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Comparative Analysis of Anthropogenic Transformations of Landscapes in the Lands of the Settlements of Belozem (Plovdiv Province) and Opalchenets (Stara Zagora Province) with Remote Sensing

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Abstract. In this study, a remote analysis of the anthropogenic activity, which plays a fundamental role in the formation of the contemporary landscapes in part of the Pazardzhik-Plovdiv lowland area - the lands of the Belozem (Plovdiv Province) and Opalchenets (Stara Zagora Province) villages - is carried out, as well as of the landscape pattern, determined by the complex interaction of natural and anthropogenic factors. The study area was selected based on the registration of some differences in the character of the land use in the lands of the two villages. Remote sensing contributes for more profound investigation of the spatial pattern and dynamics of anthropogenic landscapes in the study area. Satellite data, as well as landscape metrics analysis of the landscape pattern in the study area are used. A multi-temporal analysis was conducted to study the dynamics of landscapes over different periods. Some differences have been registered in the pattern of agricultural landscapes of the two studied lands, which could be explained by the different type of organization of the agricultural process on the territory of Plovdiv and Stara Zagora provinces. The manifestation of versatile by its character anthropogenic activity is a major factor in the formation of specific types of land use, which depend to a large extent on the socio-cultural and economic features of the environment, which in turn influences the formation of the landscape pattern. This is precisely what necessitates the study of these transformations and interactions and in a temporal aspect.

Key words: landscape pattern, anthropogenic effect, landscape metrics, satellite data, remote sensing, NDVI, NDWI.

Introduction

The landscapes in the Pazardzhik-Plovdiv field are a product of the millennial interaction between nature and people. The anthropogenic impact on the landscapes in this densely populated region of Bulgaria is characterized by significant by its intensity and stability over time manifestation. This has had a fundamental influence on the formation of the contemporary landscape pattern. However, the genesis and characteristics of the anthropogenic impact are not the same in all parts of the lowland area. The main factors that influence the specifics of the Land Use in the Pazardzhik-Plovdiv lowland area are the

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natural preconditions, the historical development, but last but not least the peculiarities of the traditions in agriculture and the distinctive features of the organization of the economy in regional and administrative-territorial aspect. Precisely because of the nuances and differences in the nature of the landscape-forming factors we consider it necessary to carry out a comparative analysis of anthropogenic transformations of the landscapes in two neighboring lands on the territory of Pazardzhik-Plovdiv lowland area - the lands of the villages of Belozem and Opalchenets. The choice of the study area is motivated by the differences in the specifics of Land Use on the territory of the two lands.

The present study examines the anthropogenic transformations of landscapes in the lands of two neighboring settlements - Belozem (Plovdiv Province) and Opalchenets (Stara Zagora Province). The study area is part of the Pazardzhik-Plovdiv lowland area and the agricultural activity is traditional. Agricultural landscapes predominate. They are the main manifestation of anthropogenic transformations within the study area. For this reason, they are subject of landscape-ecological studies in terms of anthropogenic impact on the territory.

The research is based on remote sensing. An analysis of the land cover was made using satellite data and calculating the NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index) indices. Classification of contemporary landscapes in the studied territory is made after differentiation of landscape forming factors. A comparative analysis of the peculiarities of the landscape pattern in the two lands in spatial and temporal aspect is made to reveal the temporal dynamics of the studied landscapes during different political and economic periods and to carry out the analysis of the landscape-forming factors using satellite images from 1985, 2005 and 2019. Landscape metric indicators is used to reveal the spatial features of the studied contemporary landscapes.

Material and Methods

For the purpose of the study, the lands of two neighboring villages located in two different provinces were selected - the lands of the villages of Belozem (Rakovski Municipality, Plovdiv Province) and Opalchenets (Bratya Daskalovi Municipality, Stara Zagora Province). Although located next to each other and characterized by similar natural geographical conditions, the lands of the two villages show some differences in terms of traditions and organization of the Land Use. These differences are due to different historical, demographic, economic and cultural preconditions, which have a direct impact on the landscape pattern in general.

The total area of the surveyed area is about 62 km^2. Forty two km^2 is the area of the land of Belozem, and 20 km^2 is the area of the land of Opalchenets. The area is calculated in ArcGIS 10.1 (ESRI, 2012).

For the purpose of the study LANDSAT 5 MSS, LANDSAT 5 TM and LANDSAT 8 OLI/TIRS satellite images (path 183, row 031) were used, acquired respectively on May 19, 1985, on June 27, 2005 and on June 18, 2019, were used (USGS, 2020b). All images have the same coordinate system - WGS84 / UTM zone 35N, with spatial resolution for LANDSAT 5 MSS 1985 image of 60 m and spatial resolution of the LANDSAT 5 TM and LANDSAT 8 OLI/TIRS images of 30 m. The USGS Digital Elevation Model (DEM) (USGS, 2020a) was used to determine the slope values in GIS, necessary for the classification of landscapes. Topographic maps of the studied area, Geology map of Bulgaria, Soil map of Bulgaria and CLC2018 layer were also used in order to carry out the differentiation and classification of the landscapes.

In the processing of satellite images, some preliminary activities need to be carried out to facilitate the research process and to improve its representativeness. Geometric correction of the 1985 satellite data was performed for the purposes of the present study in order to unify the spatial resolutions of the three satellite images. The spatial resolution of the 1985 image was changed from 60 m to 30 m, using the "nearest neighbor technique" for resampling the satellite image in ArcGIS 10.1 (ESRI, 2012). Georeferencing of the DEM raster layer was also performed in ArcGIS in order to adjust the relief layer to the WGS84 / UTM zone 35N coordinate system used for the purpose of the study.

The research is based on remote sensing of the temporal structure of the Land Use and Land Cover, as well as on landscape-metric analysis of the spatial landscape pattern in the scope of the studied territory. To study the anthropogenic transformations of landscapes, it is necessary to pay special attention to the Land Use and Land Cover (LULC), which can be considered as one of the landscape-forming factors. The structure and dynamics of the LULC in spatial and temporal aspect is a major reflection of the type and characteristics of the anthropogenic impact on the landscapes. It is for this reason that the study begins with an analysis of the LULC for the three time points in the three years - 1985, 2005 and 2019. The analysis was conducted by calculating the NDVI and NDWI indices in GIS, in order to establish the values of the reflectance of the vegetation, and hence determination of the genetic and spatial characteristics of the elements of the specific material-substantial manifestations of the anthropogenic activity, located on the earth's surface - settlements, agricultural landscapes, infrastructure facilities, etc.

The Normalized Difference Vegetation Index (NDVI) was calculated by combining the spectral bands of the individual satellite images and is used to differentiate vegetation from anthropogenic objects and soils. The values obtained of the NDVI were grouped into separate categories, in order to achieve maximum representativeness of the obtained results and to get a clearer notion of the objects on the earth's surface.

The NDVI index is calculated by the following formula:

$$NDVI = \frac{(NIR - R)}{(NIR + R)},$$

where NIR is the Near-infrared band and R is the Red band of the satellite image. However, different combinations of individual spectral bands are required to calculate the NDVI index. For example, the combination of NIR (band 4) and the visible (band 2) bands was used to calculate the index of for LANDSAT 5 MSS satellite image (Gallo et al., 1987). For the LANDSAT 5 TM satellite image the combination of band 4 and band 3 was used (Markogianni et al., 2016). For the LANDSAT 8 OLI / TIRS satellite image the combination of band 5 and band 4 was used (USGS, 2020a). The NDVI values range from -1 to +1. The highest values of the index are associated with the presence of areas occupied by dense vegetation. Lower values are typical for areas with sparse vegetation, as well as for plowed soils. The lowest values are an indicator for anthropogenic units or water bodies. The interpretation of the NDVI index values depends on the different phenological and biological characteristics of the vegetation, as well as the specifics of the climatic factors. The seasonal climatic dynamics directly affect the development of the plants, and hence the values of the plant leaves and stems reflectance.

The Normalized Difference Water Index (NDWI) was calculated to facilitate the differentiation of water bodies from agricultural areas and areas with natural vegetation. It should be noted that the implementation of the NDWI index in the analysis of the Land Use and Land Cover should be considered not as a main but as an additional tool in the set of remote sensing methods in the present study. The NDWI index is calculated by the combination between band 1 (Green) and band 3 (NIR) for the LANDSAT 5 MSS satellite image proposed by McFeeters (1996). Rogers et al. (2013) propose the combination between band 3 and band 5 for the LANDSAT 5 TM satellite image. And for the LANDSAT 8 OLI / TIRS satellite image a combination of band 3 (Green) and band 7 (SWIR2) was proposed by Özelkan (2019). Following the example of Özelkan (2019), threshold values of 0 for the results of 1985 and 2005 and of 0.12 for the results for 2019 have been set. Values above 0 for the results for 1985 and 2005, and above 0.12 for the results for 2019, are indicator for the presence of surface water bodies - micro-dams or rice fields in the initial stage of development.

A key stage in the present study is the analysis of the natural landscape-forming factors and their interrelations with the anthropogenic impact on the territory. On the basis of the complex of landscape-forming factors and the analysis of their landscape-forming role, differentiation and classification of the contemporary landscapes in the studied territory have been carried out. For this purpose the European Landscape Classification (LANMAP) (Mücher et al., 2010) was used. According to the experience of previous research of the author (Tamburadzhiev, 2020), as well as according to the specifics of the study territory, some additions of the classification system were implemented. The specific additions are described by Tamburadzhiev (2020).

Cartographic images were generated, visualizing the distribution of NDVI and NDWI values within the territory of the two lands, as well as of the contemporary landscapes within the scope of the studied territory.

Finally, landscape metrics at the landscape level was implemented through the vector-based Landscape Analysis Tools Extension (vLATE) for ArcGIS in order to analyze the structure of the contemporary landscapes on the territory of the lands of the villages of Belozem and Opalchenets.

Results and Discussion

The study area is part of the western part of the Upper Thracian lowland – the Pazardzhik-Plovdiv lowland area. The parent material is represented by sedimentary deposits (*s) - gravel, sands and clay. The relief is a lowland (*l) and is slightly indented. Based on previous research by the author and based on data for Plovdiv station (Tamburadzhiev, 2020) we can assume that the studied area in the present study is part of a territory with a semi-humid continental (*ShC) climate according to the classification of De Martonne and according to the differentiation of Mücher et al. (2010). The hydrological features are characterized by the presence of significant amounts of groundwater, as well as surface water bodies - Rahmanliyska River, Srebra River and Maritsa River, whose flow is part of the southern boundary of the study area. The soils are represented by the groups of Fluvisols (*F), Luvisols (*L), Vertisols (*V), as well as by the Rendzic type (*R) of the Leptosols group. The study area is part of the Upper Thracian biogeographical region according to the classification of Assenov (2006). Vegetation is represented mainly by agrophytocenoses. Natural vegetation is distributed fragmentary along the rivers. Along the Maritsa River it is represented by transitional tree-shrub vegetation. There are two forest massifs with secondary tree and shrub vegetation in the land of the village of Opalchenets. The territories adjacent to the Maritsa River are part of the Protected Zone „Maritsa" under the Council Directive 92/43/EEC (EC, 1992) on the Conservation of natural habitats and of wild fauna and flora, as well as part of the „Maritsa-Parvomay" Protected Zone under the Council Directive 2009/147/EC (EC, 2009) on the conservation of wild birds (NATURA 2000, 2013).

From the point of view of the analysis of the anthropogenic transformations of the landscapes it is very important to specify the peculiarities of the Land Use and the Land Cover (LULC) in the studied territory. For the purpose of differentiation and classification of the landscapes, a combination of data from CLC2018 (Copernicus Land Monitoring Service, 2020) and the use of remote methods for determining the features of LULC were performed. There are 10 types of LULC. According to the nomenclature of CLC2018, these are non-irrigated arable land (*nal); rice fields (*ri); pastures (*pa); complex cultivation patterns (*ccp); land principally occupied by agriculture, with significant areas of natural vegetation (*anv); broad-leaved forest (*blf); transitional woodland-shrub (*tws); water bodies; discontinuous urban fabric (*rural settlement); industrial or commercial units (*industrial units). The types of LULC are a diagnostic criterion for Level 5 of the landscape classification system.

In brackets are shown the designations of the individual levels of the landscape classification system on the maps of the contemporary landscapes of the lands of Belozem and Opalchenets, shown respectively in Fig. 4. and Fig. 5.

Maps are presented in Fig. 2., visualizing the values of the NDVI index for the surveyed territory, respectively for May 19, 1985, June 27, 2005 and June 18, 2019. The significantly greater homogenization of the spatial structure of LULC in the land of Belozem Village in 1985 compared to 2005 and 2019 is obvious. Socio-political changes after 1989 are the main reason for the reorganization of the agricultural production. The return of the land ownership of the citizens has led to the division of the arable land into smaller, in terms of area, and different, in terms of the characteristics of the cultivated crops, agricultural plots. Regarding the land of Opalchenets Village, the differences in the spatial structure of the different types of LULC are less pronounced for the three studied time points. This can be explained by the preservation of some cooperative practices in the organization of the agricultural process on the territory of Bratya Daskalovi Municipality and Stara Zagora Province, as a whole, part of which is the same land. The predominantly lower values of the NDVI index for both lands in 2005 compared to the other two time points are due to the fact that this time point is the latest of all the others - June 27. Therefore, we can assume that for some of the crops - wheat, for example, has passed the harvest period and the soils have remained exposed to the surface. The road-bed of the Trakia Highway is clearly visible in the images from 2005 and 2019. This main road artery is a prerequisite for fragmentation of the landscape pattern in the studied area. From the point of view of the patch-corridor-matrix paradigm, the road-bed of the highway facility can be considered as a buffer corridor, which actively influences the processes of normal functioning of the adjacent landscapes.

The NDWI index is calculated to distinguish areas that are covered with vegetation or with cover of anthropogenic origin (road infrastructure, buildings, etc.) from water bodies. No lakes have been registered in the study area. Water bodies are represented by micro-dams, rivers, irrigation canals and rice fields during the initial stage of rice crop development. Due to the specifics of the scale of the study, irrigation canals and rivers were not taken into account because they occupy an insignificant area within the study area.

The results of the NDWI calculation are shown in Fig. 3.

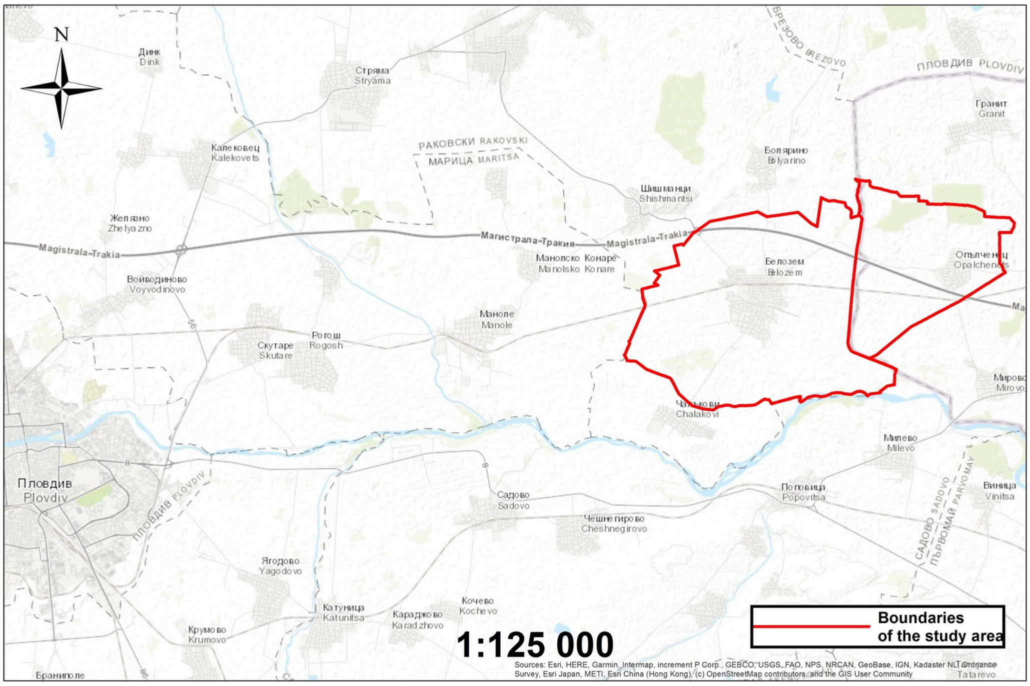

Fig. 1. Indicative map of the study area.

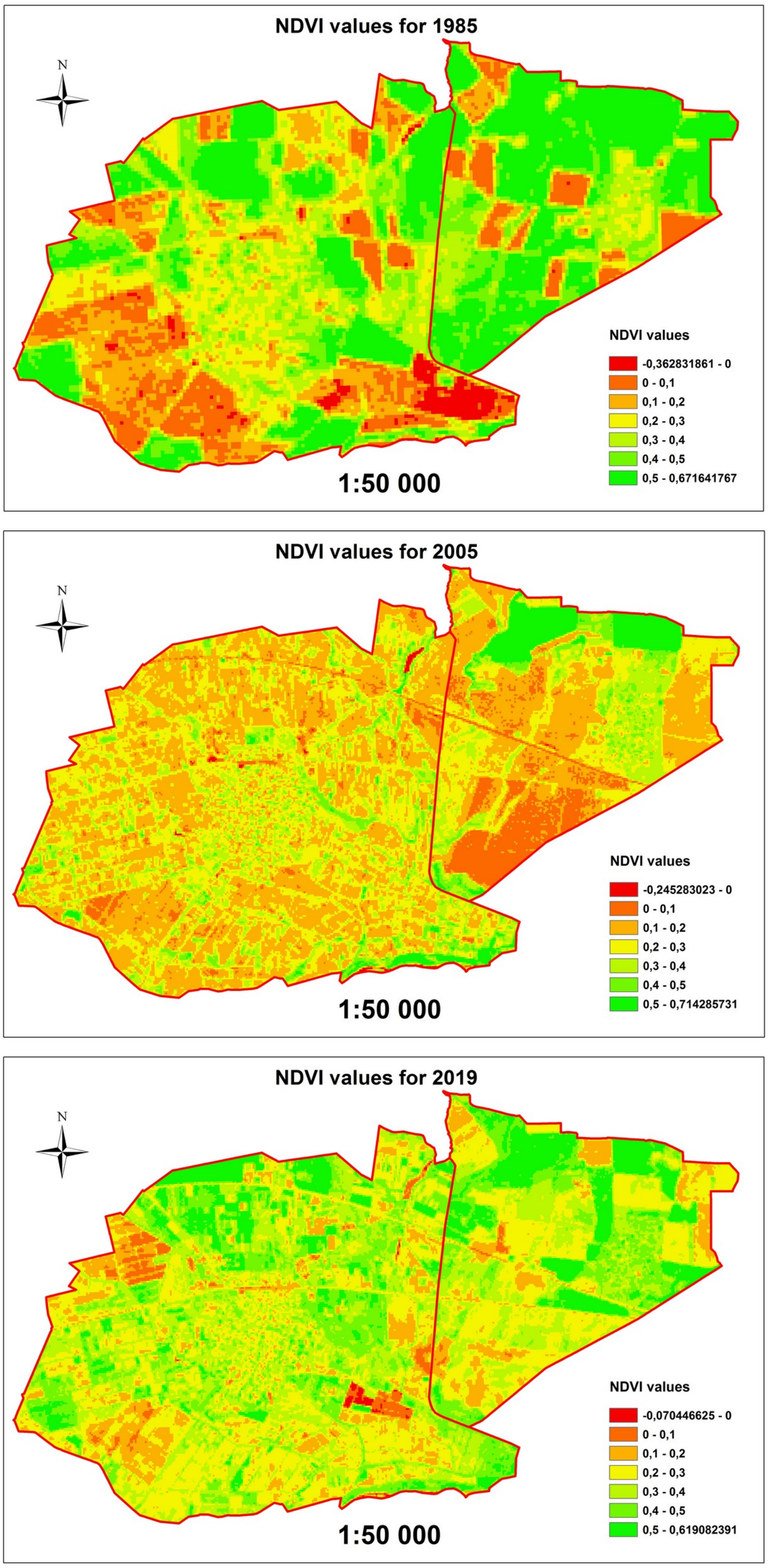

Fig. 2. NDVI values for 1985, 2005 and 2019.

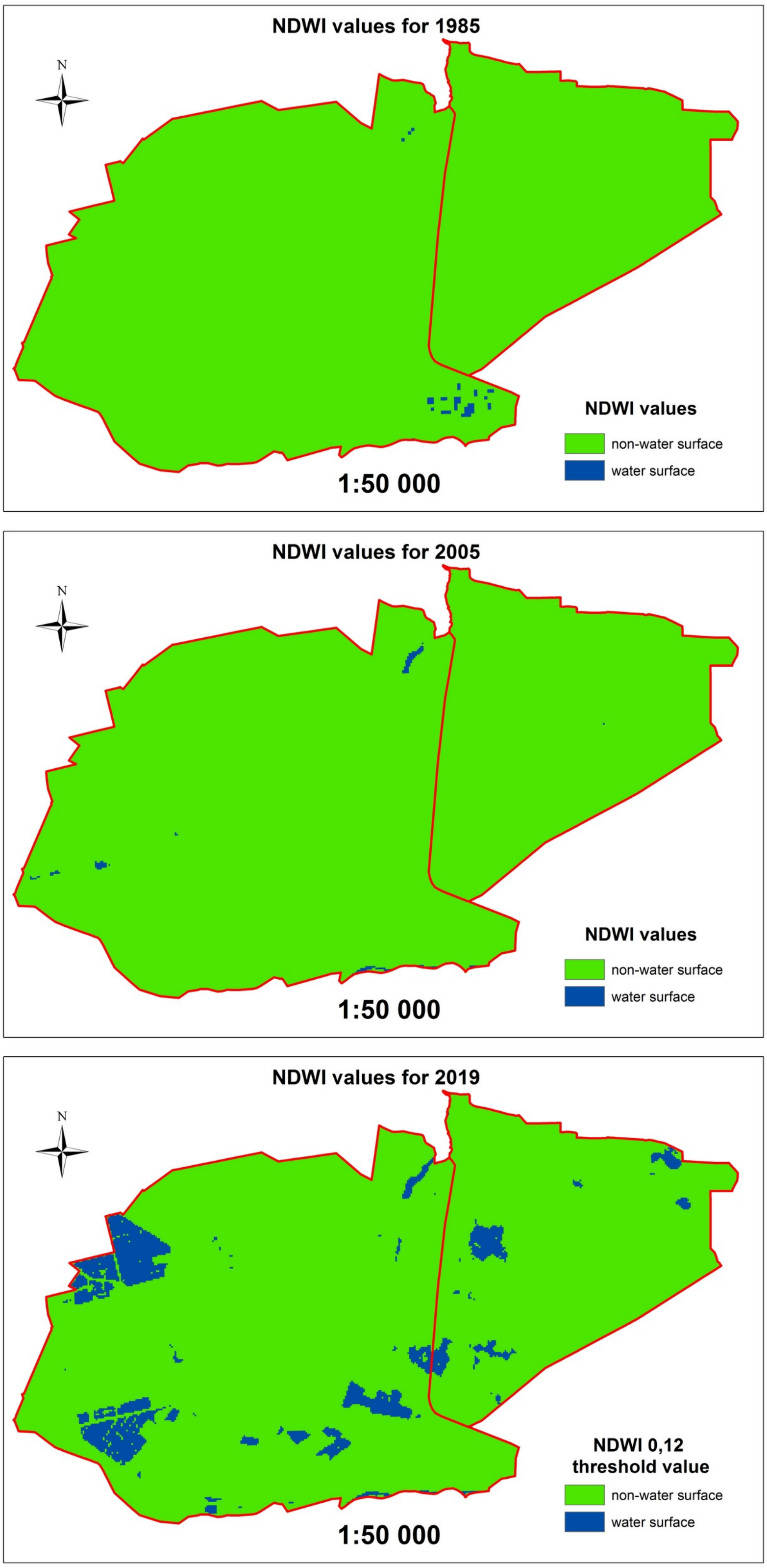

Fig. 3. NDWI values for 1985, 2005 and 2019.

The presence of surface water bodies is significant in the land of Belozem for the study period in 2019, as well as to a lesser extent for the land of Opalchenets during the same period. During the other two considered periods the surface water bodies on the territory of the two lands are insignificant in terms of spatial scope. This is probably explained by some features of the sub-branch specification of agricultural production in 1985 and 2005. Of the three time points considered, 2005 has the latest date - June 27. This could be one of the factors due to which no surface water bodies were registered during this period in the calculation of the NDWI index. It is quite possible to link the results to the fact that during the later periods of vegetative development of the rice crop the water layer in the rice fields is smaller compared to the water layer during the initial stage of development.

Based on the complex interrelations and interactions between natural factors and land use, the differentiation of the contemporary landscapes in the studied territory has been carried out. The diagnostic criteria of the used classification system are shown in Table. 1.

There are 23 different types of landscapes within the two lands. 17 of them are located on the territory of the land of Belozem and 15 of them are located on the territory of the land of Opalchenets.

The contemporary landscapes in both lands are shown in Fig. 4. and Fig. 5.

The results of the landscape metric analysis show that the landscape heterogeneity in the territory of Belozem village is more pronounced. In the Belozem land the fragmentation of the landscape structure is characterized by higher values, based on higher TE and MPE values. The landscape diversity of the Belozem land is more significant than that of Opalchenets based on higher values of Shannon's Diversity and Shannon's Evenness in Belozem. In this case, the higher degree of landscape diversity is due to the anthropogenic impact on the landscapes and not to natural preconditions. Results of landscape metrics analysis are shown in Table 2.

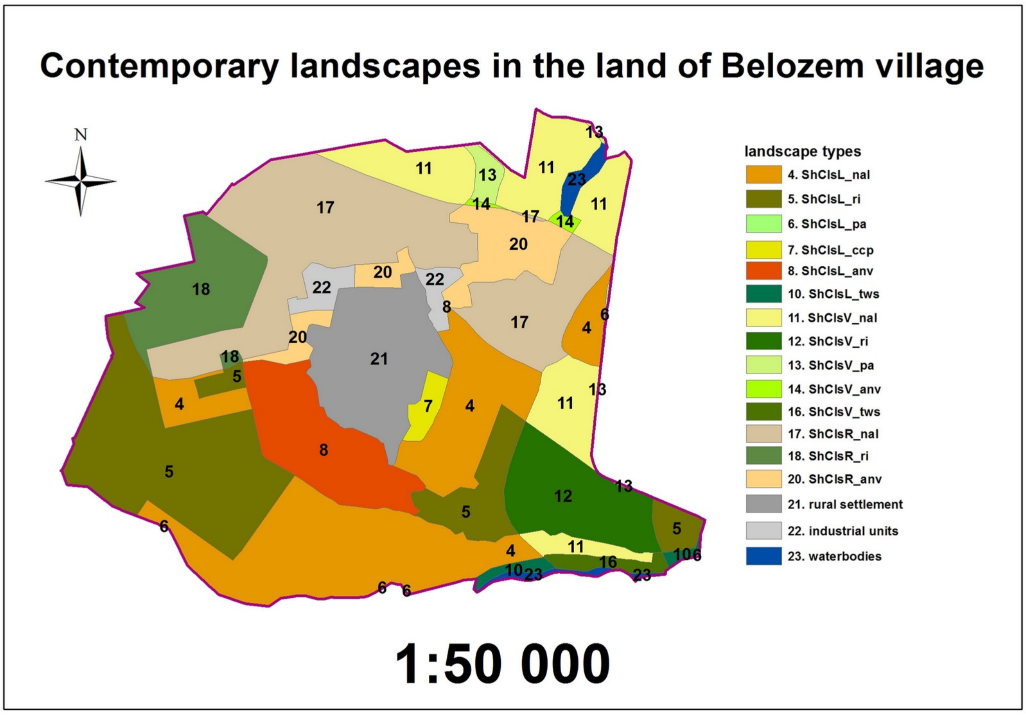

Fig. 4. Map of the contemporary landscapes in the land of Belozem Village.

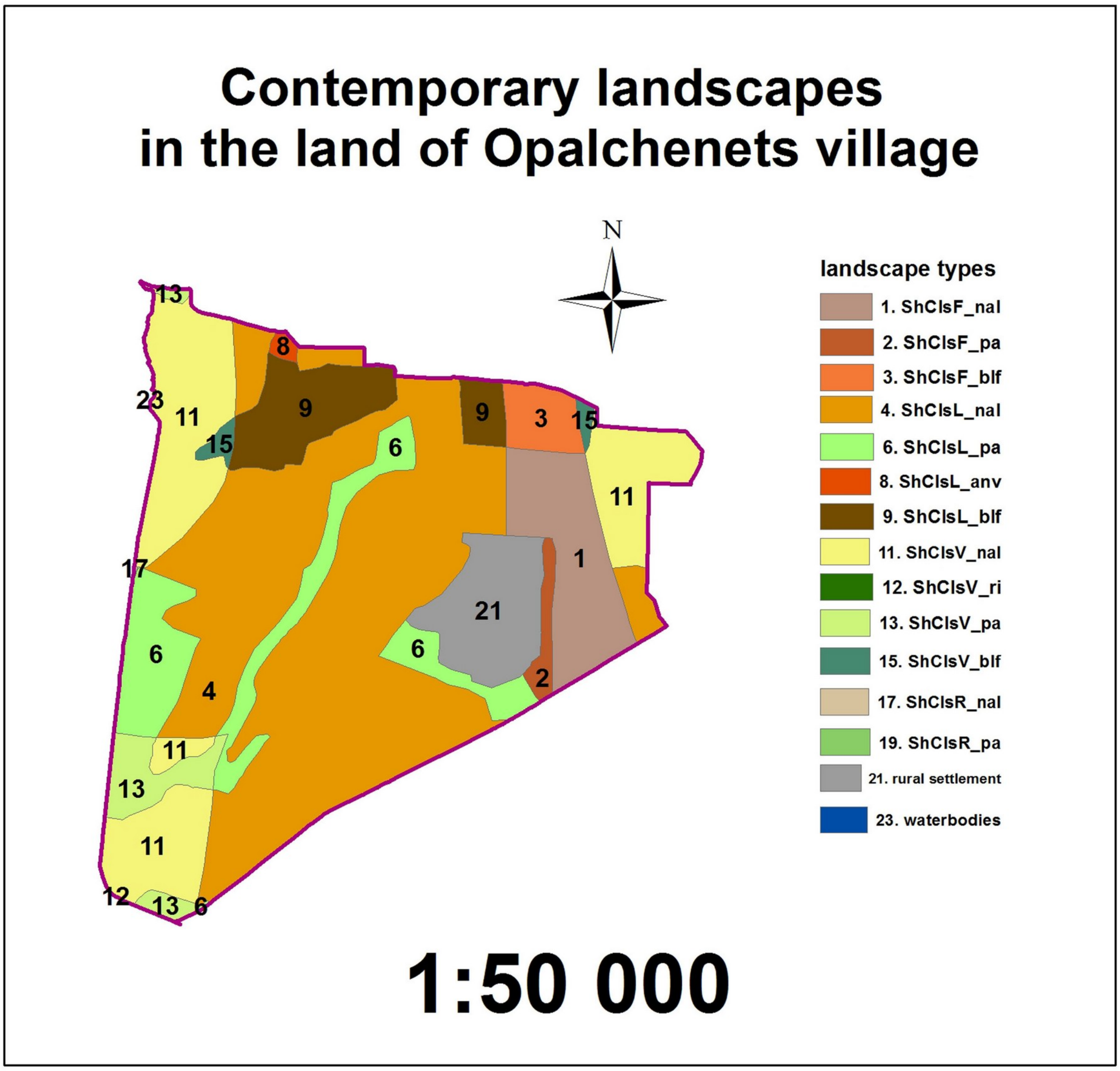

Fig. 5. Map of the contemporary landscapes in the land of Opalchenets Village.

Table 1. Diagnostic criteria and specifics of the typology classification system of the landscapes (after Tamburadzhiev, 2020).

Typology level	Diagnostic criteria	Symbol
Level 1	Climate	The 1st, the 2nd and the 3rd letters of the name (example: **ShC**lsF_nal)
Level 2	Slope	The 4th letter of the name (example: ShC**l**sF_nal)
Level 3	Parent material	The 5th letter of the name (example: ShCl**s**F_nal)
Level 4	Soil group	The 6th letter of the name (example: ShCls**F**_nal)
Level 5	Land use/ Land cover	The last letters of the name (example: ShClsF_**nal**)

Table 2. Results of landscape metrics analysis. *Legend:* Total Area (TA), Total Patches (NP), Edge Density (ED), Total Edge (TE), Mean Patch Edge (MPE), Mean Shape Index (MSI), Mean Perimeter-Area Ratio (MPAR), Mean Fractal Dimension (MFRACT).

Land	TA	NP	ED	TE	MPE	MSI	MPAR	MFRACT	Shannon's Diversity	Shannon's Evenness	Dominance
Belozem	41707669.50 sq. meters	34	44.66 meters per hectare	186281.45 meters	5478.87 meters	2.099	0.045	1.337	2.273	0.802	0.560
Opalchenets	19556636.87 sq. meters	21	53.12 meters per hectare	103887.23 meters	4947.01 meters	1.911	0.143	1.381	1.720	0.635	0.988

However, there are indicators that are characterized by higher values for the land of Opalchenets Village compared to the land of Belozem Village. These are, for example, the ED indicator, indicative of the degree of landscape fragmentation, and the Dominance indicator, indicative of the degree of landscape diversity. This should show that on the territory of both lands there are active processes of anthropogenization, which to one or another degree have an impact on the pattern and functioning of the landscapes.

Conclusions

The landscape pattern on the territory of the lands of Belozem Village and Opalchenets Village, shows some differences in spatial and temporal aspect. This is primarily due to the historical, socio-cultural, political and economic conditions affecting Land Use and Land Cover, and hence the formation of the entire landscape pattern. The temporal dynamics in Land Use and Land Cover is a major indicator of the interrelationships between the landscape pattern and the socio-political processes taking place in the field of agricultural production. The analysis of LULC is supplemented by calculating the NDVI and NDWI indices. The territories occupied with agricultural or natural vegetation are differentiated, as well as the water bodies and some infrastructural units. Significant differences were found in the spatial characteristics of the different types of Land Use in the land of Belozem for the three considered time points and relatively smaller differences for the spatial characteristics of the different types of Land Use in the land of Opalchenets for the three considered time points. After defining the main landscape-forming factors, differentiation and classification of the landscapes on the territory of the two lands was carried out. Twenty three different types of landscapes were differentiated within the study area. Seventeen of them are located on the territory of the land of Belozem and 15 of them are located on the territory of the land of Opalchenets Village. The landscape pattern of the land of the village of Belozem Village is characterized by a higher degree of fragmentation and landscape diversity, due to the active anthropogenic impact, compared to the landscape pattern of the land of the village of Opalchenets.

The study of anthropogenic transformations of landscapes through the use of remote sensing methods is an important stage in the overall process of analysis of the anthropogenic impact on a given area. Remote sensing is undoubtedly a necessary tool in the study of temporal dynamics and spatial features of landscapes. However, it is important its use to comply with the fundamental principles of landscape-ecological analysis in order to achieve maximum representativeness of the results obtained.

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