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Original paper

Land use changes analysis of Trakai Historical National Park in Lithuania

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Abstract: Remote sensing technology and the Earth system data it can obtain can provide great support for the monitoring and management of protected areas. These data can provide the ecological indicators of a place. It is very important to understand the situation concerning the natural land elements of a pro-tected area and to stop unacceptable actions in time. This paper presents an analysis of the natural elements of the land use/land cover (LULC) in the landscapes of protected areas. Freely available Sentinel-2A (S2A) multispectral data were used to classify the LULC and monitor the situation of protected areas. The research object was Trakai Historical National Park, which is an authentic land-scape in Lithuania. First, the Sentinel-2A image was processed and classified using the random forest algorithm by the special Lithuanian remote monitoring data collection, processing, use and storage system of the Environmental Protection Agency Lithuania. Next, the LULC model was statistically analysed using Quantum Geographic Information System (QGIS) software. The authors recommend automating these processes. The results show that in the period from 2021–2022, the farmland areas (cultivated meadows, decay areas, winter cereals, intensive cultivated crops and natural meadows) in Trakai Historical National Park decreased by 9.2%. Meanwhile, the forest, water and wetland areas increased by 9.6%, which makes it possible to conclude that these changes are beneficial for the ecosystems in this area.

Keywords: classification, land use, protected areas, historical national park

1. Introduction

According to the Law on Protected Areas (Lithuania Republic Law on Protected Areas, 1993), a protected area is a clearly defined area of dry land and/or water that is of scientific, ecological, cultural or other value that has a set regimen for its protection and use. Protected areas are established in order to protect natural and cultural heritage complexes and objects, biological diversity background, landscapes of country and to ensure the ecological balance of the landscape (Baškytė et al., 2019).

The protection of historical gardens and parks is regulated by international conventions, charters and guidelines also (Lichtenberg and Chengri, 2008; Dreija, 2012; Paraskevopoulou et al., 2020). The growing perception is that conservation is easier and cheaper than restoration (Baškytė et al., 2019). Globally, in 2018, there were almost 238000 protected areas (PAs); they occupied a total of 46 million km^2(20 million km^{2}of land and 26 million km^{2}of water). A total of 14.7% of the total land area and 7.3% of the total ocean area are protected (Protected Planet Report, 2018). The number and extent of PAs are continually changing, because new areas are added and expand (Lewis et al., 2018). In some countries governments not only designate new areas but also eliminate protection for some previously protected areas and this process is called PA downgrading, downsizing and degazettement (PADDD) (Mascia and Pailler, 2011; Conceição et al., 2022). The PADDD situation has never been systematically studied. First, we need to analyze it in a local municipality, city or other small place, and then it should be analysed on a global scale in a given country, region, etc.

Historic gardens and parks have been protected by a whole body of national legislation (Athanasiadou, 2019). This is very important to people's social perception of the conservation of protected areas (Lessa et al., 2021). A large study and literature review is provided by Sena-Vittini et al. (2023). One of the environmental aspects that influences PA status is a good policy framework of laws. Lithuania has individual laws for the protection of historical gardens and parks (Directorate of Trakai Historical National Park, 2023). This article focuses on Trakai Historical National Park (THNP). Activities in THNP are regulated by the following laws of the Republic of Lithuania: protected territories, environmental protection, immovable cultural heritage protection, forests, water, territorial planning, construction, tourism, other laws and legal acts, as well as special land and forest use conditions, Trakai historical regulations of the national park, construction technical regulations, and regulations for the protection of immovable cultural assets. In 1992, a separate organisation, the Directorate of Trakai Historical National Park, was established to implement the goals and tasks of THNP. During the first decade of the restoration of the independence of the Lithuanian state, a legal system for the protection of Trakai and its surroundings was formed, and it is currently being concretized and structured, resulting in the environmental protection of specific cultural and natural objects. In 2000, the Directorate of THNP brought up the issue of registering THNP on the UNESCO Heritage List (Directorate of Trakai Historical National Park, 2023). According to the currently valid criteria for the selection of World Heritage values, the complex of cultural values of THNP met the UNESCO criteria: it exhibits important mutual changes in human values, which are reflected in architecture; it has a unique or at least exceptional testimony to an aspect of a cultural tradition or civilization; it investigates an exceptional example of a building type, an ensemble of architecture and technology or a landscape that illustrates an important stage in human history; and it has exclusive traditional human settlements or land use areas. All these criteria and the area's extensive history show how important it is to protect this area from PADDD processes.

Natural elements of land use/land cover (LULC) changes in the landscape of the THNP PA and other areas can be observed using satellite remote sensing technology. The Copernicus Programme of the European Space Agency (ESA) and the Earth Observation Programme of the European Union (EU) have contributed to the effective monitoring of the Earth's surface by producing the Sentinel-2 multispectral products (Phiri et. al., 2020). These data can be used in fast methods that offer an alternative to ground-based data collection. The data from the Sentinel-2 satellites are freely available, making it easy for resource-constrained researchers to use the data and complement these data with other free, open-access data as Landsat data (Chastain et al., 2019). Sentinel-2A (S2A) multispectral data are used for LULC classification with the random forest algorithm, which provides high accuracies, where the Kappa coefficient is 0.80. The LULC results have been used for monitoring in different ways. They have also been used to understand the situation of PAs when it is assumed that no major land cover changes have occurred during that time. LULC changes reflect and shape the global interplay between economic development and biodiversity conservation therefore the aim is to shape the LULC to foster synergies or minimize trade-offs between economic development and biodiversity conservation. Trade-offs have been a central issue for PAs, which are the cornerstone of local, national and international conservation policies (Joppa and Pfaff, 2010; Tesfaw et al., 2018).

This paper proposes the assessment of land cover characteristics to control variation across a landscape in a PA based on LULC data. We focus on land-cover outcomes in two different periods: May 2021 and May 2022. The LULC results from various years come from the special Lithuanian remote monitoring data collection, processing, use and storage system prepared by the Environmental Protection Agency. The result analyses performed using geographic information systems (GISs) are important for the control of local PADDD processes.

2. Materials and methods

2.1. Research area and observation data

The selected territory of study is Trakai Historical National Park in the south-east part of Lithuania, west of the capital of Lithuania, Vilnius, in the vicinity of the city of Trakai (Fig. 1).

Fig. 1. Trakai Historical National Park

Trakai Historical National Park was established in 1992 to preserve the historical centre of Lithua-nian statehood in Trakai in its authentic natural environment. It is the only historical national park not only in Lithuania but also in all of Europe. The object is in the United Nations List of Protected Areas (UNLP). It is mostly part of the Trakai district and Elektrėnai municipality. The area of the park is 8149 ha (30% forests, 18% water, more than 32 lakes).

The centre of the historical park is the old town of Trakai, the castle on the island, which is accessible by a pedestrian bridge, and the complex of castles on the peninsula. The value of Trakai Park has been preserved well and its special status has been recognized and protected according to national legislation. The morphological structure of land relief of Trakai Park is a unique feature of the formation of lake land in the Baltic Uplands (UNESCO, 2023). Lakes Galvė, Skaištis, Totoriškiai and Lukas are connected by canals and form a single system. The largest of the lakes is Lake Galvė, which has 21 islands (the most famous is Pilies Island), and the cleanest is Lake Akmena. Trakai Historical National Park consists of Antakmeniu Hydrographic Reserve (3.1 km^2), Plomėnai Ornithological Reserve (3.14 km^2), Užutrakis Park Landscape Reserve (79.36 ha), Galvė Lake Hydrographic Reserve (374 ha), Trakai Old Town Urban Re-serve (107 ha), Trakai Island and Peninsula Cultural Reserve.

Data and statistics on the cadastral objects of PAs are collected and processed in an information system. These electronic services are provided by the Ministry of Environment of the Republic of Lithuania (State Cadastre of the Protected Territories of the Republic of Lithuania, 2023). The data can be download-ed through the Lithuanian Spatial Information Portal (Lithuanian Spatial Information Portal, 2023). For the identification of elements of natural land in the PA, we downloaded PA vector data from the Lithuanian Spatial Information Portal (Fig. 2) and selected the THNP area.

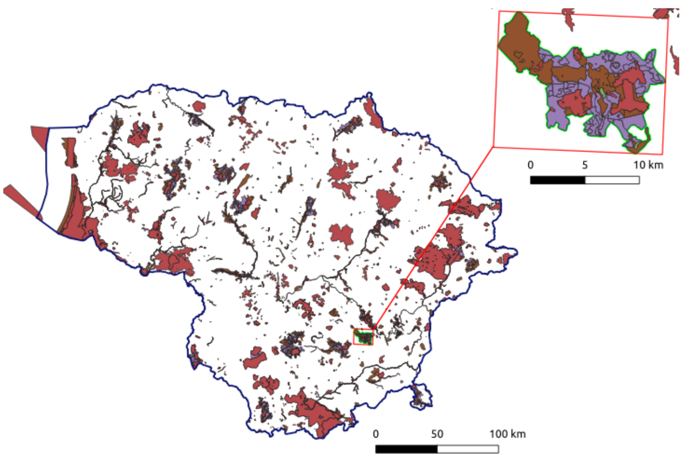

Fig. 2. Vector data of PAs in Lithuania

The file in the ESRI SHAPE format in the form of vector data can be used by GIS applications for PA analyses.

2.2. Earth observation data

The two Sentinel-2A (S2A) images used for the study were downloaded from a freely available data and information access service, the Copernicus Open Access Hub, using a specific Python script based on defined criteria. S2A multispectral satellite images taken on 05-11-2021 and 05-04-2022 in a raster format were used (Fig. 3). The images have 10 bands (B2, B3, B4, B5, B6, B7, B8, B8A, B11, B12), a pixel size of 10*10 m and an EPSG: 32635 – WGS 84 / UTM zone 35N coordinate system. The covered area of each S2A raster is 12056040.00 m^2, excluding no data pixels – the final covered areas are 11847243.20 m^2 (05-04-2022) and 12052701.20 m^2 (05-11-2021).

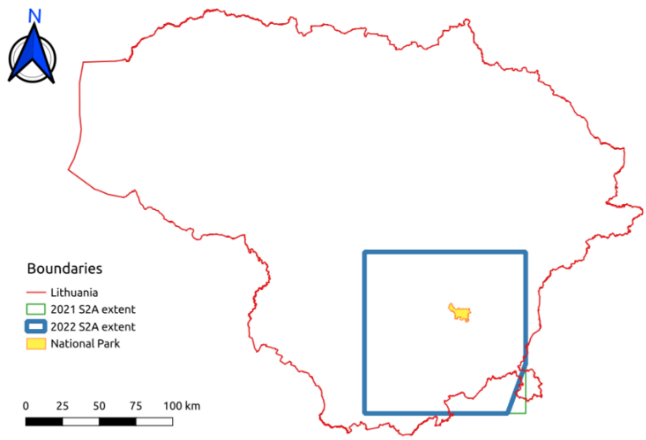

Fig. 3. Satellite image extent: S2A on 05-11-2021 and 05-04-2022

The images were corrected for atmosphere based on an algorithm called Sen2Cor in the Atmospheric/Topographic Correction for Satellite Imagery software; they had a resolution of 10 to 20 m in the visible near-infrared (VNIR) and short-wave infrared (SWIR) spectral zones, including 10 spectral bands (Warren et al., 2019). Atmospheric correction is applied on the data provider's servers before the data are made public. As a result, the data no longer require sequential processing in terms of atmospheric correction. In various sources, this process is also referred to as gamut correction or colour correction, which is part of atmospheric correction (Main-Knorn et al., 2017; Rumora et al., 2020). We used the image spectral bands with a resolution of 20 m (B5, B6, B7, B8A, B12), which were resampled to provide a resolution of 10 m. Areas covered by clouds or cloud shadows in satellite data are assigned a 'no data' value; data with a 'no data' value are not included in the comparisons or calculations performed by the classification algorithms. Thus, the mentioned areas have no influence on the result. The cloud removal process has the following steps:

1. The Scene Classification (SCL) algorithm detected of clouds, snow and cloud shadows and generated of a classification map from the downloaded Sentinel-2 satellite data. The data have special SCL layer.

2. Areas (pixels) that are covered by clouds (classes 8, 9 and 10), cloud shadows (class 3) or snow or ice (class 11) or are corrupted (class 1) are detected.
3. The detected areas (pixels) are removed; that is, they are assigned a 'no data' value. The classes used for removal are marked with the numbers 3, 8, 9 and 10. The mentioned classes are capable of detecting all types of clouds (Fig. 4).

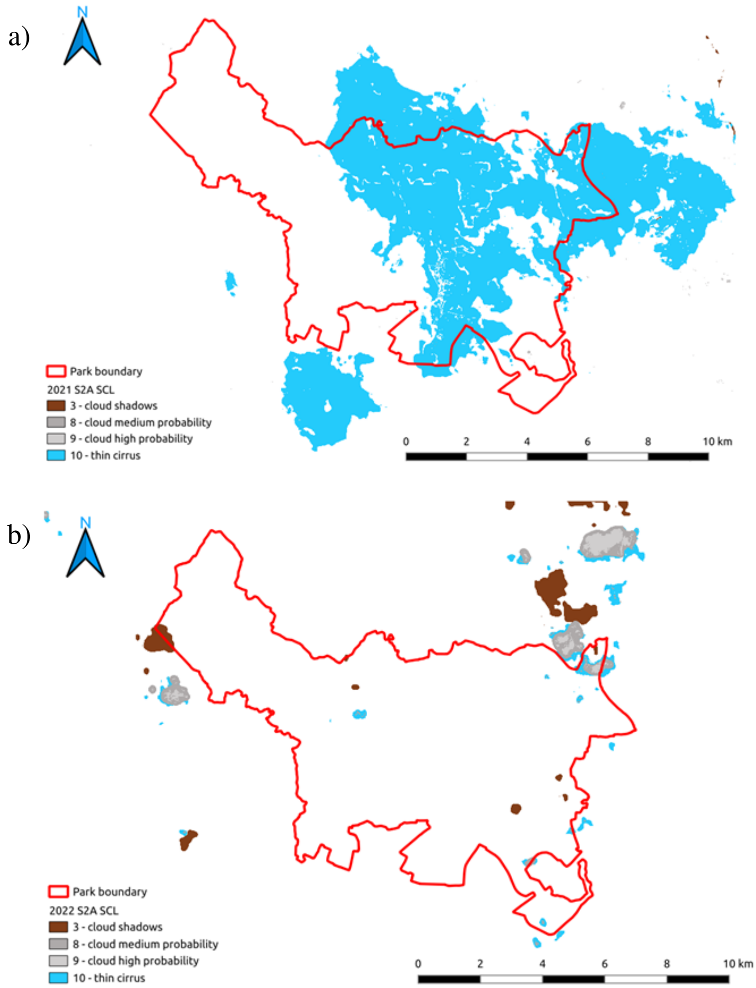

Fig. 4. The cloud layer in the park area in a) 2021 and b) 2022

A larger cloud area is present in the image from 05-11-2021, but it consists of thin cirrus clouds, which do not influence the data quality. Both images have the same cloud situation. Additionally, the entire area that was unsuitable for classification was eliminated from the data. The removal process is performed by checking the pixels in the cloud layer file and the satellite image. When one of the conciseness classes is detected in a pixel in the cloud file, the same pixel is set to 'no data' in the satellite data. An example of the cloud removal layers in the satellite data is shown in Figure 3. The S2A images were processed and segmented into 11 land cover classes using random forest algorithms and the Lithuanian GIS system of the Environmental Protection Agency. This is a machine learning system that identifies the land cover based on a ready-made library of the pixel values of classes, and it is prepared using scripts in the Python programming language. The quality of the results is assessed using the reliability coefficient (k), which is calculated according to the following Formula 1 (McHugh, 2012):

$$k = \frac{Pr\,(a) - Pr\,(e)}{1 - Pr\,(e)}, \tag{1}$$

where $Pr(a)$ represents the actual observed agreement, and $Pr(e)$ represents chance agreement. Cohen (1960) suggested that the Kappa result should be interpreted as follows: values less than or equal to 0 indicate no agreement, 0.01–0.20 indicate no agreement to slight agreement, 0.21–0.40 indicate fair agreement, 0.41–0.60 indicate moderate agreement, 0.61–0.80 indicate substantial agreement and 0.81–1.00 indicate almost perfect agreement (Cohen, 1960; McHugh, 2012). The weighted mean accuracy *F1* of the results used in all types of classification algorithms was evaluated. This value also takes into account incorrect choices. The *F1* value is generally more useful than the precision, especially if the distribution of land use classes is not uniform. *F1* represents the weighted harmonic average, or mean, of the precision (P) and recall (R) (IBM, 2023):

$$F1 = \frac{2 \cdot (P \cdot R)}{(P + R)}, \tag{2}$$

where P is defined as the number of true positives (T_p) over the number of true positives plus the number of false positives (F_p):

$$P = \frac{T_p}{\left(T_p + F_p\right)}, \tag{3}$$

where R is defined as the number of true positives (T_p) over the number of true positives plus the number of false negatives (F_n):

$$R = \frac{T_p}{\left(T_p + F_n\right)}. \tag{4}$$

F1 values are interpreted as a measure of the overall model performance; they range from 0 to 1, where 1 is the best model result. It represents a balanced model's ability to capture positive cases and be accurate. According to the general rules, an *F1* result can be excellent, very good, good or poor. The interpretation of the weighted mean accuracy (*F1*) values is presented in Table 1.

The LULC class maps and the classification results are presented in Figure 5.

Table 1. Interpretation of the weighted mean accuracy (*F1*) values

$F1$ values	Interpretation
more than 0.9	perfect
0.8–0.9	very good
0.5–0.8	good
less than 0.5	poor

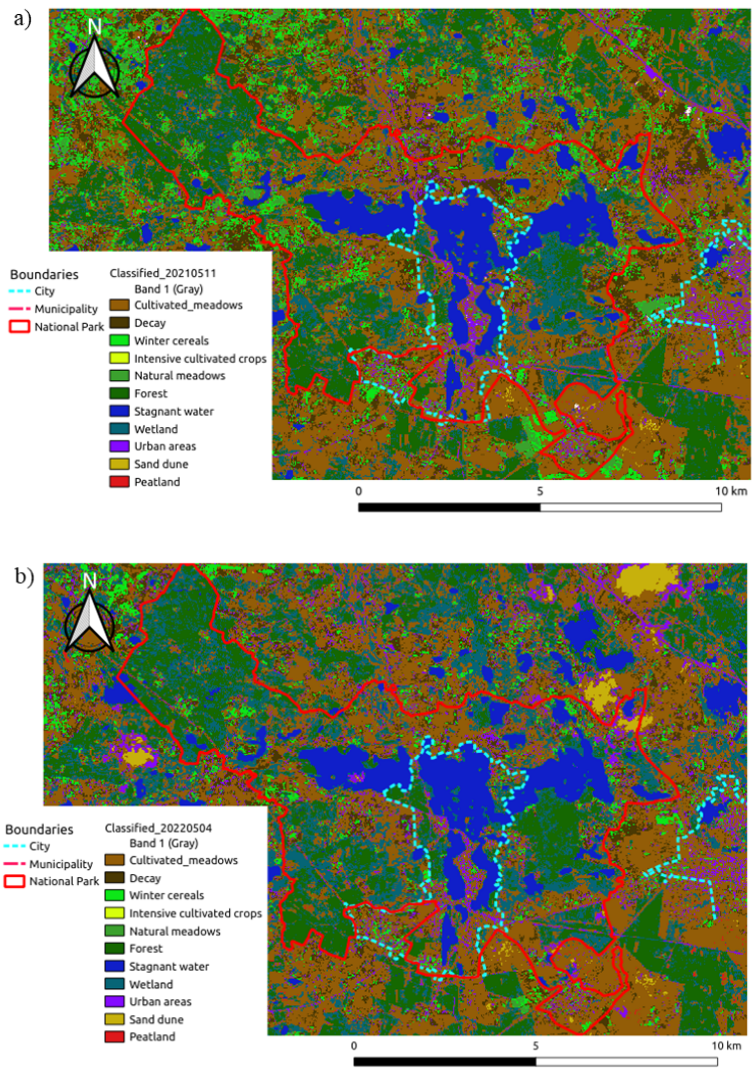

Fig. 5. Trakai Historical National Park classification results: a) 05-11-2021 and b) 05-04-2022

2.3. Earth observation data

The remote sensing data results are provided in terms of the LULC element in a raster (10980*10980 pixels) format. The PAs are in the vector data format (Fig. 2). Accordingly, for a GIS application, data should be converted into the appropriate format. This increases the flexibility, making it possible to consider various data sources and processing methods to perform an analysis of a given land area. The LULC data processing stages for the PA are following: 1) Data conversion stage, when the raster data volume is reduced by reducing the raster coverage and the raster is converted into a vector; 2) Data filtering stage, when the unnecessary vector meshes are discarded, the vector grid is separated and the border cell clipping is performed; 3) Statistics stage, when the area is added as an attribute, a statistical table is compiled and the results are summarized. The LULC data processing stages for the PA are provided in Figure 6 too.

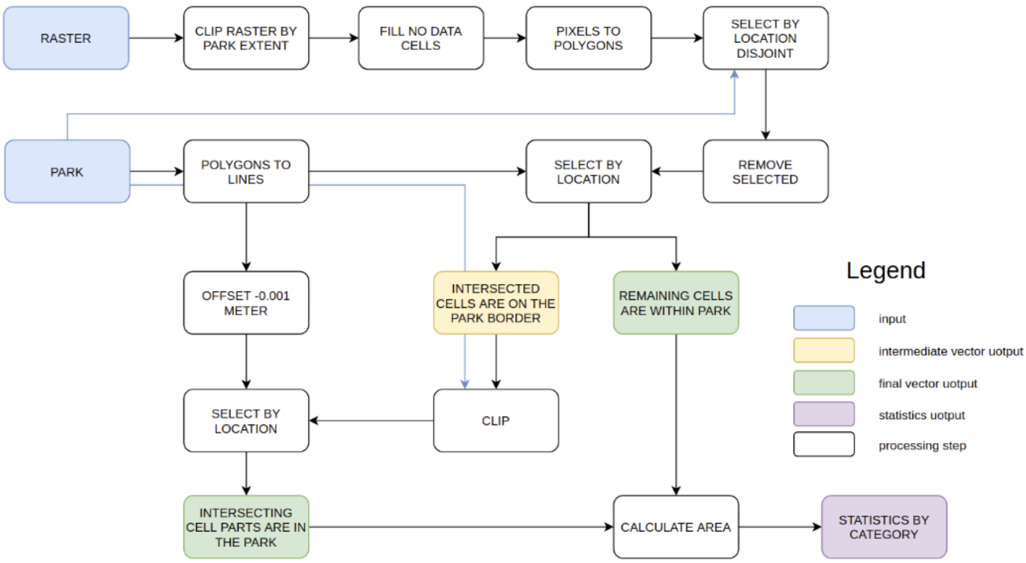

Fig. 6. Data processing stages

3. Results

3.1. Summary of LULC data quality results

The classification quality of the S2A images was evaluated using the reliability coefficient (k), precision (P), recall (R) and weighted harmonic average ($F1$) (see Formulas 1–4). The confusion matrix table (Fig. 7) summarizes the performance of the land cover classification model (a machine learning model). The first columns and row contain the code of land use classes, at their intersection the numbers of pixels whose values corresponded to the pixel values of the library prepared for machine learning.

	[11]	[12]	[14]	[16]	[21]	[31]	[41]	[43]	[51]	[61]	[62]
[11]	709	0	0	0	0	1	0	18	0	0	0
[12]	17	66	9	0	0	0	0	0	2	0	0
[14]	20	0	216	0	46	0	0	2	1	0	0
[16]	0	0	0	115	0	0	0	0	0	0	0
[21]	0	1	53	0	299	0	0	0	0	0	0
[31]	0	0	3	0	0	319	0	1	0	0	0
[41]	0	0	0	0	0	0	59	0	0	0	0
[43]	15	0	0	0	0	10	0	101	0	0	0
[51]	24	0	3	0	0	0	0	5	289	0	0
[61]	36	0	0	0	0	0	0	0	0	90	0
[62]	2	0	0	0	0	0	0	10	0	0	438

Fig. 7. The summarized confusion matrix of the land cover classification model

The confusion matrix helps to visualize the number of points for each classification code. According to the results, it is easy to understand the number of correct predictions and errors for each code. Example, cultivated meadows class (ID11) had the 709 correct prediction and only 1, 18 points (errors) moved to the forest (ID31) and wetlands (ID43) classes. A small number of errors points contributed to the high accuracy of k (Table 2). Interpretations of k values described on the end of Chapter 2.2, Formula 1).

Table 2. The reliability coefficient (Cohen's Kappa)

Source	ID	k value
cultivated meadows	11	0.91
decay areas	12	0.82
winter cereals	14	0.76
intensive cultivated crops	16	1.00
natural meadows	21	0.86
forests	31	0.98
stagnant water	41	1.00
wetlands	43	0.77
urban areas	51	0.94
sand dunes	61	1.00
peatlands	62	0.99
	average	0.89

The LULC classification results present perfect k values (Table 2). The coefficients for intensive cultivated crops (ID16) and stagnant water (ID41) are at the maximum value of 1. Lower results were obtained for winter cereals (ID14), which were correlated with cultivated (ID11) and natural meadows (ID21). Additionally, wetlands (ID43) were correlated with cultivated meadows (ID11) and forests (ID31). All correlations are shown in Figure 7. The LULC classification quality results are test-ed using the S2A image from 2021. The summary values are presented in Table 3.

Table 3. Accuracy results of S2A image classification

Image data	*k*	*P*	*R*	*F1*
05-11-2021	0.89	0.94	0.88	0.91
05-04-2022	0.91	0.96	0.85	0.90

The Kappa values, considering the recommended interpretation of these values (McHugh, 2012), are 82–100% reliable, and the weighted mean accuracy (*F1*) average value is 0.905, which indicates perfect results (according to Table 1).

3.2. Land use changes results

The areas of different land cover classes were calculated separately for the grids and the parts of the grids located within the boundaries of the park territory for the years 2021 and 2022. Then, we analysed the results. The differences between the grids are as follows: some represent areas that are fully included in the park, and their size is constant (100 m^2); meanwhile, others represent areas that are partly included in the park, and their sizes vary because only the covered part of the park area is used in the calculations. The areas of the grid cells in pixels and m^2 are provided in Tables 4 and Table 5. The deviations are provided in Table 6.

Table 4. Land cover area results for 2021

Class ID	Class title	The area of the grid cells within the park border		The area of the parts within the park from grid cells on the park border		Summarised results
		pixel count	area (m^2)	pixel count	area (m^2)	area (m^2)
0	removed pixels	174	17400	2	127.16	17527.16
11	cultivated meadows	261814	26181400	4931	240556.49	26421956.49
12	decay areas	54444	5444400	938	44503.09	5488903.09
14	winter cereals	39317	3931700	633	29238.50	3960938.50
16	intensive cultivated crops	3	300	1	96.75	396.75
21	natural meadows	12651	1265100	156	7529.20	1272629.20
31	forests	147060	14706000	911	49046.95	14755046.95
41	stagnant water	120410	12041000			12041000.00
43	wetlands	139401	13940100	821	45372.00	13985472.00
51	urban areas	26883	2688300	1064	52816.05	2741116.05
61	sand dunes	46	4600	3	130.04	4730.04
62	peatlands	339	33900	2	143.58	34043.58
	total area		80254200		469559.81	80723759.81

Table 5. Land cover area results for 2022

Class ID	Class title	The area of the grid cells within the park border		The area of the parts within the park from grid cells on the park border		Summarised results
		pixel count	area (m^2)	pixel count	area (m^2)	area (m^2)
0	removed pixels	0	0	0	0	0
11	cultivated meadows	219333	21933300	4881	235881.64	22169181.64
12	decay areas	38920	3892000	832	40104.54	3932104.54
14	winter cereals	22914	2291400	304	14096.34	2305496.34
16	intensive cultivated crops	1	100	0	0	100.00
21	natural meadows	1353	135300	6	162.20	135462.20
31	forests	164326	16432600	781	43031.34	16475631.34
41	stagnant water	133181	13318100	223	11169.45	13329269.45
43	wetlands	186996	18699600	1491	79997.71	18779597.71
51	urban areas	34091	3409100	905	43115.80	3452215.80
61	sand dunes	120	12000	5	197.12	12197.12
62	peatlands	1307	130700	34	1803.67	132503.67
	total area		80254200		469559.81	80723759.81

The total area of the THNP territory has not changed between 2021 and 2022 according to the size in pixels of the park in the images; it is 8072.4 ha. All state and national parks have planning schemes, all PAs of conservation priority have boundary plans approved by the government and biosphere polygons have boundary plans approved by the Minister of the Environment. Land use changes are strictly regulated. The results of the changes in the land use areas are provided in Table 6.

Farmland areas (cultivated meadows, decay areas, winter cereals, intensive cultivated crops, and natural meadows) decreased by 746.53 ha (9.2%). This result shows that agriculture did not expand in the research area. Human activity and nature conservation interact with each other. If they are not harmonized and if economic development is not balanced, it is possible to lose protected areas with natural and cultural heritage value and their uniqueness and attractiveness; it is also possible to undermine the available recreational, aesthetic and other resources. The landscape may begin to degrade, and other undesirable processes may begin. The results show that forests, bodies of water and wetlands increased by about 780.3 ha (9.6%). The nature restoration process is underway in this research area. Trakai Historical National Park is rich in intermediate marshes and marshes, and there are natural eutrophic lakes, lakes with kelp communities, natural strophic lakes and active high marshes; therefore, the movement and changes in these areas have natural causes. Urbanization (land recreation) processes represent only 0.88%. To be able to preserve and learn about areas with natural and cultural value, and to rationally use the territories where they are located, it is necessary to regulate construction development and recreational use.

Table 6. Changes in land use areas between 2021 and 2022

Class ID	Class title	Change between 2021 and 2022		Deviation (%)
		area (m^2)	area (ha)	
0	no data	–17527.16	–1.75	–0.02
11	cultivated meadows	–4252774.85	–425.28	–5.27
12	decay areas	–1556798.55	–155.68	–1.93
14	winter cereals	–1655442.16	–165.54	–2.05
16	intensive cultivated crops	–296.75	–0.03	–0.01
21	natural meadows	–1137167.00	–113.72	–1.41
31	forest	1720584.39	172.06	2.13
41	stagnant water	1288269.45	128.83	1.60
43	wetlands	4794125.71	479.41	5.94
51	urban areas	711099.75	71.11	0.88
61	sand dunes	7467.08	0.75	0.01
62	peatlands	98460.09	9.85	0.12
	total area	80723759.81	0.01	

4. Discussion and conclusions

Research concerning LULC has become important for overcoming the problems of the loss of biodiversity, the loss of ecosystems and a lack of ecological and environmental protection. In a national park, it is necessary to observe activity restrictions to 1) avoid damaging areas with natural and cultural heritage value, 2) carry out sustainable development of the area and 3) strictly regulate development and methods of construction. Sustainable development provides prerequisites for the use of natural resources (land, forests, etc.), considering the existing natural conditions, the diversity of the landscape and its peculiarities.

To preserve areas of value, it is necessary to have not only the necessary legal, administrative, planning, educational and other prerequisites but also tools that can quickly record changes in the protected territory. Protection and management mechanisms must be implemented to help restore damaged complexes and facilities. For the analysis of land use changes, the authors recommend using GISs in which the proposed processes are automated.

The dynamics of PADDD highlight the situation in the PA. The proposed application of remote sensing to identify land user changes is not new, but it has not yet been used for this type of monitoring. The data are available in the Copernicus Open Access Hub database, and the field classification systems or methods that use machine learning algorithms have already been intensively applied in many research areas.

This article is summarized as follows:

1. A special system for downloading, processing and classifying the data was created.
2. Automated result analyses were performed (see Table 2). Data processing stages were developed.

3. PADDD was analysed; this type of analysis can be used to highlight the situation in small or large PAs.

After performing experimental calculations for THNP (Lithuania), the authors conclude that it has a good protection situation. The biggest changes in classes between 2021 and 2022 occurred in the cultivated meadows class (decreased by 425 ha) and wetlands class (increased by 479 ha). An unchanged or weakly changing situation was observed for the intensive cultivated crops, sand dunes and peatlands classes. The results show that the land use changes do not pose a threat to the landscape of the park. The landscape is even improving: the areas of cultivated fields are decreasing and being replaced by areas that do not harm nature.

This study indicates the significant impact of the legislative basis in preserving the heritage of THNP and its development activities in terms of the LULC changes and proves that the integration of remote sensing technologies and GIS is an effective tool for observing land use changes, especially over a long period. The evaluation of LULC changes is very useful for policy-makers, environmental management groups, the Directorate of THNP and the public, allowing them to better understand the surrounding areas.

Author contributions

Conceptualization: J.S.V., E.T.; collection and assembly of data: J.S.V., R.B.; data analysis and interpretation: R.B., E.T.; article writing: J.S.V., E.T.; critical revision and final approval of the article: J.S.V., E.T.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon rea-sonable request.

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