forest losses amounted to approximately 302 ha, which corresponds to a decrease in forest cover of 0.97% since 2000. According to the analytical data downloaded from the GFW website, forest losses in the Skole Beskydy NNP during the period 2017-2022 are shown in Figure 10. Forest cover losses, including those due to fires in the Skole Beskydy NNP, are shown in Figure 11.

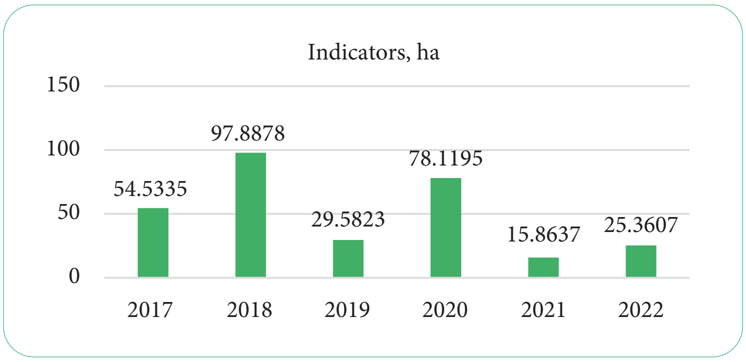

Figure 10. Diagram of forest loss within the Skole Beskydy NNP from 2017 to 2022
Source: made by the authors

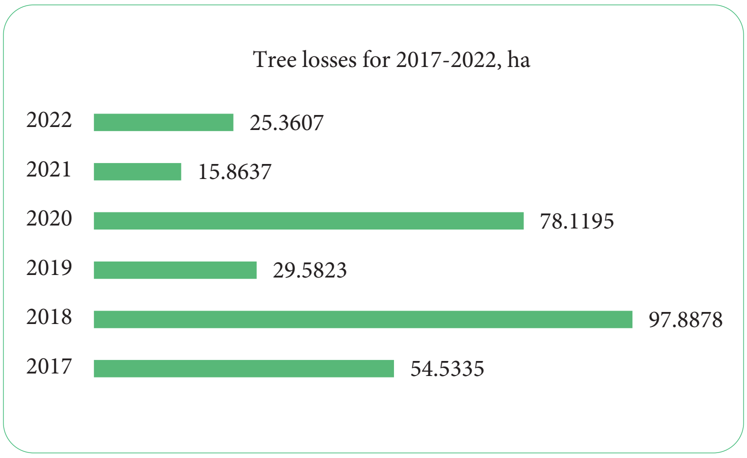

Figure 11. Diagram of forest loss with the indicator of losses from fires from 2017 to 2022
Source: made by the authors

According to the analysis, it is evident that the proportion of forest loss due to fires was highest in 2020 (0.6089 hectares), accounting for 0.77% of the total forest loss in that year. The overall forest loss during the period from 2017 to 2022 amounts to 301.3475 hectares, with 0.8633 hectares attributed to fires, representing 0.0029% of the total share. Due to differences in research methodology, it is not possible to directly compare forest loss estimates from the GFW maps with the results of calculating vegetation absence using the NBR index. However, it is possible to make relative comparisons to understand the overall trend in forest cover changes. The results obtained from the GFW maps represent the loss of tree cover (loss of vegetation at the level of stands of more than 5 metres). On the other hand, the results of the analysis using the NBR index provide an assessment for only one satellite image on a specific date and reflect both absent vegetation and some recovering vegetation. A comparison of vegetation absence according to the NBR index with forest loss results from the GFW website is shown in Figure 12.

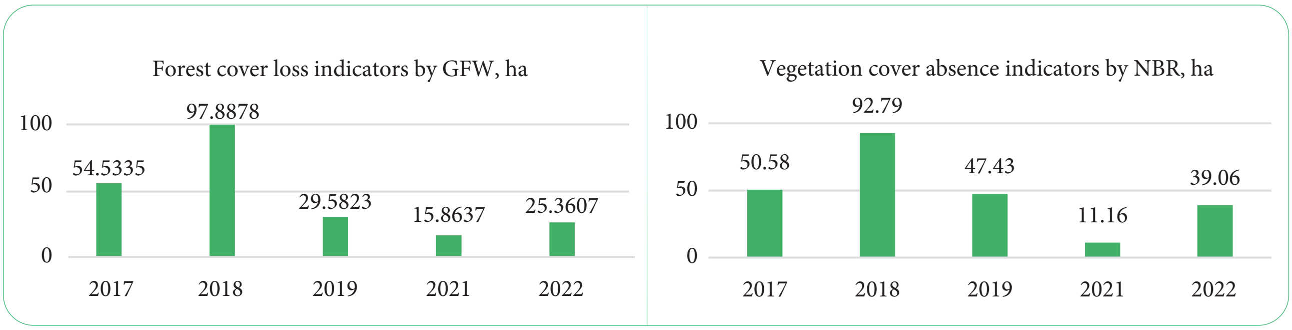

Figure 12. Comparison of diagrams showing the dynamics of forest cover changes based on GFW maps and the NBR index
Source: made by the authors

As shown in Figure 12, the forest loss indicators from GFW for 2017-2022 differ slightly from the calculated NBR index values, but the trend of change dynamics is similar. Determining forest loss using vegetation index analysis becomes challenging when deforestation is small scale or selective. The results obtained from the GFW data can be considered more accurate due to the use of multispectral satellite imagery from the Landsat 5 Thematic Mapper, Landsat 7 Thematic Mapper plus and Landsat 8 Operational Land Imager sensors. The data were processed and analysed on the basis of a large number of satellite images (Shimizu *et al.*, 2020). Observations of the clear land surface in the satellite images were collected and a controlled algorithm was applied to identify tree cover loss at the pixel level. To provide a broader perspective on the dynamics of forest loss and gain within the Skole Beskydy NNP, data for a longer period were analysed. Using data from the GFW resource, which allows for the analysis of forest loss from 2001 to 2022 and tree cover gain from 2000 to 2020, Figure 13 was created.

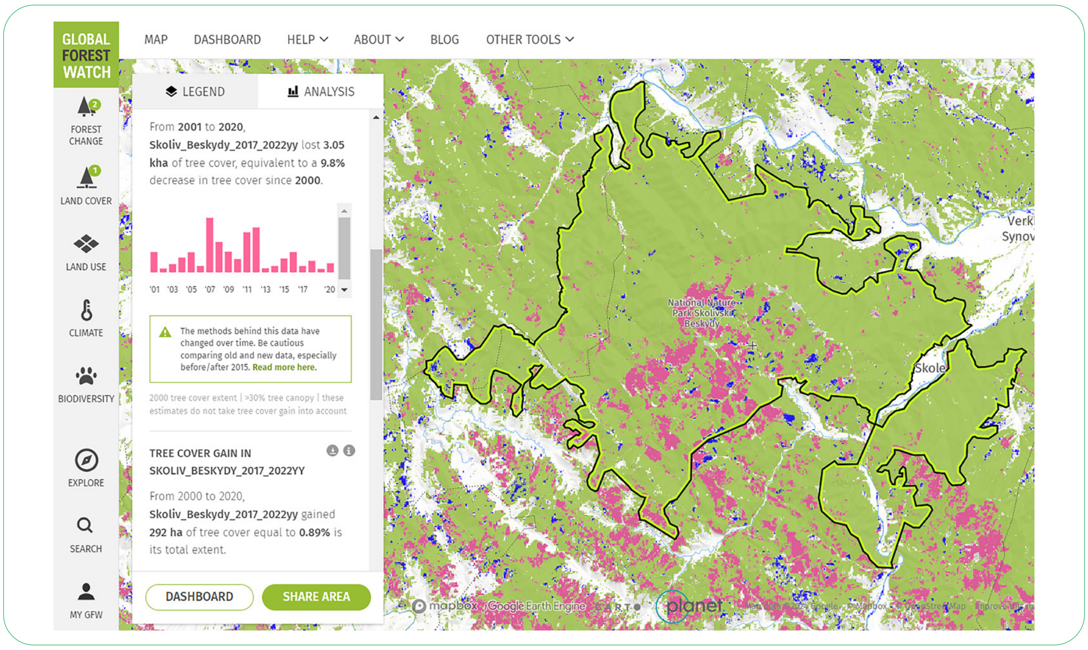

Figure 13. Forest loss and gain from the GFW website

Source: made by the authors

At the time of the study, the resource allowed analysis of forest loss up to and including 2022. However, information on forest cover gain is only available up to 2020. Therefore, to obtain a comprehensive and accurate comparative map of forest loss and gain, data up to 2020 were used. The image shows the changes that have occurred: pink dots represent tree loss from 2001 to 2020, while blue dots represent forest gain from 2000 to 2020. From 2001 to 2020, the Skole Beskydy NNP lost 3.05 thousand hectares of tree cover, which is a decrease of 9.8% since 2000. From 2000 to 2020, the Skole Beskydy NNP will gain 292 hectares of tree cover, which is 0.89% of its total area.

The use of vegetation indices allows for obtaining data on changes in forest cover caused by fires and other factors. This is corroborated by researchers M. Mishkin & J.A. Navarrete Pacheco (2022), who indicate in their study the effectiveness of remote sensing combined with GIS for the management and conservation of natural resources. Studies conducted in reserves have shown that rapid assessments of forest loss, combined with field studies, can lead to more effective interventions in crisis areas. Analysing the dynamics of forest change can provide accurate identification of focal areas for further intervention in forest conservation and management strategies. The analysis conducted using the NDVI has proven useful for characterizing vegetation cover and obtaining cartographic products essential for forest monitoring and detecting changes in forests. Similar conclusions were reached by researchers G.L. Spadoni *et al.* (2020). In their work, scientists created raster forest maps for the territory of Italy using remote sensing methods. Specifically, Sentinel-2 multispectral images were used to obtain NDVI values.

The NBR index also proved effective in determining forest loss within the study area. Visual analysis of images without vegetation cover using both NDVI and NBR indices confirmed the similarity of results in areas without forest cover. In the study by T. Kartika *et al.* (2019), NBR was used to detect forest loss in Riau province. The research results showed that the analysis of forest cover changes using the NBR index provides good results, and the information obtained can be used to detect deforestation, among other purposes. O. Soshenskyi *et al.* (2022) investigated the extent of forest damage caused by forest fires in the Luhansk Region. The scientists used a slightly different methodology, namely different indices – the Composite Burn Index and the Geometrically Structured Composite Burn Index. The authors of the study confirmed the effectiveness of remote sensing data, particularly in cases where it is necessary to map the effects of fires. However, they found that the Composite Burn Index is not always suitable for use, as it can overestimate the level of fire danger.

An important and effective tool for studying the state of forests is the use of the GFW online platform. Inaccurate information about forest resources can hinder forest conservation, restoration efforts, and sustainable management. Remote sensing methods have become key tools for monitoring forest cover. The GFW dataset, as an interactive remote sensing product, is currently used by more than 2 million users, including researchers, conservationists, and local communities, to analyse changes in forest cover. Therefore, understanding the accuracy of the GFW dataset is crucial. Researchers D. Zhang *et al.* (2020) conducted a study on assessing the accuracy of the global forest cover in 2000 in China. The study validated the dataset using a simplified procedure of visual interpretation with the aid of high-resolution optical images in Google Earth to map uncertainties and inaccuracies in the GFW Tree Cover 2000 data in China. They then estimated the forest area in China after considering the data uncertainties and compared these findings with data from China's National Forest Inventory Report to elucidate where and how inventory based on ground data differs from remote sensing data based on presence or absence. The results showed that the overall accuracy of the GFW Tree Cover 2000 data was 94.5%, indicating the high accuracy of the GFW resource data.

Comparative analysis of results from the NBR index and GFW data showed a similar trend in the dynamics of change. A comprehensive approach to analysing changes in forest cover proved to be effective in identifying new areas of absence of vegetation. The production of maps based on GFW data with absent forest cover can be useful for forest protection and improvement of forest management systems. This is supported by research by K. Shea (2022) which measured the impact of forest monitoring. Both qualitative and quantitative analyses provided compelling evidence that the GFW resource contributes to reducing deforestation. The thematic research findings confirmed the evidence from the quantitative assessments and identified specific user groups that were using the tools to directly or indirectly reduce deforestation. There was evidence that the data facilitated increased awareness and decision-making to improve enabling conditions. In Cameroon, for example, the government used the data to inform decisions on forest tenure and management planning. In Uganda, the National Forestry Authority regularly reviewed the data to monitor forest management. Staff of the Uganda Wildlife Authority used GFW data to plan ranger routes for forest patrols, while in Cameroon civil society used it for independent monitoring and reporting of illegal activities.

Thus, the obtained results from GFW data in the form of forest loss maps can be recommended for further study of the state of forest resources within the Skole Beskydy NNP and for monitoring illegal logging activities, as it can be concluded that the main part of the forest loss is attributed to anthropogenic factors. A series of images depicting forest loss over the years is shown in Figure 14.

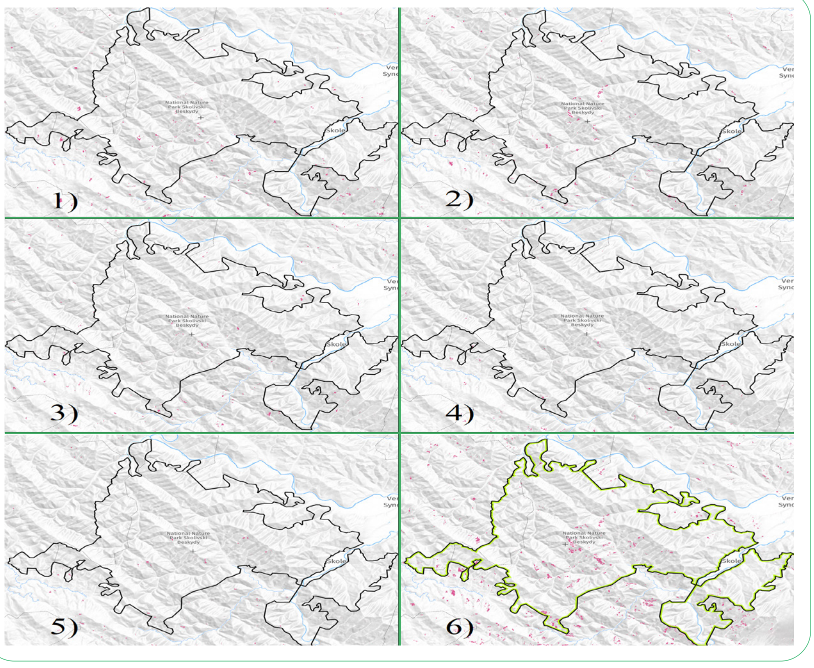

Figure 14. Recommended forest cover loss snapshots based on GFW data

Note: 1 – 2017; 2 – 2018; 3 – 2019; 4 – 2020; 5 – 2021; 6 – 2017-2022

Source: made by the authors

The analysis results from open data sources, acquired series of images, can be utilized in further studies of this area and compared with ground-based data. It is believed that optimal results can be achieved through the integrated use of both satellite and ground research. This implies that ground-acquired data can be used for satellite image analysis, and satellite observation results can serve as a basis for conducting ground-based field studies. Additionally, the data from image series can be employed within the framework of public monitoring and for real-time forest cover change response capabilities.

Conclusions

The application of selected remote sensing methods allowed the assessment of forest cover changes in the Skole Beskydy NNP. Satellite imagery, vegetation index analysis and information from the GFW resource were used to observe changes in forest cover and to identify both natural and anthropogenic influences on these changes. According to the data obtained, the largest forest loss due to fires occurred in 2020 (0.6089 ha), accounting for 0.77% of the total forest loss in that year. The total forest loss from 2017 to 2022 was 301.3475 ha, of which 0.8633 ha was due to fires, representing 0.0029% of the total. In the period from 2001 to 2020, the Skole Beskydy NNP lost 3.05 thousand ha of forest cover, which is a decrease of 9.8% since 2000. In addition, the forest cover increased by 292 ha between 2000 and 2020, which represents 0.89% of the total area of the park. The results of the analysis indicate a low level of forest loss due to natural factors, in particular losses due to fires. The primary cause of deforestation is linked to human activities.

Detecting changes in forest cover can often be a challenging task, especially in large and inaccessible areas. Tools to detect changes in such areas require a comprehensive approach. The use of remote sensing techniques is becoming an effective means of monitoring changes in forest cover, as they allow rapid detection of changes with minimal resource expenditure. The analysis of selected remote sensing methods combined with GIS also confirms their effectiveness in monitoring long-term changes in forests and comparing their dynamics. Research confirms that the relevance and prospects of using these methods to conserve forests and improve their management systems increase over time. Monitoring of forests within national parks is important in the context of their recreational use. Therefore, further research should continue to monitor and analyse changes in forest cover in other Ukrainian National Nature Parks.

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Conflict of Interest

None.

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Динаміка зміни лісових насаджень на території національного природного парку «Сколівські Бескиди»

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Анотація. Актуальність дослідження обумовлена проблемою оцінки стану та використання лісового покриву на території Національного природного парку «Сколівські Бескиди», необхідністю розробки ефективних методів моніторингу та збереження лісових екосистем. Метою дослідження було вивчення динаміки зміни лісових покривів у межах Національного природного парку «Сколівські Бескиди», а також оцінка втрат лісових ресурсів на цій території та рекомендування отриманої серії знімків для покращення системи управління лісокористуванням. Дослідження проведено з використанням комплексного підходу й комбінації різних методів дослідження змін лісового покриву та їх порівняння. Основою для застосування технологій дистанційного зондування було використання специфічних мультиспектральних супутникових знімків, які комбінувалися з атрибутивною інформацією щодо геопросторових даних про лісові угіддя. Продемонстровано найпрогресивніші методи дослідження змін лісових насаджень на основі даних дистанційного зондування з використанням геоінформаційних систем. Отримання супутникових знімків відбувалося з набору геопросторових даних супутника «Landsat 8» за допомогою порталу даних Геологічної служби США. Виконано розрахунок та порівняння нормалізованого коефіцієнта вигорання та нормалізованого диференційного вегетаційного індексу. Також був проведений аналіз із використанням онлайн ресурсу «Global Forest Watch». У результаті дослідження було виявлено зміни лісового покриву, надано оцінку змінам, розроблено карту відображення змін лісу, які відбулися в Національному природному парку «Сколівські Бескиди» за 2000-2020 роки. За результатами проведеного аналізу встановлено низький рівень втрат лісових насаджень у зв'язку з природними факторами, зокрема втрат від пожеж. Основна частина втрат лісів зумовлена антропогенними факторами. Практичне значення результатів полягає в можливості використання отриманої серії знімків у межах громадського контролю та покращення системи лісокористування

Ключові слова: супутникові знімки; супутник; вегетаційний індекс; втрати лісів; приріст лісів; покрив дерев