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USE LANDSAT IMAGE TO EVALUATE VEGETATION STAGE IN SUNFLOWER CROPS

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Abstract

Remote sensing is of great interest for the study and characterization of the vegetation and of the agricultural crops, in order to monitor them and to develop predictable patterns regarding the evolution of the crops and also for the purpose of the decision making process in real time. The main purpose of this research was the study of the sunflower crops dynamics based on spectral information obtained from satellite images. Vegetation dynamics was differently expressed by the indexes NDVI, NDBR and NDMI determined based on spectral information. NDVI has registered an ascending slope since the beginning of the vegetation period until the flowering (65 BBCH code) when the maximum value was recorded ($NDVI_{GS6}$ = 0.4074). Later the distribution of this indicator recorded a descending slope until the physiological maturity. NDVI in correlation with the NIR band had lower values in the stages 12-14 BBCH code ($p<0.01$; $R^2 = 0.642$) and 80-81 BBCH code ($p<0.01$; $R^2 = 0.605$) and higher values at flowering stage, 65 BBCH code ($p<0.01$; $R^2 = 0.966$), and physiological maturity, 92-97 BBCH code ($p<0.01$; $R^2 = 0.993$; $F = 3148.2$). NDVI index has most closely correlated with vegetation phenophases and it highlighted, by the different level of correlation with the spectral information, the dynamics and variability in the sunflower crop.

Key words: *GIS, growing stages, image analyses, NDVI, sunflower.*

INTRODUCTION

Multispectral satellite images were used to assess vegetation and crops since the 1970s. Each multispectral band contains specific information and their combination results in new and more complex information, and it provides a higher safety in characterizing vegetation and especially crops, and also other objects of interest.
Remote sensing is used to analyze different aspects like crop area assessment (Quinghan et al., 2008), land cover and land use (Löhnertz et al., 2006; Begue et al., 2014), mapping crop season and crop phenology (Xin et al., 2003; Sakamoto et al., 2005; Brown and de Beurs, 2008; Pan et al., 2015), aspects of growth dynamics of the crops (Shang et al., 2014), determination of vegetation indicators (Gitelson 2004; Jiang et al., 2008; Kumhálová et al., 2014), current monitoring in agriculture (Zhang et al., 2003; Eerens et al., 2014).
Some research have studied the evolution of the vegetation in different areas affected by natural factors or human activities (Huang and Siegert, 2006; Schroeder et al., 2011; Poenaru et al., 2012; Lanorte et al., 2014).
Special attention was dedicated to the study of crops. Jakubauskas, et al. (2002) have studied the possibility of identifying the crops using harmonic analysis of time-series AVHRR NDVI data. Yang et al. (2008) have investigated the impact of using band ratio and vegetation indices of the AWIFS images to the crop classification accuracy, via supervised classification.
Similar research was also done by Liu et al., (2011) who assessed the possibility to identify and extract the corn planting area based on multi-temporal HJ-1 satellite data and Wilson et al., (2014) who studied the possibility for separating different species of crops using hyperspectral data.
Lu (2005) and Lu et al. (2008) have evaluated

the possibility for integration of vegetation inventory data and Landsat TM image for vegetation classification in the western Brazilian Amazon. They managed to classify the vegetation by methods which have an accuracy of 61-79% (up to 89%).

Ding et al. (2014) have studied temporal dynamics of spatial heterogeneity over cropland based on time-series NDVI, near infrared and red reflectance of Landsat 8 OLI imagery.

Given the interest in the study of agricultural crops by satellite techniques for monitoring, developing predictable models for the evolution of crops and decision making in real time, the present research aimed to study the dynamics of sunflower crops based on spectral information obtained from satellite images.

MATERIALS AND METHODS

Research has used technology based on satellite images for assessing vegetation stages of sunflower crop. The area targeted by the study was located in the Teaching and Experimental resort of USAMVB Timisoara, under the coordinates 21°11'15″ - 21°12'45″ E / 45°47'15″ - 45°48'0″ N, Figure 1.

The satellite images used in the present study represent the period April-September (sunflower vegetation period) from the sites: http://earthexplorer.usgs.gov/ and www.landsat .gsfc.nasa.gov.

Image analysis was performed with ArcGIS 10 software by analyzing satellite images and extracting the information contained in spectral bands (R, G, B, NIR), respectively their combinations used in the calculation of indicators NDMI, NDBR and NDVI, according to relations (1), (2), (3).

Due to the very low visible reflectance, the contrast between the reflectance in "Red" (ρR) and reflectance in near infrared (ρIRA) was found to be more relevant as basis for the quantitative analysis methods of the vegetation based on these spectral bands (Huang et al., 2013).

$$NDMI = (NIR - IR) / (NIR + IR) \quad (1)$$

$$NDBR = (NIR - MIR) / (NIR + MIR) \quad (2)$$

$$NDVI = (NIR - R) / (NIR + R) \quad (3)$$

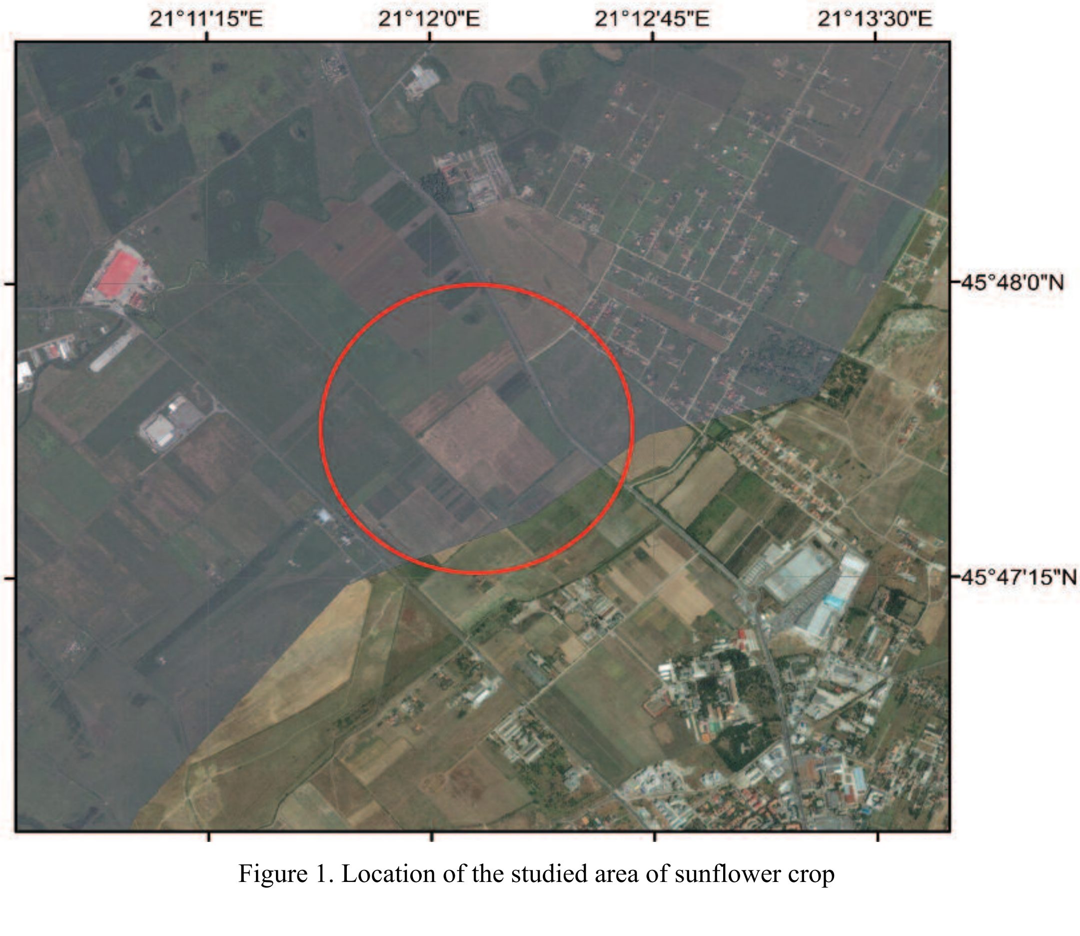

Figure 1. Location of the studied area of sunflower crop

Following the vegetation stages of sunflower crop was achieved according to BBCH code (Maier, 2001) through periodic observations on plant growth and development, in order to correlate the data with information obtained from the analysis of satellite images.

Experimental data were analyzed in terms of statistical safety according to the appropriate mathematical-statistical methods (p, R^2, test F). In order to assess interdependencies between certain spectral bands and the indexes used to evaluate vegetation stages of sunflower crop, were used regression analysis and the result was the polynomial functions of second degree, with safety related parameters.

RESULTS AND DISCUSSIONS

The stages of vegetation for sunflower crop was analyzed based on spectral information obtained from satellite images LANDSAT 8, through several spectral bands and the indexes NDVI, NDBR and NDMI determined.

After the analysis of the respective indexes in relation to vegetation stages of sunflower crop, the result was a correlated distribution of index values NDVI and NDBR and the stages of vegetation, results are presented in Table 1.

NDVI index first reported by Rouse et al (1973) and the most known and used index for the detection of surfaces covered with green plants in multispectral satellite data, had average values between 0.0508 - 0.4074. It is the index most closely correlated with vegetation phenophases of sunflower crop. It had an ascending slope since the beginning of the vegetation period until flowering (65 BBCH code) when it recorded the maximum value ($NDVI_{GS6}$ = 0.4074), afterwards the distribution of the index followed a descending slope until physiological maturity, Figure 2.

Differentiating vegetation with high accuracy by analyzing satellite images has also been reported in other studies (Wang and Tenhunen, 2004; Bagan et al., 2005; Xie et al., 2008; Herbei and Sala, 2014).

From the analysis of the experimental data a correlation was identified of the NDVI index with biophysical characteristics of sunflower crop in spectral satellite signal, expressed in the NIR band.

The correlation between NDVI and NIR band had low values in the first stages of vegetation ($p<0.01$; $R^2 = 0.642$, in 12-14 BBCH code) due to a degree of unevenness resulting from the presence of weeds in the crop. Also a lower correlation was identified in the stage 80-81 BBCH of ripening ($p<0.01$; $R^2 = 0.605$) as a result of differentiated evolution of sunflower plants. High correlations of NDVI with NIR band were registered at flowering 65 BBCH code ($p<0.01$; $R^2 = 0.966$; $F = 670.34$) relation (6) and at phenological phase of physiological maturity, 92-97 BBCH code ($p<0.01$; $R^2 = 0.993$; $F = 3148.2$) relation (9), which indicated a very high level of uniformity of the crop in these stages of vegetation.

Table 1. Index values NDMI, NDBR and NDVI in relation with vegetation stages of sunflower crop

Time of year for determining	Stage of vegetation	NDMI	NDBR	NDVI
22_Apr	Growth stage 1: Leaf development 2-4 Leafs (12-14 BBCH)	0.17190±0.018*	0.28672±0.049*	0.05078±0.043*
24_May	Growth stage 3: Stem elongation (32-33 BBCH)	0.11795±0.013	0.20595±0.016	0.22890±0.019
09_Juni	Growth stage 6: Flowering; Full flowering (65 BBCH)	0.15322±0.045	0.30720±0.057	0.40743±0.043
19_July	Growth stage 7: Development of fruit (71-73 BBCH)	0.11432±0.028	0.41089±0.042	0.25001±0.046
12_Aug	Growth stage 8: Ripening (80-81 BBCH)	0.09615±0.016	0.23169±0.019	0.24849±0.018
28_Aug	Growth stage 9: Plant dry (92-97 BBCH)	0.00895±0.085	0.11917±0.077	0.20813±0.098
13_Sept	After harvest: land with plant debris and disking field	0.18254±0.002	0.29009±0.009	0.03519±0.013

* ±Standard Deviation

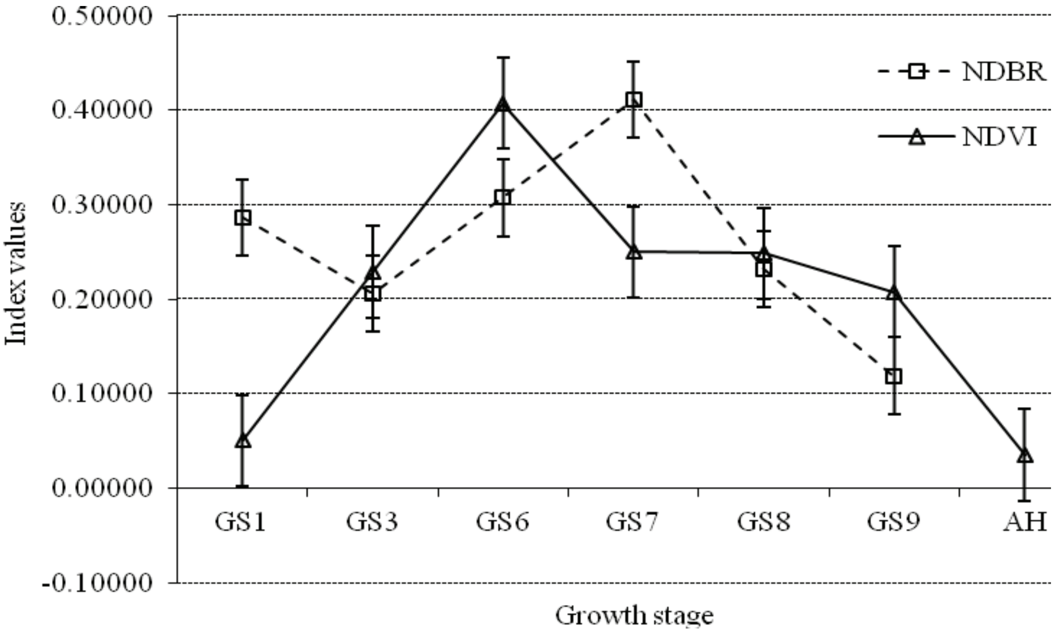

Figure 2. Distribution of specific indexes NDBR and NDVI for sunflower crop in the vegetation period:
GS1 – 12-14 BBCH; GS3 – 32-33 BBCH; GS6 – 65 BBCH; GS7 – 71-73 BBCH;
GS8 – 80-81 BBCH; GS9 - 92-97 BBCH; AH - After harvest

The particular distribution of the correlation values for the index NDVI with NIR band during the study period was described in relations (4) - (9), Table 2 and it is represented in Figure 3.

Also after harvesting the sunflower crop, on the land covered in plant debris and disking field, there was a more reduced correlation registered ($p<0.01$; $R^2 = 0.435$; $F = 18.083$).

Moreover, in other studies of analysis and characterization of the vegetation by analyzing the satellite images, there were higher correlations found between the spectral bands and the indexes NDVI, NDWI, NDBR and NDMI (Herbei et al., 2015 a,b).

Table 2. Description functions of the relation between NDVI index and NIR band for characterizing the vegetation stages of sunflower crop

Vegetation stage	Equation	Equation number	p	R^2	F
12-14 BBCH	$NDVI = 1.003E-10x^2 - 7.188E-06x + 0.1702$	(4)	< 0.01	0.642	42.193
32-33 BBCH	$NDVI = 1.809E-09x^2 - 3.399E-05x + 0.2549$	(5)	< 0.01	0.898	209.77
65 BBCH	$NDVI = -1.644E-09x^2 - 9.588E-05x - 1.107$	(6)	< 0.01	0.966	670.34
71-73 BBCH	$NDVI = -2.361E-10x^2 + 1.849x - 0.00886$	(7)	< 0.01	0.854	137.77
80-81 BBCH	$NDVI = -2.141E-09x^2 + 9.303E-05x - 0.8894$	(8)	< 0.01	0.605	36.058
92-97 BBCH	$NDVI = -2.453E-09x^2 + 9.695E-05x - 0.569$	(9)	< 0.01	0.993	3148.2
AH - After harvest	$NDVI = 5.145E-10x^2 - 3.651E-05x + 0.6818$	(10)	< 0.01	0.435	18.083

Lower correlation between NIR band and NDVI index in the stages 71-73 and 80-81 BBCH is based on differentiated status of the plants in their respective stage of vegetation and at the same time, it expresses the high variability of the plants in the sunflower crop in terms of the rate of forming, filling and maturation of the seeds.

Gitelson (2004) has communicated the research results regarding wide dynamic range vegetation index for remote quantification of biophysical characteristics of vegetation. He found that the sensitivity of the WDRVI to moderate-to-high LAI (between 2 and 6) was at least three times greater than that of the NDVI. By enhancing the dynamic range while using

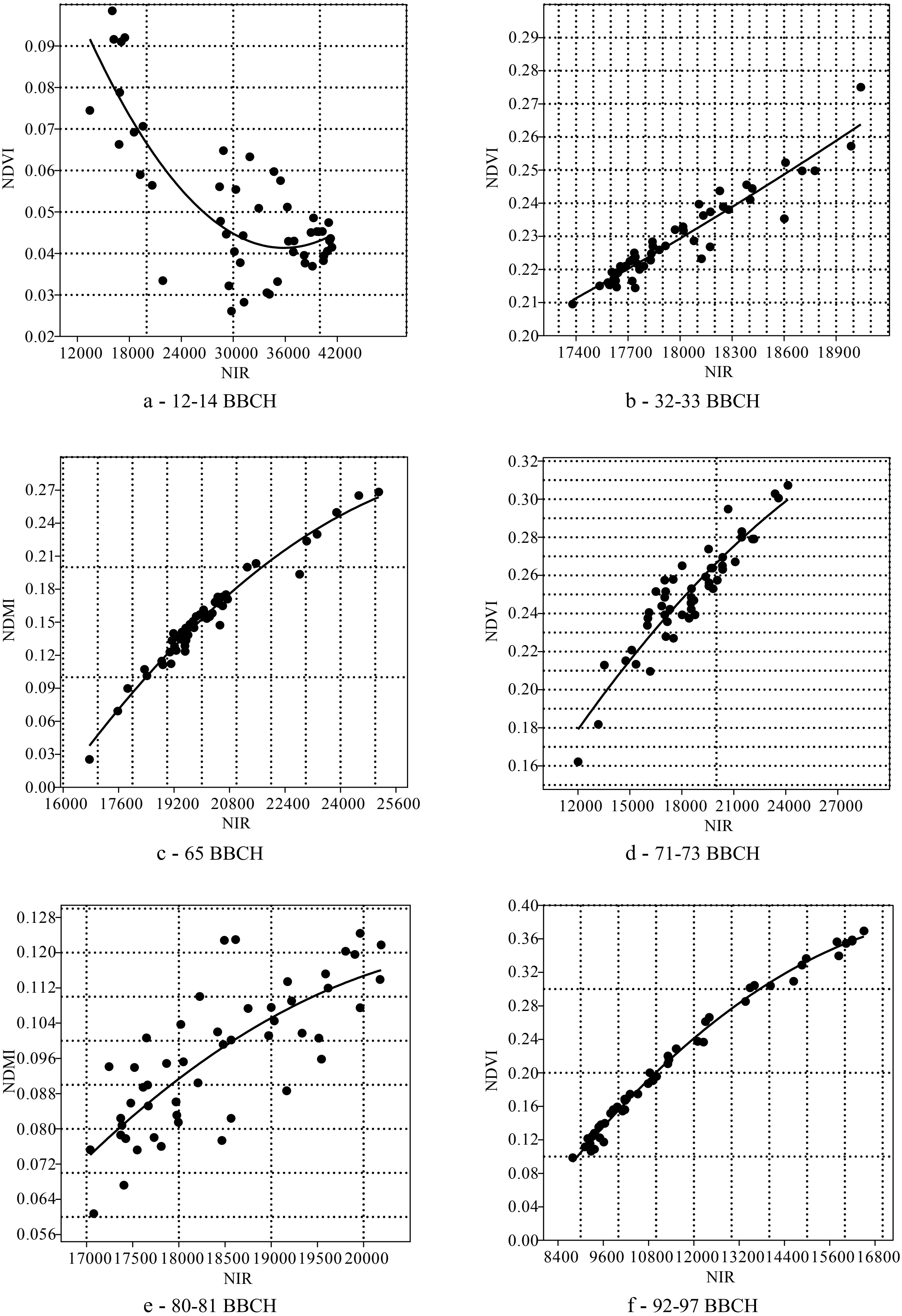

Figure 3. Particular distribution of NDVI values according to the NIR band in several successive stages of vegetation of the sunflower crop; a - f stages of vegetation studied

the same bands as the NDVI, the WDRVI enables a more robust characterization of crop physiological and phenological characteristics. He also considered that although this index needs further evaluation, the linear relationship with vegetation fraction and much higher sensitivity to change in LAI will be especially valuable for precision agriculture and monitoring vegetation status under conditions of moderate-to-high density.

Peña-Barragán et al. (2006) and López-Granados et al. (2008) have studied phenological stages of sunflower and *Ridolfia sagetum* (an umbelliferous weed frequent and abundant in sunflower crops in the Mediterranean basin) using remote sensing in order to create the foundation for the decisions in applying herbicides.

Some research has sought to estimate biomass production for sunflower crop based on high spatial and temporal resolution remote sensing data (Claverie et al., 2012).

The importance of accurate knowledge of phenological stages in different crops was highlighted in other research as well. Bolton and Friedl (2013) developed linear models to predict maize and soybean yield in the Central United States using spectral indices derived from MODIS data. Based on the studies, they have highlighted the importance of evaluating the phenological stages of crops. The results obtained have confirmed that crop phenology improved model predictions and that the best times to predict crop yields were 65-75 days after greenup for maize and 80 days after greenup for soybeans.

The spectral image analysis in multiple phenological stages based on some specific vegetation indexes (NDVI, ANVI, VNVI and RVI) was used also in the study of some invasive species (Ouyang et al., 2013).

Considering the importance of the evaluation with a high accuracy for phenological stages on crops with various scopes, new methods of investigation have been proposed. You et al. (2013) have used a new method to define such thresholds for identifying the start and end of the growing season (SOS/EOS) for 43 different agricultural zones in China. They found that the developed NDS threshold method had a significantly higher accuracy compared with other methods. At the same time they concluded that the method is mainly limited by the observed data and the necessity of reestablishing the thresholds periodically.

Plant phenology was studied by spectral monitoring also by Cole et al. (2014) with the purpose of identifying the optimal moments for peat lands study by hyperspectral remote sensing.

NDBR index provided information regarding the amount of biomass within the sunflower crop. During the recording of the data based on the satellite images, it started with a higher value as a result of the vegetation mass given by the sunflower plants and weeds present in the crop (12-14 BBCH code). After treatment with herbicide, a decrease of the index values was recorded, at the evaluation in the month of May (32-33 BBCH code), followed by another ascending trend with a maximum value registered in the month of July, period which coincides with the filling of the seeds (71-73 BBCH). After came the phenophases of seed maturation, associated gradually with the drying of the basal leaves of the plants, and then advancing to the upper levels until August when they reach physiological maturity (92-97 BBCH), when the minimum value was recorded.

Compared with NDVI index which registered the maximum value at flowering (65 BBCH), correlated with the maximum reflectance, the NDBR index has registered the maximum value later, in the filling period of the seeds when the sunflower crop had the maximum biomass recorded. Subsequently, by the drying of basal leaves, and gradually those on the upper levels of the stem and the whole plant and by seed maturation, the amount of total biomass decreased as reflected in the value of the NDBR index. NDMI index provided information about the humidity of the soil and the vegetation cover of the sunflower crop. In the period of vegetation of the crop, high values of NDMI index were recorded based on the satellite images in the stage 2-4 leaves (12-14 BBCH) when the degree of soil coverage by plants was reduced and in the flowering phenological phase (65 BBCH), subsequently this index had a decreasing slope until harvest. The highest values for this index were registered after harvest on the land with plant debris and disking field.

CONCLUSIONS

The present studies have facilitated the characterization of the vegetation stages for sunflower based on the satellite images with high accuracy. NDVI, NDBR and NDMI indices had specific values according to the stages of vegetation analyzed and the specific properties of the crop in the certain stages. The dynamic of the vegetation was expressed differently by the NDVI, NDBR and NDMI indices. The most faithfully expressed stages of vegetation NDVI index, which values had correlated to the vegetation stages analyzed, with a maximum value at flowering stage (65 BBCH code). The differentiated correlation of index NDVI with NIR band had highlighted the differentiated variability of sunflower crop in relation to vegetation stages analyzed. With a certain deviation, NDBR index has registered the maximum level at the stage BBCH of seed filling, marking distinctively this certain stage of vegetation. The image analysis based on satellite images can be the basis of crop phenological characterization in order to achieve predictive and decision-making models.

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