Study on spatial-temporal variations of Meteorological-Agricultural droughts in Turkey

Ali Ünal Şorman [1], Ali Danandeh Mehr [2], Sinan Jasim Hadi [1]

[1] Department of Civil Engineering, Near East University, Nicosia, Mersin TRNC - aliunal.sorman@neu.edu.tr, sinan.jasim@yahoo.com
[2] Civil Engineering Department, Engineering Faculty, Antalya Bilim University, Antalya, Turkey - ali.danandeh@antalya.edu.tr

KEY WORDS: Drought Analysis, Standardized Precipitation Evapotranspiration Index, Vegetation condition index, Turkey, NDVI, CORINE

ABSTRACT:

In this study, the meteorological drought represented by Standardized Precipitation Evapotranspiration Index (SPEI) and agriculture drought represented by Vegetation Condition Index (VCI) are analysed in seven regions over Turkey. VCI calculated using the Normalized Difference Vegetation Index (NDVI) data obtained from NOAA AVHRR, SPEI obtained from the SPEI global database with the version (SPEI base v2.5), and Land use/cover obtained from CORINE datasets. The study covers the period from January 1982 to December 2015 due to the availability of NDVI data. The correlation between monthly and seasonal VCI and SPEI (lag months 1, 3, 6, 9, and 12) was investigated in a regional and provincial scale. Monthly correlation found to be the highest in the Central Anatolia, Aegean, Marmara and Mediterranean regions respectively, while other regions have lower and non-homogenous values. One lag time of the VCI with respect to SPEI 12 improves the correlation. The regional correlation showed that, the highest correlation between two parameters is obtained for all the regions with SPEI 12 during summer, then followed by Autumn, and Spring months, the maximum values are recorded for the Central Anatolia (0.656) and Mediterranean (0.625) in Summer, and Aegean (0.643) in Autumn respectively; rather lower correlation values did occur in Marmara (0.515) in Autumn, Eastern Anatolia (0.501), SE Anatolia (0.375) and Black Sea (0.297) regions in Summer. The provincial investigation between seasonal VCI and SPEI indicated that the presence of a positive correlation in general in most of the provinces in all seasons with several exceptions in the Eastern Anatolia, South eastern Anatolia, Black sea, and Marmara. The land cover types with high correlation coefficients are noticed to be covered by forest, agricultural lands, non-irrigable lands and mostly covered by fruits (grape, olive etc.) using CORINE land cover map.

1. INTRODUCTION

Drought is a stealthy climate disaster that heavily affects all the aspect of the natural environment and human beings (Mishra and Singh 2010). Recently, the importance of the drought has been increased due to the increase in water demand and the threatening of the climate change (Mishra and Singh 2010; Mehr, Kahya, and Özger 2014). Droughts affect surface and groundwater resources leading to several problems such as: reduction in water supply, deterioration in the water quality, reduction in power generation, decrease in productivity, failure of crop, distribution of riparian habitats, and eventually suspension of recreation activities including the host of economic and social activities (Mishra and Singh 2010; Riebsame, Changnon Jr, and Karl 1991). Drought can be defined as: deficit in the precipitation, deviation from the normal hydrologic condition, the percentage of the years in which crops fail due to the scarcity of moisture (Dabanlı, Mishra, and Şen 2017). All the climate zones are prone to droughts regardless if they are low or high rainfall areas. Droughts mostly depend on the decrease in the amount of the precipitation received through a long period that could be a season or a year.

Several drought indices have been developed and the most common used index is Standardized Precipitation Index (SPI) due to its simplicity in terms of the required data as only the precipitation is used. In the last 150 years, there has been an increase in the temperature about (0.5-2^0) in addition to the faster increase in 21st century obtained by the climate models due to the climate change. Therefore, the use of an index contains the temperature in their formulation is better. Such an index is Palmer drought severity index (PDSI) but PDSI does not have the characteristic of multi-scalar that important for both differentiating between different types of droughts and evaluating drought associated with different hydrological systems. Therefore, a new index namely standardized precipitation evapotranspiration index (SPEI) was developed by (Vicente-Serrano, Beguería, and López-Moreno 2010) and revisited by (Beguería et al. 2014).

Several studies conducted for investigating the variability and vulnerability of the droughts over Turkey (Dogan, Berktay, and Singh 2012; Dabanlı, Mishra, and Şen 2017; SirdaŞ and Sen 2003; Sönmez et al. 2005). Another important aspect of the drought analysis is the linkage between the categories of the droughts such as Meteorological and Agricultural droughts. Even though the precipitation, soil moisture, and vegetation growth link is broadly documented (Farrar, Nicholson, and Lare 1994; Gu et al. 2008; Wang et al. 2007; Törnros and Menzel 2014), their link in the aspect of drought analysis requires more investigation. An issue considering the Precipitation, soil moisture, and vegetation growth is that they are measured on the earth by pointy manner as they measured using station dispersed around a specific region. These limits the spatial extent of the data and, hence restricts the spatial information discovery (Törnros and Menzel 2014; Dutta et al. 2015). Therefore, remote sensing data are needed for investigating the spatial variability. In addition, low cost, reliability, repetitions and synoptic view of remote sensing data are advantages made these data popularly accepted (Dutta et al. 2015). In the aspect of this study, an example of remote sensing data Normalized Difference Vegetation Index (NDVI) and Vegetation Condition Index (VCI) have been widely accepted as indices of the agriculture drought (Dutta et al. 2015; Nicholson and Farrar 1994; Kogan 1995; Ji and Peters 2003; Anyamba, Tucker, and Eastman 2001). In a regional scale, VCI provides more accurate results than NDVI (Bajgiran et al. 2008) and as a result the VCI obtained from NOAA-AVHRR based NDVI has been broadly acknowledged in drought analysis due to its appropriateness in evaluating several parameters such as intensity, duration, severity, and emergence of drought (Dutta et al. 2015; Quiring and Ganesh 2010).

https://doi.org/10.5194/isprs-archives-XLII-3-W4-483-2018

The objective of this study is to investigate the correlation between the monthly and seasonal meteorological drought and agricultural drought over Turkey in a provincial and regional scale as well as the use of land use map as an attributing layer. The metrological drought represented by SPEI derived from CruTS v3.24.01 data and the agricultural drought represented by the VCI obtained from NOAA-AVHRR based NDVI. The detail description of the data used can be seen in the following sections.

2. STUDY AREA

The location of Turkey is in the northern subtropical climate zone of the Earth lies between 36-42°N and 26-45°E, and situated in the western part of Asia and eastern part of Europe. There are seven regions in Turkey divided according to the difference in altitude (Dabanlı, Mishra, and Şen 2017) (See Figure 1). The climate of Turkey varies in different regions because of the presence of several mountains extended in parallel with the coasts, although large areas located in the Mediterranean geographic area (Sensoy et al. 2008).

3. METHODOLOGY

The main objective of this study to investigate the correlation between the meteorological and agricultural drought over Turkey in monthly and seasonal time scale. The meteorological drought is represented by SPEI which is obtained from the global SPEIbase v2.5 calculated using CruTS v3.24.01. The agricultural drought represented by VCI which is calculated from the NOAA-AVHRR based NDVI. The SPEI data is monthly data covers the period January-1901 to December-2015 while the NDVI data is biweekly covers the period July-1981 until now. First of all, the NDVI data were composited to get the monthly data using Maximum Value Composite (MVC) and to have full annual data the months of 1981 was removed. In order to have consistency in the data SPEI data were subset to the same period January-1982 to December-2015. The pixel wise VCI was then calculated for every month using eq. (6). After having the SPEI (1, 3, 6, 9, 12) and VCI for the same period, the spatial subset for only Turkey was obtained. In order to investigate the provincial correlation each province was represented by the average of the pixels included in the province boundary for every month and season for monthly and seasonal correlation respectively. For the regional scale, the same procedure used by taking the average of all the provinces located in each region. The trend of the regional monthly VCI and SPEI12 was investigated using three tests: Mann-Kendall for identifying the significance of the trend, Sen Slope Estimator for obtaining the magnitude of the trend, and Pettit test for identifying the most probable change time point. As mentioned earlier, the monthly and seasonal correlation was conducted in this study and the seasons are as follow: DJF; December, January, and February, MAM; March, April, and May, JJA; June, July, and August, SON; September, October, and November, and these seasons names are Winter, Spring, Summer, and Autumn respectively. The land cover map obtained from European Environment Agency (EEA) namely Corine Land Cover (CLC) for the year 2012 for the comparison of the high or low correlated areas with their land cover (EEA 2000). The CL map classified for 44 classes which makes the comparison difficult, therefore the map was reclassified into 9 classes by aggregating the categories have common higher code.

3.1 Standardized Precipitation Evapotranspiration Index (SPEI):

SPEI is one of the simplest indices in terms of the calculations. As in SPI the monthly or weekly precipitation is used, in SPEI, monthly or weekly climate water balance which is the difference between the precipitation and potential evapotranspiration used. In this study, the SPEIbase version 2.5 (available at http://spei.csic.es/) are used. In this data set, the FAO-56 Penman–Monteith equation (Allen et al. 1998) used for the calculation of the potential evapotranspiration instead of Thornthwaite equation (Thornthwaite 1948) which is used in the earlier version of SPEIbase v1.0 (Beguería et al. 2014). Then, the climate water balance calculated by:

$$D_i = P_i - PET_i \quad (1)$$

Where P_i is the precipitation of a specific month, PET_i the potential evapotranspiration for the same month and this equation gives the deficit D_i of the water of that month. The calculated D_i are the combined for the desired time scale for further consideration. According to (BegueríA, Vicente-Serrano, and Angulo-Martínez 2010; Vicente-Serrano, Beguería, and López-

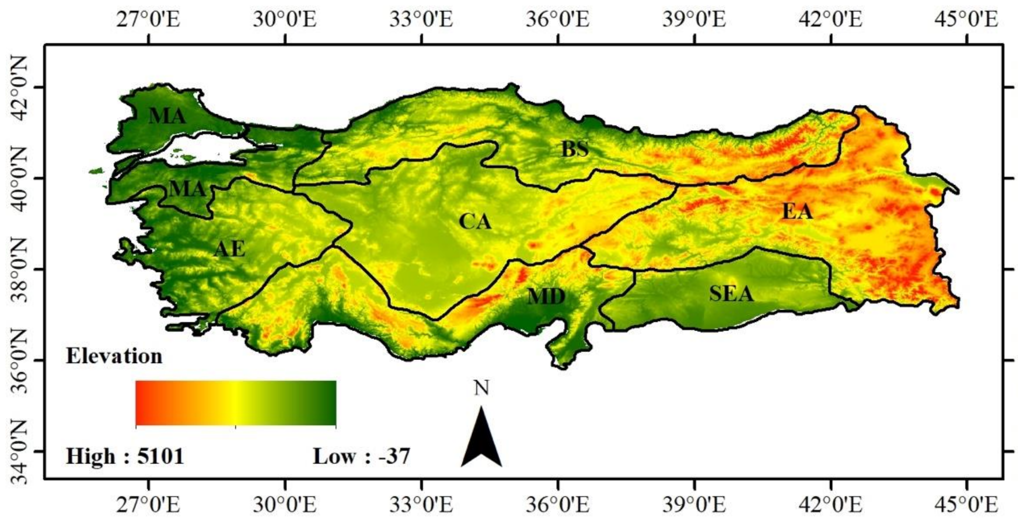

Figure 1. Regions of Turkey with the elevation. Regions; BS: Black Sea, EA: Eastern Anatolia, SEA: South Eastern Anatolia, CA: Central Anatolia, MD: Mediterranean, AE: Aegean, MA: Marmara.

Moreno 2010; Beguería et al. 2014), the best fitting distribution to the data is Log-Logistic.
The three parameters Log-logistic density function is expressed as:

$$f(x) = \frac{\beta}{\alpha}\left(\frac{x-\gamma}{\alpha}\right)^{\beta-1}\left(1+\left(\frac{x-\gamma}{\alpha}\right)^{\beta}\right)^{-2} \quad (2)$$

Where α, β, and γ are the scale, shape and centre parameters, respectively, and that is for γ<D< ∞. In order to obtain the parameters, (Vicente-Serrano, Beguería, and López-Moreno 2010) used probability weighted moments (PWMs) based on the plotting position approach. (Beguería et al. 2014) found some problems in using this approach, and hence suggested the use of unbiased PWMs in which the Log-logistic distribution of D is then given as:

$$F(x) = \left[1+\left(\frac{\alpha}{x-\gamma}\right)^{\beta}\right]^{-1} \quad (3)$$

Using $F(x)$ the SPEI can be calculated as the standardized values and that can be done using:

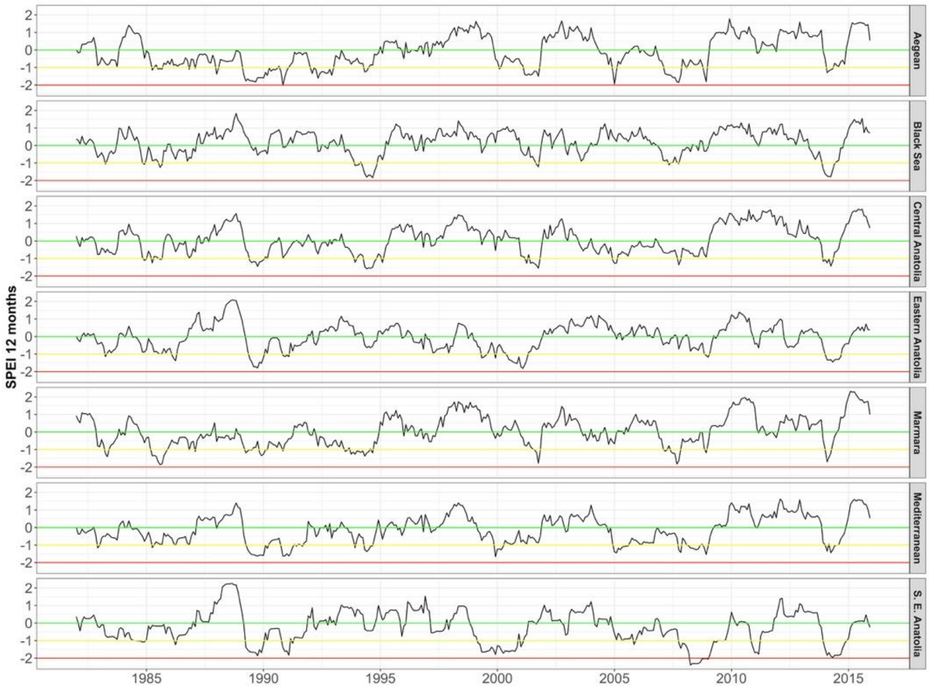

Figure 2. The time series of the regional SPEI 12.

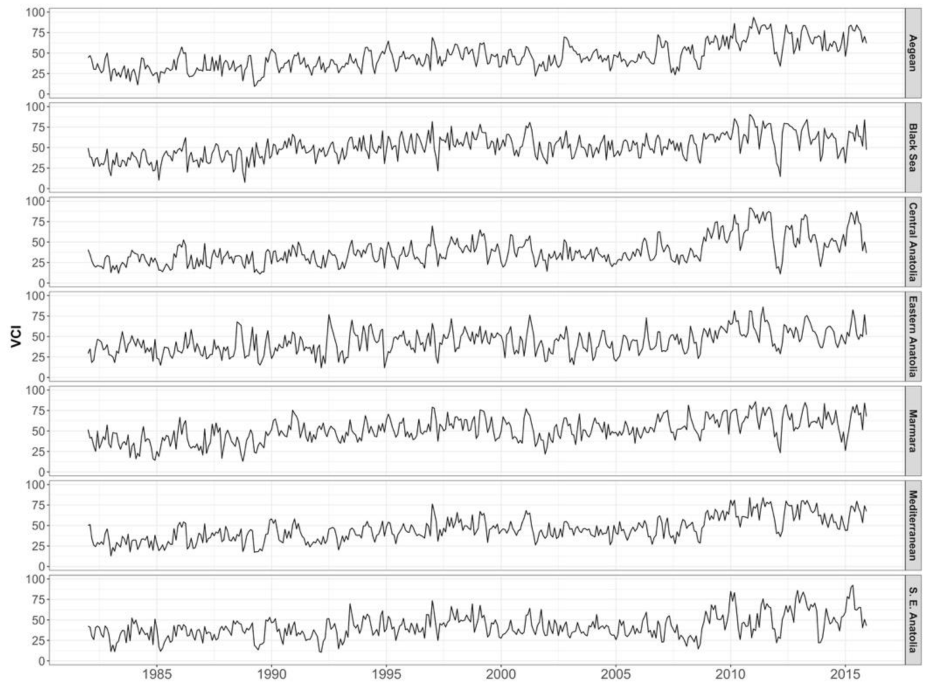

Figure 3. The time series of the regional VCI.

https://doi.org/10.5194/isprs-archives-XLII-3-W4-483-2018 | © Authors 2018. CC BY 4.0 License.

$$SPEI = W - \frac{C_0 + C_1 W + C_2 W^2}{1 + d_1 W + d_2 W^2 + d_3 W^3} \quad (4)$$

Where

$$W = -2\ln(P) \quad (5)$$

For $P \leq 0.5$, $P = 1 - F(x)$ is the probability of exceedance of a specific D value. For $P \geq 0.5$, the P value is replaced by $1 - P$ and the SPEI value is inverted. The values of the constants are as follow: C_0=2.515517, C_1=0.802853, C_2=0.010328, d_1=1.43278 8, d_2=0.189269, d_3=0.001308 (Beguería et al. 2014). In this context, the SPEI with 0 value refers to 50% of the cumulative probability of Log-logistic distribution of D.

As the global SPEI data produced using CruTS v3.23, the period January-1901 to December-2015 covered by this data. The last versions of CruTS datasets consists of 0.5^o latitude-longitude grid cells covering the global with the exception of Antarctica region. The datasets provide monthly values of ten climate variables. Six of these variables are independent: Precipitation (pre), Mean temperature (tmp), Diurnal Temperature Range (dtr), Wet-day Frequency (wet), Vapour Pressure (vap), and Cloud Cover (cld). The remain four (i.e. Maximum temperatures (tmx), Minimum temperatures (tmn), frost day frequency (frs), and potential evapotranspiration (pet)) are calculated and estimated using the independent variables. The CruTS was evaluated in global scale by (Jones and Harris 2008) and in a local scale over Turkey by (Hadi and Tombul 2017). After the obtaining SPEI and for having consistency for both SPEI and VCI, a temporal subset from January-1982 to December-2015 was obtained for several scales (1, 3, 6, 9, 12).

3.2 Vegetation Condition Index (VCI)

VCI is calculated by using Global Inventory Modeling and Mapping Studies (GIMMS) NDVI. The GIMMS NDVI are acquired by the Advanced Very High-Resolution Radiometer (AVHRR) sensor onboard a National Oceanic and Atmospheric Administration (NOAA) satellite. The last version that is used in this study 3g.v1.0 covers the period July-1981 to December-2015. These data are produced in biweekly (half month) temporal scale. In order to have monthly scales similar to SPEI, the Maximum Value Composite (MVC) approach applied in which the maximum value is chosen in order to minimize the effect of the aerosols and clouds (Tucker et al. 2005).As not all the months of the year of 1981 are available, the NDVI considered in this study starting from January-1982. After that, the following equation is used for the calculation of VCI (Kogan 1995):

$$VCI = 100 * \frac{(NDVI_i - NDVI_{min})}{(NDVI_{max} - NDVI_{min})} \quad (6)$$

$NDVI_i$ is the pixel-wise NDVI value of the month under analyzing, $NDVI_{min}$ and $NDVI_{min}$ are minimum and maximum values of months for all years in which only the month under analyzing i is considered. VCI is the standardization of NDVI and it splits the climate signal (short-term) from the ecological signal (long-term), and hence, it is better indicator than NDVI in monitoring the water stress condition (Kogan 1995). The values from 100% to 50% indicate above normal vegetation condition, between 50% and 35% indicates a drought condition, and less than 35% indicates severe drought condition (Dutta et al. 2015; Kogan 1995).

4. RESULTS ANS DISCUSSION

The main objective of this study is to investigate the monthly and seasonal variation of the correlation between the VCI and SPEI with several temporal scales (1,3,6, 9, and 12) where these two indices are indicators of Agricultural and Meteorological droughts respectively.

In terms of the temporal analysis (Figure 2 and 3), all the regions have witnessed no extreme drought (i.e. < -2.0) throughout the whole studied period except one event happened in Southeastern Anatolia in the year 2008 but it has short duration. The trend results shown in Table 1 for the SPEI and Table 2 for VCI. The SPEI12 trend results indicated that although the value of the slope is not high, there is a significant increasing trend in the SPEI in all regions except Southeastern Anatolia which has a decreasing trend and significant at a level 0.1 only and not 0.05. Aegean, Black sea, and Marmara has close change point in the trend that in 1994-1995. Central Anatolia and Mediterranean also have very close change point in 2009. It is worth mentioning that all the change points are significant indicating the abrupt change is happening. The trends of VCI are significantly increasing in all regions and the increase values are higher than the ones in the SPEI trends. The change point is within 1993 for regions: Aegean, Black sea, Eastern Anatolia, Marmara, and Southeastern Anatolia while in Central Anatolia and Mediterranean the change point is within 1996. The changes are significant in all regions.

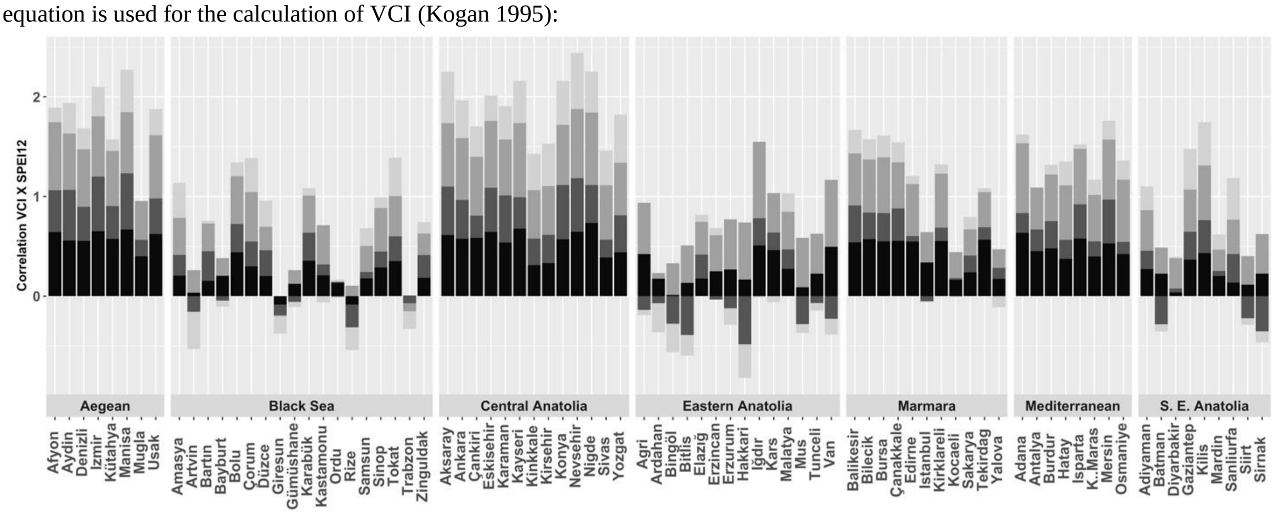

Figure 4. Provincial seasonal correlation between VCI and SPEI 12. Light to dark grey shades represents: winter, spring, summer, and autumn respectively.

Table 1. The trend analysis results of the regional SPEI12.

Region	Sen Slope	Change point (Pettit)
Aegean**	0.0030	1994-11**
Black Sea**	0.0010	1995-05**
Central Anatolia**	0.0018	2009-01**
Eastern Anatolia**	0.0006	2001-12**
Marmara**	0.0028	1994-12**
Mediterranean**	0.0020	2009-03**
S. E. Anatolia*	-0.0007	1998-11**

** Significant at 0.05, * Significant at 0.1
The ** in the regions are the significance in the trend using Mann-Kendall
The ** in the change point are the significance in the change point.

Table 2. The trend analysis results of the regional VCI.

Region	Sen Slope	Change point (Pettit)
Aegean**	0.0946	1993-12**
Black Sea**	0.0721	1993-04**
Central Anatolia**	0.0733	1996-09**
Eastern Anatolia**	0.0522	1993-05**
Marmara**	0.0719	1993-12**
Mediterranean**	0.0826	1996-09**
S. E. Anatolia**	0.0487	1993-05**

** Significant at 0.05, * Significant at 0.1
The ** in the regions are the significance in the trend using Mann-Kendall
The ** in the change point are the significance in the change point.

The correlation between the VCI and SPEI is examined for every scale and the time lags investigated are 1, 3, 6, 9, and 12. For the monthly data, the highest correlation for most of the provinces was found between the VCI and SPEI 12 and to save some space the comparison among the scales correlation are not shown here. Another important issue considered here is that correlating the SPEI with one to three leads of VCI by hypothesizing that deficit in precipitation or increase in PET need some time to be reflected on the agricultural deficit. There is no large difference among the correlation of different lags but the highest correlation can be obtained with the lag 1 VCI. The Central Anatolia and Aegean regions has the provinces with the highest correlation such as Manisa, Izmir, Nevsehir, Nigde, Aksaray, and Ankara respectively.

Seasonal correlation between VCI and SPEI (1, 3, 6, 9, and 12) was also conducted in this study and the results are listed in Table 3. According to the table, the SPEI 12 has the highest correlation values with VCI in all the regions and seasons similar to the monthly temporal scale. Considering the SPEI 12 correlations, in all the regions, the summer season has the highest correlations followed by autumn season while the least correlated season is winter followed by spring. The highest correlation belongs to Central Anatolia in all seasons followed by Aegean and Mediterranean regions. The highest correlations belong to Central Anatolia are 0.656 and 0.621 for summer and autumn seasons. In the contrast, Black seas Eastern Anatolia and Southeastern Anatolia has the lowest correlation respectively and Southeastern Anatolia has negative correlation for winter and spring seasons. Marmara Region stands in the middle with highest correlation values 0.514, and 0.515 for summer and autumn seasons.

As mentioned earlier, taking the averages of the regions may misleads the results in case of the existence of non-homogeneity. Therefore, a provincial correlation was also conducted to have smaller spatially averaged areas and use it as an indicator of homogeneity (Figure 4). Central Anatolia, Aegean, and Mediterranean regions which have the highest correlation have homogenous correlation among the provinces in each region. In other words, the correlation of all provinces in any region for any season is similar indicating that no significant heterogeneity in these three regions. Provinces in Black sea, Eastern Anatolia, and south eastern Anatolia which have the lowest correlations (Table 3) show non-homogeneous behaviour. In these regions, in the time of several provinces have a positive correlation for a specific season, other provinces have negative correlation. Marmara region does not have the high variation in the aforementioned regions and not the high homogeneity shown in Central Anatolia, Aegean, and Mediterranean regions as most of the provinces has a homogeneous behaviour with only three anomaly provinces.

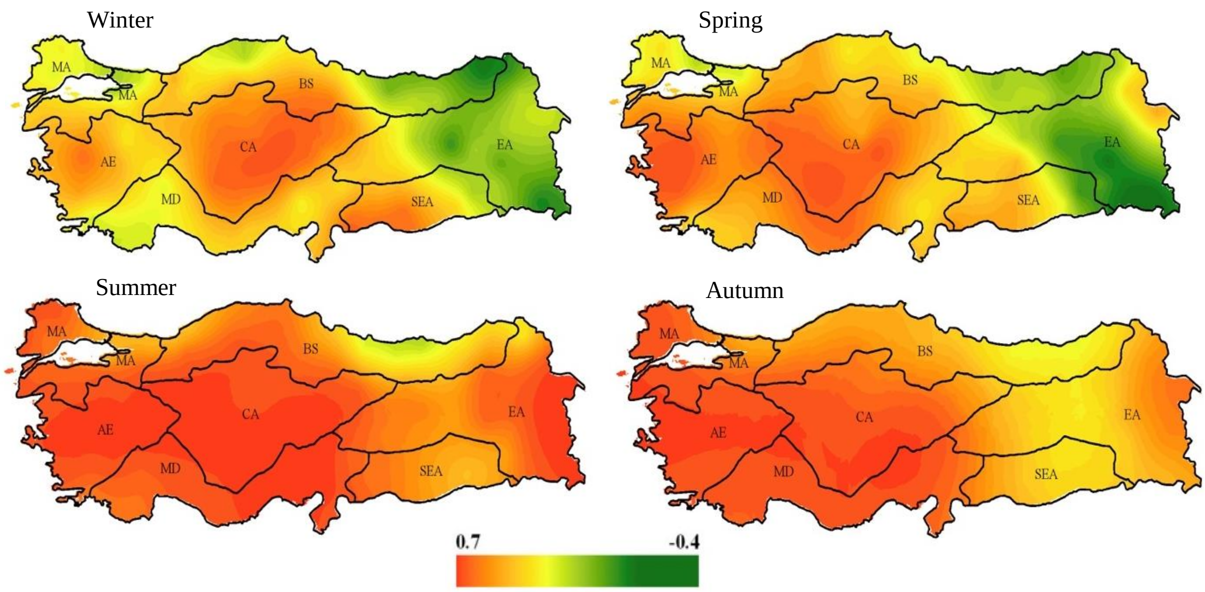

Figure 5. The spatial variation of the correlation between VCI and SPEI 12 based on the provincial scale.

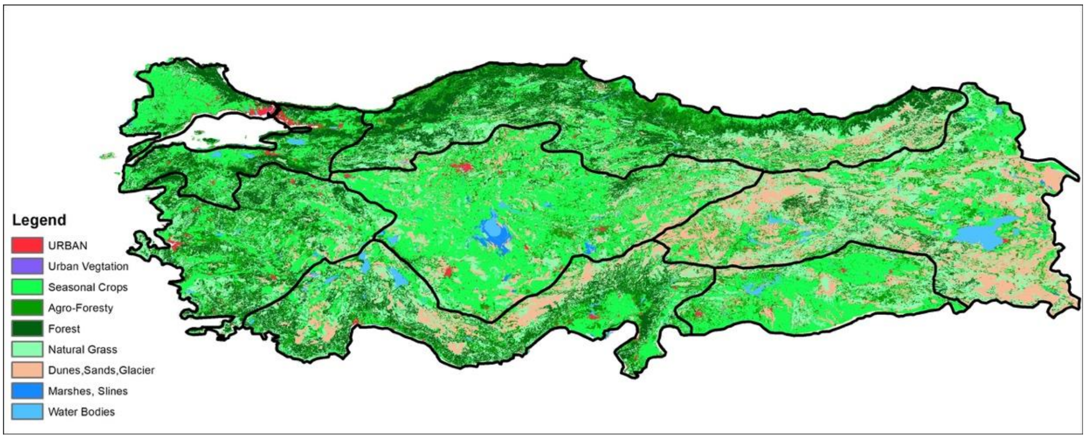

Figure 6. Land use cover map of Turkey obtained from (EEA, 2000) and reclassified.

Table 3. The seasonal correlation of the VCI and SPEI with different scales for each region.

	VCI with SPEI 01						
Seasons	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	S. E. Anatolia
WINTER	0.169	0.054	0.410	-0.057	-0.055	0.147	0.134
SPRING	0.172	0.213	0.246	0.091	0.016	0.098	0.065
SUMMER	-0.038	0.106	0.217	0.478	0.033	0.111	0.301
AUTUMN	0.410	-0.049	0.030	0.095	0.357	0.178	0.170
	VCI with SPEI 03						
Seasons	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	S. E. Anatolia
WINTER	0.205	-0.082	0.398	-0.276	-0.049	0.170	0.291
SPRING	0.303	0.215	0.373	0.030	0.189	0.163	0.010
SUMMER	0.486	0.113	0.471	0.659	0.184	0.488	0.531
AUTUMN	0.481	0.000	0.203	0.269	0.527	0.267	0.208
	VCI with SPEI 06						
Seasons	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	S. E. Anatolia
WINTER	0.333	0.025	0.526	-0.205	0.139	0.236	0.333
SPRING	0.400	0.081	0.464	-0.139	0.126	0.280	0.066
SUMMER	0.596	0.297	0.640	0.639	0.509	0.557	0.395
AUTUMN	0.586	-0.024	0.404	0.286	0.426	0.388	0.197
	VCI with SPEI 09						
Seasons	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	S. E. Anatolia
WINTER	0.286	-0.011	0.415	-0.197	0.032	0.147	0.241
SPRING	0.437	0.133	0.503	-0.102	0.229	0.317	0.092
SUMMER	0.604	0.265	0.654	0.566	0.426	0.636	0.401
AUTUMN	0.578	0.151	0.523	0.221	0.493	0.398	0.174
	VCI with SPEI 12						
Seasons	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	S. E. Anatolia
WINTER	0.288	0.119	0.486	-0.133	0.087	0.136	0.180
SPRING	0.442	0.125	0.435	-0.121	0.214	0.272	0.041
SUMMER	0.613	0.297	0.656	0.501	0.514	0.625	0.375
AUTUMN	0.643	0.221	0.621	0.222	0.515	0.578	0.232

Therefore, the spatial variation of the correlation was also conducted using the provincial scale (Figure 5).

The spatial variation of the provincial-based correlation between the VCI and SPEI 12 proves what was interpreted earlier. The winter spatial distribution (Figure 5) shows the highest correlation over Central Anatolia region with homogeneous values while in the regions of South eastern Anatolia and Black Sea the values differ greatly from part to part although some high correlations are seen in some parts. The same patterns are seen in the spring that Black sea, Eastern Anatolia, and South Eastern Anatolia has high variation in the values in their different parts unlike the very small difference in the Central Anatolia, Aegean, and Mediterranean regions. Spring correlation are slightly higher than winter values. Summer which has the highest correlation values across the whole country shows more homogeneous correlation values across the provinces within any region. Autumn has the second higher correlation values after summer and as in the other seasons Central Anatolia, Aegean, and Mediterranean have very small variation within the regions on the contrast of other regions.

According to land cover map shown in Figure 6, Central Anatolia which showed the highest correlation is dominated by Natural grass and Seasonal Crops which contains Non-irrigated arable land and Permanently irrigated land and as in summer these areas have growing seasons with the higher precipitation the correlation increased in this season. The Aegean region which has the second highest correlation after central Anatolia, also dominated by Seasonal crops, Agro-forestry which behaves similarly being in growing mode in summer.

5. CONCLUSION

The monthly and seasonal correlation between Vegetation Condition Index (VCI) and Standardized Precipitation Evapotranspiration Index (SPEI) with multi scales; 1, 3, 6, 9, and 12 investigated in this study over Turkey. Due to the availability of NDVI data used in the calculations of VCI, the period of January-1982 to December-2015 is taken into consideration. The trend analysis indicates that VCI values has a significant increasing trend which implies decrease in the agricultural drought. According to SPEI, all the regions has witnessed similar drought events for the covered period with slight differences and the severe drought has not been happened only one time in the South Eastern Anatolia but that could be due to the areal averaged SPEI values over the whole regions in which non-homogeneity could be neglected. Therefore, the detail analysis for each province is very important. The trend analysis of SPEI shows a significant increasing trend in all regions. The highest monthly correlation found between VCI and SPEI 12 and it gives better correlation with one lagged VCI. Central Anatolia, and Aegean have the highest correlation and Mediterranean and Marmara following them while other regions has the lowest correlations with non-homogeneity between the provinces in each region. The seasonal correlation also found to be highest between VCI and SPEI 12. Summer found to be the highest correlated season followed by Autumn while the Winter and Spring are the lowest correlated for all regions. In all seasons, Central Anatolia is the highest correlated region, and the second highly correlated region is Aegean while the third is Mediterranean. Other regions show less correlation with non-homogeneity among the provinces in each region. Using CORINE land cover map with appropriate reclassification, the land cover types with high correlation coefficients are noticed to be covered by Seasonal crops which includes Non-irrigated arable land and Permanently irrigated land, Natural Grass, and Agro-Forestry.

6. REFERENCES

Allen, Richard G., Luis S. Pereira, Dirk Raes, and Martin Smith. 1998. 'Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56', *FAO, Rome*, 300: D05109.

Anyamba, A., C. J. Tucker, and J. R. Eastman. 2001. 'NDVI anomaly patterns over Africa during the 1997/98 ENSO warm event', *International Journal of Remote Sensing*, 22: 1847-60.

Bajgiran, Parinaz Rahimzadeh, Ali A. Darvishsefat, Ali Khalili, and Majid F. Makhdoum. 2008. 'Using AVHRR-based vegetation indices for drought monitoring in the Northwest of Iran', *Journal of Arid Environments*, 72: 1086-96.

BeguerÍA, Santiago, Sergio M. Vicente-Serrano, and Marta Angulo-Martínez. 2010. 'A multiscalar global drought dataset: the SPEIbase: a new gridded product for the analysis of drought variability and impacts', *Bulletin of the American Meteorological society*, 91: 1351-56.

Beguería, Santiago, Sergio M. Vicente-Serrano, Fergus Reig, and Borja Latorre. 2014. 'Standardized precipitation evapotranspiration index (SPEI) revisited: parameter fitting, evapotranspiration models, tools, datasets and drought monitoring', *International Journal of Climatology*, 34: 3001-23.

Dabanlı, İsmail, Ashok K. Mishra, and Zekai Şen. 2017. 'Long-term spatio-temporal drought variability in Turkey', *Journal of Hydrology*, 552: 779-92.

Dogan, Selim, Ali Berktay, and Vijay P. Singh. 2012. 'Comparison of multi-monthly rainfall-based drought severity indices, with application to semi-arid Konya closed basin, Turkey', *Journal of Hydrology*, 470: 255-68.

Dutta, Dipanwita, Arnab Kundu, N. R. Patel, S. K. Saha, and A. R. Siddiqui. 2015. 'Assessment of agricultural drought in Rajasthan (India) using remote sensing derived Vegetation Condition Index (VCI) and Standardized Precipitation Index (SPI)', *The Egyptian Journal of Remote Sensing and Space Science*, 18: 53-63.

EEA. 2000. 'Corine Land Cover', *European Environment Agency, Copenhagen*.

Farrar, T. J., S. E. Nicholson, and A. R. Lare. 1994. 'The influence of soil type on the relationships between NDVI, rainfall, and soil moisture in semiarid Botswana. II. NDVI response to soil oisture', *Remote sensing of Environment*, 50: 121-33.

Gu, Yingxin, Eric Hunt, Brian Wardlow, Jeffrey B. Basara, Jesslyn F. Brown, and James P. Verdin. 2008. 'Evaluation of MODIS NDVI and NDWI for vegetation drought monitoring using Oklahoma Mesonet soil moisture data', *Geophysical Research Letters*, 35.

Hadi, Sinan Jasim, and Mustafa Tombul. 2017. "Conversion of CruTS 3.23 data and evaluation of precipitation and temperature variables in a local scale." In *International Conference on Advances in Sustainable Construction Materials & Civil Engineering Systems (ASCMCES-17)*, 05007. UAE: EDP Sciences.

Ji, Lei, and Albert J. Peters. 2003. 'Assessing vegetation response to drought in the northern Great Plains using vegetation and drought indices', *Remote sensing of Environment*, 87: 85-98.

Jones, P.D, and I. Harris. 2008. 'Climatic Research Unit (CRU) time-series datasets of variations in climate with variations in other phenomena', NCAS British Atmospheric Data Centre, Accessed 10/08/2016. http://catalogue.ceda.ac.uk/uuid/3f8944800cc48e1cbc29a5ee12d8542d.

Kogan, F. N. 1995. 'Application of vegetation index and brightness temperature for drought detection', *Advances in Space Research*, 15: 91-100.

Mehr, Ali Danandeh, Ercan Kahya, and Mehmet Özger. 2014. 'A gene–wavelet model for long lead time drought forecasting', *Journal of Hydrology*, 517: 691-99.

Mishra, Ashok K., and Vijay P. Singh. 2010. 'A review of drought concepts', *Journal of Hydrology*, 391: 202-16.

Nicholson, S. E., and T. J. Farrar. 1994. 'The influence of soil type on the relationships between NDVI, rainfall, and soil moisture in semiarid Botswana. I. NDVI response to rainfall', *Remote sensing of Environment*, 50: 107-20.

Quiring, Steven M., and Srinivasan Ganesh. 2010. 'Evaluating the utility of the Vegetation Condition Index (VCI) for monitoring meteorological drought in Texas', *Agricultural and Forest Meteorology*, 150: 330-39.

Riebsame, William E., Stanley A. Changnon Jr, and Thomas R. Karl. 1991. *Drought and natural resources management in the United States. Impacts and implications of the 1987-89 drought* (Westview Press Inc.).

Sensoy, Serhat, Mesut Demircan, Yusuf Ulupinar, and İzzet Balta. 2008. 'Climate of Turkey', *Climate of Turkey. 2007. Devlet Meteoroloji İşleri Genel Müdürlüğü, 13 Feb. 2009< http://www. dmi. gov. tr/index. aspx*.

SirdaŞ, SevinÇ, and Zekai Sen. 2003. 'Spatio-temporal drought analysis in the Trakya region, Turkey', *Hydrological Sciences Journal*, 48: 809-20.

Sönmez, F. Kemal, Ali Ümran KÖmÜscÜ, Ayhan Erkan, and Ertan Turgu. 2005. 'An analysis of spatial and temporal dimension of drought vulnerability in Turkey using the standardized precipitation index', *Natural Hazards*, 35: 243-64.

Thornthwaite, Charles Warren. 1948. 'An approach toward a rational classification of climate', *Geographical review*, 38: 55-94.

Törnros, T., and L. Menzel. 2014. 'Addressing drought conditions under current and future climates in the Jordan River region', *Hydrology and Earth System Sciences*, 18: 305.

Tucker, Compton J., Jorge E. Pinzon, Molly E. Brown, Daniel A. Slayback, Edwin W. Pak, Robert Mahoney, Eric F. Vermote, and Nazmi El Saleous. 2005. 'An extended AVHRR 8-km NDVI dataset compatible with MODIS and SPOT vegetation NDVI data', *International Journal of Remote Sensing*, 26: 4485-98.

Vicente-Serrano, Sergio M., Santiago Beguería, and Juan I. López-Moreno. 2010. 'A multiscalar drought index sensitive to global warming: the standardized precipitation evapotranspiration index', *Journal of Climate*, 23: 1696-718.

Wang, Xianwei, Hongjie Xie, Huade Guan, and Xiaobing Zhou. 2007. 'Different responses of MODIS-derived NDVI to root-zone soil moisture in semi-arid and humid regions', *Journal of Hydrology*, 340: 12-24.