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REMOTE SENSING FOR DESERTIFICATION MONITORING IN BRAILA COUNTY

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Abstract

Desertification of agricultural areas has been growing as a key subject in continental land management, as large parts of traditional farming zones degraded over the years, as a consequence of climate changes and antropic vicious actions. Soil degradation up to desertification of large agricultural areas in Braila county plains, results as an interaction between local salinised soil and climate variation, leading to long periods of draoughts. Remote sensing for the determination of the intensity and extension of desertified areas is a solution to better understand the impact of this phenomena in Braila county. The objective of this paper is to determine whether climatic variations continue the present trend, through a comparation based on the Normalized Difference Drought Index – NDDI from MODIS producs processed with spatial analyst of ArcGis, for 2000-2005-2010-2016. The time interval was chosen due to agroclimatheric classifications, considering 2000 is classified as draght year, 20005 a normal climateric year and 2010 a rainy year. A multi-temporal series of MODIS data were gathered, 8 days synthesis, in order to determine NDDI, with empirical formulas based on the spatial images computed values, for the normalised differenced vegetation index – NDVI and normalised difference water index – NDWI. Measuring the NDVI variation based on the clorofile absorbed radiation in the red spectral band and closed infrared reflectancy, allowed us to identify the impact on vegetation cover, while computing NDWI from green and closed infrared spectral band, delivered information on the vegetation water content. The resulted values of NDDI, computed for the vegetation period, April to October, confirm 2016 as a rather normal year for agricultural purpose.

***Key words**: agriculture, desertification, land degradation, remote sensing*

INTRODUCTION

Agricultural soil quality has been an important issue forever, both for the intensive and extensive growing systems. Engineering solutions to upgrade the soil production capacity are being developed continuously, but applied over long periods of time, resulted in depraved ecosystems consequences. It is the case of parts of Braila County in Romania, where large traditional agricultural areas converted to deserted zones, as a result of natural local conditions, land reclamation systems and climatic conditions.

Since 1997, Romania has ratified the UNCCD convention, through Law 629 and National Strategies and Action Plans have been elaborated in order to identify problem areas and solutions to control and combat desertification and its catastrophic consequences. Soil and ecosystems quality evaluation for the studied area have been conducted since 1970's, along with the development and implementation of the land reclamation systems.

The main engineering works consisted in irrigation and drainage structures, aiming to protect agricultural crops against natural drought and high levels of phreatic waters, Braila County being the second county with more than 380,000 km^2 of agricultural areas with land reclamation works in the country, after Constanta County.

The studied area is situated in south – east of Romania and is part of the Romanian Plain, one of the most productive agricultural zones in the country.

Intensification and extension of the soil degradation processes along with higher natural environmental resources vulnerability to aggressive factors, is a consequence of the agricultural industrialisation and technology severe rhythm, in order to multiply the productivity and contribution of agriculture to the economic development of the country (Robescu, 2008).

This is confirmed by the multi annual evaluation of soil quality and environmental factors evolution, conducted by the National Research and Development Institute for Soil Science, Agricultural Chemistry and Environment (ICPA) which entailed a long term degradation of some peculiar areas, where natural conditions were ignored, for the aforementioned scope.

Phases of these analysis starting with 1973, indicated a natural tendency of the soil for secondary salinization, conducting to a massive loss of agricultural crops endorsed in the area, corroborated with the phreatic uplift varying from 1 to 3 metres, due to precipitations and irrigations contribution.

Following 1990, the irrigation systems in the areas have been chaotically used, despite intensive warnings of the ICPA regarding soil and ecosystems degradation in vulnerable areas.

The negative effects led to the desertification of more than 2,000 ha in the county, affecting the integrity of the environment, both agricultural and wildlife and destroying ecosystems and their services for the local communities. The vulnerable agricultural areas in Braila County have been locally quantified according to the publications of the Agricultural Chamber of Braila, but it is still unclear if there is a classification for the degraded soils or whether areas affected by desertification have been separately taken into account.

The analysis of the paper is focusing on the evaluation of desertification extent in Braila County, by computing values of drought indexes, extracted from satellite images. The main objective is to be able to make a comparison between 2000, which is considered to be a drought year, 2005, considered to be a normal climatic year and 2010 a rainy year, to determine values of climatic indexes in 2016. For this comparison, values for an important parish in Great Island of Braila (Marasu) were extracted from the processed images, as presented.

The determination of 2016 values in a cycle of alternating climatic indexes is attained by computing 3 out of the 50 essential climate variables defined by GCOS (Global Climate Observing System) regarding the terrestrial domain, land cover, including vegetation type.

MATERIALS AND METHODS

The objective of this paper is to determine the variation of the normalised differenced drought index – NDDI, for Braila County, between 2000-2005-2010-2016, in order to identify areas of high vulnerability to desertification and to establish for the vegetation period, whether 2016 draws up to drought periods.

The satellite images MODIS (Moderate Resolution Imagining Spectroradiometer) used for this study allow a detalied analisys for the land cover, mostly regarding the vegetation densenesse, because of the resolution, spatial, spectral and temporal and last but not least because of free access allowed by NASA (Wardlow, 2008).

Data processing was using the software application ArcGis.

For the computed values of NDDI, 2 prior steps were mandatory: the calculation of normalised difference vegetation index – NDVI and normalised difference water index – NDWI. All 3 aforementioned normalised differenced indexes are actually satellite images resulted from spatial analysis of the MODIS products, synthesis of 8 days in the time interval, in grey tones, for each year's vegetation period.

Their determination is possible by conducting different arithmetic operations for spectral bands, namely by amplifying the spectral band corresponding signature in which an element has the highest reflectance or by diminishing the objective signature for the band with lowest reflectance (Bogdan, 2008). The resulted image pixels have floating values between (-1) and (+1). This kind of normalised differenced indexis can be applied to most of the multispectral images. The NDVI – normalised differenced vegetation index was first introduced by Dr. John Rouse, in 1973, as a tool to classify the vegetation areas and types, the state of vegetation and/or land use (Boelman et al., 2003). The general values of NDVI vary function on the radiation absorption by the chlorophyll, in the red spectral zone and it's reflectance to the close infrared, in the interval (-1) and (+1) defining the consistency of green vegetation. The light grey images, with values of NDVI close to (+1) represent a high consistency of vegetation while dark tone of grey (on the processed images) with values

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around (-1) indicates low vegetation cover areas, with soil or rocks exposed to erosion. Values of NDVI close to zero, defined by intermediary tones of grey and are associated to lawn areas. The empiric computing formula (1) expresses the spectral differences signature, at the limits of visible, red area and infrared area (close infrared):

$$\text{NDVI} = \frac{(B\_1*0{,}0001 - B\_2*0{,}0001)}{(B_1*0{,}0001 + B\_2*0{,}0001)} \text{........(1)}$$

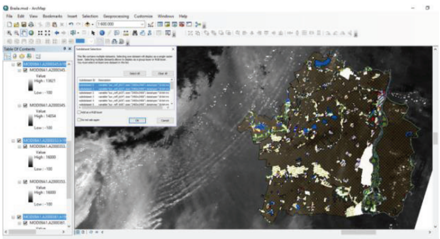

Figure 1. Rb1 and Rb2 selection for NDVI determination

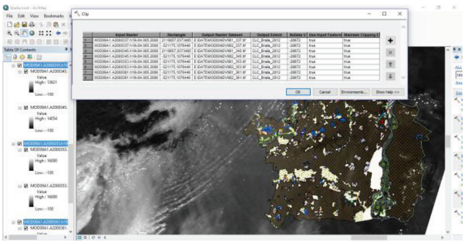

Figure 2. Rb1 and Rb2 *Clip* from MODIS product

The spectral bands were processed by using the function ArcToolbox – Data Management – Raster Processing – Clip – Batch, which allowed to differentiate the 2 spectral bands (B1&B2) for the analisyed sector, Braila County and the multiplied factor for each band is 0,0001, characteristic for the product (Figure 1 and Figure 2).

The NDWI – normalised differenced water index was introduced by McFeeters in 1996 and is largely used for the classification of water corps, differences of tubidity and vegetation water content. The determination of NDWI values is based on the green spectral bands and closed infrared, which brings up the spectral response of humidity from soils, rocks and plants. The computed values are between (-1) and (+1) where values below zero indicate water corps while values above zero (0) with light grey indicate dry land (Elmore, 2000). The empiric formula used for NDWI is (2):

$$\text{NDWI} = \frac{(B\_2*0{,}0001 - B\_6*0{,}0001)}{(B\_2*0{,}0001 + B\_6*0{,}0001)} \text{.......(2)}$$

Similar to the determination of NDVI values, the spectral bands were processed by using the function ArcToolbox – Data Management – Raster Processing – Clip – Batch, which allowed to differentiate the 2 spectral bands (B2&B6) for the analisyed sector, Braila County, and the multiplied factor for each band is 0,0001, characteristic for the product. The NDDI, normalised differenced draought index, was computed using the data extracted for NDVI and NDWI, applying the empiric formula (3):

$$\text{NDDI} = \frac{(\text{NDVI}-\text{NDWI})}{(\text{NDVI}+\text{NDWI})} \text{......................(3)}$$

RESULTS AND DISCUSSIONS

The computed values for NDVI in Braila county, show for 2016 vegetation period a slightly decrease for the vegetation index, between 2010, considered a rainy year and 2016, the analysed interval. Values in the table below have been extracted for Marasu parish, in Great Island of Braila. The area is of particular interest as part of the most fertile and new created agricultural soil in the county, but with desertification issues as well. NDVI values are at their minimum in April, for each of the analysed years, compared to the following month, mainly because of the lack of precipitations in March, which may have caused a delay of the vegetation phase start.

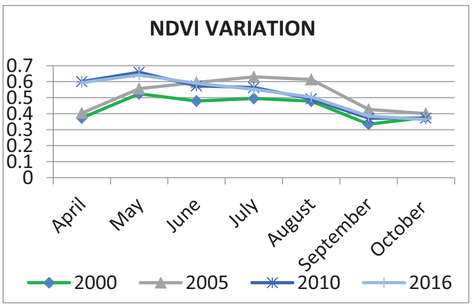

Figure 3. NDVI variation from April to October
2000 – 2005 – 2010 – 2016

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The NDVI data show a rather equal set of values between the four years, with a slight grow in 2005, 2010 and 2016 compared to 2000 for the next periods from May to August (Figure 3). As presented in Figure 4 and Figure 5, the drought phenomena in 2000 began early in April, affecting plant evolution from the start, while the vegetation season in 2016 compared to 2005 (Figure 5) and 2010 (Figure 6) confirms a normal climatic year. Only during the last vegetation phenophase a visible difference occurs between 2000 and 2005.

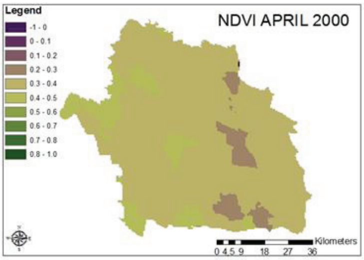

Figure 4. NDVI values for April 2000

Years 2010 (Figure 6) and 2016 (Figure 7) on the other hand, reveals greater values due to high level of precipitations overall the interval, as presented in Figure 3.

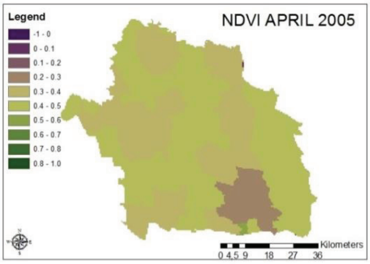

Figure 5. NDVI values for April 2005

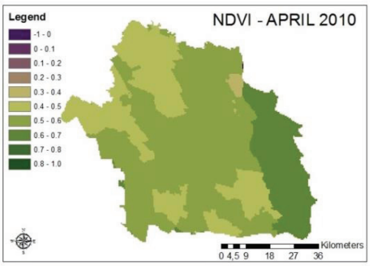

Figure 6. NDVI values for April 2010

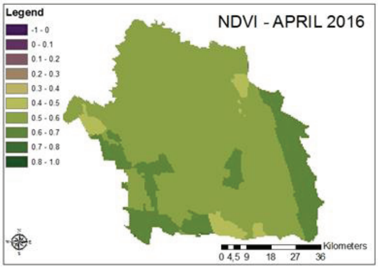

Figure 7. NDVI values for April 2016

The amount of water available in the internal leaf structure largely controls the spectral reflectance, therefore NDWI has a higher potential for drought monitoring because of the two spectral bands used for its calculation, that are responsive to changes in the water content (SWIR band). As a result, NDWI is influenced by both the desiccation and wilting of vegetation and could represent a more sensitive drought indicator than traditional remote sensing-based indices such as the Normalized Difference Vegetation Index (NDVI), which do not account for changes in the vegetation's water content. This index increases with vegetation water content or from dry soil to free water. For the analised interval, values of the NDWI are the lowest in April 2000 with comparable values for 2010 and 2016, as presented in Figure 8, with an increse for May and June.

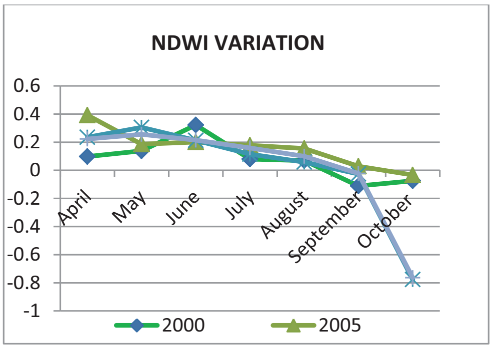

Figure 8. Variation of NDWI from April to October, 2000 – 2005 – 2010 – 2016

The vegetation water content in April, for the analised interval is maintaining the same pattern as NDVI, confirming very low values in 2000 (Figure 9) and rather normal values in 2005 (Figure 10) and 2016 (Figure 12).

Towards the end of the vegetation season, NDWI data are negative, for all the 4 analised years, in September and October, with a small exception in September 2005, where NDWI is little above zero.

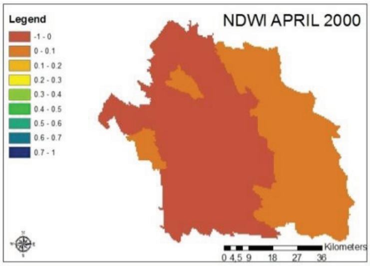

Figure 9. NDWI values for April 2000

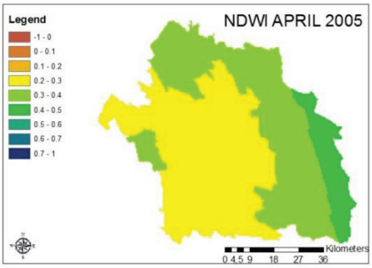

Figure 10. NDWI values for April 2005

The distribution of NDWI confirms the computed values of NDVI for the analysed area, considering the test parish is situated at the site of Danube. For this matter, 2010 registers an exception in April (Figure 11) considering the year's characteristic of high precipitations.

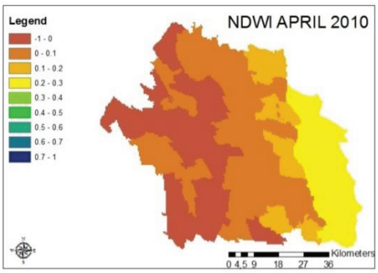

Figure 11. NDWI values for April 2010

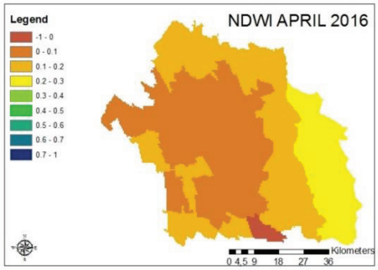

Figure 12. NDWI values for April 2016

Last but not least, values for the NDDI - normalised difference drought index were computed for the vegetation period of years 2000, 2005, 2010 and 2016.

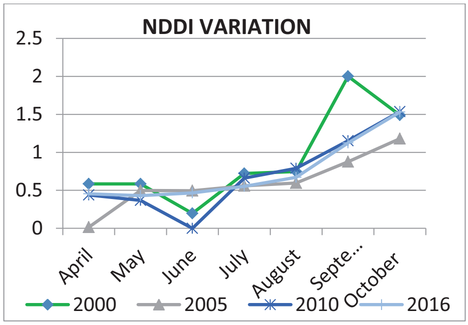

Figure 13. Variation of NDDI from April to October, 2000 – 2005 – 2010 – 2016

While values of 2000 are the highest (Figure 14), assuming drought installation for data higher of 0.5 with a maximum of 2.00 in September 2000, years 2005, 2010 and 2016 reach values above 1.10 in September and October towards the end of the vegetation season, as presented in Figure 13.

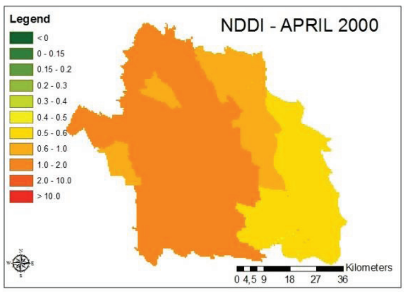

Figure 14. NDDI values for April 2000

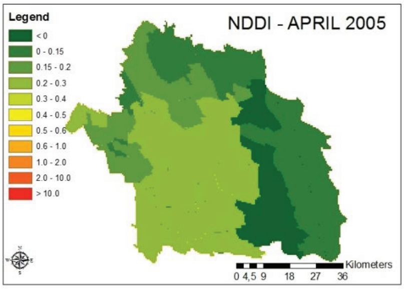

Figure 15. NDDI values for April 2005

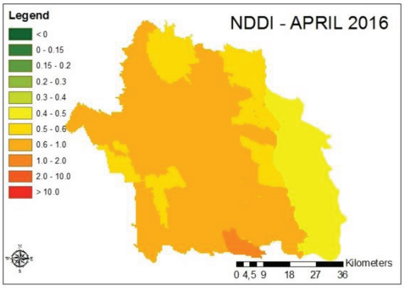

Figure 16. NDDI values for April 2005

By combining the three indexes for drought "pattern" the desertification tendency is recognizable for the study area, confirming the effects of low precipitations and high temperatures in 2000 compared to 2005 (Figure 14 and Figure 15); NDDI values for 2016 are quite low in April (Figure 16) but over the vegetation period, values are comparable to 2005, as presented in Figure 13.

Based on the climatic considerations where 2005 was a normal year for agriculture and 2010 with high precipitations, 2016 would rather be classified as a normal year, with NDDI data bellow 0.5 from April to July and increasing values at the end of vegetation season.

CONCLUSIONS

Vegetation and drought indices were applied to all MODIS images, from April to October for four different years for mapping and monitoring soil degradation up to desertification.

The use of remote sensing techniques has enhanced and improved the desertification monitoring of some vulnerable areas, especially considering the scarce availability of measured ground truth data. The advantage of multi-annual imagery availability allows the overlay and cross-checking of doughty, normal or rainy years in order to identify solutions for agricultural land exploitation. An interesting aspect pulled out of this study is that drought seems to be a constant from July to October in each of the analysed years. Both selected indexes (NDVI and NDWI) indicated the major drought hot-spots in the study area, confirmed by the values extracted for an intensive agricultural area on the Danube border. Values of the NDWI compared to NDDI indicate across Braila county large areas of agricultural land severely affected by drought, where vegetation cover is at minimum or is completely missing, exposing fertile coating to diverse degradation factors.

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