COMPARATIVE ANALYSIS OF TWO SATELLITE SYSTEMS IN SERVICES FOR AGRICULTURE. CASE STUDY: THE USAMVBT TEACHING AND EXPERIMENTAL RESORT

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Abstract. *Monitoring crops using satellite imagery has been proven to be particularly useful in agriculture, especially in precision agriculture, crop management and agricultural production. The present study performed a comparative analysis of two satellite systems: Landsat 8 OLI (produced by the United States of America through NASA) and the Sentinel 2 MSI Constellation (produced by the European Space Agency under the European Union supervision) in the context of normalized differential indices of vegetation, soil adjusted vegetation index and differential moisture index. In order to carry out the study, satellite images were acquired from 5 different periods - January 2018 to November 2018 - from the USGS website. The 2 mentioned satellite systems offer to the general public medium resolution satellite images: 30 m for Landsat and 10 m in three visible bands and one near-infrared band, respectively 20 m in red edge band and shortwave infrared bands for Sentinel 2 MSI. Based on spectral information from the satellite images provided by the two satellite systems, 4 normalized vegetation indices were calculated: NDVI (Normalized Difference Vegetation Index), NDBR (Normalized Burn Ratio), NDMI (Normalized Difference Moisture Index), and SAVI (Soil Adjusted Vegetation Index). Based on these indices, a characterization of an agricultural area within the USAMVBT Teaching and Experimental Resort was achieved, and it created a general analysis model to characterize the vegetation land cover. In this study the analysis was focused on one agricultural crop, the analysis of different vegetation stages and crop dynamics as well. For the accuracy assessment, the data obtained was correlated with information obtained from the land, referring to the agricultural crops that occupied the studied land. Different study models that describe the dynamics crop vegetation cover are helpful in the estimation of the biomass production and determining the optimal harvesting time corelated with the purpose of the crops.*

***Keywords**: agriculture, NDBR, NDVI, NDMI, SAVI, satellite imagery, Landsat 8 OLI, Sentinel 2 MSI*

INTRODUCTION

Crops are of great interest economically, socially and environmentally thus methods and techniques relying on satellite images are increasingly promoted (LUO et al., 2011; YANG et al., 2013). The study of biomass crops using techniques that rely on satellite images are of great interest for real-time monitoring of vegetation stages, crop health and optimal harvesting periods (RAYMOND HUNT Jr et al., 2005; MOREL et al., 2014).

The availability of free medium resolution (10–30 m) satellite imagery was well received due to them providing increased accuracy, as well as information about land cover use. Satellite sensors provide a wide range of spatial, spectral, and temporal properties to the scientific community.

Since 1970, there have been multiple developments when it comes to multispectral satellite imagery. One of its biggest uses is to assess vegetation as well as crops. From each image we can extract multispectral bands that contain specific information. This information combined with other bands that can be extracted results in newer, much more complex information, resulting in a better and more detailed characterization of crops.

For a long period of time, analyzing different aspects, as crop area assessments(QINGHAN et al., 2008), aspects of land use and land cover (LÖHNERTZ et al., 2006, BEGUE et al., 2014), mapping crop phenology and crop development (XIN et al., 2002; SAKAMOTO et al., 2005, BROWN and BEURS, 2008), variations in dynamics of crop growth (SHANG et al., 2014), vegetation indicators evaluation (GITELSON, 2004, JIANG et al., 2008, KUMHÁLOVÁ et al., 2014), monitoring of current activities in agriculture (ZHANG et al., 2003, EERENS et al., 2014), the relationship between some spectral bands and NDVI or the use of mathematical algorithms for classification based on Landsat 8 images (HERBEI et al, 2015a, 2015b) was done using remote sensing using satellite imagery.

Human activities and natural factors have affected evolution of vegetation in different areas leading to extensive studies being researched (HUANG and SIEGERT, 2006, SCHROEDER et al., 2011, POENARU et al., 2012, LANORTE et al., 2014).

JAKUBAUSKAS et al. (2002) paid special attention to crops study and studied the identifying crops using NDVI data correlated with analysis of different data series. Yang et al. (2008) analyzed the effect of using band ratio, related to vegetation indices (AWIFS images), to increase crop analysis attributes and accuracy of classification by supervised classification. Additional research in the field was made by LIU et al. (2011), who have tested the possibility of identifying and extracting the areas of corn planting on the bases of multi-temporal satellite data, and also by WILSON et al. (2014), who have studied separating types of crops on the bases of differentiated data and hyperspectral data. DING et al. (2014) have studied temporal dynamics of spatial heterogeneity over the cropland, on the bases of time-series NDVI, on the bases of red and infrared imagery reflectance of Landsat 8 OLI.

MATERIAL AND METHODS

This study aimed to compare and explore the interactive use of Landsat 8 OLI and Sentinel 2 MSI data in mapping land user and cover of a parcel USAMVBT Teaching and Experimental Resort. The area studied is located near the city of Timisoara and is property of the USAMVBT Teaching and Experimental Resort (figure 1).

Figure 1. RBG Sentinel 2A imagery of the study area

Within the Copernicus Program, Sentinel 2 has the purpose of observing the Earth and systematically captures high resolution optical images (10 m - 60 m), on terrestrial surfaces, and coastal waters. Launched in 2013, the 8th American Observation satellite, used in Earth Observation, by the name of Landsat 8, serves its purpose as an observation satellite.

To achieve the goal of the paper and conduct a reliable comparison analysis between the two satellite systems, the imagery was carefully selected, so that there are no clouds covering the studied area, as well as being captured during daytime. Five images were downloaded from the year 2018 for both satellite systems, from the NASA USGS portal https://earthexplorer.usgs.gov. The images for Landsat 8 OLI are from: 27 January, 3 May, 7 August, 10 October and 11 November. To proceed with the download of Sentinel 2 MSI imagery, we tried to find images close to the date selected for Landsat, or even from the same days. Therefore, the imagery selected for Sentinel 2 MSI has been acquired on following dates: 27 of January, 2 May, 8 August, 9 October and 11 November. The software used for the analysis of both types of imagery is ArcGIS.

Empirical functions define vegetation indices which include the vegetation cover structure as well as the physiological parameters related to an important factor related to vegetation, that being the photosynthesis. Indices correlated with leaf surface index and absorbed photosynthetic active radiation correlate to the concept of vegetation index (VI), which began from the idea that satellite bands can display sensitivity to the absorption and reflection of chlorophyll from the leaf, thus the vegetation cover can be analyzed using mathematical formulas, depicting variations between types of vegetation and their density (MYNENI et al., 1995; SILLEOS et al., 2006). Normalized Differential Vegetation Index (NDVI) is one of the most useful indicators, characterizing vegetation cover. It was first introduced by ROUSE et al. (1974) in the scientific literature. Additionally, another indicator, the NDVI index, is used to analyze a large number of vegetation attributes and properties, including calculating area covered in the leaf index, chlorophyll concentrations in the leaves, check the plant productivity, as well as the fraction of land covered with vegetation and the quantity of accumulated water.

Table 1

Formulas for the indices used

LANDSAT 8 OLI	SENTINEL 2 MSI
NDVI=$\frac{NIR-RED}{NIR+RED}=\frac{B5-B4}{B5+B4}$	NDVI=$\frac{NIR-RED}{NIR+RED}=\frac{B8-B4}{B8+B4}$
NDBR=$\frac{NIR-SWIR2}{NIR+SWIR2}=\frac{B5-B7}{B5+B7}$	NDBR=$\frac{NIR-SWIR2}{NIR+SWIR2}=\frac{B8-B12}{B8+B12}$
NDMI=$\frac{NIR-SWIR1}{NIR+SWIR1}=\frac{B5-B6}{B5+B6}$	NDMI=$\frac{NIR-SWIR1}{NIR+SWIR1}=\frac{B8-B11}{B8+B11}$
SAVI=$\frac{(NIR-RED)*(1+L)}{NIR+RED+L}=\frac{(B5-B4)*(1+L)}{B5+B4+L}$	SAVI=$\frac{(NIR-RED)*(1+L)}{NIR+RED+L}=\frac{(B8-B4)*(1+L)}{B8+B4+L}$

RESULTS AND DISCUSSIONS

Based on the spectral bands obtained from the satellite image analysis, a series of indices (table 2, figure 2, figure 3, figure 4) were calculated for the characterization of the studied area: NDVI (Normalized Difference Vegetation Index, ROUSE et al., 1974), NDBR (Normalized Burn Ratio, KEY and BENSON, 1999), NDBI (Normalized Difference Moisture Index, WILSON and SADER, 2002), SAVI (Soil Adjusted Vegetation Index, HUETE, 1988). Similar satellite imagery studies for the evaluation and characterization of an area based on the distribution of NDVI, NDBR, NDMI were made by HERBEI et al. (2015a,b) and HERBEI and SALA (2016). In these studies, different geographical areas were evaluated, from plain areas with agricultural crops, through the analysis of the dynamics of vegetation and biomass production, but also in mountainous areas, through the analysis of soil morphology and dynamics of vegetation (HERBEI et al., 2015a,b; HERBEI and SALA, 2016).

Table 2

The mean values of the indices calculated for the characterization of the studied area

LANDSAT 8 OLI	NDVI	NDBR	NDMI	SAVI
27 January	0.135759377	0.124622863	0.057521373	0.203632597
3 May	0.479412763	0.757263817	0.345413964	0.719106478
7 August	0.285879791	0.174681928	-0.000990692	0.428811306
10 October	0.094335178	0.008680615	-0.072320045	0.141499178
11 November	0.066487816	0.08607922	-0.054602419	0.099728704
SENTINEL 2 MSI	NDVI	NDBR	NDMI	SAVI
27 January	0.326237444	0.302191738	0.115713432	0.464363316
2 May	0.690077028	0.706286151	0.286869147	1.011194637
8 August	0.497822642	0.23908352	0.066567561	0.647872191
9 October	0.126504176	-0.065983088	-0.182173354	0.175259656
11 N November	0.097284574	-0.041144856	-0.194088765	0.12993738

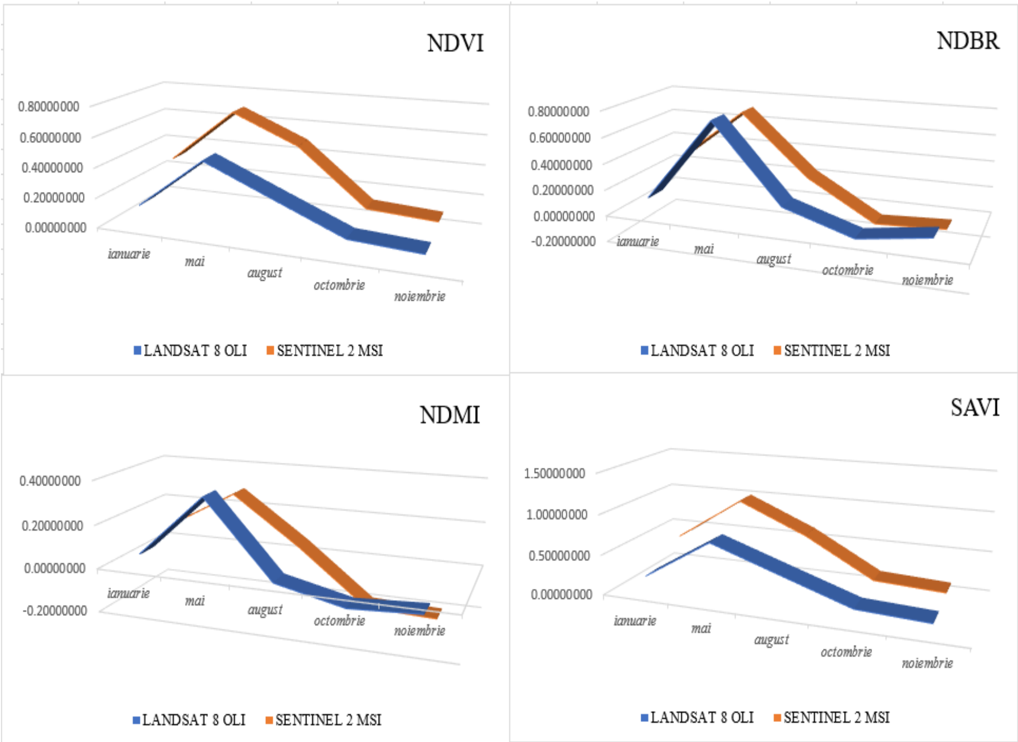

Figure 2 Graphic representation of the Sentinel 2 MSI and Landsat 8 OLI indices

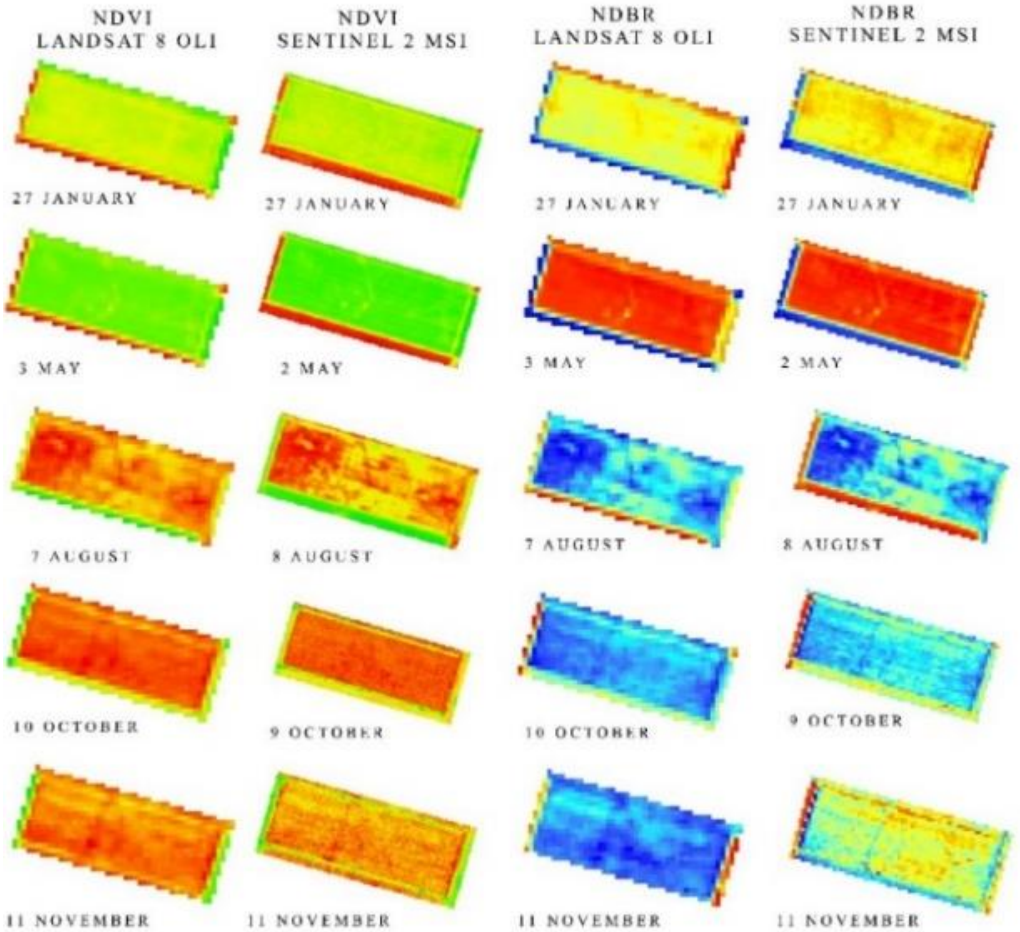

Figure 3 Normalized Difference Vegetation Index and Normalized Burn Ratio

Through the correlation analysis we found are very high correlations between the clustered indices based on the spectral information in the LANDSAT system. In the case of the indices calculated on the spectral data from the SENTINEL system, very high correlations were recorded between the SAVI and NDVI, SAVI and NDBR and NDMI and NDBR indices, the high correlations between the SAVI and NDMI indices and the average correlations between NDBR and NDVI, respectively between NDMI and NDVI, table 3.

Table 3

Correlations between the indices calculated for the two satellite systems studied

LANDSAT Indexes					SENTINEL Indexes				
	NDVI L	NDBR L	NDMI L	SAVI L		NDVI S	NDBR S	NDMI S	SAVI S
NDVI L					NDVI S				
NDBR L	0.93				NDBR S	0.755			
NDMI L	0.893	0.977			NDMI S	0.637	0.985		
SAVI L	0.999	0.93	0.893		SAVI S	0.932	0.936	0.87	

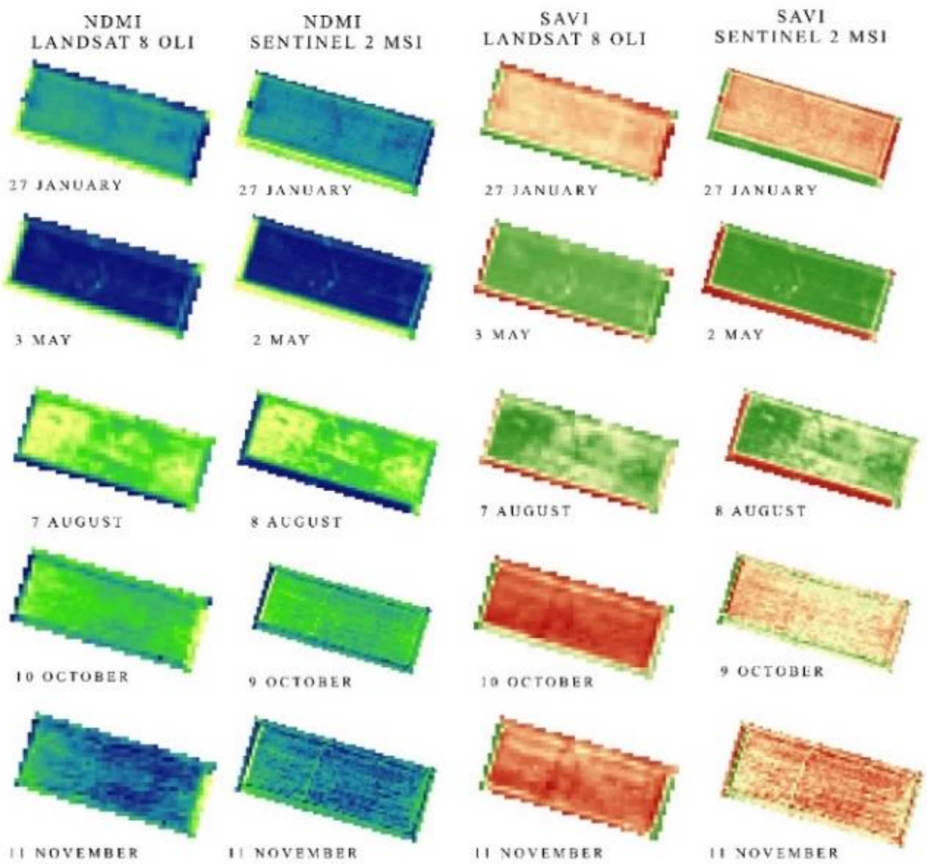

Figure 4 Normalized Difference Moisture Index and Soil Adjusted Vegetation Index

For the accuracy assessment, the USAMVBT Teaching and Experimental Resort provided information about the land use of the studied parcel. Thus, in the year of 2018, the studied parcel was sown with wheat.

The degree of adjustment (matching) of the values between the same indices (figure 5) obtained based on the spectral information from the two satellite systems was analyzed. The high values for the correlation coefficient R^2 indicated that in the wheat field imaging analysis, under the case studies of USAMVBT Teaching and Experimental Resort, the two satellite systems provided accurate information that could be used with high precision for characterizing the temporal dynamics of the autumn wheat crop.

Also the values of the indices obtained in the satellite system can be predicted based on the value of the same index from the other satellite system, under conditions of high statistical security, considering the values of the obtained R^2 coefficients (R^2= 0.973, p = 0.0262 for NDVI; R^2 = 0.909, p = 0.090 for NDBR; R^2= 0.959, p = 0.040 for NDMI; R^2 = 0.962, p = 0.0381 for SAVI).

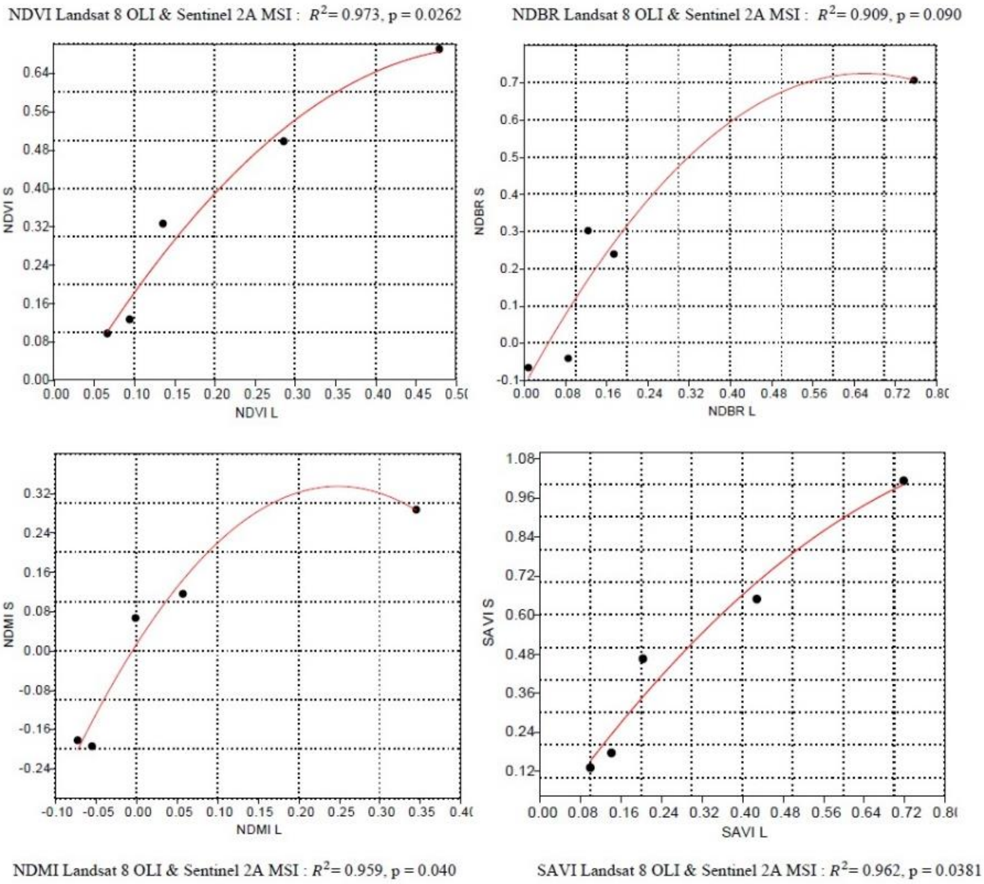

Figure 5 Relations between calculated indices of the two satellite systems

From September to March the rooting phase takes place in wheat crops. After emergence, wheat undergoes four important stages in its evolution: the active autumn period (when rooting and twinning take place), slow winter vegetation period or crypto vegetation (hidden vegetation), the regeneration period in spring (when twinning continues), the period of intensive growth in spring - early summer, going through the phenomena of straw elongation, thinning, flowering, fertilization, formation and ripening of the grain.

The autumn vegetation period take place underground. The slow winter vegetation period is captured on the satellite imagery in January. This was characterized by the positive response of NDVI, NDBR and NDMI indices and the negative response obtained from the SAVI index, because of the weak presence of the chlorophyll

During the regeneration period in spring, the parcel turns green, thus in the presence of the chlorophyll, the response of the RED and NIR bands of the satellites is very high, as the results of NDVI, NDBR and SAVI indices are positive in the present study and the response of the SAVI index is negative.

During the summer months, the crop losses the chlorophyll and turns into a yellow color. The lack of chlorophyll can easily be seen in the negative response of the NDVI, NDBR NDMI indices and the positive response of SAVI in August, due to the harvest of the crop in

July.

During the late autumn (October and November), NDVI, NDBR, NDMI indices are negative and SAVI index is positive, due to the plowing actions and the preparation of the parcel for the next sowing.

CONCLUSIONS

Based on the satellite imagery, the indices NDVI, NDBR, NDMI and SAVI were determined, according to which the studied area was characterized. Both satellites systems presented the same performance regarding the accuracy. However, the imagery offered by Sentinel is at 10 m resolution, this being translated in better analysis on smaller areas. Also, the revisiting time difference between Sentinel and Landsat is 10 days, thus for a more complex land use and land cover vegetation analysis, change detection analysis, or prediction models in the field of agriculture, Sentinel is the better choice. The Landsat mission has an impressive imagery collection of millions of images collected all over the world starting with the year 1972, while the first imagery captured by Sentinel was in the year 2015.

The two satellite systems are compatible and can be used together in different studies, for example to characterize the vegetation cover, or the dynamic analysis of the vegetation stages.

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