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Monitoring Vegetative Stages of Sunflower and Wheat Crops with Sentinel-2 Images According to BBCH-Scale

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Abstract: Nowadays, due to the decrease in agricultural land and increasing population and food demand, mapping, examination and monitoring of agricultural products are important. With the remote sensing technique, it has been faster and economical to monitor agricultural products on a large scale. The aim of this study, is to monitor the vegetative stages of wheat (*Triticum aestivum L.*) and sunflower (*Helianthus annuus L.*) which are the main agricultural products in Tokat province of Turkey using different vegetation indices produced by satellite images. Vegetation Indices produced from multi-temporal Sentinel-2 satellite images were used for monitoring vegetative stages, namely, Normalized Differential Vegetation Index, Normalized Differential Vegetation Index red-edge, Green Normalized Difference Vegetation Index and Normalized Different Index. Biologische Bundesanstalt, Bundessortenamt and the Chemical Industry scale were used in the monitoring of vegetative stages for both plants. Since the temporal resolution of the Sentinel-2 satellites were 5 days, images were obtained at each stage of two plants from January to September. The reflectance values of two plants in all stages were obtained according to four different indices. As a result of the study, the highest reflectance values for wheat and sunflower plants were observed during flowering period.

Keywords: BBCH-Code, Sentinel-2, Sunflower (*Helianthus annuus L.*), VIs, Wheat (Triticum aestivum L.),

BBCH Ölçeğinde Sentinel-2 Görüntüleri ile Ayçiçeği ve Buğday Bitkilerinin Vejetatif Aşamalarının İzlenmesi

Öz: Günümüzde tarım arazilerinin azalması ve artan nüfus sayısı ile artan yiyecek talebi sebebiyle tarımsal ürünlerin haritalanması, incelenmesi ve takibi önem arzetmektedir. Uzaktan algılama tekniği ile birlikte tarımsal ürünlerin büyük ve küçük ölçekte takibini yapmak hızlı ve daha ekonomik olmuştur. Bu araştırmanın amacı, Tokat ilinde başlıca tarım ürünü olan buğday (*Triticum aestivum L.*) ve ayçiçeği (*Helianthus annuus L.*) bitkilerinin uydu görüntüleri yardımıyla üretilmiş farklı bitki indeksleri ile mahsüllerin vejetatif evrelerini izlemektir. Vejetatif evreler izlenirken Sentinel-2 uydu görüntülerinden üretilen Bitki İndeksleri (Vegetation Indices) kullanılmıştır. Normalize edilmiş fark bitki örtüsü indeksi (Normalized Differential Vegetation Index), Normalize edilmiş fark bitki örtüsü indeksi kırmızı-kenar (Normalized Differential Vegetation Index red-edge), Yeşil normalize edilmiş fark bitki örtüsü indeksi (Green Normalized Difference Vegetation Index) ve Normalize Fark Bitki örtüsü indeksi (Normalized Different Index) kullanılmıştır. Vejatatif evrelerin takibinde Biologische Bundesanstalt, Bundessortenamt and Chemical industry ölçeği kullanılmıştır. Çalışmanın sonucunda, Buğday ve ayçiçeği bitkisi için en yüksek yansıtım değerleri çiçeklenme döneminde görülmüştür. Sentinel-2 uydusunun zamansal çözünürlüğünün 5 gün olmasından dolayı Ocak ayından Eylül ayına kadar iki bitki için de her evrede görüntü elde edilmiştir. Bölgede üretimi fazla olan iki bitkinin dört farklı indekse göre yansıtım değerleri elde edilmiştir.

Anahtar Kelimeler: Ayçiçek (*Helianthus annuus L.*), BBCH-Code, Buğday (*Triticum aestivum L.*), Sentinel-2, VIs,

1. Introduction

Satellites have been used in monitoring and mapping agricultural products since the 1970s. Satellites can provide cheaper and easier data in large areas which make them advantageous. Thanks to the development of technology and multispectral sensors mounted on satellites, various analysis such as chlorophyll content of the plant, estimation of plant nitrogen content, discriminating heavy metal stress levels, cropland mapping, monitoring of vegetation types, Short-term land cover changes, drought, and yield model etc. can be extracted (Alexandridis et al. 2014; Belgiu and Csillik, 2018; Dereli, 2018; Iqbal et al. 2013; Shamal and Weatherhead, 2014; Ozdogan et al. 2010; Walsh and Shafian, 2018; Zhang et al. 2018).

Herbei and Sala (2015), monitored sunflower plant with Landsat 8 satellite data. As a result of the study, they stated that the NDVI index was in the closest relationship with NIR bands. Based on satellite imagery, it simplifies the characterization of sunflower vegetation stages, and image based analysis can become more effective for crop phenology monitoring. Shahrokhnia and Ahmadi (2019) aimed to model between Vegetation Indices (VIs) and rainfall data in their study in Iran. They found high correlation between peaks of VIs and total spring sediments in late April and early May. As a result, they concluded that the correlation of VI's with rainfall distribution characteristics could provide advantages for the monitoring of vegetation and management of crop production in dry and semi-dry regions. Marino and Alvino (2019) examined two different types of wheat in two small fields with VIs in Italy. In their study, they concluded that the usage of high-resolution images to analyze the frequency value of VIs in different areas in agricultural studies may be a useful approach to detect precision in agriculture. Claverie et al (2012), aimed to yield estimation with irrigation maize and Sunflower plants in Toulouse, France. In the study, a simple algorithm for yield estimate (SAFY) model was used by using Formasat-2 satellite images. As a result of the study, they observed that the sunflower plant is consistent but significant differences for the maize plant. It is also stated that the Sentinel-2 satellite can create great potential thanks to its temporal resolution and high number of bands.

This research aimed to study the dynamics of sunflower and wheat based on VIs derived from Sentinel-2 images according to BBCH-Scale. In this study, a catalog of VIs values were created that can be beneficial for agricultural analysis for real-time or future studies for researchers, decision-makers and farmers.

2. Materials and Method

2.1. Study Area

The study was carried out at the Middle Black Sea Gateway Zone Agricultural Research Institute Tokat Province in Black Sea Region in Turkey in a plain area. The study was conducted between January and September 2019. The research area has two fields which are wheat cultivated area 2.42 ha and sunflower cultivated area 1.77 ha (Figure 1).

The study area is in a soil subgroup of Typicustifluvent in Yeşilırmak Series. Yeşilırmak series is the dominant soil series in Kazova. (Oguz, 1993). The soil of the area has 0 - 2% slope, flat, close to the flat slope properties, formed by alluvium carried by Yeşilırmak A and C horizon very deep soils. The lime content is homogenous in Kazova. The clay content varies from 36.8 to 42.8%. the pH ranges from 7.72 to 7.90. The dominant cation is Ca and MG.

The average annual temperature is 12.8 C, the average annual rainfall is 444.4 mm and the average number of snowfall days is 13 in Tokat Province (Tokat Governorship, 2019).

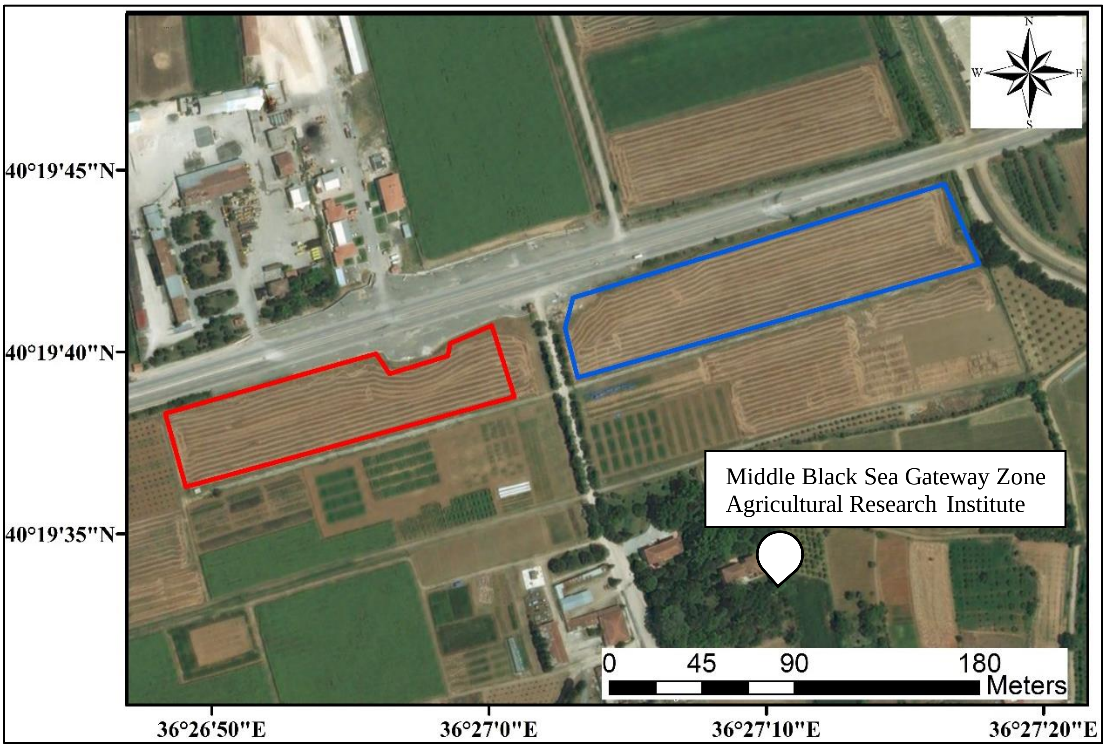

Figure 1. The study area, wheat illustrated by a blue polygon, and sunflowers illustrated by a red polygon.
Şekil 1. *Çalışma alanı, mavi alan buğday bitkisini kırmızı alan ayçiçeği bitkisini göstermektedir.*

2.2. Satellite Data and Vegetation Indices

In our study, Sentinel-2 satellites, which are part of the Copernicus program financed by ESA, were used. Sentinel-2 satellites are equipped with multispectral cameras. Twin satellites Sentinel-2a and Sentinel-2b have a shorter temporal resolution as 5 days (ESA, 2019). Since the temporal resolution is shorter and it has red-edge and near-infrared wavelength bands, it provides a great advantage in vegetation monitoring, mapping and health condition studies.

For the analysis 12 images of Level-2A (cloud-free) Sentinel-2 Satellites are acquired during the plant growth stages (Figure-2).

In the literature, many VIs have been produced to determine the condition of plants using optical images. The state of the red-edge in plant reflection is a measure of chlorophyll content (Frampton et al. 2013). For this reason, the indexes are produced by using reflections in the red and green regions in general. With the development of satellite technologies, the indices are enriched in number and sensitivity thanks to the band located in the red-edge region in new generation satellites. In this study, the VIs used are given in Table-1.

Table 1. VIs used in the study.
Çizelge 1. *Çalışmada kullanılan bitki indeksleri*

Acronym	Equation adapted to Sentinel-2 bands	References
NDVI	$\frac{B8 - B4}{B8 + B4}$	(Rouse et al. 1974)
NDVIre	$\frac{B8 - B5}{B8 + B5}$	(Gitelson and Merzlyak 1994)
GNDVI	$\frac{B8 - B3}{B8 + B3}$	(Gitelson et al. 1996)
NDI45	$\frac{B5 - B4}{B5 + B4}$	(Ghosh et al. 2018)

2.2. Crops and BBCH-Code

The sunflower plant is from the daisy family and is generally an annual herbaceous plant species. It is generally used for seed and oil production and as well as ornamental purposes. After harvesting, the stems can be used for heating and animal feeding. It is one of Turkey's most important oil plants. Tokat province is one of the top 10 cities in Turkey with the most cultivated (TUIK, 2019). The sunflower plant was planted in our study area in early May and harvested at the beginning of September.

The sunflower has been planted with pneumatic seed drills with a 70 cm row range and 22 cm row over. 12kg N/da and 9kg P2O5/da were fertilized. All of the phosphorous fertilizer was applied as Diamaonyumphosphate (DAP) with cultivation, half of the nitrogen fertilizer with cultivation, the remaining half as Nitropower (33% N) with urea and ammonium nitrate before initial irrigation. Irrigation was applied at the stages of stem elongation, heading and development of fruit.

The Wheat plant is a one-year herbaceous plant that can be grown all over the world. Continental climate prefers cultivated areas. Wheat, flour-made animal feed, etc., can be grown for many purposes. The wheat plant was planted in our study area in mid-January and harvested at the beginning of July.

Wheat was planted with seed drills in November. 16kg N/da and 9kg P2O5/da were fertilized. All of the phosphorous fertilizer was applied as DAP with cultivation, half of the nitrogen fertilizer with cultivation, the remaining half as Nitropower (33% N) with urea and ammonium nitrate in stem elongation.

BBCH-Scale is extensively standardized the phenological stages of plants (Maier 2001). Plant views integrated with satellite data dates according to BBCH-scale are given in Figure-2.

BBCH-NAME	LEAF DEVELOPMENT	TILLERING	STEM ELENGATION	BOOTING	HEADING	FLOWERING	DEVELOPMENT OF FRUIT	RIPENING	SENESCENCE
BBCH-CODE	12	23	32	41	55	65	73	83	92-93
WHEAT PHASE PHOTOS									
IMAGE DATE	29.01.2019	10.03.2019	06.04.2019	26.04.2019	04.05.2019	14.05.2019	29.05.2019	05.06.2019	03.07.2019
BBCH-CODE	10		37-39		53	61	71	80-81	92
SUNFLOWER PHASE PHOTOS									
IMAGE DATE	14.05.2019		29.05.2019		05.06.2019	25.06.2019	03.07.2019	14.08.2019	01.09.2019

Figure 2. Plant views integrated with satellite data dates according to BBCH-scale. Sentinel-2a images date to cells filled with green color.
Şekil 2. *Uydu görüntü tarihlerinde bitkilerin görünümü ve BBCH-scale kodları. Yeşil dolgulu alanları Sentinel-2a görüntülerini göstermektedir.*

3. Results and Discussion

The indice values of wheat and sunflower plants were produced by Sentinel-2 satellites images. The values obtained are compatible with BBCH-Code (Table 2). In addition to the index values, standard deviation of the indices in stages is shown in table-3. In the study, the maps with the highest NDVI value of the sunflower and wheat plant are given in figure 3. The values change between 0 and 1. Higher values represent the crop that has a higher concentration of chlorophyll.

Wheat plant showed the highest index value in 23rd BBCH-Code than 12th BBCH-Code. The increase of the VIs value indicates the increase of presence and health status of the growing plant. The contradiction here is the presence of wild weeds up to the 23rd BBCH-Code. The index values decreased because weeds were removed between 12th BBCH-Code and 23rd BBCH-Code. Therefore, the reflectivity in the first phase is not reliable due to in presence of wild weeds in the field. An increase in index values is observed from 23rd BBCH-Code to 65th BBCH-Code, except NDVIre. NDVIre index increased up to 55th BBCH-Code. After these stages, the reflectance values decreased until the senescence stage. As the index values of the two vegetations are close to each other on 5 June 2019, the time series of studies to be conducted in this region should be checked for crop type classification studies (Figure 4). With the yellowing of the wheat, the decrease in reflectance value was very high in the 83th BBCH-Code (Figure 5).

Table 2. Index values produced by Sentinel-2
Çizelge 2.*Sentinel-2 ile üretilen indeks değerleri*

Date	Stage of Vegetation (BBCH-Code)	NDVI (B8-B4)/(B8+B4)*	NDVIre (B8-B5)/(B8+B5)*	GNDVI B8-B3)/(B8+B3)*	NDI45 (B5-B4)/(B5+B4)*
Wheat (Triticum aestivum L.)					
29.01.2019	12	0.660 ± 0.035**	0.424 ± 0.034**	0.661 ± 0.023**	0.328 ± 0.040**
10.03.2019	23	0.584 ± 0.050	0.400 ± 0.048	0.555 ± 0.036	0.243 ± 0.027
06.04.2019	32	0.725 ± 0.069	0.537 ± 0.075	0.676 ± 0.054	0.315 ± 0.052
26.04.2019	41	0.826 ± 0.053	0.651 ± 0.062	0.761 ± 0.045	0.389 ± 0.061
04.05.2019	55	0.877 ± 0.035	0.712 ± 0.045	0.819 ± 0.032	0.446 ± 0.063
14.05.2019	65	0.879 ± 0.035	0.710 ± 0.046	0.829 ± 0.028	0.456 ± 0.070
29.05.2019	73	0.708 ± 0.048	0.521 ± 0.046	0.700 ± 0.040	0.299 ± 0.038
05.06.2019	83	0.415 ± 0.032	0.263 ± 0.027	0.486 ± 0.025	0.171 ± 0.021
25.06.2019	87	0.172 ± 0.008	0.098 ± 0.011	0.324 ± 0.010	0.074 ± 0.011
03.07.2019	92-93	0.172 ± 0.012	0.035 ± 0.009	0.353 ± 0.019	0.073 ± 0.014
Sunflower (Helianthus annuus					
14.05.2019	10	0.103 ± 0.012**	0.047 ± 0.028**	0.319 ± 0.010**	0.057 ± 0.025**
29.05.2019	16	0.203 ± 0.036	0.103 ± 0.038	0.362 ± 0.034	0.102 ± 0.031
05.06.2019	37-39	0.425 ± 0.067	0.250 ± 0.059	0.469 ± 0.050	0.196 ± 0.041
25.06.2019	53	0.797 ± 0.028	0.563 ± 0.058	0.703 ± 0.018	0.425 ± 0.035
03.07.2019	61	0.804 ± 0.014	0.516 ± 0.050	0.717 ± 0.009	0.437 ± 0.033
30.07.2019	71	0.758 ± 0.020	0.509 ± 0.018	0.636 ± 0.013	0.406 ± 0.028
14.08.2019	80-81	0.561 ± 0.074	0.301 ± 0.051	0.481 ± 0.043	0.317 ± 0.053
01.09.2019	92	0.288 ± 0.073	0.153 ± 0.045	0.396 ± 0.038	0.142 ± 0.041
*Equation adapted to Sentinel-2 bands					
**±Standard deviation					

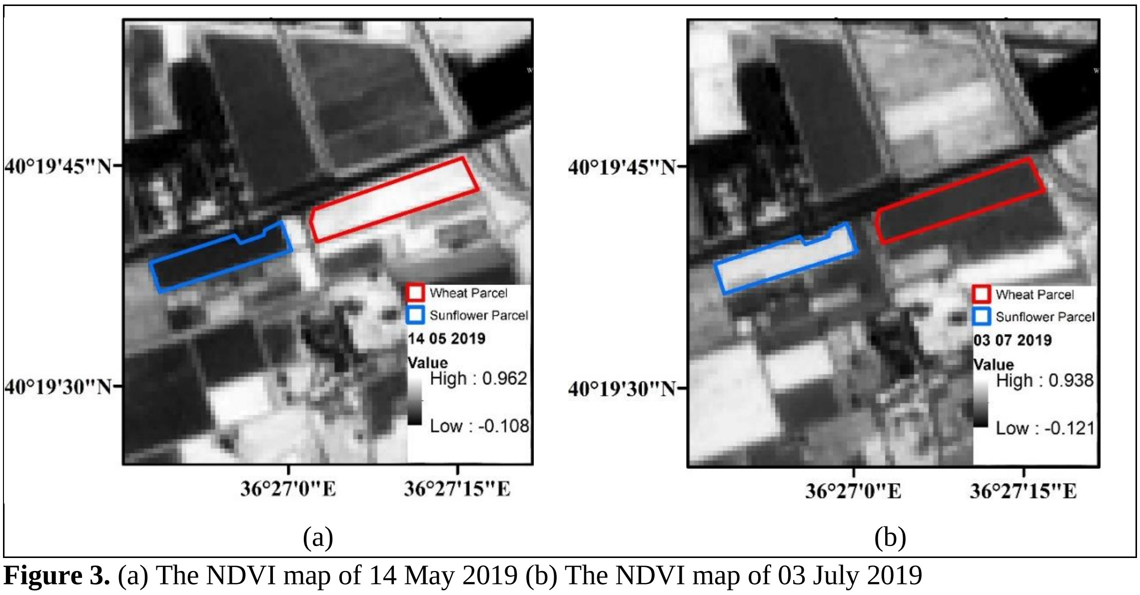

Figure 3. (a) The NDVI map of 14 May 2019 (b) The NDVI map of 03 July 2019
Şekil 3. *(a) 14 Mayıs 2019 NDVI haritası (b) 3 Temmuz 2019 NDVI haritası*

The sunflower plant was cultivated at the beginning of May. After planting, index values increased up to 61st BBCH-Code. The only NDVIre index showed its peak value at the 53rd BBCH-Code. After 61st BBCH-Code, index values decreased, and the sharpest decline was 80-81st BBCH-Code (Figure 6).

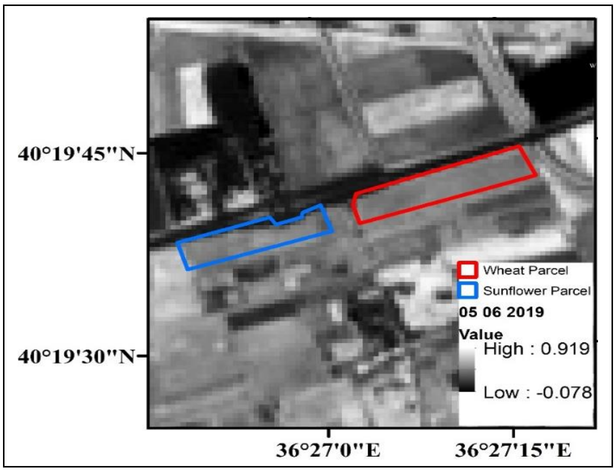

Figure 4. The map has similar index values of wheat and sunflower plants (Table 3). It is produced according to NDVI.
Şekil 4. *Ayçiçeği ve buğday bitkilerinin benzer indeks değerlerine ait olduğu harita (Çizelge 3). NDVI'a göre üretilmiştir.*

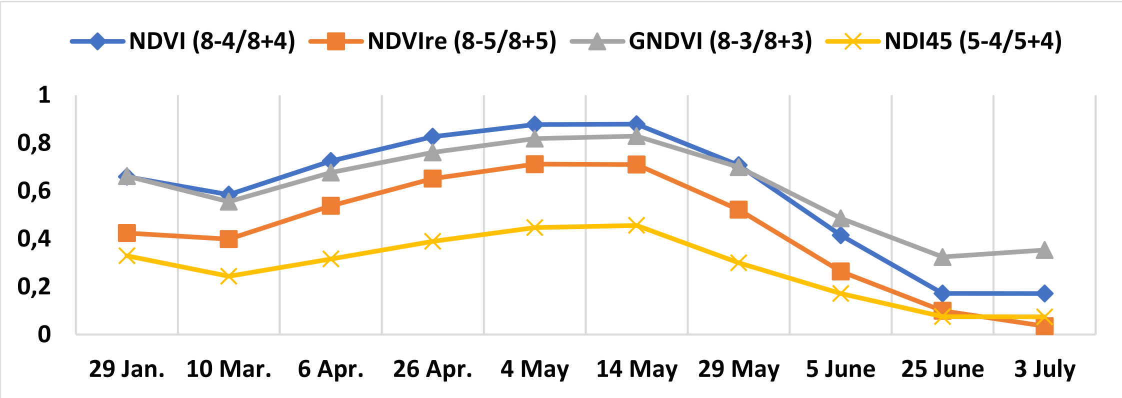

Figure 5. Wheat VIs values graph
Şekil 5. *Buğday bitki indeksleri değerleri grafiği*

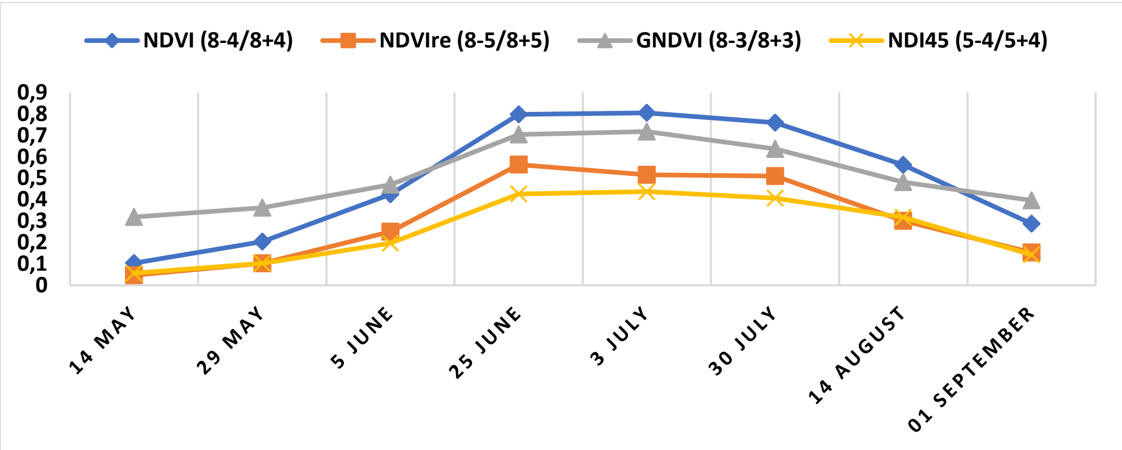

Figure 6. Sunflower VIs values graph
Şekil 6. *Ayçiçeği bitki indeksleri değerleri grafiği*

On June 5, the index values between the two plants give close values during their growing stages. The results also indicated that VIs gave similar results in both plants. NDVI provided highest values while NDI45 presented the lowest values among the VIs.

4. Conclusion

Since plant monitoring is more advantageous in terms of cost and time, the use of remote sensing technique has increased in the last two decades. Plant growth, cultivation and harvest time may differ according to climate types and micro climates. For this purpose, the index values of plants with Sentinel-2 satellites were monitored according to the stages in the BBCH-Scale.

It is useful to collect detailed information from the land in the classification studies and other studies to be held on this date. The data collected in the study lasted from January to October. The temporal resolution of Sentinel-2 satellites for 5 days made it possible to follow and discrimiante the plants which may overlap in some seasons. In the future studies, it is aimed to determine the dynamics of the region precisely by collecting data from more agricultural land in the region.

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