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MONITORING THE CROPS PHENOLOGY USING TIME SERIES SENTINEL 2 IMAGES

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Abstract
It is important to know the beginning and the end of the growing season at the plot level, in order to understand the dynamics of crops and agricultural systems, but also to know the phenological values related to the crop calendar. Detailed data of seasonal vegetation changes can be obtained using the time series of Sentinel 2 images, by recognizing the spectral signal that cultures have in all phenological stages. In recent decades, studying the phenology of vegetation has become increasingly. The influence of climate change on the evolution of vegetation can be quantified by a series of biological indicators, highlighting the impact of changing phenological dynamics on ecosystem functions and functionality. By studying the phenology of the terrestrial surface in accordance with the crop calendar using time series of vegetation indices obtained from Sentinel 2 images, a new way of monitoring the vegetation response to climate change has been developed. The study area is located in Iasi county, between 47 ° 18′01 ″ N and 27 ° 05′54 ″ E, maize, wheat and soybeans being the most important crops grown in the region. The analyses were carried out in a cropland area located in NE of Romania characterized by continental climate (hot dry summers and cool winter). Soils are mainly chernozem (48.62%), followed by alluviosols (6.78%) and anthrosols (2.43%). The aim of this study was to understand the phenological stages of the crops and to monitor the crops taking into account the time-series images and vegetation indices. In order to achieve this, based on the specifics of the agricultural land use, the updated crop calendar highlighted the phenological stages of crops, being selected from fifteen Sentinel 2 only nine (2018-2019) satellite images to monitoring multiannual vegetation changes. Vegetation indices included in the analysis were: Normalized Differentiation Vegetation Index (NDVI), Enhanced Vegetation Index (EVI2) and Adjusted Soil Vegetation Index (SAVI). For the development of efficient agricultural management policies that facilitate the implementation of sustainable systems, it is necessary an efficient mapping of agricultural lands.

Keywords crops, phenology, crop calendar, time series, Sentinel 2.

INTRODUCTION

The monitoring of agricultural areas is of high importance in the context of global challenges such as population growth, increasing food demand and climate change. [1] Therefore, the monitoring of actual agricultural areas to understand and to adapt to possible climate changes is crucial.

Based on phenology definition: "the study of the timing of recurring biological events, the causes of their timing regarding biotic and abiotic forces, and the interrelation among phases of the same or different species" [2], the phenological monitoring improves the understanding of crop development and growth processes.

Crop phenology refers to the developments, differentiation and initiation of organs of a crop [2]. Accurate monitoring of crop development patterns like phenology and growth is an importantcomponent of farm management since it allows the
rapid assessing of the critical stages occur during growth, in favorable weather conditions. The vegetation phenology is a relevant indicator of crop productivity and health. Phenological stage monitoring gain more and more importance in the decision-making process of the agricultural management [3].

Satellite imagery plays a unique and important role in the sustainable management of farms by monitoring crop and soil properties [4].

In recent years, most studies using satellite imagery to monitor natural crops and vegetation have focused on using optical images. [5] The

continuous identification of the phenological status of the crops is highly recommended, especially for farmers and decision-makers when interventions are required such as, irrigation, fertilization, pesticides application and yield handling [6].
The recent availability of Sentinel-2 images it is seen as an opportunity to provide an affordable service to monitor growth over time. Indeed, the two satellites (2a and 2b) have particularly valuable features [7,8]: a revisit period of 5 days that could enable the observation of significant changes in canopy growth (e.g. new phenological stage or biotic and abiotic stresses); 13 different spectral bands, 10 of which being - particularly interesting for the computation of vegetation indices. Spectral features extracted from optical data can serve as indicators of vegetation condition, chlorophyll content, plant water content and phenology by providing information about the reflective and emissive characteristics of crops at the visible and near-infrared wavelengths. Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) are the most frequently used compared to other indices. To learn more about scheduling fertilization and harvesting operations, efficient irrigation and pest management, knowledge of crop phenology is essential. In this way, it is easier to make some predictions about the healthy stage of the crops. [9]
Multi-temporal Sentinel-2 images might increase the classification results, because the spectral signature and phenological indices can better describe the vegetation dynamics of the target crop types. [10]
The objective of the present paper was to analyze the time series images based on vegetation spectral indices NDVI, EVI2 and SAVI in order to accomplish the assessment of crop phenology during the grow cycle, based on three phenological period of crops: planting, mid-season and harvesting.

MATERIAL AND METHODS

Study Area

The Belcesti commune is located in the central-northern area of the county, in the southwest of the Jijia Plain, on the banks of the Bahlui catchment. The relief is developed on sedimentary rocks, respectively clays and sarmatic marls with fine alternations of fine sands. The current relief of the commune derives from an old sea plain that rose slightly and was followed by the withdrawal of the Sarmatic sea, the old relief being replaced by relief of lower hills and hills separated by wide valleys. [11] The characteristic climate of Belcesti commune is temperate-continental climate of excessive shade, specific to the Moldavian Plain. Pedological cover consist mainly from chernozem (48.62%), followed by alluviosols (6.78%) and anthrosols (2.43%)..

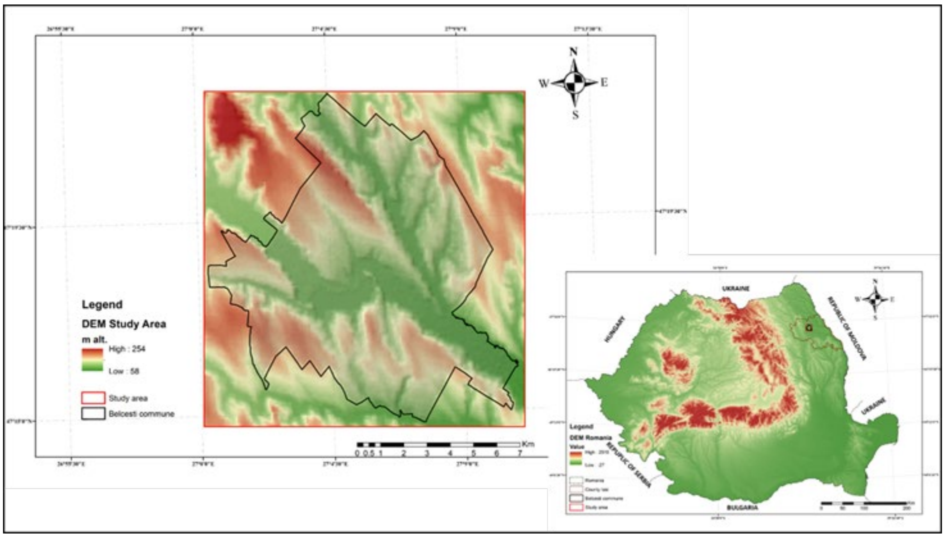

Figure 1. The study area located in north-eastern part of Romania.

Remote sensing data

Fifteen optical images were acquired by Sentinel 2 satellites, covering a temporal range between April 2018 to October 2019. In this study, only the images acquired during the whole growing cycle consist from three vegetation period (planting, mid-season, harvesting) were considered. The pre-processing of L1C (Top of Atmosphere or TOA reflectance) Sentinel 2 images, which includes

ortho-rectification, cloud removal (using cloud mask produced by Sen2Cor/ SNAP), radiometric calibration, and atmospheric correction, was produced using SNAP/Sentinel 2 toolbox. The output of the pre-processing corresponded to L2A (bottom of atmosphere or BOA reflectance). [12] The values derived from surface reflectance data were used to calculate different vegetation spectral indices such as: the “greenness" indicator of the surface known as NDVI, EVI 2 for reducing saturation effects found in densely vegetated surface as well as improving linearity with biophysical vegetation properties and SAVI to minimize soil brightness and for determination of vegetation vigor Three crop types (soybean, maize and wheat) are analyzed based on their variated spectral reflectance during the vegetation periods. In order to classify the images was chosen six plots, two for each crop, located in different parts of the study area. For each plot was generated the spectral signature of the crop, according to the phenological stages. Phenological profiles for all the crops extracted gives the opportunity to identify the maximum reflectance value, in order to recognize for each crop, the difference and monitor the crops..

NDVI=((NIR-Red))/((NIR+Red)) (1)

EVI2=2.4*((Nir-Red))/((NIR+Red+1)) (2)

SAVI=(NIR-Red))/((NIR+Red+L))*(1+L),where L=0.5 (3)

RESULTS

In this section are presented the Sentinel-2 images acquired for entire grown cycle. (Figures 2). To compare spectral indices were used reflectance value in the near infrared and visible red wavelength range (B5 to B9). (Figures 3-6).

In figures 3a - 3c, were plotted the spectral signature for different dates such as: 21.04.2018(3a), 26.04.2019(3b) and 01.05.2018(3c) specific for the time period of planting for soybeans, maize, wheat.

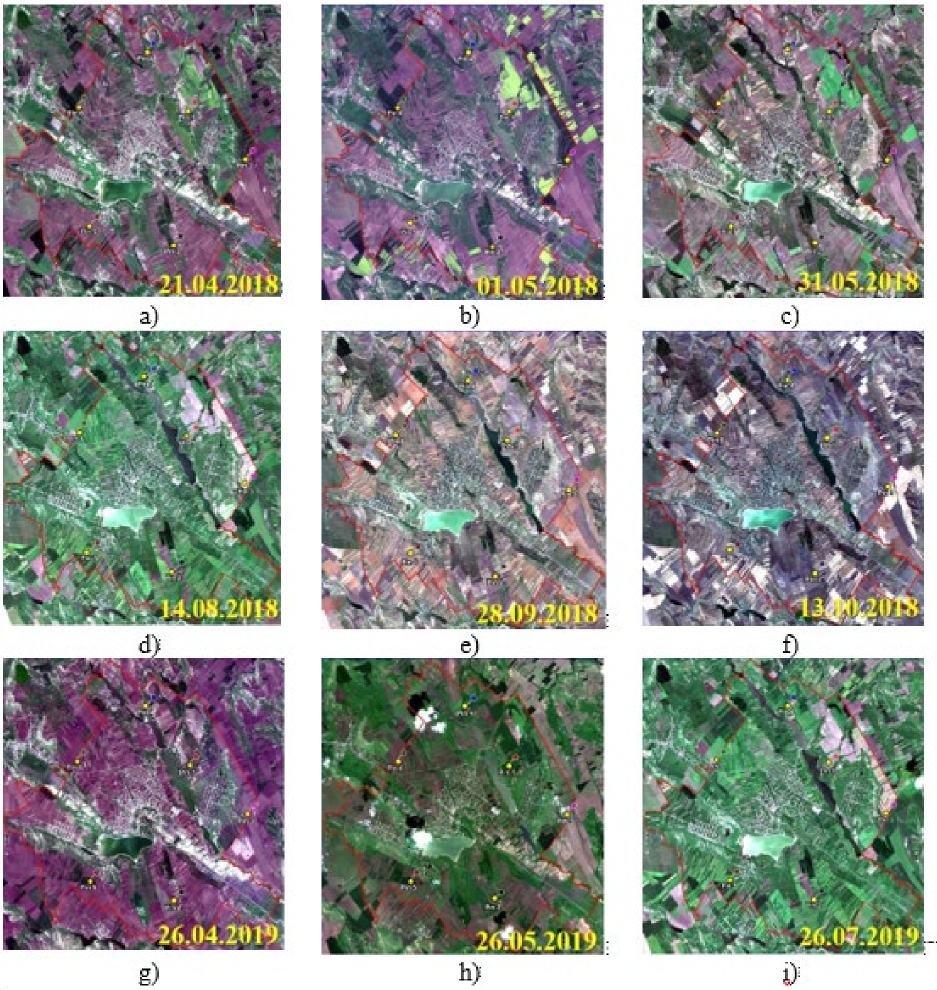

Figure 2. Acquisition dates of Sentinel 2 time-series used in the current study.

Table 1. The maximum reflectance values of crops between 2018-2019**.**

Date / Crop	2018						2019		
	21.04	**1.05**	**31.05**	**14.08**	**28.09**	**13.10**	**26.04**	**26.05**	**26.07**
	Reflectance (dl)								
SOYBEANS	0.44	0.46	0.34	0.39	0.23	0.22	0.34	0.55	0.41
MAIZE	0.31	0.38	0.35	0.37	0.22	0.23	0.31	0.48	0.43
WHEAT	0.38	0.39	0.34	0.38	0.25	0.21	0.36	0.30	0.37

During the planting period, when the plants are not developed, the reflected values are below 0.5 (Table 1) and as the leaves develop, the percentage of near-infrared reflection increases, due to the extension of the size of the leaf surface, implicitly the yield of the photosynthesis process of the crops is more great. Lately, when the crops approach the harvest time, the reflectance decreases, the leaves get a yellow color. The spectral profiles indicate that the maximum growth occur between bands B4 and B9, in 2018, values varying slightly between 0.45-0.46 for soybeans, 0.38-0.39 for wheat and 0.33-0.38 for maize while in 2019 can be noticed a different behavior 0.34- soybean, 0.26- wheat and 0.31- maize, the phenophases being delayed with negative influences on production via a plant's response to a particular stimulus such as the climatic conditions (mean temperature 14.1-16C in April 2018 respectively 8.1-10 C in 2019 and precipitation amount of <10 mm in 2018 comparable with 21-30 mm in 2019)

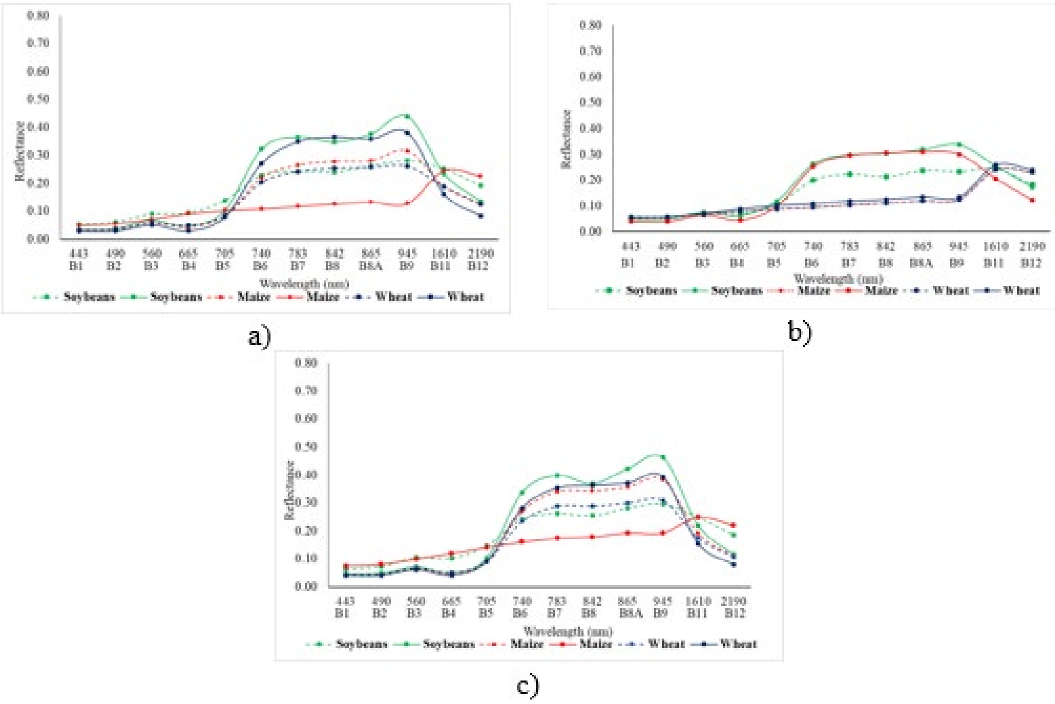

Figure 3. Spectral signature for: a) 21.04.2018, b) 26.04.2019, c) 01.05.2018

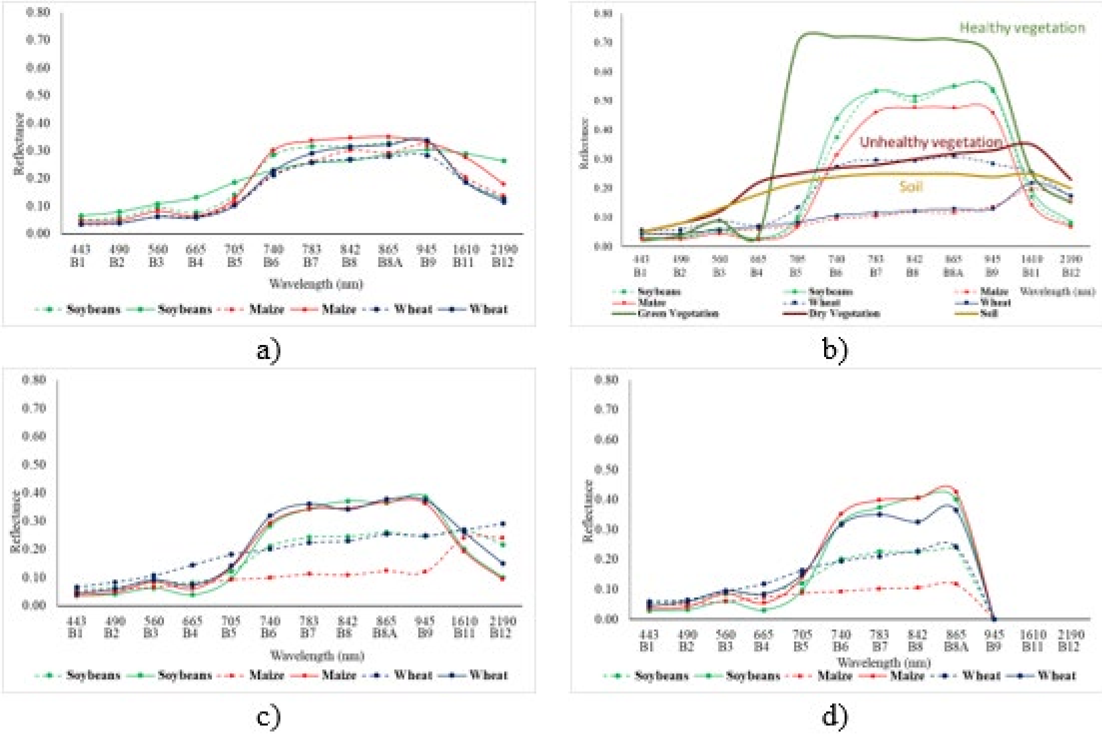

Figure 4. Spectral signature for: a) 31.05.2018, b) 26.05.2019, c) 14.08.2018, d) 26.07.2019.

For the mid-season period, the dates taking into consideration are 31.05.2018 (4a), 26.05.2019 (4b), 14.08.2018 (4c) and 26.07.2019 (4d). The difference between spring and summer crops observe in figure 4. Examination of the reflectance profiles of the crops selected clearly indicates the vegetation is stressed by landscape position, climatic conditions, different soil properties, soil tillage, in figures 4a and 4c the maximum reflectance slightly varying between 0.34-0.39, while figures 4b -4d highlights a slight increase in reflectance to values of 0.55 for soybeans, 0.48 for maize and 0.36 for wheat.

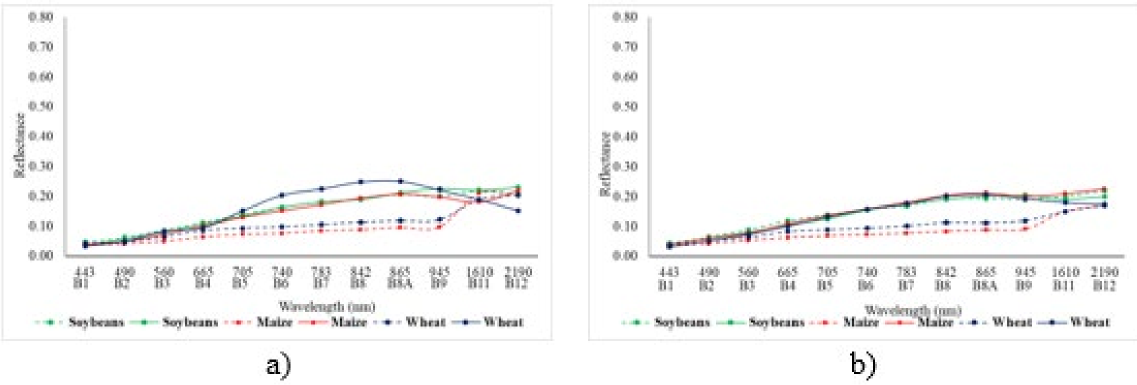

Figure 5: Spectral signature for: a) 28.09.2018, b) 13.10.2018.

Figures 5a and 5b, present the last vegetation period, the harvesting with specific dates: 28.09.2018 (5a) and 13.10.2018 (5b). The shape of the spectra is completely different from the previous two, being difficult to highlight the maximum value of the reflectance, the maximum values indicating the lack of vegetation, being close with the specific values of the soil background

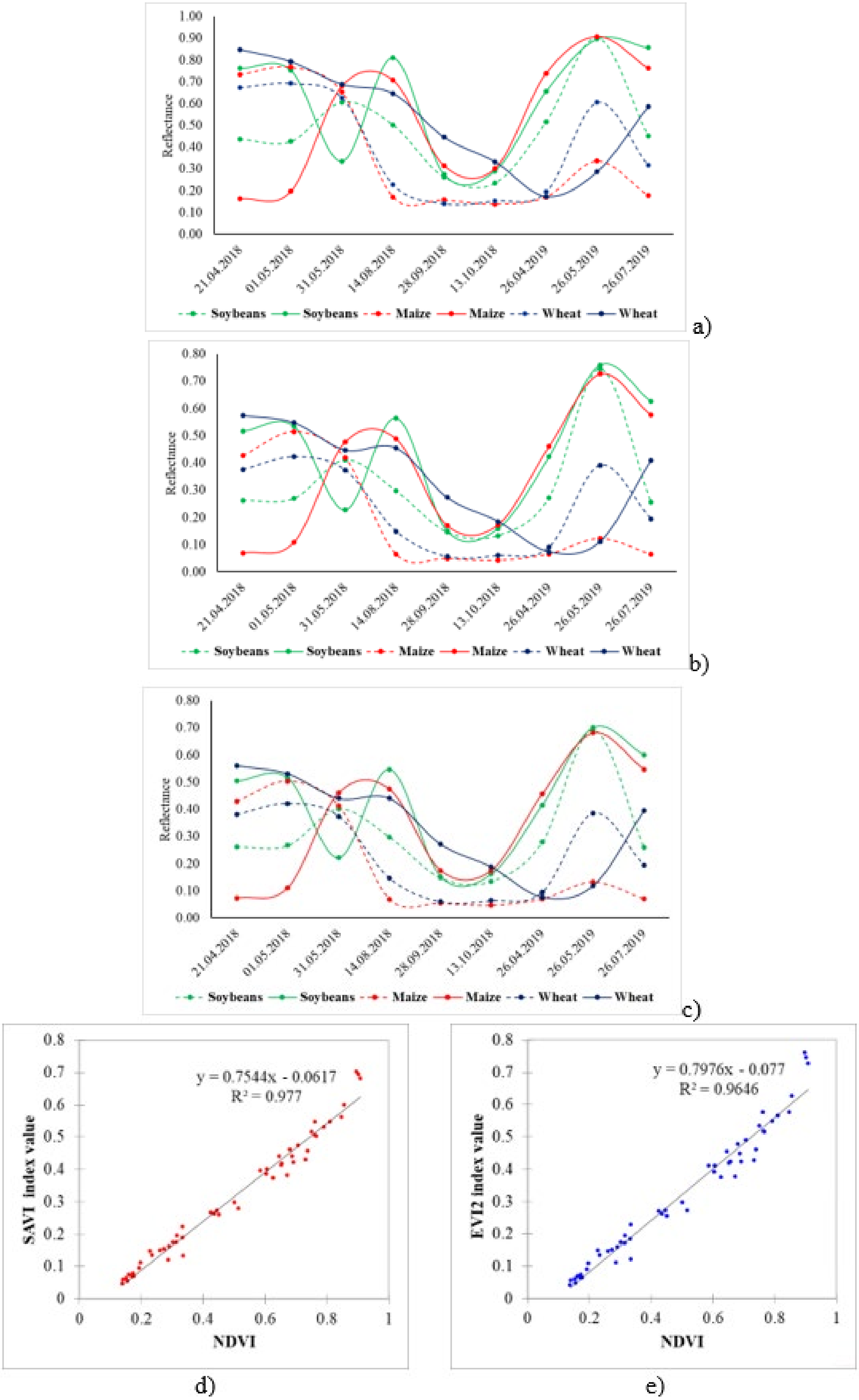

Figure 6: Spectral signature for: a) NDVI, b) EVI2, c) SAVI, d) SAVI/NDVI, e) EVI2/ NDVI.

The vegetation indices analyzed provide information regarding the vigor of the crops in the field. However, the comparison of red and broadband and NIR vegetation indices shows better accuracy of distance-based vegetation indices versus slope vegetation indices.

The patterns of reflectance during the growing season capture impressive amounts of information regarding changes in visible and near infrared (NIR) wavelengths, being decisive in the accomplish and interpretation of seasonal patterns. Figure 6 shows the existence of a general tendency in the changes of crops as well as, differences between cultures. During a full year, from sowing to harvesting, changes occurred which affected the values of the reflectance of the bare soil. There were significant differences in the seasonal NDVI values for the growing season mostly for the soybean and maize cultures. The vegetation indices were represented against the NDVI, the difference between the highest and the smallest vegetation indices increasing with the increase of the NDVI, Surprisingly SAVI is saturated more easily compared to EVI2, although it was expected that EVI2 would better highlight the evolution of the analyzed cultures. (Figures 6d, e).

CONCLUSION

The aim of this study was to understand the phenological stages of the crops and to monitor the crops taking into account the time-series images and vegetation indices. Moreover, the study also underlined the spatial behaviors of crop phenology, impacts of sowing times/agronomic practices on crop behavior and the temporal shifts. The phenology of these crops, captured by the acquisition of the images, was quite variable, from the development of the seeds to the development of the main product. The health changes of the plants during the growing period can be quantified using crop reflectance. Healthy plants are generally characterized by lower reflectance in visible bands and higher in NIR bands than unhealthy plants. The main conclusion of the present study indicated that the crops from the study area are stressed by different limiting factors such as (landscape position, climatic conditions, different soil properties, soil tillage). Once limiting factors of crop yield are identified, corrective solutions need to be developed. If the current solutions are possible, the conclusions and the results obtained should be transmitted to the decision maker as quickly as possible, who by applying detailed and high accuracy information processing can apply efficient, protective or stimulating treatments.

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