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MULTI-TEMPORAL ANALYSIS OF LAND USE/LAND COVER (LULC) IN THE NORTHERN RURAL PART OF THE PAZARDZIK-PLOVDIV FIELD USING REMOTE SENSING

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This study is based on the analysis of satellite images from 1985, 2005 and 2019 in order to differentiate the types of Land use and Land cover (LULC) on the example of the northern rural part of the Pazardzhik-Plovdiv field. The analysis is performed by calculating the values of the NDVI and NDWI indices representing the spectral reflectance of vegetation and water bodies for the three time points – May 1985, June 2005 and June 2019. After obtaining the NDVI and NDWI values, LULC supervised classification was performed for the three study periods. 5 different types of LULC have been established within the investigated area, 4 of which are distinguished on the basis of the reflectance values of vegetation and waterbodies. A comparative analysis of the changes in the LULC was done between the results for 2005 and 2019. Significant differences are observed in the type of Land use and Land cover during the period examined, which is mainly related to the transformations in the agricultural policy of the country after Bulgaria's accession to the European Union and its impact on the spatial structure of the LULC.

Key words: remote sensing, satellite data, land use, land cover, NDVI, NDWI, classification.

INTRODUCTION

The initial stage in the process of studying the landscape features of a certain territory is related to the analysis of the landscape-forming factors. Land Use/Land Cover (LULC) are a fundamental factor in the differentiation of contemporary landscapes, in the analysis of the state, structure and dynamics of landscapes, as well as in the complete investigation of the landscape diversity of any territory of the earth's surface. The study of the genesis, the characteristic manifestations and the degree of impact of the anthropogenic activity on landscapes is related to a complex of research processes, part of which is the analysis of the specifics of LULC. This research focus is particularly relevant in the implementation of landscape-ecological analysis in areas with active agricultural activity.

The specifics of the agricultural production, the peculiarities of its dynamic seasonal phases and their effects on the state and the structure of landscapes, both in spatial and temporal aspects, require a thorough and multi-aspect vision for this type of anthropogenic impact. However, accurate LULC analysis of a given territory is sometimes difficult to carry out only through fieldwork. That's why, the implementation of remote sensing is a necessary additional method, allowing the extension and work out in detail of the whole complex of analytical methods in landscape-ecological studies in order to achieve optimal representativeness of the final results.

The focus of this study falls on the identification of LULC types in agricultural areas by using the reflectance of vegetation and waterbodies. From a spatial point of view, the study is realized for a territory in the northern rural part of the Pazardzhik-Plovdiv field, Bulgaria, where a diverse range of different types of agrarian land use is traditionally registered, and the degree of urbanization is negligible. For the purpose of the study, LANDSAT multispectral satellite images were used, dated to the spring-early summer period: May 1985, June 2005 and June 2019. The choice of these years was motivated by the intention to make an attempt to achieve representative periodization to establish the relationship between the characteristic peculiarities of the different socio-political and socio-economic processes in Bulgaria, on the one hand, and their impact on land use, on the other. The years 1985, 2005 and 2019 are associated respectively with the periods of planned economy and cooperative agriculture before 1989, the period before Bulgaria's accession to the European Union, and the current period of full membership of the country in the community. The NDVI and NDWI indices for May 1985, June 2005 and June 2019 were calculated for getting results on the reflectance of vegetation and waterbodies, on the basis of which a supervised classification of Land use and Land cover was carried out for the three examined time points. A comparison was made between Land use and Land cover in June 2005 and June 2019 to identify changes in LULC at the beginning of the summer season. Cartographic products in

GIS environment and diagrams were generated, visualizing the different stages of the research process, as well as the final results.

METHODOLOGY

STUDY AREA

The object of this study is the Land use/Land cover in agricultural territories. Of particular importance for the investigation of the object of research is the choice of a representative study area.

The study area covers the lands of 19 villages in Plovdiv Province, located in the northern part of the Pazardzhik-Plovdiv field. These are the lands of the villages in Saedinenie Municipality – Lyuben, Nedelevo, Golyam chardak, Malak chardak, Tseretelevo, Tsarimir, in Hisarya Municipality – Novo Zhelezare, in Kaloyanovo Municipality – Zhitnitsa, Duvanlii, Kaloyanovo, Dolna Mahala, Chernozemen, Dalgo pole, Razhevo, Razhevo Konare, Glavatar, in Brezovo Municipality – Padarsko and Borets, and in Rakovski Municipality – Momino selo. The area of the territory is about 418 km^2. The study area is a lowland area with slopes of up to 3° and with slightly indented relief. In terms of climate, the investigated area falls in the Transitional-Continental climate region (Yordanova et al. 2002), with average January air temperatures above 0°C (Yordanova et al. 2002), average temperatures in July – 22–24 °C (Yordanova et al. 2002), and an annual rainfall of 500-600 mm (Yordanova et al., 2002). The main rivers that cross the study area are Pyasachnik and Stryama. Soils are represented by the groups of Fluvisols, Luvisols, Planosols, and Vertisols (Yordanova et al. 2002). The predominant vegetation is represented by agrophytocenoses. According to Asenov (2006), south of the Pyasachnik reservoir and the Pesnopoy Gorge of the Stryama River, small areas are occupied by xerophytic oak forests, with the participation of Quercus cerris, Quercus pubescens, Quercus virgiliana, Carpinus orientalis, Cotinus coggygria and Colutea arborescens. Parts of the protected area of "Yazovir Pyasachnik" (Council Directive 2009/147/EC on the conservation of wild birds) and the protected areas of "Pyasachnik River" and "Stryama River" (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora) of the Natura 2000 ecological network fall within the study area. One of the main types of landscapes that Nam (2003) describes as dominant in the Upper Thracian sub-region of the Upper Thracian-Burgas region, part of which is the study area, are landscapes of agrophytocenoses on Vertisols, Alluvial Planosols, Shallow and Chromic Luvisols. This also applies significantly to the landscape diversity of the study area. The population of the surveyed area is 15 395 according to the 2011 census.

The choice of a particular territory is based on the reasons for the inclusion in the research process of different by their nature types of Land use and Land cover, which are characteristic of the rural part of the lowland and are related mainly to active agricultural activity. At the same time, as a criterion for the selection of the territory for the present study was taken into account the remoteness from the area with the strongest urban links of the Plovdiv agglomeration, described by Tamburadzhiev (2020).

In fig. 1 the study area is presented.

SUBJECT OF RESEARCH

The subject of research of this study are the identification of the different types of Land use and Land cover in the years 1985, 2005 and 2019 within the territory under consideration, through the implementation of Remote Sensing, as well as the implementation of comparative analysis of changes in LULC on the basis of the received results for the different categories in 2005 and 2019. 2005 is excluded from the comparative analysis of the Land use and Land cover, since the satellite data used for the same year are of slightly earlier date. For this reason, we consider it is appropriate to make a comparative analysis only between the 2005 and 2019 data, since the satellite source information for these two years has approximately the same seasonal-temporal characteristics.

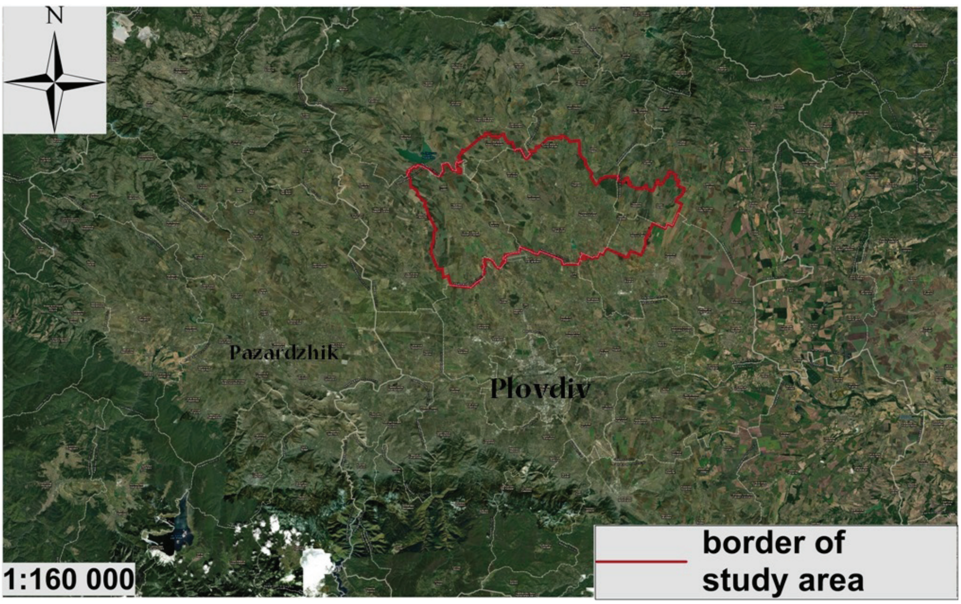

Fig. 1. Study area

DATA

LANDSAT 5 Multispectral Scanner (MSS), LANDSAT 5 Thematic Mapper (TM) and LANDSAT 8 Operational Land Imager (OLI) / Thermal Infrared Sensor

(TIRS) satellite images (path 183, row 031), acquired respectively on May 19, 1985, on June 27, 2005 and on June 18, 2019 are used. (https://earthexplorer.usgs.gov/). All images have the same coordinate system – WGS84 / UTM zone 35N. The spatial resolution of the LANDSAT 5 MSS 1985 image is 60x60 m, and the spatial resolution of the other two images is 30x30 m. The USGS Digital Elevation Model (DEM) (https://earthexplorer.usgs.gov/) was used to determine the slope values and the boundaries of the study area in the GIS environment. The European Environmental Agency river layer (https://www.eea.europa.eu/) was used. The settlement layer was extracted through Google Earth Pro. Topographic maps of the surveyed area from book-stock sources were used.

DATA PRE-PROCESSING AND PROCESSING METHODS

Satellite image processing and cartographic products generation were accomplished through the ArcGIS software package. Before implementing the spectral analysis of satellite images, it is necessary to unify their spatial resolution. For this purpose, a geometric correction of the 1985 satellite information has been made, by changing the spatial resolution from 60x60 m to 30x30 m. The nearest neighbor technique for resampling the satellite image in ArcGIS was used. Georeferencing of the DEM raster layer in ArcGIS was performed in order to adjust the relief layer to the WGS84/UTM zone 35N coordinate system used for the purpose of the study. Atmospheric correction of satellite data was not applied for the purposes of this study due to the low cloud cover values for the images from the three years studied.

A layer of the settlements within the study area was generated in Google Earth Pro. The layer was converted from KML format to SHP format to be visualized and processed in ArcGIS.

The Normalized Difference Vegetation Index (NDVI) (first used by Townshend and Justice (1986) and Tucker and Sellers (1986) for assessment of above-ground biomass and primary productivity (McFeeters 1996) was calculated for each of the three years, by combining the spectral bands of the individual satellite images. The results obtained provide information on the reflectance of the vegetation within the study area. Then, the Normalized Difference Water Index (NDWI) was calculated to define the spatial extent of the waterbodies and to differentiate them from the agricultural lands and the natural vegetation. The values obtained of the NDVI and NDWI indices are grouped into separate categories and cartographic images are generated, visualizing the distribution of NDVI and NDWI values within the study area. Supervised classification of the Land use and Land cover has been carried out through the maximum likelihood method implemented in ArcGIS. The classification is based on the interpretation of the values of the NDVI and NDWI indices, on the basis of exemplary reference values existing in the scientific literature, and on the basis of some specifics of the investigated space. The results of the classification are presented on maps for the three years examined and are grouped into separate categories, reflecting the types of Land use and Land cover in terms of the reflectance of the objects from the earth's surface. A comparative analysis of the changes in LULC was made between 2005 and 2019. The reasons for the participation of the results for Land use and Land cover only for 2005 and 2019 in the comparative analysis have already been highlighted in the "Subject of research" subsection.

RESULTS AND DISCUSSION

NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

The inclusion of defining the NDVI index as a method of Remote Sensing is related to the reflectance of the vegetation, expressed as the ratio between the Near-infrared and the Red spectral bands. In this way areas occupied by vegetation can easily be differentiated. By analyzing the values of the NDVI index, other objects from the earth's surface, such as waterbodies or anthropogenic facilities, for example, can be spatially determined and registered. Also, "reflectance-based remote sensing products like NDVI have been used to specify ecosystem growing season dynamics" (Reed et al. 1994; Schwartz 1997; White et al. 1997; Jenkins 2002). Therefore, the implementation of this index is useful not only for differentiating of separate LULC groups, but also for studying the seasonal and annual temporal dynamics of the vegetation component of the landscapes. The formula for calculating the NDVI index is:

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

where NIR is the Near-infrared band and R is the Red band of the satellite image. However, there are some specifics in the numbering and the name of the bands in the different developments of the LANDSAT program. For example, the NIR (band 4) and the visible (band 2) bands are used to calculate the NDVI index for LANDSAT 5 MSS satellite images (Gallo et al. 1987), but can also be calculated by Near-infrared1 (NIR1) band (band 3) and the Red band (band 2) (Chen et al. 2019). For the purpose of this study, the combination of band 4 and band 2 of the LANDSAT 5 MSS satellite image (from 1985) was used. For the LANDSAT 5 TM satellite image (from 2005), the combination of band 4 and band 3 (Markogianni et al, 2016) was used in calculating the NDVI index, and for the LANDSAT 8 OLI / TIRS satellite image (from 2019) the combination of band 5 and band 4 was used (https://www.usgs.gov/land-resou r ces/nli/landsat/landsat-normalized-difference-vegetation-index?qt-science_supp o rt_page_related_con=0#qt-science_support_page_related_con). The NDVI values range from –1 to +1, the largest of which are associated with the so-called „healthy-leaf vegetation", which is characterized by significant accumulation of chlorophyll in the leaves and the stems of the plants. As

Bozhkov (2016) points out, "low chlorophyll levels will result in different spectral characteristics of vegetation and therefore – in low NDVI values". The results obtained for 1985, 2005 and 2019 are shown in figs. 2, 3 and 4.

NORMALIZED DIFFERENCE WATER INDEX (NDWI)

In the present study, the NDWI index is used as an additional indicator for differentiating water surfaces from vegetation and soils.

Within the study area, dams, as well as rice fields in the initial stages of development, are considered as waterbodies. Gao (1996) proposes the use of Near-infrared (NIR) and Short-wave infrared wavelengths (SWIR) using the formula NDWI = (NIR – SWIR) / (NIR + SWIR) to obtain specific values of the NDWI index. However, this method is applicable to the determination of water content in plants and soil.

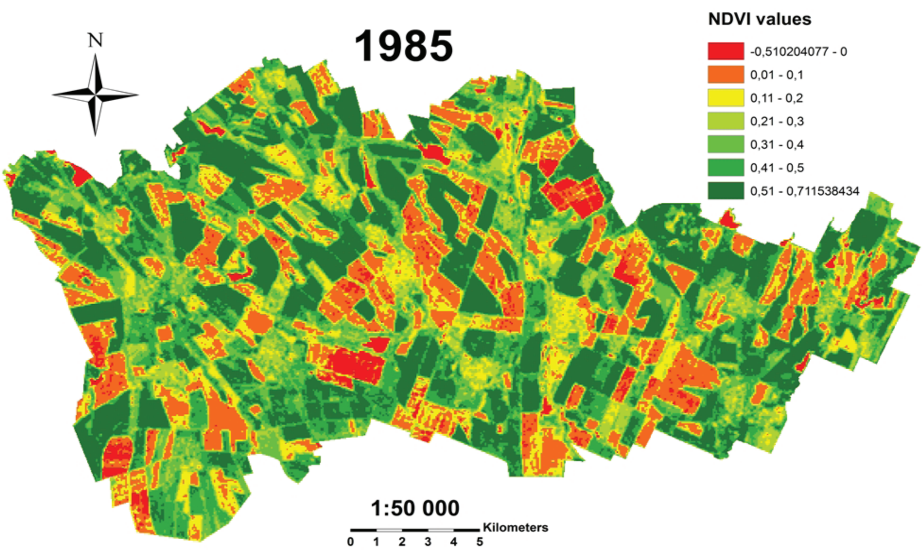

Fig. 2. NDVI values for 1985

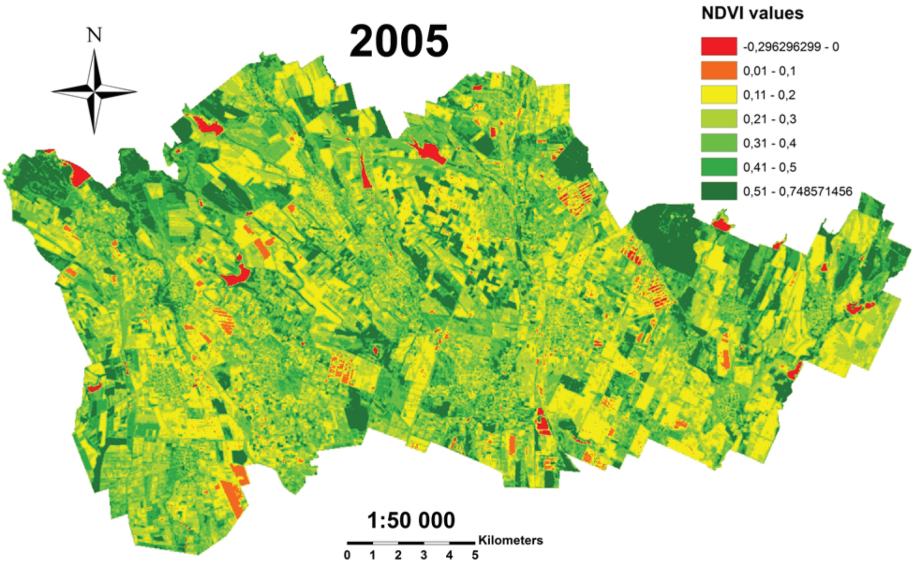

Fig. 3. NDVI values for 2005

With respect to changes in the state of waterbodies, however, McFeeters (1996; Xu 2006) offers a combination of Green and Near-infrared (NIR) wavelengths using the formula NDWI = (Green – NIR) / (Green + NIR), which is used for the purposes

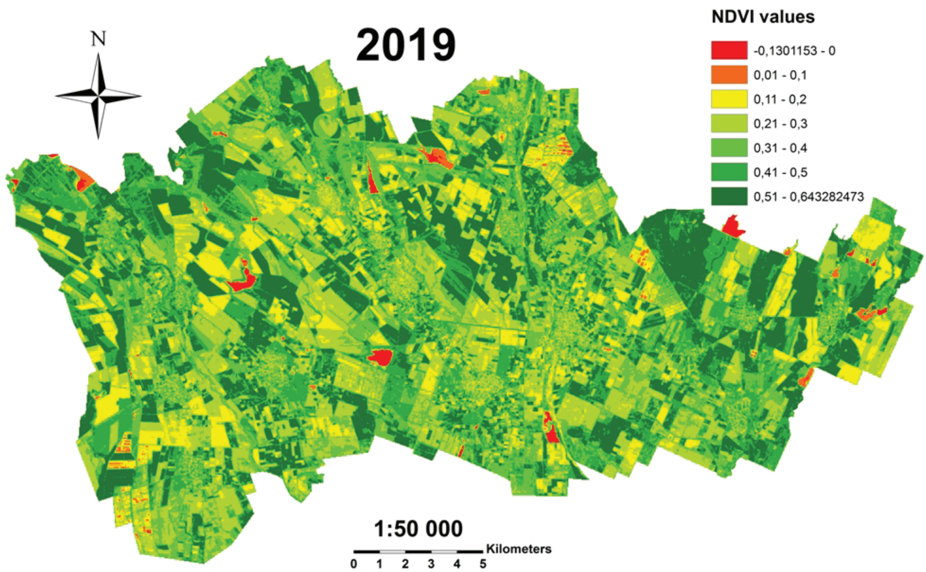

Fig. 4. NDVI values for 2019

of this study as well. For the LANDSAT 5 MSS satellite image (from 1985) the combination between band 1 (Green) and band 3 (NIR) (McFeeters 1996) was used, for the LANDSAT 5 TM satellite image (from 2005) the combination between band 3 and band 5 (Rogers et al. 2003) was used, and for the LANDSAT 8 OLI / TIRS satellite image (from 2019) was used the combination of band 3 (Green) and band 7 (SWIR2) (Özelkan 2019).

The classification of the NDWI values is based on the example of Özelkan (2019). For this purpose a threshold value of 0 for the 1985 and 2005 results and a threshold value of 0,12 for the 2019 results respectively, are defined. Values above 0, respectively for 1985 and 2005, and above 0,12 for 2019, respectively, are associated with the presence of a surface water body. The results of the NDWI index calculation are shown in fig. 5.

LAND USE/LAND COVER (LULC) CLASSIFICATION

In the current study, the classification of Land use and Land cover on the territory of the northern rural part of the Pazardzhik-Plovdiv field is carried out in terms of the reflectance of vegetation and waterbodies. For this reason, the separate LULC classes in the classification system are bound by the results of the calculation of the NDVI and NDWI indices.

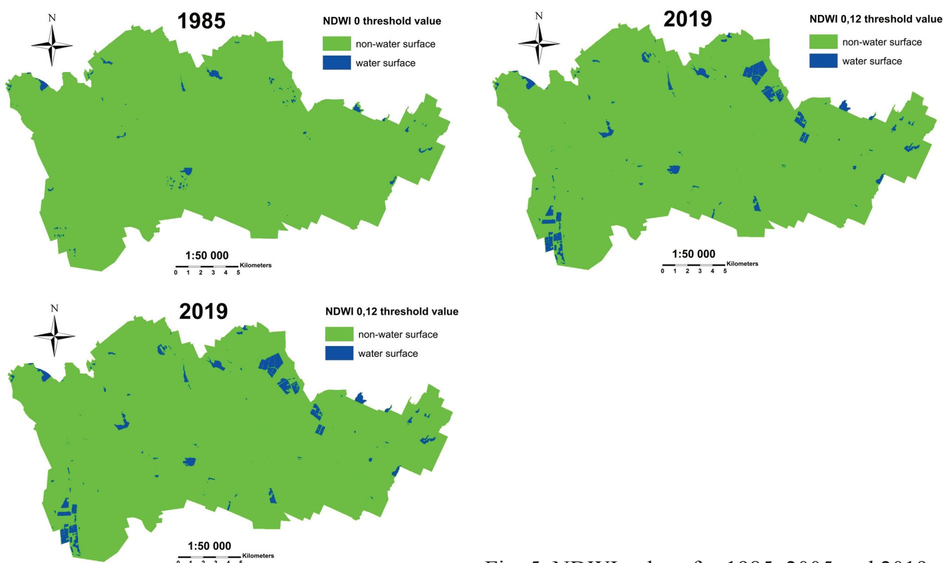

Fig. 5. NDWI values for 1985, 2005 and 2019

The classification of the Land use based on the NDVI index values is a challenge in terms of considering the phenological features of the vegetation as a major factor for the seasonal changes in the reflectance values of the objects from the land surface. In the analysis of the changes in Land cover and Land use in this study, a number of important aspects have been taken into account, related to the seasonal specificity of the development of crops and the methods for their cultivation. For example, in the analysis of the reflectance of annual crops, the temporal dynamics of the phenological phases of the plants were taken into account.

The differentiation of the particular types of Land use/Land cover is based on reference values for the NDVI and NDWI indices, presented in the scientific literature, relevant to the temporal dating of the satellite images used in this study and to the species characteristics of the natural and the agricultural vegetation in the Pazardzhik-Plovdiv field. For example, Sellers (1985) states, citing Miller (1972) and Dickinson (1983), that the reflectance of maize leaves during the growing season is 0,105 in the visible spectrum and 0,577 in the near infrared spectrum. Therefore, the NDVI value for maize calculated by the already pointed out formula is 0,69 during the growing season. (Ma et al. 2001; Flynn 2006) correlate the values of the NDVI index for maize to the range 0,50–0,80. Goodwin et al. (2018) reported that NDVI values for wheat in the 5 and 6 stages of plant development (out of a total of 11 stages) varied between 0,33–0,67 and 0,34–0,80, respectively. Flynn (2006) presents data on the NDVI index in the 4 and 5 stages of wheat development, grounded by Raun et al. (2001), respectively with a value of 0,83. In the region of the Pazardzhik-Plovdiv field, the ripening stage of the wheat begins from the end of May and ends to the harvest period, which begins in mid-June. This gives us reason to consider that during this period the amount of chlorophyll in the wheat plants is significantly lower and, respectively, the NDVI values for this crop are closer to the minimum values indicated in the reference sources. For sunflower, NDVI index values range between 0,23 at the end of May, when stage 3 in plant growth takes place, associated with stem growth, to 0,41 at stage 6 in plant development in early June, when begins the flowering (Herbei et al., 2015). For vineyards, NDVI values range from 0,73 to 0,84 for the months of November and December (Junges et al. 2019). However, these data on vineyard NDVI values refer to a study area in Southern Brazil. Therefore, by comparing the vegetation period of the vine in the Southern Hemisphere to its pass in the Northern Hemisphere, and considering that in the moderate latitudes of the Northern Hemisphere the vegetation period of the vine begins in March, we could consider to a considerable extent that is logical to equate November and December for the southern part of Brazil to May and June in the temperate latitudes of the Northern Hemisphere. Flynn (2006) also provides data on NDVI values for different grassland species, ranging from 0,6 to 0,89 (Mitchell et al. 1990; Todd et al. 1998; Moges et al. 2004; Flynn 2006), and Gamon et al. (1995) report NDVI values for annual grasslands in California from 0,15 to 0,45. NDVI values for rice vary between 0,59 and 0,89 for the stage of rice panicle development and between 0.5 and 0.84 for the milky stage (González-Betancourt et al. 2018). Nam et al. (2018) specify that for the Pazardzhik-Plovdiv field the rice growing season is from May-June to September. Therefore, within the considered temporal range of the current study, significant values of water level in the rice paddies, typical for the initial stages of the rice crop development, are considered, which is a major factor for the obtaining of lower NDVI values for the rice paddies in May and June. Oleson et al. (2000; Montandon et al. 2008) provide data on NDVI values for crops, grasses, shrubs, mixed and deciduous forests in the upper part of the Mississippi River basin (i.e. in temperate-climate region) as follows: crops, grasses and shrubs have a value of 0,75, mixed forests and forests have a value of 0,816, and deciduous forests have a value of 0,824. For forests in the temperate belt in France, for example, Pettorelli et al. (2006) point out NDVI values in the range 0,3–0,7 as relevant.

These values, of course, are indicative, but depend on the different phenological and biological characteristics of the different varieties of the crops examined, as well as the specifics of the climatic factors in the particular parts of the Earth's surface, which directly affect the development of the plants, and hence on the values of the reflectance of the leaves and stems.

In regard to the soil component, Jovanovic et al. (2018) propose NDVI values from 0,05 to 0,20–0,21. It should be made clear that the reflectance of the soil can be registered during the ploughing, after the harvest, or in cases in which the crop canopy or natural vegetation canopy has a low density.

The settlements within the study area are of rural type and are characterized by a sustainable trend of population decline. This is a valid argument to consider that there are no logical prerequisites for increasing the built-up area of the villages. Even assuming that there is a certain tendency for expansion of the territorial scope of the settlements, the changes would have negligible dimensions. For this reason, we considered it was necessary to register the spatial extent of the settlements in the form of a constant value, which did not change during the studied period.

Based on the analysis of the results obtained after the calculation of the NDVI and NDWI indices for the three time points examined, and according to the proposed reference values, a supervised classification was performed using the maximum likelihood method implemented through the ArcGIS software package. 5 types of Land use / Land cover within the study area are differentiated: 1) "healthy-leaf" vegetation; 2) annual crops and grasslands with lower reflection; 3) sparsely vegetated areas; 4) waterbodies; and 5) settlements. It should be emphasized here that the names of the classes "sparsely vegetated areas" and "waterbodies" are not strictly related to the definition of classes with identical names in the Corine Land Cover nomenclature. The "healthy-leaf" vegetation category includes areas with NDVI values above 0,41. It includes woodlands, shrubs, grasslands (for 1985), orchards, vineyards, maize, wheat (for 1985), vegetables, legumes, etc. Wheat and grasslands fall into this category only in the NDVI analysis for May 1985, because then their chlorophyll content is higher than at the end of June, since the data for 2005 and 2019 is. The “annual crops and grasslands with lower reflection” category unites areas with NDVI values from 0,21 to 0,40 and includes agricultural areas with wheat (for 2005 and 2019), sunflower and other crops that are in the initial or in the final stages of their growing period or are characterized by less canopy density, as well as grasslands (for 2005 and 2019). The “sparsely vegetated areas” category combines areas with NDVI values from 0,11 to 0,20 for 2019 and form 0,01 to 0,20 for 1985 and 2005. This category includes bare soils, plough soils and harvested fields. The “waterbodies” category includes areas with NDVI values below 0,1 for 2019 and below 0 for 1985 and 2005. It includes dams and rice fields in the aquatic development phase. The “settlements” category is differentiated based on a comparative analysis of available map materials and a manual drawing of polygons in Google Earth Pro. The results of the classification of Land use and Land cover in terms of the reflectance of vegetation and waterbodies for the three time points studied are shown in figs. 6, 7 and 8.

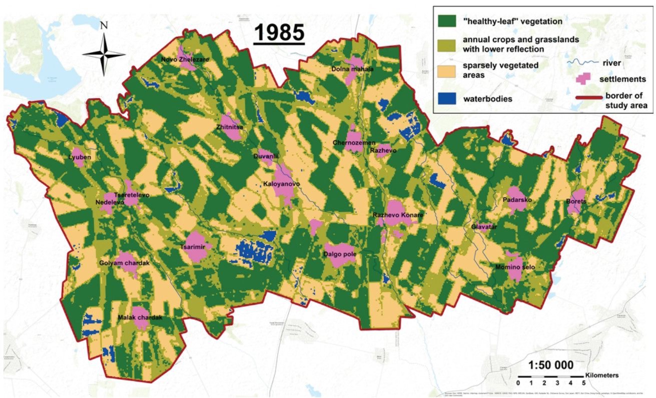

Fig. 6. Classification of the LULC in May 1985

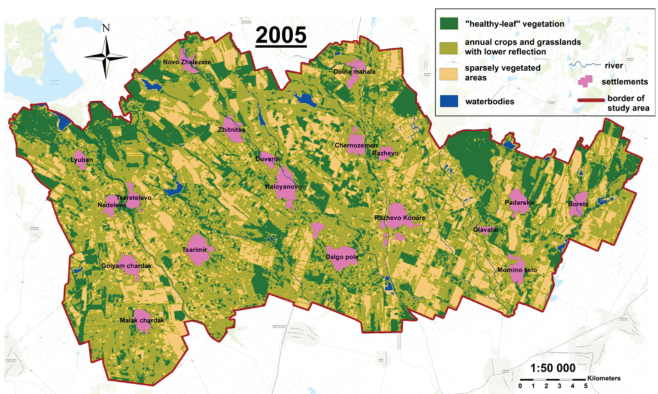

Fig. 7. Classification of the LULC in June 2005

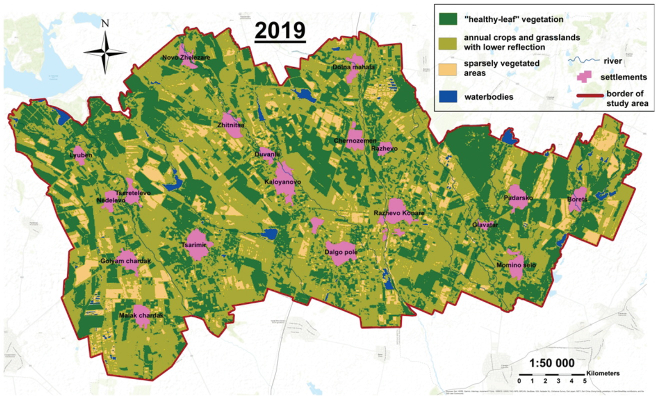

Fig. 8. Classification of the LULC in June 2019

The visual interpretation of the spatial extent of the LULC types indicates significant differences between 1985, on the one hand, and 2005 and 2019, on the other. It seems that there is greater fragmentation of the areas in 2005 and 2019 compared to 1985. This can be explained by the peculiarities of the organization of the agricultural production in the period before 1989, when the branch was subordinated to the principles of the cooperative agriculture, characterized by the cultivation of large areas, intended for the cultivation of a single type of agricultural crop.

The analysis of land use/land cover type could be extended in the direction of differentiation of particular types of crops, by the example of Gikov et al. (2019), which, however, requires amplification of the scope of the study to include a wider range of data and methodological practices.

POST-CLASSIFICATION ANALYSIS

Data on the area distribution of the particular Land use/Land cover categories by time points are presented in table.1 and fig. 9. The "healthy-leaf" vegetation category occupies the largest area in May 1985, whereas in June 2005 and June 2019 the area of the "annual crops and grasslands with lower reflection" occupies the largest area. This can be explained by the fact that at the end of June, much of the vegetation has already passed from the initial stage of development of the growing season to the middle stage of development. The "sparsely vegetated area category" has larger area in May 1985 compared to the other time points, because during this month the leaves of some crops that are in the initial stages of their growing season are not as well developed, as in corn and vegetables. In May 1985, and a larger area of water surface was registered, which may be related to the higher level of the water layer in the rice fields during the earlier stages of the rice crop development. A significantly smaller area of the "healthy-leaf vegetation" category was observed in June 2005 compared to the previous period for 1985 and the period for 2019. This is probably related to the species characteristics of the crops involved in the agricultural turnover during the three years examined. In June 2019, a significantly smaller area of the “sparsely vegetated areas” category is observed compared to the area of the same category in 2005, which is likely to be related to the harvest period beginning for the study area from mid-June and ends by early July, as mentioned earlier. This assumption could only be confirmed or rejected by analyzing the statistical literature related to the country’s economic turnover in 2019, which issue, however, is the objective of another study.

Table 1

Area distribution of the LULC categories in May 1985, June 2005 and June 2019

Land use/Land cover class	Area in square km in 1985	Area in square km in 2005	Area in square km in 2019
“Healthy-leaf” vegetation	155	88	133
Annual crops and grasslands with lower reflection	117	204	210
Sparsely vegetated areas	103	88	35
Waterbodies	7	3	4
Settlements	36*	36*	36*

* constant value

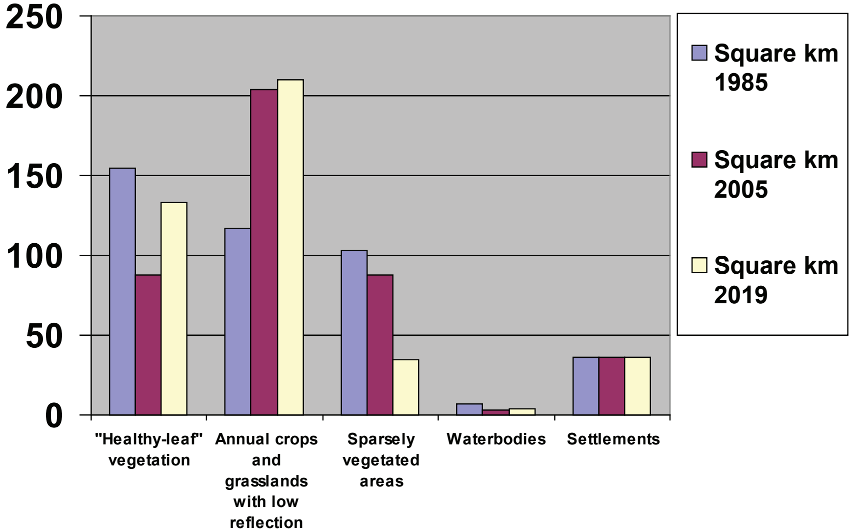

Fig. 9. Area distribution of the LULC categories in May 1985, June 2005 and June 2019

Pixel-level “from-to” change analysis (Fonji et al. 2014) was performed to identify changes in Land use and Land cover for June 2019 compared to June 2005. The analysis was carried out in GIS environment by comparing the Land use and Land cover layers for the two time points and combining them into one common layer. There are 13 categories of LULC changes from June 2005 to June 2019. Each of these categories is defined on a “change from-to” principle. 12 different combinations of LULC changes were differentiated, as well as one category reflecting the areas for which no changes were registered during the study period. The classification category of “settlements”, which, as it became clear, is regarded as unchanged or slightly changed during the study period, was not taken into account in the comparative analysis of The LULC changes. Fig. 10 shows the results the results of the comparative analysis between Land use and Land cover in June 2005 and June 2019.

Regarding the distribution of the LULC changes between June 2005 and June 2019, it seems that 50% of the examined categories have not changed. 22% of the LULC categories in 2005 were transformed into the “healthy-leaf vegetation” category in 2019, 21% of the LULC categories in 2005 were transformed into the „annual crops and grasslands with lower reflection” category in 2019, 6% of the LULC categories in 2005 were transformed into the “sparsely vegetated areas” category in 2019 and only 1% of the LULC categories in 2005 were transformed into the “waterbodies” category in 2019. This comparison is made with the proviso that the area data of the “settlements” category is not included. The results of the distribution of changes in Land use and Land cover between the two time points are reflected in the diagram in fig. 11.

It is noteworthy that a significant part of the Land use/Land cover categories have been transformed into another category for the relatively short period of 14 years. This is indicative for the differences in the nature of the processes which go in the agricultural sector of the economy on the territory of Bulgaria in the periods before and after the country's accession to the European Union, but it is also an indicator of the influence of climatic conditions on the pass of the growing season of agricultural crops, which directly influences the values obtained from calculation of the the reflectance of vegetation in a certain temporal range. The insignificant transformations in the “waterbodies” are a well-grounded reason to believe that the rice-cultivating sub-sector of the crop production does not find suitable conditions for increasing its spatial extent in the northern parts of the Pazardzhik-Plovdiv field. No changes were observed in the spatial extent of the micro-dams located in the study area of the lowland.

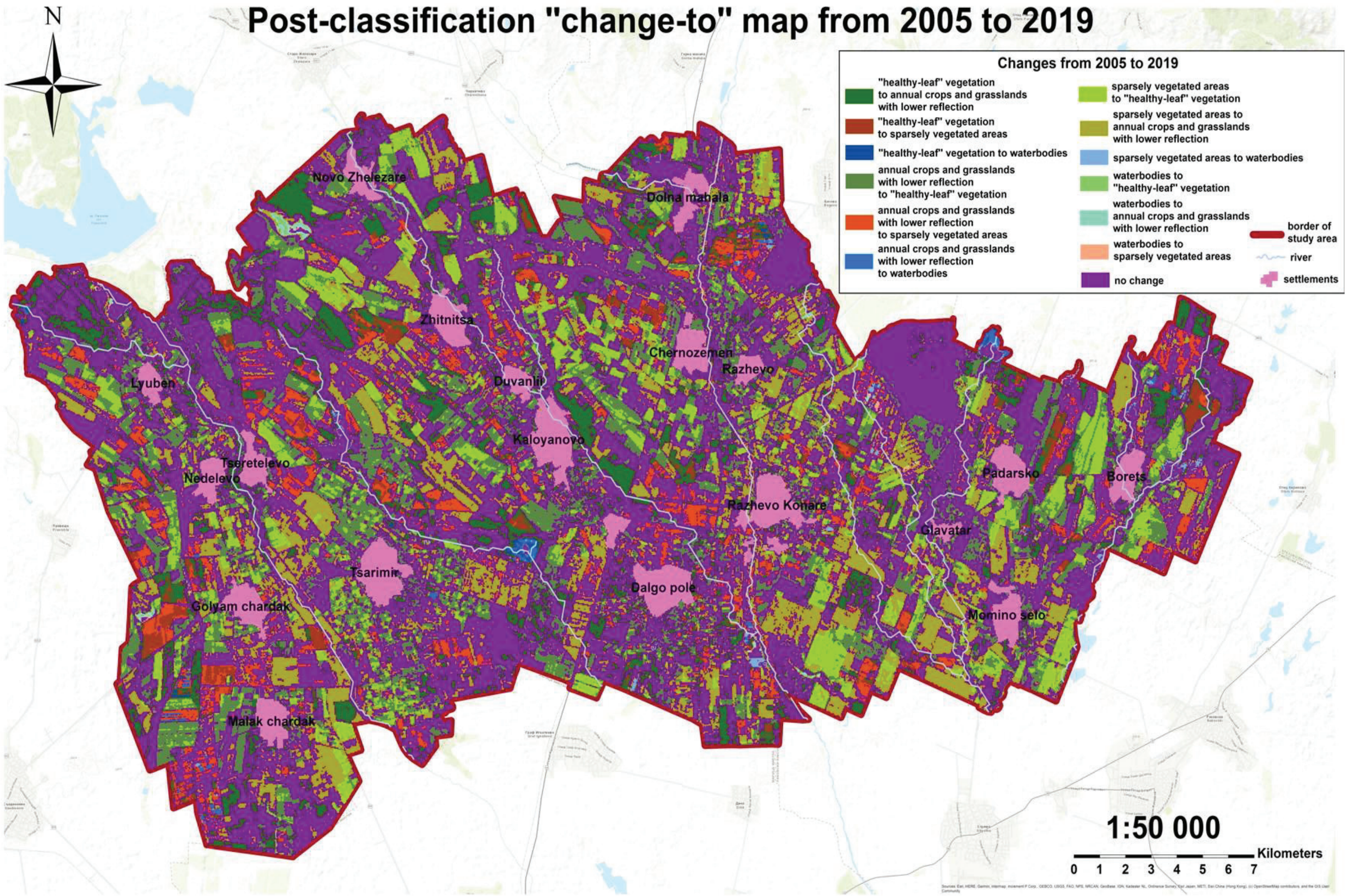

Fig. 10. Post-classification “change-to” map from June 2005 to June 2019

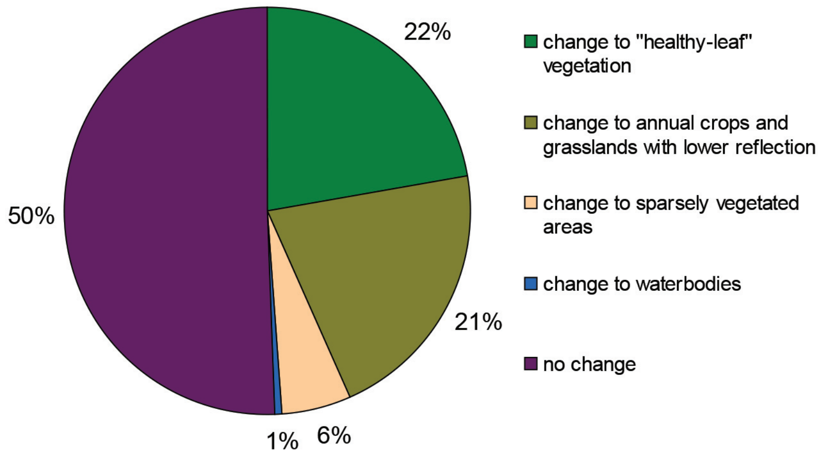

Fig. 11. Distribution of LULC changes between 2005 and 2019 (in %)

CONCLUSIONS

The use of Remote Sensing methods in the analysis of the specifics and transformations of Land use and Land cover by processing satellite images provides a unique opportunity to improve the analysis of the landscape features and the temporal dynamics of the landscapes in a certain area. As a result of the present study, 5 types of Land use/Land cover were differentiated within the scope of the studied sample area in the northern rural part of the Pazardzhik-Plovdiv field for May 1985, June 2005 and June 2019 – "healthy- leaf" vegetation, annual crops and grasslands with lower reflection, sparsely vegetated areas, waterbodies and settlements. The first 4 types were determined based on the calculation of the NDVI and NDWI indices and the grouping of the values obtained into 4 categories. The classification of the different LULC categories in terms mainly of the reflectance of vegetation was done by analyzing and comparing the reference values for the NDVI and NDWI indices applicable to the environmental features of the study area. The generation of the supervised classification allowed a comparative analysis between Land use/Land cover in June 2005 and June 2019. 12 LULC transformation categories were differentiated based on this analysis. It was found that 50% of the LULC did not change during the investigated period, 22% of the categories in 2005 were transformed into the „healthy-leaf vegetation" category in 2019, 21% of the categories in 2005 were transformed into the "annual crops and grasslands with lower reflection" category in 2019, 6% of the categories in 2005 were transformed into the „sparsely vegetated areas" category in 2019 and 1% of the categories in 2005 were transformed into the "waterbodies" category in 2019.

Despite the lack of intensive urbanization processes within the study area, the analysis of the specifics of Land use/Land cover showed significant differences not only between the periods before 1989 and after 1989, which is logical given the differences in the peculiarities of the economic system in the country and the organization of the agricultural production during the two periods. Significant transformations in the LULC were also observed between the periods before and after Bulgaria's accession to the European Union. This is primarily related to the new conditions for the development of the agricultural sector and the implementation of the common European policy in the agricultural sector in our country.

The use of satellite data is a fundamental method in the analysis of the LULC and its changes. The current study proposes a model for the study of this issue, which could be applied to other areas with high agricultural activity. However, interpreting the values of the reflectance of the components of the natural environment for the purpose of classifying the LULC categories and performing a comparative analysis of the transformations, is a great challenge in terms of taking into account the peculiarities of the vegetation species, the phenological phases of the growing season, the specifics of the climate manifestations in a global and local aspect and of the seasonal dynamics of the climate elements, the characteristic features of the soil types, the traditional agricultural practices in a certain territory etc. Therefore, the involvement of a wide range of specialists in the implementation of Remote Sensing in the investigation the Land use/Land cover and its transformations in temporal aspect is of great importance in order to specify and refine the theory and the empiricism of this scientific issue, and to improve the representativeness of the results obtained and enhancing the quality of their interpretation.

REFERENCES

Asenov, A. 2006. Biogeography of Bulgaria. Sofia: An-Di (in Bulgarian).

Bozhkov, P. 2016. Spatial and temporal analysis of vegetation canopy and their relation with slope processes in Zemen Gorge (West Bulgaria). – In: Proceedings of „International seminar of ecology – 2016, Sofia, 223–229.

Chen. F., S. Lou, Q. Fan et al. 2019. Normalized Difference Vegetation Index Continuity of the Landsat 4–5 MSS and TM: Investigations Based on Simulation. – *Remote sensing*, 11, 1681.

Dickinson, R. E. 1983, Land surface processes and climate-surface albedos and energy balance. – *Adv. Geophys*., 25, 305.

Flynn, E. S. 2006. Using NDVI as a pasture management tool. University of Kentucky, Master’s Thesis. 412.

Fonji, S. F., G. N. Taff. 2014. Using satellite data to monitor land-use land-cover change in North-eastern Latvia. – *SpringerPlus*, 3:61.

Gallo, K. P., C. S. T. Daughtry. 1987. Differences in Vegetation Indices for Simulated Landsat-5 MSS and TM, NOAA-9 AVHRR, and SPOT-1 Sensor Systems. – *Remote Sensing of Environment*, 23:439–452.

Gamon, J. A., C. B. Field, M. L. Goulden et al. 1995. Relationships between NDVI, canopy structure, and photosynthesis in three Californian vegetation types. – *Ecological Applications*, 5(1), 28–41.

Gao, B. 1996. NDWI – A Normalized Difference Water Index for Remote Sensing of Vegetation Liquid Water From Space. – *Remote Sensing Environment*, 58:257–266.

Gikov, A. P. Dimitrov, L. Filchev, E. Roumenina et al. 2019. Crop type mapping using multi-date imagery from the Sentinel-2 satellites. – *Proceedings of the Bulgarian Academy of Sciences*, 72, № 6.

González-Betancourt, M., Z. L. Mayorga-Ruíz. 2018. Normalized difference vegetation index for rice management in El Espinal, Colombia. – *Revista DYNA*, 85(205), 47–56.

Goodwin, A. W., L. E. Lindsey, S. K. Harrison et al. 2018. Estimating Wheat Yield with Normalized Difference Vegetation Index and Fractional Green Canopy Cover. – *Crop Forage Turfgrass Manage.*

Herbei, M. V., F. Sala. 2015. Use Landsat image to evaluate vegetation stage in sunflower crops. – *AgroLife Scientific Journal*, vol. 4, № 1.

Jenkins, J. P., B. H. Braswell, S. E. Frolking et al. 2002. Detecting and predicting spatial and interannual patterns of temperate forest springtime penology in the eastern U.S. – *Geophys. Res. Lett*., 29(24), 2201.

Jovanović, M. M., M. M. Milanović, B. R. Vračarević. 2018. Comparing NDVI and Corine Land Cover as Tools for Improving National Forest Inventory Updates and Preventing Illegal Logging in Serbia. – *Vegetation*. INTECH.

Junges, A. H., D. C. Fontana, C. S. Lampugnani. 2019. Relationship between the normalized difference vegetation index and leaf area in vineyards. – *Agrometeorology. Bragantia, Campinas*, v. 78, № 2, 297–305.

Ma, B. L., L. M. Dwyer, C. Costa et al. 2001. Early prediction of soybean yield from canopy reflectance measurements. – *Agron. J*. 93:1227–1234.

Markogianni, V., E. Dimitriou. 2016. Landuse and NDVI change analysis of Sperchios river basin (Greece) with different spatial resolution sensor data by Landsat/MSS/TM and OLI. – *Desalination and Water Treatment*, 1–12.

McFeeters, S. K. 1996. The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. – *Int. J. Remote Sensing*, vol. 17,№ 7, 1425–1432.

Miller, L. D. 1972. Passive remote sensing of natural resources. Dept. Watershed Science, Colorado State University, Colorado.

Mitchell, A. R., P. J. Pinter, Jr., J. N. Guerrero et al. 1990. Spectral reflectance measurements of alfalfa under sheep grazing. – *Agron. J.* 82:1098–1103.

Moges, S. M., W. R. Raun, R. W. Mullen et al. 2004. Evaluation of green, red, and near infrared bands for predicting winter wheat biomass, nitrogen uptake, and final grain yield. – *J. Plant Nutr*. 27:1431–1441.

Montandon, L. M., E. E. Small. 2008. The impact of soil reflectance on the quantification of the green vegetation fraction from NDVI. – *Remote Sensing of Environment*, 112, 1835–1845.

Nam, K. 2003. Physical Geography of Bulgaria. Sofia: Geosfera (in Bulgarian).

Nam, K., I. Tamburadzhiev. 2018. Landscape ecological preconditions for rice producing in Bulgaria. – In: Proceedings of the IX International Agricultural Symposium “Agrosym 2018”. Jahorina, Bosnia and Herzegovina, 1452–1458.
Oleson, K. W., W. J. Emery, J. A. Maslanik. 2000. Evaluating land surface parameters in the biosphere–atmosphere transfer scheme using remotely sensed data sets. – *Journal of Geophysical Research*, 105, 7275–7293.
Özelkan, E. 2019. Water Body Detection Analysis Using NDWI Indices Derived from Landsat-8 OLI. – *Pol. J. Environ. Stud*., vol. 29, № 2, 1759–1769.
Pettorelli, N., J. M. Gaillard, A. Mysterud et al. 2006. Using a proxy of plant productivity (NDVI) to track animal performance: the case of roe deer. – *Oikos*, 112:565–572.
Raun, W. R., G. V. Johnson, M. L. Stone et al. 2001. In-season prediction of potential grain yield in winter wheat using canopy reflectance. – *Agron. J*., 93:131–138.
Reed, B. C., J. F. Brown, D. VanderZee et al. 1994. Measuring phenological varability from satellite imagery. – *J. Veg. Sci*., 5, 703–714.
Rogers, A. S., M. S. Kearney. 2003. Reducing signature variability in unmixing coastal marsh Thematic Mapper scenes using spectral indices. – *Int. J. Remote Sensing*, vol. 25, № 12, 2317–2335.
Schwartz, M. D. 1997. Spring index model: An approach to connecting satellite and surface phenology. – In: Phenology in seasonal climates. H. Lieth, M. D. Schwartz (eds). Leiden, The Netherlands: Backhuyas Publishers, 23–38.
Sellers, P. J. 1985. Canopy reflectance, photosynthesis and transpiration. – *Int. J. Remote Sensing*, vol. 6, № 8, 1335–1372.
Tamburadzhiev, I. 2020. Analysis of the anthropogenization of the landscapes in the area of Plovdiv agglomeration. – In: Proceedings of “International seminar of ecology – 2019”, dedicated to the 75th anniversary of USB and 150th anniversary of BAS, Sofia, 55–66.
Todd, S. W., R. M. Hoffer, D. G. Milchunas. 1998. Biomass estimation on grazed and ungrazed rangelands using spectral indices. – *Int. J. Remote Sensing*. 19:427–438.
Townshend, J. R. G., C. O. Justice. 1986, Analysis of the dynamics of African vegetation using the Normalized Difference Vegetation Index. – *International Journal of Remote Sensing*, 7, 1435–1445.
Tucker, C. J., P. J. Sellers. 1986. Satellite remote sensing of primary productivity. – International *Journal of Remote Sensing*, 7, 1395–1416.
White, M. A., P. E. Thornton, S. W. Running. 1997. A continental phenology model for monitoring vegetation responses to interannual variability. – *Glob. Biogeochem. Cycles*, 11, 217–234.
Xu, H. 2006. Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. – *International Journal of Remote Sensing*., vol. 27, № 14, 3025–3033.
Yordanova, M., S. Velev, I. Drenovski. 2002. Geography of Bulgaria Physical and Socio-economic geography of Bulgaria. Part one Physical Geography. Geography Institute of BAS. Sofia: ForKom (in Bulgarian).

https://earthexplorer.usgs.gov/
https://www.eea.europa.eu/
https://www.usgs.gov/land-resources/nli/landsat/landsat-normalized-difference-vegetation-index?qt-science_support_page_related_con=0#qt-science_support_page_related_con