

NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) IN THE EVALUATION OF PHENOLOGICAL DYNAMICS IN *DACTYLIS GLOMERATA* L. AND *MEDICAGO SATIVA* L

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Abstract. The fodder species *Medicago sativa* L. and *Dactylis glomerata* L. are appreciated for their yield, due to their high perenniality and the large number of scythes in a year, as well as for their different use. In recent years, fodder crops and grasslands have been given a special place in precision agriculture, and by using remote sensing and implicitly the Normalized Difference Vegetation Index (NDVI), the vegetation status of crops is appreciated. In this context, the paper aims to capture the time dynamics, in different phenological stages, of the species *Dactylis glomerata* L. and *Medicago sativa* L., based on spectral information extracted from the analysis of PlanetScope satellite images, with a spatial resolution of 3 m. carried out in the experimental lots of the Lovrin Agricultural Research and Development Station - taking into account two plots cultivated with *Dactylis glomerata* L. (1.22 ha) and *Medicago sativa* L. (0.8 ha), located in the second and third year of vegetation. The analysis of the spectral information, materialized by NDVI values, with the data collected in the field regarding the dynamics of crop development (BBCH Code) led to the extraction of some useful conclusions for the agricultural practice regarding the health status of the two crops. NDVI values in *Dactylis glomerata* L. and *Medicago sativa* L. were different depending on crop evolution. Thus, at the end of winter, the NDVI index had the same average values for both crops (0.746), validated by field observations on crop health. Later on, for the *Medicago sativa* L. crop, the values of the NDVI index are increasing until sprout phenophase, when green mass was mowed for fodder. In the seed culture of *Dactylis glomerata* L. the values of the NDVI index are also increasing in the vegetative phase and reach the maximum threshold of 0.833, on 12.05.2020, in the phenophase - 50% of flowering (BBCH), after which it there is a decrease in them alongside with the change of the color of the plants as a result of the appearance of spikelets and later their ripening. The values of the NDVI index immediately after harvest in the two crops are different, being determined by their biological peculiarities.

Keywords: NDVI, remote sensing, BBCH, fodder plants, dynamics.

INTRODUCTION

The two fodder species *Medicago sativa* L. and *Dactylis glomerata* L. are appreciated for their yield, due to their high perenniality and the large number of scythes in a year. They can be grown in pure culture or in mixtures with other fodder species.

The species *Medicago sativa* L. is cultivated all over the globe (Tucak et al., 2014), and in Romania it occupies the largest areas in fodder plants, being also cultivated in sustainable agriculture (Lupașcu, 2004; Mazăre et al., 2019). Being a legume, the species *Medicago sativa* L. gives a special quality to the feed, through its high protein content (Radu et al., 2010; Karayilanli and Ayhan, 2016), high consumability and digestibility (Putnam and Undersander, 2006).

The species *Dactylis glomerata* L. is found spontaneously in grasslands in Europe Bland and Dent, 1964). Numerous works report the presence of this species in various grasslands in Romania (Moisuc et al., 1997; Moisuc et al., 2000; Marușca et al., 2019). The perennial mixture of *Medicago sativa* L. and *Dactylis glomerata* is also a classic L. (Rotar et al., 2013). The two species also enter into complex mixtures (Brown et al., 2006; Cojocariu et al. 2008; Mălinaș et al., 2014; Rechițean and Rechițean, 2021) necessary for the reseeding of natural grasslands.

In recent years, fodder crops and grasslands have been given a special place in precision agriculture. On large areas of grasslands, precision agriculture uses remote sensing and GIS (Mulla, 2013; Simon et al., 2017; Zhang et al., 2018; Lowenberg-DeBoer and Erickson, 2019; DeLay et al., 2021), for the analysis of orthophotoplans obtained from photogrammetric flights (Simon et al., 2018) or satellite images. Dynamic vegetation analysis can be determined using vegetation indices.

One of the best known and most widely used vegetation indices is the Normalized Difference Vegetation Index (NDVI), described by Rouse and colleagues in 1973. In many studies and practical applications, this index is used in mapping vegetation, in establishing the typology and health of plants, in correlations with various components of the environment, and in recent years, with remarkable results in

precision agriculture (Tieszen et al., 1997; Langner et al., 2006; Vaiphasa et al., 2011; Gong et al., 2015; Houborg and McCabe, 2016; Cojocariu et al., 2021).

NDVI can be applied to multispectral satellite imagery, which consists of the red band and the near-infrared band, given that its calculation formula speculates the difference in spectral response of vegetation in these ranges of the electromagnetic spectrum (Fan et al., 2009; Gu et al., 2013; Gandhi et al., 2015; Ozyavuz et al., 2015).

The aim of the research was to capture the temporal dynamics, in different phenological stages, of the species *Dactylis glomerata* L. and *Medicago sativa* L., based on the spectral information extracted from the analysis of satellite images. The values of the NDVI index in the species *Dactylis glomerata* L. were correlated with the data taken from the field according to the BBCH System for the coding of the phenological growth stages of the plants.

MATERIAL AND METHODS

1. Experimental site and biological material

The research was carried out in the Lovrin administrative-territorial unit, south of the locality of the same name, in the experimental lots of the Lovrin Agricultural Research and Development Station - Improvement of Fodder and Protein Plants Laboratory (Figure 1). Two plots cultivated with *Dactylis glomerata* L., on an area of 1.22 ha and *Medicago sativa* L., on an area of 0.8 ha were considered. (Figure 2).

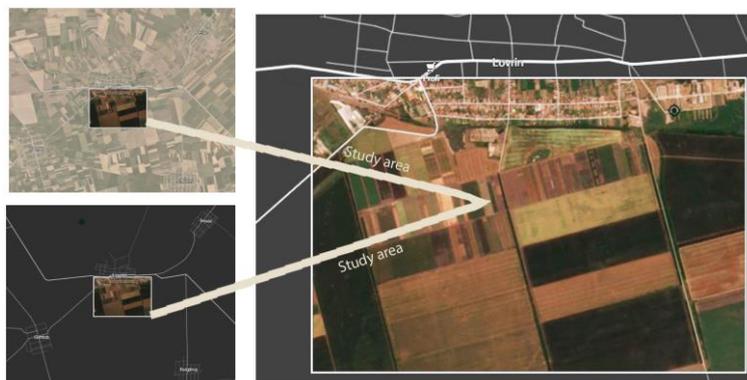


Figure 1. Location of the study area (processing after PlanetScope)

The Quen variety of *Medicago sativa* L. was used as biological material, sown in the fall of 2018 and the LVDG1 line was sown in the fall of 2020 in the species *Dactylis glomerata* L. In other words, we are talking about two cohesive crops: the culture of *Medicago sativa* L. being in the third year of vegetation and the culture of *Dactylis glomerata* L. in the second year of vegetation.

The sowing distance was 12.5 cm for both crops.

Alfalfa was harvested for green mass forage on 10.05.2022.

In the species *Dactylis glomerata* L., seed production was monitored and biometric observations and measurements were performed on the phenological growth stages of plants according to - BBCH system to coding the phenological growth stages of plants (Meier, 2018); a practical approach used by many scientists in agriculture (Meier et al., 2009).

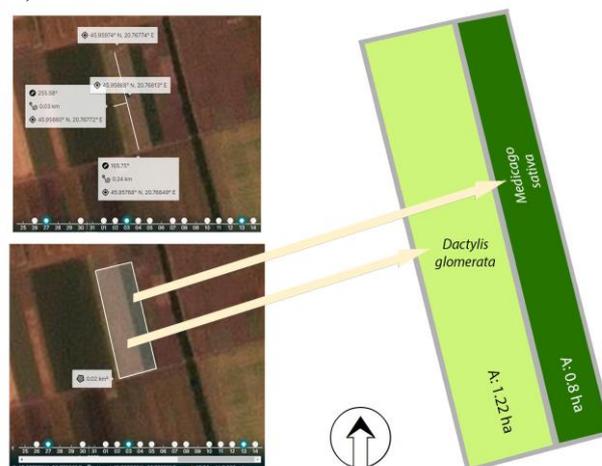


Figure 2. The plot plan of the experimental device (processing after PlanetScope)

2. Used materials

For the analysis of the plots in the experimental device, seven PlanetScope satellite scenes (reflectance images) were used, downloaded free of charge from the Planet Platform, acquisitioned at different time points (Figure 3), depending on the growth and development stages - BBCH analyzed at culture of *Dactylis glomerata* L. The characteristics of the satellite scenes used are shown in Table 1.



Figure 3. Date of acquisition of satellite imagery

Table 1. Characteristics of the satellite scenes used

Scene ID	Data achiziției	Cloud Percent.	Ground sample distance	Pixel Resolution	Off-nadir angle	Sun elevation	Sun azimuth	Instrument
20220414_083429_68_2423	14.04.22	0.00%	4 m	3 m	0.9°	45.0°	134.6°	Super Dove (PSB.SD)
20220426_083648_68_2440	26.04.22	0.00%	4 m	3 m	0.3°	49.3°	133.0°	Super Dove (PSB.SD)
20220502_083901_24_2464	02.05.22	0.00%	4 m	3 m	5.0°	50.7°	131.5°	Super Dove (PSB.SD)
20220512_083854_26_2458	12.05.22	0.00%	4 m	3 m	4.0°	53.3°	129.7°	Super Dove (PSB.SD)
20220527_085133_48_2262	27.05.22	0.00%	3.8 m	3 m	5.1°	57.5°	130.5°	Super Dove (PSB.SD)
20220603_091111_47_24a3	03.06.22	0.00%	4 m	3 m	5.0°	60.5°	135.9°	Super Dove (PSB.SD)
20220613_092046_11_2414	13.06.22	0.00%	3.9 m	3 m	5.0°	62.8°	140.4°	Super Dove (PSB.SD)

3. Research methodology

The working protocol involved several steps, which are described below.

1. Selection of satellite scenes used as a support in the analysis of the crop dynamics considered - the phenological phases of the *Dactylis* and alfalfa crops were taken into account, thus, for each phase, a satellite scene was selected, according to the calendar in Figure 3;

2. Satellite data processing, in ArcGIS 10.4 software, involved:

- decomposition of satellite scenes into four component bands (*Make Raster Layer* function) and thus obtaining an individual image of each spectral band (three in the visible range and one in the near infrared range)
- extraction of the area of interest - initially, a group of plots with different crops was selected to follow the variations of NDVI values, and later, only the plots considered in this study were extracted;
- obtaining NDVI images on the seven previously created subsets (*Raster Calculator* function), by applying the formula $NIR-RED / NIR + RED$ (NIR - near infrared band, RED red band);
- extracting NDVI values for *Dactylis glomerata* L. and *Medicago sativa* L. crops (*Zonal Statistics as Table* function).

3. Correlation of spectral information, materialized by NDVI values, with data collected in the field on the dynamics of crop development.

RESULTS AND DISCUSSIONS

In addition to the other uses of NDVI, this index can be applied with results in accordance with the reality in the field, to assess the state of vegetation of the plants in accordance with the phenological phase in which they are (Wagenseil and Samimi, 2006; Hu et al., 2009; D'Allestro and Parente, 2015; Boori et al., 2020).

In the case of this study, seven images of the NDVI index (Figure 4) were generated in the calendar data corresponding to the growth phenophases of *Dactylis glomerata* L. according to the BBCH scale, for the monitoring of *Dactylis glomerata* L. and *Medicago sativa* L. crops (Table 1). According to the calculation formula, being normalized images, NDVI values vary from -1 to +1, which means that in images, abundant vegetation has assigned values close to 1, and areas without vegetation, negative values or close to 0 (Lillesand et al., 2014).

In the case of the study area (fig. 4), the NDVI values are between 0.267 (specific to April) and 0.905 (at the end of May).

On plots cultivated with *Dactylis glomerata* L. and *Medicago sativa* L., NDVI values differ from one phenological stage to another (Table 1).

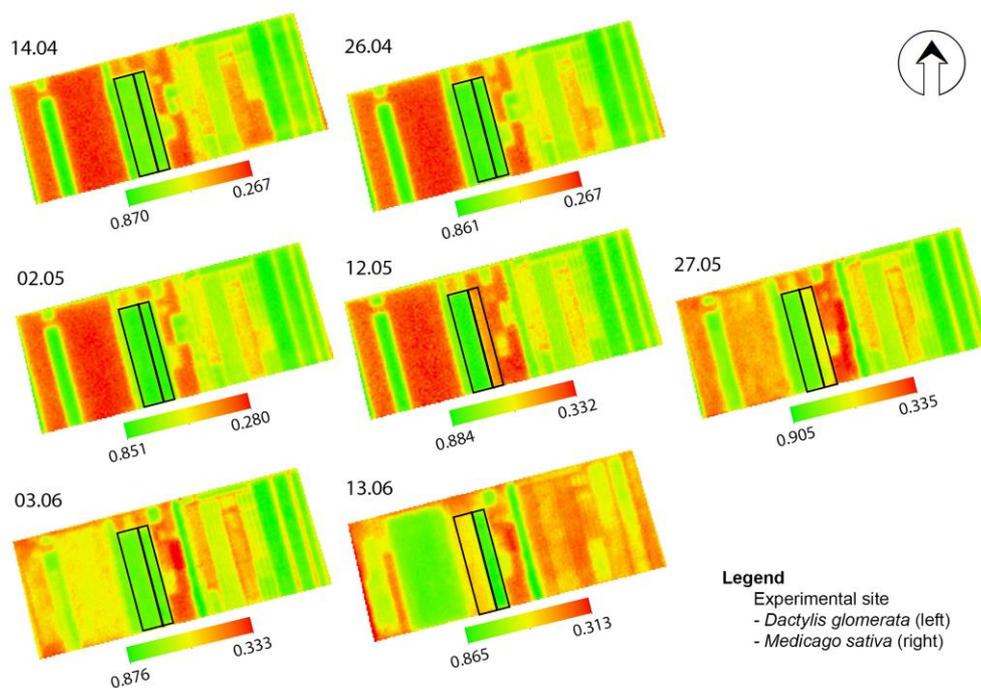


Figure 4. NDVI images in different phenophases of cultures

Table 1. NDVI values on phenophases for *Dactylis glomerata* L. and *Medicago sativa* L. crops

Acquisition date / BBCH Code	NDVI values									
	<i>Medicago sativa</i> L.					<i>Dactylis glomerata</i> L.				
	Min	Max	Mean	Range	Std	Min	Max	Mean	Range	Std
BBCH Code	19 - 9 or more leaves unfolded									
14.04.22	0.610	0.796	0.746	0.186	0.030	0.686	0.787	0.746	0.101	0.015
BBCH Code	55 - Middle of heading									
26.04.22	0.666	0.825	0.793	0.159	0.021	0.703	0.833	0.792	0.130	0.019
BBCH Code	59 - End of heading: inflorescence fully emerged									
02.05.22	0.727	0.829	0.797	0.102	0.019	0.640	0.841	0.793	0.201	0.031
BBCH Code	65 - 50% of the flowering									
12.05.22	0.450	0.674	0.544	0.224	0.041	0.703	0.885	0.833	0.182	0.032
BBCH Code	69 - End of flowering									
27.05.22	0.541	0.735	0.675	0.194	0.030	0.708	0.858	0.815	0.150	0.025
BBCH Code	71 - Watery ripe									
03.06.22	0.649	0.856	0.785	0.207	0.028	0.691	0.820	0.786	0.129	0.019
BBCH Code	89 - Fully ripe									
13.06.22	0.678	0.865	0.801	0.187	0.033	0.530	0.674	0.589	0.144	0.023

In the first evaluation of the two cultures, respectively the middle of April, for both cultures, the NDVI had an average value of 0.746; transposed in the field by the light green color - which is identified by a good health of fodder crops and a uniformity of plants in the field. The same situation is found at the end of April (26.04.2022) when we have a pronounced green color in both species: the average values of NDVI being 0.793 in the *Medicago sativa* L. Crop and 0.793 in the *Dactylis glomerata* L. crop.

In the next stage of vegetative growth, respectively in 02.05.2022 the average values of the NDVI index are increasing in both experimental fields, the higher values being registered in the culture of *Medicago sativa* L. (0.797). The explanation would be that legumes have a faster growth and a different configuration of the leaves.

On 10.02.2022 the alfalfa was mowed for green mass feed, a fact followed in the low values of the NDVI index on 12.05.2022 (0.544). After mowing, the species *Medicago sativa* L. regenerates quickly, a fact indicated by the increases in time of the NDVI index values, so that on 13.06.2022 its average value was 0.801.

In the *Dactylis glomerata* L. crop the values of the NDVI index reach the maximum threshold of 0.833, on 12.05.2020, in the phenophase - 50% of the flowering (BBCH). With the appearance of spikelets and later their ripening, there is a change in the color of the plants, a fact highlighted by a reduction in the values of the NDVI index, so that on 03.06.2022 its value was 0.786. This date in the *Dactylis glomerata* L. crop analyzed corresponds to phenophase 89 BBCH - Fully ripe: grain hard, difficult to divide with thumbnail and the seed harvest follows.

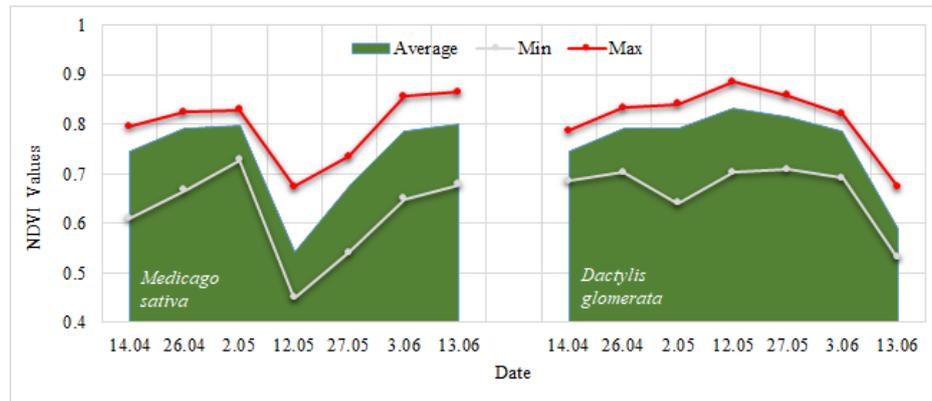


Figure 5. NDVI values for the species *Dactylis glomerata* and *Medicago sativa*

Figure 5 shows two important aspects for the analyzed crops: 1. The average values of the NDVI index are close to the maximum value, which denotes the uniformity and health of the crops and 2. Immediately after harvesting the base floor of the species *Dactylis glomerata* L. has a higher consistency and therefore a higher chance of recovery after harvest.

It should be noted that both species analyzed are perennials and regenerate several times during a year. Both species were harvested at a distance of 6 cm from the ground to stimulate regeneration. Immediately after harvest, the NDVI index in the culture of *Medicago sativa* L. had an average value of 0.544, lower than in the culture of *Dactylis glomerata* L. (0.589), the explanation being that the lower floor in the species *Dactylis glomerata* L. is better represented by shoots with green leaves.

CONCLUSIONS

From the analysis of NDVI values in time intervals, for the appreciation of the growth and development phenophases in the fodder species *Medicago sativa* L. and *Dactylis glomerata* L. cultivated in the experimental field from SCA Lovrin, a series of aspects relevant to agricultural practice can be deduced.

At the end of winter, the NDVI index had the same average values for both crops (0.746), validated by field observations on crop health.

In the *Medicago sativa* L. crop, the values of the NDVI index are increasing until the sprouting phenophase, when green mass was mowed for fodder, which is also shown in the NDVI maps.

In the *Dactylis glomerata* L. crop the values of the NDVI index are also increasing in the vegetative phase and reach the maximum threshold of 0.833, on 12.05.2020, in the phenophase - 50% of the flowering (BBCH), after which a their decrease with the change of the color of the plants as a result of the appearance of the spikelets and later their ripening.

The values of the NDVI index immediately after harvest in the *Medicago sativa* L. crop was 0.544, lower than in the *Dactylis glomerata* L. crop (0.589), due to the different way of representing the vegetative mass of the lower floor of the two crops.

The research findings are consistent in precision agriculture, which is increasingly used in the field.

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