Tarım Bilimleri Dergisi
Tar. Bil. Der.
Dergi web sayfası:
www.agri.ankara.edu.tr/dergi

Journal of Agricultural Sciences
Journal homepage:
www.agri.ankara.edu.tr/journal

TARIM BİLİMLERİ DERGİSİ — JOURNAL OF AGRICULTURAL SCIENCES 24 (2018) 510-516

Index-based Assessment of Agricultural Drought using Remote Sensing in the Semi-arid Region of Western Turkey

Tugba YILDIRIM[a], Serafettin ASIK[a]

[a]*Ege University, Department of Farm Structures and Irrigation, 35100, Izmir, TURKEY*

ARTICLE INFO
Research Article DOI: 10.15832/ankutbd.337136
Corresponding Author: Tugba YILDIRIM, E-mail: tugbaayildirim@hotmail.com, Tel: +90 (555) 566 46 45
Received: 08 September 2017, Received in Revised Form: 04 December 2017, Accepted: 18 December 2017

ABSTRACT

The purpose of the study was to analyze agricultural drought in citrus areas of Seferihisar Kavakdere Plain by calculating NDVI and SAVI values and the surface temperature. The results showed that NDVI and SAVI have negative correlations with surface temperature during irrigation seasons, where significantly increased temperature and decreased rainfall reduced moisture availability for plants. The correlation coefficients between NDVI and surface temperature are -0.893 for 2013 and -0.600 for 2014. The correlation coefficients between SAVI and surface temperature are -0.857 for 2013 and -0.783 for 2014. The combination of NDVI, SAVI and surface temperature provides very useful information for agricultural drought monitoring and an early warning system.

Keywords: Remote sensing; Surface temperature; Vegetation index

1. Introduction

Drought is a complex natural hazard that can cause devastating losses across large regions (Moorhead et al 2015). Agricultural drought is the decrease in the productivity of crops because of irregularities in rainfall, increase in the temperature rate, etc. which cause a decline in the soil moisture (Sruthi & Aslam 2015). The monitoring agricultural drought is imperative for countries whose economic viability is strongly tied to agriculture (Lessel et al 2016). The agriculture sector is much affected by drought as it is highly dependent on the weather, climate, soil moisture, etc. Drought has been a recurrent phenomenon in Turkey for the last several decades. The drought occurrences have been generally closely related to lack of precipitation combined with high temperatures (Mengu et al 2011).

Drought is a severe problem, which influences different aspects of human life. It can cause the degradation of environment and many economic problems, especially in the agriculture sector (Goddard et al 2003; Ebrahimi et al 2010).

Rainfall, soil moisture, increasing temperature and changes in vegetation cover are the primary parameters affecting drought (Ebrahimi et al 2010).

Satellite derived vegetation indices are optical measures of canopy ‘greenness,’ useful in the assessment of active photosynthesizing and transpiring foliage (Glenn et al 2007). Different vegetation indices are available today, but none of the major indices is considered inherently outstanding to the rest in all circumstances, and some indices are better suited than others for certain uses. NDVI and SAVI are widely used for vegetation studies at a regional as well as a global level because they are simple to calculate (Sruthi & Aslam 2015).

NDVI and SAVI are calculated from the visible and near-infrared light reflected by vegetation. Healthy vegetation absorbs most of the visible light that hits it, and strongly reflects near-infrared light. Unhealthy or sparse vegetation results more visible light and less near-infrared light (NASA 2017).

NDVI and SAVI are vegetation indices that give information on the development status of plants and they can be determined by remote sensing. These indices are being used to estimate vegetation photosynthesis activity and monitor drought (Koksal 2008; Escribano-Rodríguez et al 2012; Camoglu et al 2013). Values of NDVI are between -1 and +1. While the NDVI of green areas is between 0 and 1, that of water and cloudy areas are less than 0. Vegetated surfaces are described by high NDVI values while soils typically result in low but positive NDVI that can vary somewhat with soil type, wetness, and brightness (NDVI~0.05 to 0.24) (Bausch 1993; Glenn et al 2007).

NDVI is used for description of continental land cover, vegetation classification, and vegetation phenology (Tarpley et al 1984; Tucker et al 1985; Dutta et al 2013), as well as for monitoring agricultural drought. SAVI is another vegetation index which considers soil background reflectance. In addition to NDVI and SAVI, climate variables (precipitation, temperature) are used in agricultural drought assessment (Bunting et al 2017).

This study focuses on the agricultural drought of the Seferihisar Kavakdere Plain through the analysis of three biophysical parameters, namely NDVI, SAVI and surface temperature. With this study, the drought tendency and the period of drought will be determined by examining the change of NDVI/SAVI values with respect to years and the influence of temperature and precipitation. Thus, by determining the periods when there is a trend of drought, effective use of water resources and proper planning of irrigation (how much and when to irrigation) may be considered.

2. Material and Methods

2.1. Material

The study area is located at Seferihisar in Izmir which is on Kavakdere plain in the west of Turkey in 2013 and 2014. Seferihisar Kavakdere Plain is located at latitude 38º 9' 28.8036'' N and longitude 26º 53' 33.7200'' E. The area has a semi-arid climate. The average rainfall is 613.1 mm based on rainfall data for 1981-2010. The major land use is citrus (pink), grape (blue) and olive trees (green) (Figure. 1). The total agricultural area is around 500 hectares. The greatest part of this is planted with 3045 da of citrus (about 61%) and grapes (about 33%), while the rest is dominated by olive-trees.

An aerial photograph was acquired to determine crop pattern. The polygons of citrus areas were determined by screen digitizing method (Bolca et al 2007) by using Microstation-Bentley software (Microstation 1995). The geo-rectification of all geographic data was performed using the UTM projection system, zone 35 European Datum 1950 (Figure 2).

2.2. NDVI and SAVI indices

The data needed for NDVI and SAVI were obtained by using Landsat satellite images (Moorhead et al 2015).

The NDVI is the ratio of the differences in reflectivities for the near-infrared band (NIR) and the red band (RED) to their sum (Waters et al 2002). The NDVI is a sensitive indicator of the amount and condition of green vegetation. Values for NDVI range between -1 and +1. NDVI was computed using Equation (1);

$$\mathrm{NDVI} = (NIR\text{-}RED) / (NIR+RED) \quad (1)$$

The SAVI is an index that attempts to "subtract" the effects of background soil from NDVI so that

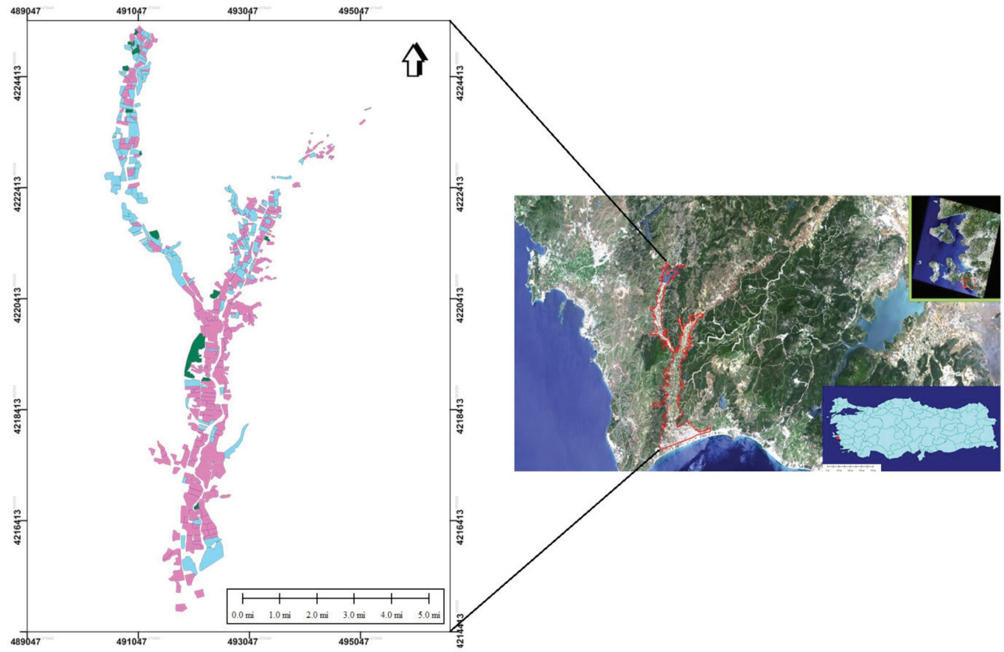


Figure 1- Seferihisar Kavakdere Plain (Pink:Citrus, Blue:Grape, Green:Olive)

Figure 2- Citrus trees in the study area

impacts of soil wetness are reduced in the index. It was computed using Equation (2);

$$SAVI = (1+L)\,(NIR-RED) / (L+NIR+RED) \quad (2)$$

L is soil brightness correction factor. If L is zero, SAVI becomes equal to NDVI (Waters et al 2002). Using a constant soil adjustment factor (L), the SAVI models the first order of soil-vegetation interactions, and significantly reduces soil background effects across a wide range of vegetation conditions (Huete 1988; Qi et al 1993; Qi et al 1994).

The NDVI and SAVI values of Kavakdere Plain were determined from May to October for citrus growing seasons.

2.3. Surface temperature

The surface temperature of the study area were calculated using thermal bands of Landsat. Surface temperature was calculated using Equation (3) (Waters et al 2002);

$$T_s = \frac{K_2}{\ln\left(\frac{\varepsilon_{NB} K_1}{R_C} + 1\right)} \quad (3)$$

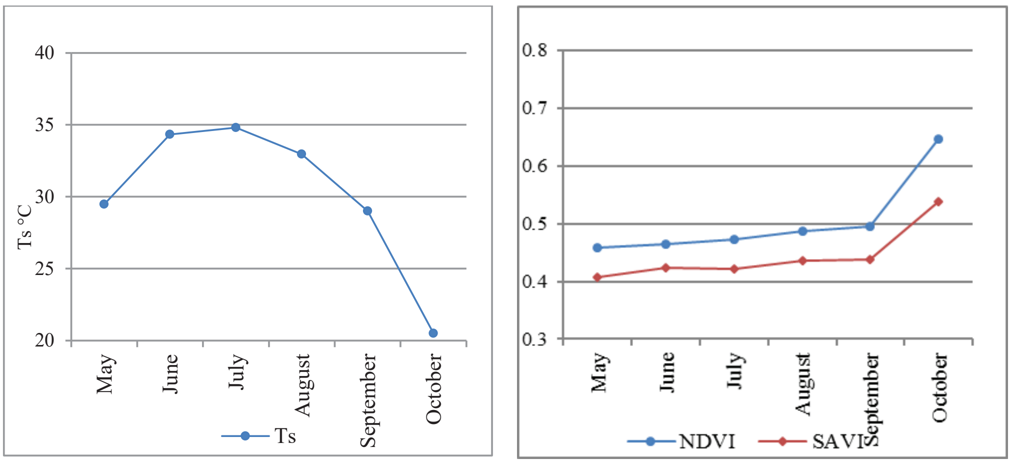
Where; T_s, surface temperature (K); ε_{NB}, narrow band emissivity; R_c, the corrected thermal radiance; K_1, K_2, constants for Landsat images.

Correlation coefficients were calculated to determine association between NDVI/SAVI and surface temperature.

3. Results and Discussion

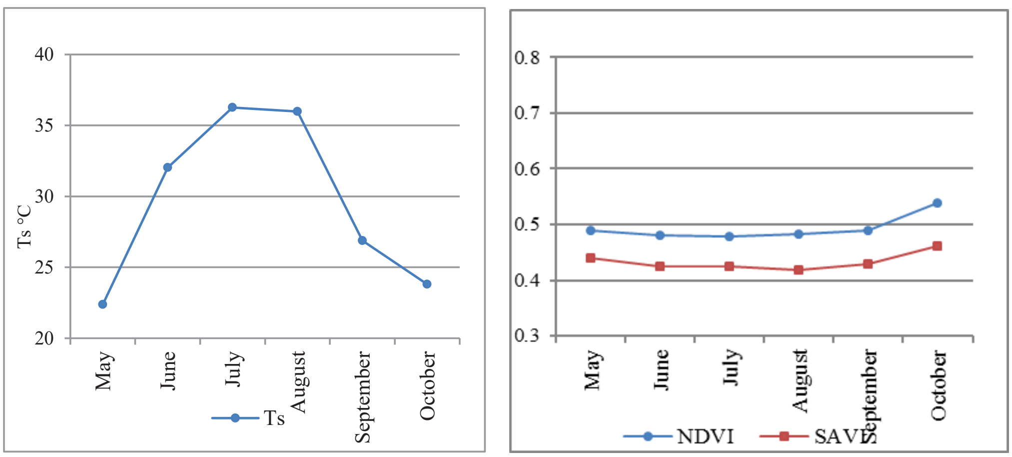
Figures 3(a) and (b), and Figures 4(a) and (b) represent the line graph obtained for surface temperature and NDVI and SAVI of every month of the growing season for 2013 and 2014.

It can be clearly seen that surface temperature and NDVI/SAVI are inversely proportional to each other. When the temperature is greater, NDVI/SAVI values are less, and this indicates a decrease in the vegetation density (Tucker 1979; Santos & Negri 1996). Reflection values of NIR started to display an increase in June when citrus trees were growing, after that were followed by a decrease in September.



(a) (b)

Figure 3- (a), Surface temperature; (b), NDVI and SAVI for Citrus (2013)



(a) (b)

Figure 4- (a), Surface temperature; (b) NDVI and SAVI for Citrus (2014)

In the both years, NDVI/SAVI values were lower during the hotter months of the growing season (June, July and August) whereas they were higher in September and October. The decrease in soil moisture due to irregular or no rainfall together with increased temperature caused the agricultural drought to be severe. By calculating the correlation coefficients between surface temperature and NDVI/SAVI, it can be clearly seen that they show a correlation. The correlation coefficients between NDVI and surface temperature were -0.893 for 2013 and -0.600 for 2014, the same coefficients for SAVI and surface temperature were -0.857 for 2013 and -0.783 for 2014. Negative correlation between NDVI/SAVI and surface temperature was found on the Kavakdere Plain, where significantly increased temperature and decreased rainfall reduced moisture availability for plants. Sruthi & Aslam (2015) conducted an analysis of the correlation between surface temperature and NDVI for 2002 and 2012 in the Raichur region of India and obtained results of -0.635 and -0.586. Ozelkan et al (2011) found a negative correlation between NDVI and surface temperature. Kornieli et al (2009) indicated that when water was the limiting factor for vegetation growth, NDVI-Surface temperature correlation was negative. These values agreed with the results of the present study.

SAVI values were lower than the NDVI values, because SAVI takes into account not only vegetation but also the effects of the soil reflection. Qi et al (1994) stated that the SAVI index measured the vegetation index more sensitively because, differently from other vegetation indices, it included a soil correction factor which took account of reflections from plants and soil.

NDVI and SAVI values for October were higher in 2013 than in 2014, because there were less rainfall and higher temperature in October 2014 than in October 2013 (Table 1). In a study by Zougrana et al (2015) in the south-west of Burkina Faso, a positive correlation was found between NDVI and rainfall. It was found by Bunting et al (2017) that SAVI had a strong correlation with precipitation and negative relationship with temperature in southwestern US. Kornieli et al (2009) indicated that the strongest negative correlations were between NDVI and surface temperature with low precipitation (moisture-limited growth) areas in the western US.

Precipitation is the major responsible factor of vegetation growth that is indicated by NDVI (Dutta et al 2013) and SAVI.

Temperature is an important factor that may affect NDVI (Ji & Peters 2005; Dutta et al 2013) and SAVI variation. It was found that during drought periods, vegetation indices values were relatively low, while surface temperature were relatively high (Kogan 2000; Kornieli et al 2009). Drought resulting from decreased rainfall and increasing temperatures lead a reduction in NDVI and SAVI in areas of vegetation. High summer temperatures are one of the most important factors causing drought. NDVI and SAVI are the most common vegetation indices which are obtained from satellite and used to monitor the areas affected by drought (Escribano-Rodríguez et al 2012).

Table 1- Climate data of study area

		May	*June*	*July*	*August*	*September*	*October*
2013	Rainfall (mm)	50.4	0.0	0.0	1.4	8.4	107.2
	Max.Temperature (°C)	33.0	36.1	37.0	38.0	32.6	28.8
	Min.Temperature (°C)	11.7	13.4	18.3	18.9	12.5	6.4
2014	Rainfall (mm)	4.4	21.8	0.0	0.0	4.0	39.8
	Max.Temperature (°C)	29.6	34.6	35.0	38.1	32.3	29.1
	Min.Temperature (°C)	11.8	12.6	17.6	17.8	12.3	9.4

4. Conclusions

In conclusion, the spatial and temporal drought status of the Kavakdere Plain was evaluated over two years using vegetation indices and temperature data obtained from Landsat images. Irregular or no rainfall and high temperatures in the area caused a fall in NDVI and SAVI values in the citrus growing season. In particular, these indices were lower in the second year of the study, associated with an increase in temperatures and a decrease in rainfall. This indicates an increasing trend to drought in the area. The significant relationship between NDVI/SAVI, temperature, and rainfall in the agricultural areas emphasizes that drought inhibits density of green vegetation. This shows that the lowest NDVI/SAVI values occur in the extreme dry conditions. Therefore, early drought detection is important for planning of the water resources and the irrigation management in Kavakdere Basin, whose economy strongly depends on agriculture.

References

Bausch W (1993). Soil background effects on reflectance-based crop coefficients for corn. *Remote Sensing of Environment* 46: 213-222

Bolca M, Turkyilmaz B, Kurucu Y, Altinbas U, Esetlili M T & Gulgun B (2007). Determination of impact of urbanization on agricultural land and wetland land use in Balcovas' delta by remote sensing and GIS technique. *Environmental Monitoring and Assessment* 131(1-3): 409-419

Bunting E L, Munson S M & Villarreal M L (2017). Climate legacy and lag effects on dryland communities in the southwestern US. *Ecological Indicators* 74(2017): 216-229

Camoglu G, Kaya U, Akkuzu E, Genc L, Gurbuz M, Pamuk Mengu G & Kızıl U (2013). Prediction of leaf water status using spectral indices at young olive trees. *Fresenius Environmental Bulletin* 22(9a): 2713-2720

Dutta D, Kundu A & Patel N R (2013). Predicting agricultural drought in eastern Rajasthan of India using NDVI and standardized precipitation index. *Geocarto International* 28(3): 192-209

Ebrahimi M, Matkan A A & Darvishzadeh R (2010). Remote Sensıng for Drought Assessment In Arıd Regıons (A Case Study of Central Part of Iran, "Shırkooh-Yazd"). *ISPRS TC VII Symposium-100 Years ISPRS*, Vienna, Austria, July 5-7, 2010, IAPRS, Vol. XXXVIII, Part 7B, pp. 199-203

Escribano-Rodríguez J A, Tarquis A M & Hernandez Díaz-Ambrona C G (2012). Pasture Drought Insurance Based on NDVI and SAVI, Geophysical Research Abstracts Vol. 14, EGU2012-13945

Glenn E P, Huete A R, Nagler P L, Hirschboeck K K & Brown P (2007). Integrating Remote Sensing and Ground Methods to Estimate Evapotranspiration. *Critical Reviews in Plant Sciences* 26: 139-168

Goddard S, Harms S, Reichenbach S, Tadesse T & Waltman W J (2003). Geospatial Decision Support For Drought Risk Management. *Communication of the ACM* 46(1): 35-37

Huete A R (1988). A soil-adjusted vegetation index (SAVI), *Remote Sensing of Environment* 25: 295-309

Ji L & Peters A (2005). Lag and seasonality considerations in evaluating AVHRR NDVI response to precipitation. *Photogrammetric Engineering and Remote Sensing* 71(9): 1053-1061

Kogan F N (2000). Satellite-observed sensitivity of world land ecosystems to El Nino/La Nina. *Remote Sensing of Environment* 74: 445-462

Koksal E S (2008). Irrigation water management with water deficit index calculated based on oblique viewed surface temperature. *Irrigation Science* 27(1): 41-56

Kornieli A, Agam N, Pinker R T, Anderson M, Imhoff M L, Gutman G G, Panou N & Goldberg A (2009). Use of NDVI and land surface temperature for drought assessment: Merits and Limitations. *Journal of Climate* DOI: 10.1175/2009JCLI

Lessel J, Sweeney A & Ceccato P (2016). An agricultural drought severity index using quasi-climatological anomalies of remotely sensed data. *International Journal of Remote Sensing* 37(4): 913-925

Mengu G P, Akkuzu E, Anac S & Sensoy S (2011). Impact of climate change on irrigated agriculture. *Fresenius Environmental Bulletin* 20(3): 823-830

Microstation (1995). Microstation 95 version Intergraphs aster file formats (Bentley System, Summit Software Company). Huntsville, AL: Intergraph Corporation

Moorhead J E, Gowda P H, Singh V P, Porter D O, Marek T H, Howell T A & Stewart B A (2015). Identifying and evaluating a suitable index for agricultural drought monitoring in the Texas High Plains.

Journal of American Water Resources Association 51(3): 807-820

NASA (2017). (Accessed 2017 January 20) .http://earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php

Ozelkan E, Papila I, Avcı D Z U & Karaman M (2011). Drought determination by using land surface temperature and normalized difference vegetation index. International Society for Photogrammetry and Remote Sensing *34th International Symposium on Remote Sensing of Enviroment,* Sydney, Australia, 10-15 April 2011, pp. 1-4

Santos P & Negri A J (1996). A Comparison of the normalized difference vegetation index and rainfall for the Amazon and Northeastern Brazil. *Journal of Applied Meteorology* 36: 958-965

Sruthi S & Aslam M A (2015). Agricultural drought analysis using the NDVI and land surface temperature data; a case study of Raichur District. *Aquatic Procedia* 4(2015): 1258-1264

Qi J, Huete A R, Moran M S, Chehbouni A & Jackson R D (1993). Interpretation of vegetation indices derived from multi-temporal SPOT images. *Remote Sensing of Environment* 44: 89-101

Qi J, Chehbouni A, Huete A R, Kerr Y H & Sorooshian S (1994). A Modified soil adjusted vegetation index. *Remote Sensing of Environment* 48: 119-126

Tarpley J P, Schneider S R & Money R (1984). Global vegetation indices from NOAA-7 meteorological satellite. *Journal of Climate and Applied Meteorology* 23: 491-494

Tucker C J (1979). Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment* 8: 127-150

Tucker C J, Townshend J R G & Goff T E (1985). African land-cover classification using satellite data. *Science* 227: 369-375

Waters R, Richard A, Tasumi M, Trezza R & Bastiaanssen W (2002). Surface Energy Balance Algorithms for Land, Advanced Training and Users Manual. A NASA EOSDIS/Synergy grant from the Raytheon Company through The Idaho Department of Water Resources

Zougrana B J B, Conrad C, Amekudzi L K, Thiel M & Dapola Da E (2015). Land Use/Cover Response to Rainfall Variability: A Comparing Analysis between NDVI and EVI in the Southwest of Burkina Faso. Climate 2015, 3: 63-77; doi:10.3390/cli3010063