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THE USE OF VEGETATION INDICES IN THE CONTEXT OF PRECISION AGRICULTURE

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Abstract

The main purpose of this research is to study the dynamics of an agricultural parcel based on spectral information obtained from Rapid Eye satellite images between May to September 2016. The dynamics of vegetation was differently expressed by the NDVI, SAVI and MSAVI2 indices determined based on spectral information. Starting from the Rapid Eye satellite imagessomespectral information characterizing the studied areas were extracted, based on spectral bands. R, G, B, Red Edge, NIR. Three vegetation indices (NDVI, SAVI and MSAVI2) have been computed and interpreted.

Key words: *Remote sensing, vegetation indices, NDVI, SAVI, MSAVI2.*

INTRODUCTION

The continuous development of human society in the last decades has also implied the rapid progress of some techniques and technologies oriented towards the quantitative and qualitative knowledge and evolution of the environmental components (Sala, 2011), as well as the designing of the most efficient systems for processing, organizing and storing the obtained information (Gitelson, 2004). All of these can be obtained by remote sensing (Herbei et. al., 2014 Herbei and Sala, 2016).

Remote sensing is the technical field that deals with the detection, measurement, recording and visualization in the form of images of electromagnetic, radiation issued by objects and phenomena from Earth or the Universe from a distance without having direct contact with them (Kokalj and Oštir, 2007; Kumar, 2004).

Remote sensing (Herbei, 2015), regardless of the nature of the applications, whether passive or active, uses electromagnetic radiation to obtain body images at a certain altitude (airplane, satellite, helicopter) because in this way the image can be used to obtain maps and plans, the interpretation of objects is optimal and easy (Richards, 1999).

The electromagnetic spectrum is a physical model that shows the known and measured electromagnetic radiation, depending on their wavelength and specific energy level, representing the total electromagnetic radiation present in the Universe (Jensen, 1996).

The spectrum shows a series of areas where electromagnetic radiation is delineated based on the wavelength. Remote sensing applications are limited to producing images that are impossible in certain spectral areas (Lillesand, and Kiefer 1994).

The Rapid Eye satellite system was successfully launched on August 29, 2008 from the Kazakhstan Baikonur Cosmodrome (Planet Team, 2017). Rapid Eye built by MacDonald Dettwiler will provide image users with a data source that contains an unparalleled combination of over-surface coverage, frequent revision intervals, high-resolution and multispectral capabilities (Table 1, Spectral Bands of the Rapid Eye Satellite Sensor).

Table 1. RapidEye Satellites Spectral Bands

RapidEye - bands	Wavelength (nanometer)	Use	Rezolution (meter/pixel)
B1- Blue	440-510	Batimetricmapping, differentiation of thesoilandvegetation of the conifer type	5
B2 - Green	520-590	Highlighting top vegetation, whichisuseful for evaluatingplantvigor	5
B3 - Red	630-685	Differentiateplants in vegetation	5
B4 - RedEdge	690-730	Coverthe part of thespectrumwherethereflectivityincreasesdrasticallyfromtheredportiontothe NIR spectrum	5
B5 - NIR	760-850	Highlightsbiomassandshorelines	5

MATERIAL AND METHOD

This study was carried out within the teaching camp of the Banat University of Agricultural Sciences and Veterinary Medicine, „ King Michael I of Romania", Timisoara being studied the surrounding agricultural lands (Figure 1). To compute the indices for the agricultural land satellite images were used (Herbei et. al., 2015), captured in 2016 from the following months May, July and September, which were obtained from the www.planet.com portal (Figure 2).

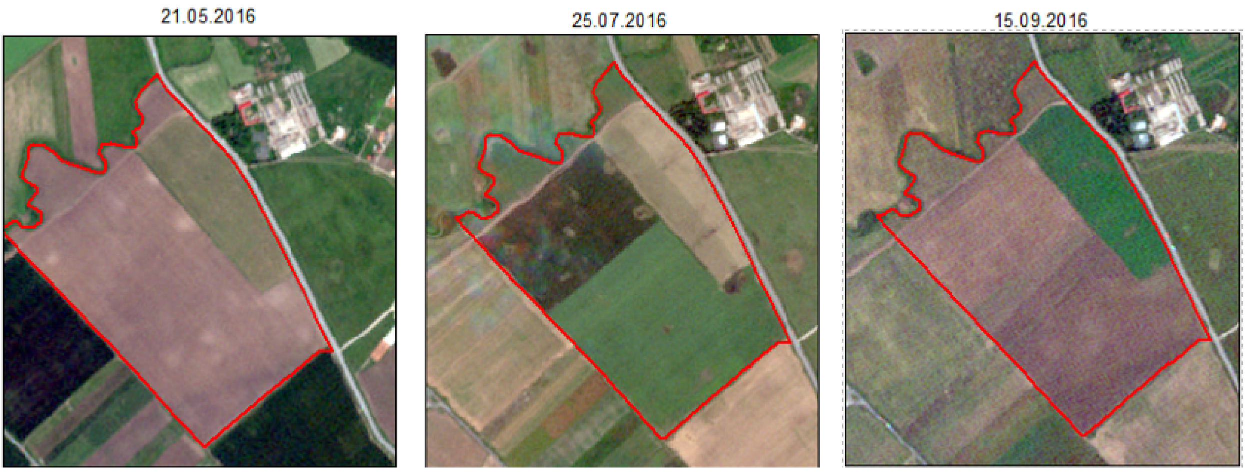

Figure 1. Natural Colour Map of Study Area (Red – Green - Blue)

Figure 2. False Colour Map of Study Area (Nir – Red - Gren)

The vegetation indexes are mathematical formulas that obtain a result with a numerical value between -1 and 1. The indices can study different domain areas such as hydrological, cartographic, forestry and agriculture.

The **Normalized Difference Vegetation Index** (NDVI) was proposed in 1974 by Rouse et. aland is an index of plant "greenness" and is one of the most commonly used vegetation indices. Vegetation indices are based on the observation that different surfaces reflect different types of light differently. Photo synthetically active vegetation, in particular, absorbs most of the red light that hits it while reflecting much of the near infrared light.
Vegetation that is dead or stressed reflects more red light and less near infrared light. Likewise, non-vegetated surfaces have a much more even reflectance across the light spectrum (Carlson and Ripley, 1997).
By taking the ratio of R and NIR bands from a satellite image, an index of vegetation "greenness" can be computed. NDVI is calculated on a per-pixel basis as the normalized difference between the R and NIR bands from an image (Huete and Jackson, 1987).
The formula for calculating the NDVI index is:

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

where NIR is the near infrared band value for a cell and RED is the red band value for the cell. NDVI can be calculated for any image that has a red and a near infrared band. The biophysical interpretation of NDVI is the fraction of absorbed photo synthetically active radiation (Huete and Jackson, 1988).
Many factors affect NDVI values like biomass, total plant cover, plant photosynthetic activity, plant and soil moisture or plant stress. Because of these things, NDVI is correlated with many agricultural and ecosystem attributes (e.g., net primary productivity, canopy cover, bare ground cover). Vegetation indices like NDVI make it possible to compare satellite images over time to look for significant changes (Huete et. al., 1999). The output of NDVI is a new image. And the image pixels can range from -1.0 to +1.0. Higher values signify a larger difference between the red radiation and near infrared radiation recorded by the sensor.
Low pixel values mean there is little difference between the red signals and near infrared signals. This happens when there is little photosynthetic activity, or when there is just very little NIR light reflectance (water reflects very little NIR light).

The Soil Adjusted Vegetation Index (SAVI), proposed in 1988 by Hueteand is structured similarly to the NDVI index, but with the addition of a soil brightness correction factor.
Adjusting for the influence of soils comes at a cost to the sensitivity of the vegetation index. Compared to NDVI, SAVI is generally less sensitive to changes in vegetation (amount and cover of green vegetation), and more sensitive to atmospheric differences.
The formula for calculating the SAVI index is:

$$SAVI = \frac{NIR - RED}{(NIR + RED + L)} * (1 + L)$$

where NIR is the reflectance value of the near infrared band, RED is reflectance of the red band, and L is the soil brightness correction factor. The value of L varies by the amount or cover of green vegetation: in very high vegetation regions, L=0; and in areas with no green vegetation, L=1. Generally, an L=0.5 works well in most situations and is the default value used. When L=0, then SAVI = NDVI.

The Modified Soil-Adjusted Vegetation Index (MSAVI2) is the soil-adjusted vegetation index that attempts to approach a portion of the NDVI limitation when applied in areas with a high surface area of exposed soil.MSAVI has been used in a number of rangeland studies where it has often been correlated to field data on vegetation cover (Senseman et al. 1996, Chen 1999), biomass and/or leaf area index (Phillips et al. 2009), and as an input layer for mapping land cover or vegetation classes. One significant limitation of the MSAVI is that it sacrifices some overall sensitivity to changes in vegetation amount/cover to correct for the soil surface brightness. MSAVI may not be as sensitive to vegetation change as another index like NDVI. MSAVI would also be more sensitive to differences in atmospheric conditions between areas or times. MSAVI requires only a red and a near infrared band to calculate.The formula for calculating the MSAVI2 index is as follows:

$$MSAVI2 = \frac{\left(2 * NIR + 1 - \sqrt{(2 * NIR + 1)^2 - 8 * (NIR - RED)}\right)}{2}$$

RESULTS AND DISCUSSIONS

In order to calculate the vegetation indices and for the extraction of spectral information, the ERDAS Image v. 11 (Figure 3), ArcGIS v. 10.5 and PAST 3 (Hammer et. al., 2017) software was used (Figures 4, 5, 6).

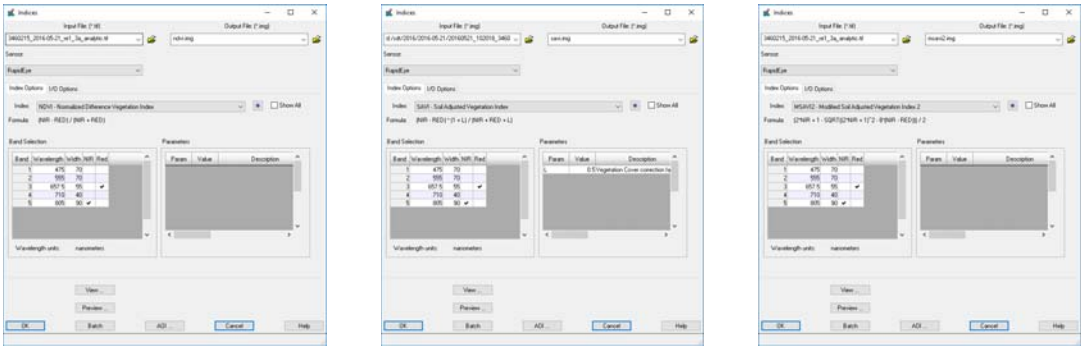

Figure 3. The calculating NDVI, SAVI and MSAVI2 in Erdas Imagine

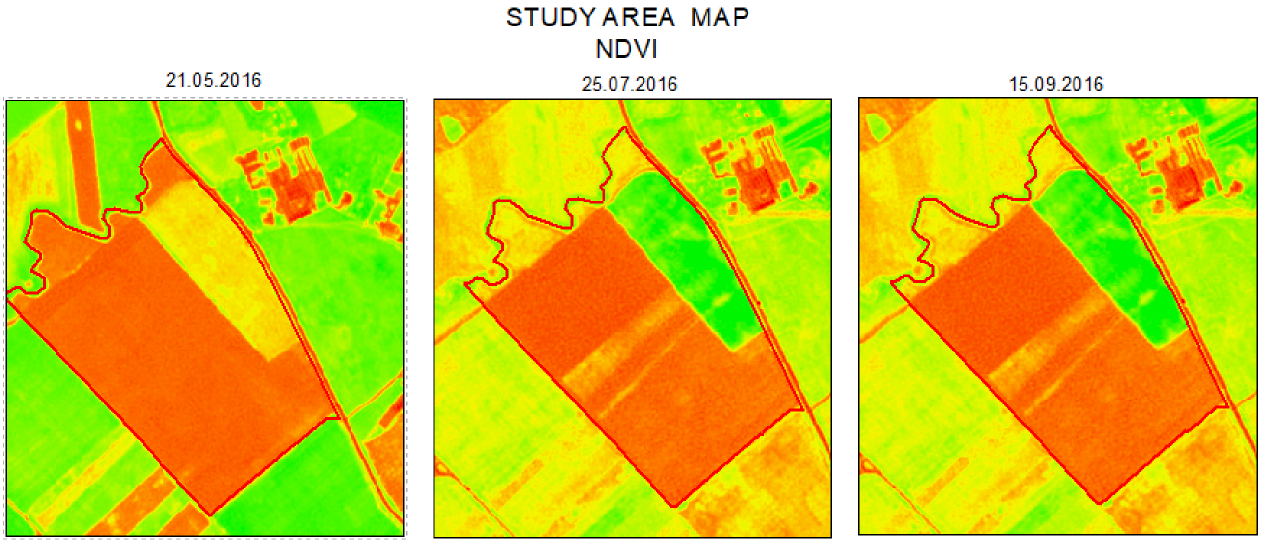

Figure 4. The NDV Map of Study Area

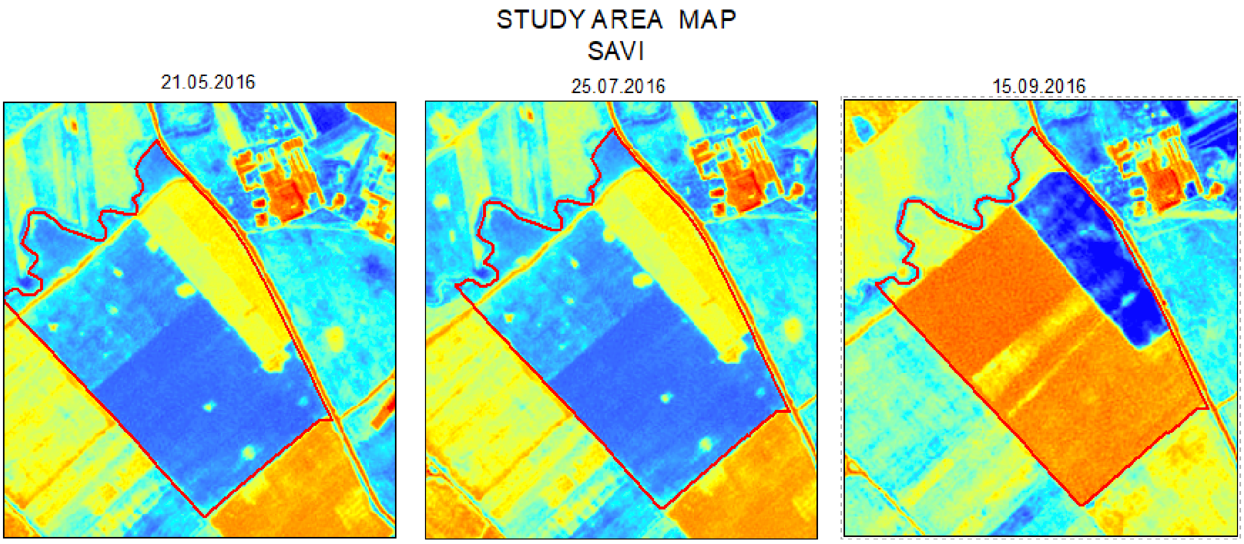

Figure 5. The SAVI Map of Study Area

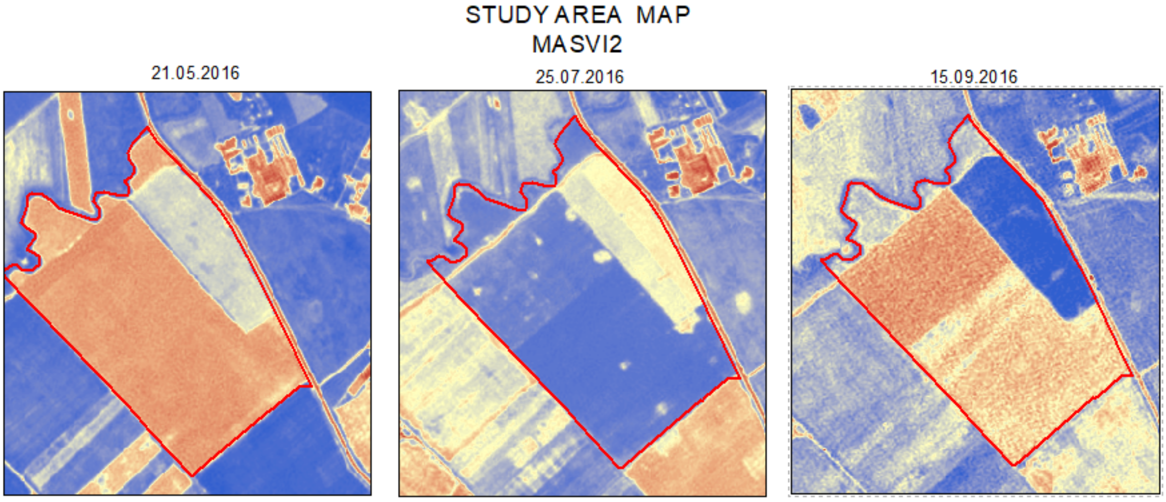

Figure 6. The MSAVI2 Map of Study Area

The NDVI recorded an upward slope, as shown in Figure 5, from the beginning of the study period, May to July, when it recorded the maximum value (NDVI = 0.63425), after which the distribution of this index followed a downward slope until September (Figure 7).

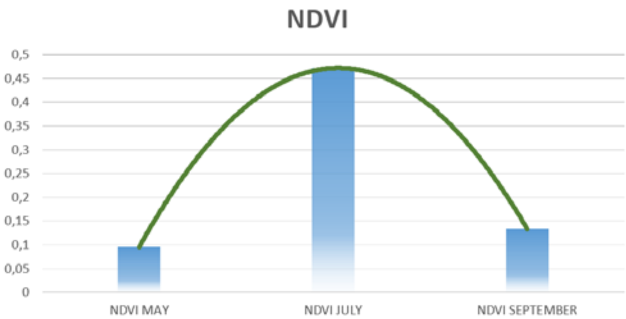

Figure 7. NDVI distribution

SAVI recorded a downward slope (Figure 8) from the beginning of the study period, May to September, when it had a minimum value (Figure 8).

Figure 8. SAVI distribution

MSAVI 2 recorded an upward slope (Figure 9) from the beginning of the study period, May to July, when it recorded the maximum value after which the distribution of this index followed a downward slope until September (Figure 9). \Correlations (Senseman et. al., 1996) were also made between the NDVI, SAVI, and MSAVI 2 indices.

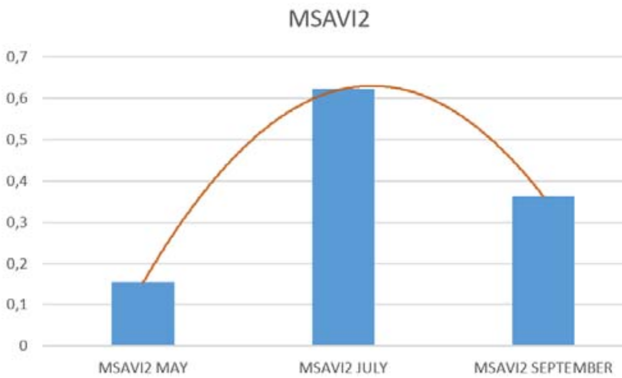

Figure 9. MSAVI2 distribution

Data analysis revealed a high correlation identified in the month of Septemberfor indices NDVI, SAVI and MSAVI2 with the characteristics from the satellite spectral signal, presented in band Red Edge (Tables 2, 3, 4).

Table 2. Correlation for the SAVI, NDVI, MSAVI 2 indexes – May

	NDVI	SAVI	MSAVI2	RE
NDVI MAY	1			
SAVI MAY	-0,688473948	1		
MSAVI2 MAY	0,994456853	-0,725387998	1	
RE MAY	0,551566314	-0,61284423	0,570965	1

Table 3. Correlation for the SAVI, NDVI, MSAVI 2 indexes – July

	NDVI	SAVI	MSAVI2	RE
NDVI JULY	1			
SAVI JULY	1	1		
MSAVI2 JULY	0,997148	0,997148	1	
RE JULY	0,859869	0,859876	0,832352	1

Table 4. Correlation for the SAVI, NDVI, MSAVI 2 indexes – September

	NDVI	SAVI	MSAVI2	RE
NDVI SEPTEMBER	1			
SAVI SEPTEMBER	1	1		
MSAVI2 SEPTEMBER	0,97312	0,973118915	1	
RE SEPTEMBER	0,977537	0,977538436	0,913709	1

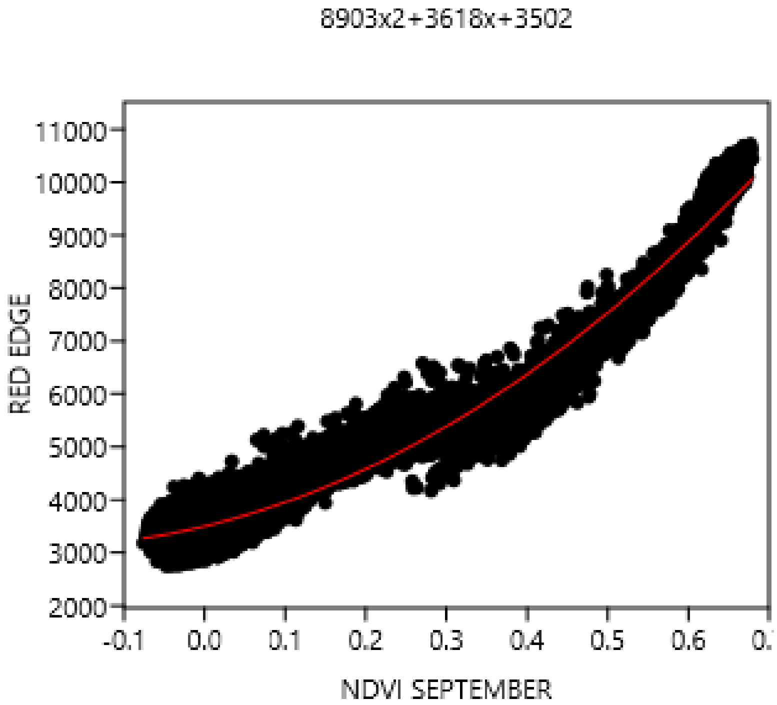

Figure 10. The graphic correlation of theRed Edge band with NDVI

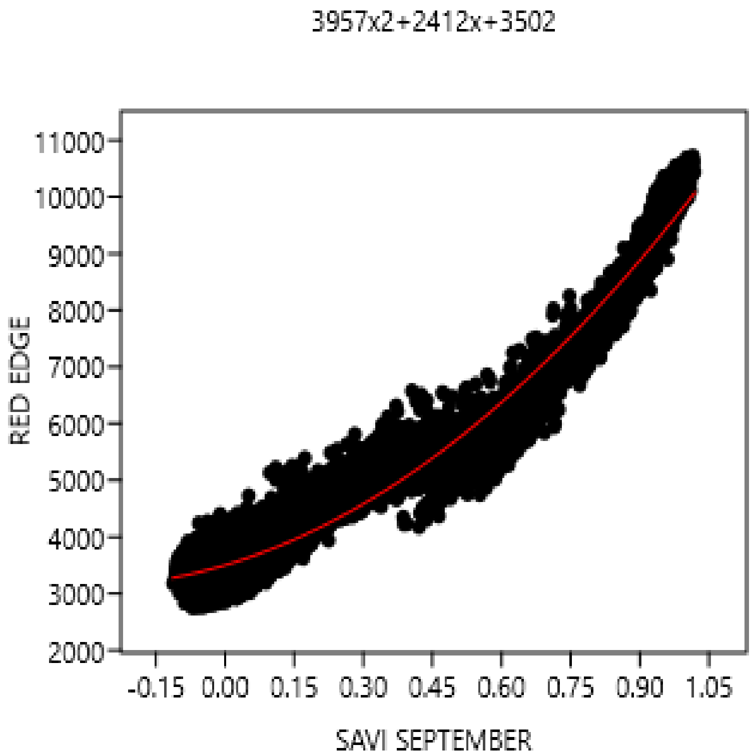

Figure 11. The graphic correlation ofthe Red Edge band withSAVI

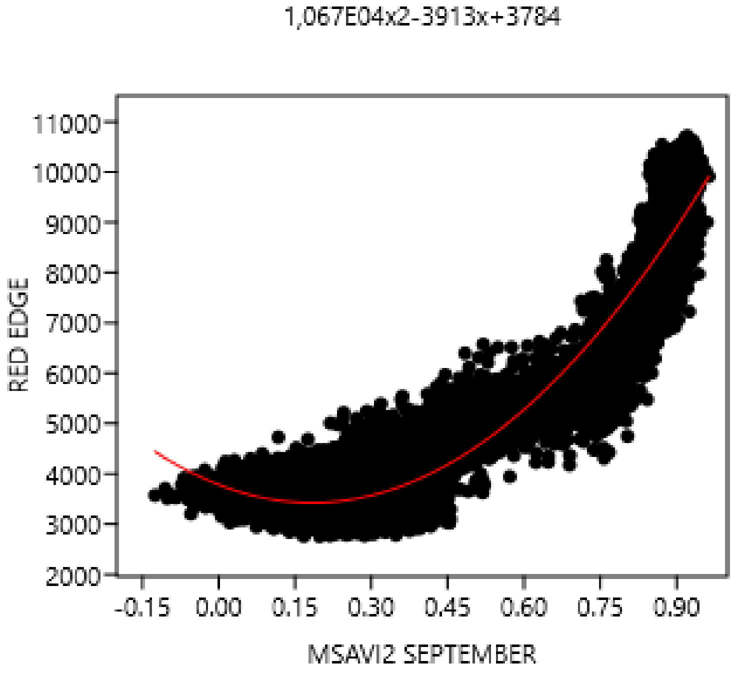

Figure 12. The graphic correlation of the Red Edge band withMSAVI2

It can be seen from the graphs above that the best correlations between the indices (NDVI, SAVI and MSAVI 2) and the Red Edge tape were found in the last month of study, September.

CONCLUSIONS

The study has enabled thecharacterization of vegetation stages on agricultural crops based on high-precision satellite imagery. In this research were calculated 3 vegetation indexes and the relation of the Red Edge band from Rapid Eye with NDVI, SAVI and MSAVI2. For the evaluation of the level of correlation there have been used adequate mathematical functions and extracted values of the correlation coefficients r and p which represent the level of the correlation and the accuracy of the results.The high level of correlation between Red Edge and NDVI, SAVI and MSAVI2 recommends assessing these indices with specific meaning about vegetation status, based on these values, in the case that their determination was not possible in the field.

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