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Full Length Research Paper

Assessment of the dry and wet period severity with hydrometeorological index

Fatih Keskin[1]* and Ali Unal Sorman[2]

[1]State Hydraulic Works, Investigation and Planning Department, Inonu cad. No: R-7 Yucetepe/Ankara/Turkey.
[2]Middle East Technical University, Civil engineering Department, Water Resources Laboratory Ankara/Turkey.

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The paper examines the existing condition of water resources for the basin of Çamlidere dam in the vicinity of capital city of Ankara, Turkey and highlights the hydrological elements that are mostly prone to the change of atmospheric conditions. After the evaluation of environmental conditions, the standardized precipitation index (SPI), standardized runoff index (SRI) and standardized potential evapotranspiration index (SEI) have been calculated with monthly air temperature, precipitation and stream runoff records in and around the basin. The calculated index values are used for defining the hydrometeorological dryness and wetness severity in the basin named as Aggregated Drought Index (ADI). The aggregated drought index was able to clarify the long wet and dry periods with a high correlation between the North Atlantic Oscillation (NAO) and El-Nino Southern Oscillations (ENSO) indices. The determined monthly ADI values provide an indication to predict wet or dry conditions in advance for the study basin.

Key words: Drought, wetness, north Atlantic oscillation, southern oscillation, aggregated drought index, camlidere dam, Turkey.

INTRODUCTION

Droughts are one of the world most severe and collectively affecting natural disasters that cause an average US$6-8 billion in global damages yearly (Wilhite, 2000). Agricultural crop damage is expected to be same order of magnitude in Turkey because of the 2007 severe drought events took place in the country. The usable water sources consist of soil moisture, groundwater, snow pack, runoff and reservoir storage. Any drought is directly related with the one or more of these five sources of supply. The time lag from the precipitation occurrence until water is available in each useable form differs greatly. Water uses also have characteristic time scales. Consequently, the impacts of a water deficit are a complex function of water source and water use. The time scale over which precipitation deficits accumulate becomes extremely important and functionally separates different types of drought. Agricultural (soil moisture) droughts, for example, typically have a much shorter time scale than hydrologic (groundwater, runoff and reservoir storage) droughts (Mckee et al., 1993).

There are several studies not directly related to drought but focused on analyzing the conditions and trends of hydrological variables (Van Belle and Hughes, 1984; Zhang et al., 2000, 2001). There are also studies (Kadıoğlu 1997; Turkeş et al., 2002; Karabörk, 2007) examining the temperature trends of Turkey in which warming and cooling trends in some parts of Turkey were found with the precipitation station records. Some studies (Turkeş, 1996; Kalayci and Kahya, 2006; Karabörk, 2007) focus on the precipitation and runoff records in Turkey and detected significant trends in nearly one-third and half of the stations in the context, respectively. Ünal and Karaca (2003) made a study for clustering the climate zones in Turkey and found six different zones (Zone A, B, C, D, E and F) (Figure 1) where zone D is representing the Central Anatolia of Turkey within which our study area is located. Drought can be examined in three different types which are referring to a water deficit in a hydrological cycle with a connection that a drought in one stage of the cycle can lead to a drought also in other stages. It starts with a less than normal amount of preci-

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*Corresponding author. E-mail: fatihk@dsi.gov.tr. Tel: +90-312-4178300. Fax: +90-312-4171378.

Figure 1. Climate zones of Turkey, Unal and Karaca (2003).

pitation which is called a meteorological drought. After that soil moisture droughts and hydrological droughts might develop. An agricultural drought is characterized by low soil moisture content, which is not sufficiently supply water to cultivated plants. The term hydrological drought is applied to less than normal amounts of water in the different types of water bodies, represented by low water levels in streams, reservoirs and lakes as well as a low groundwater level.

Several different indices have been developed to define types of droughts. These indices have been presented in different studies (Heim, 2002; Keyantash and Dracup, 2002) where most of them (Standardized Precipitation Index (SPI), Standardized Runoff Index (SRI), Surface Humidity Index (SHI)) are separate indices and define one of the types of drought. There were also some studies to define the several separate indices with one index. Palmer Drought Severity Index (PDSI) was the most widely used index of drought in United States but not usable because of its limitations (refer to Keyantash and Dracup, 2002). Another index called Surface Water Supply Index (SWSI) (Shafer and Dezman, 1982) assesses the impact of the hydrological drought by integrating snow pack and surface water levels in analysis. Later Keyantash and Dracup (2004) defined a new index called Aggregate Drought Index (ADI) which is a multivariate index that considers the meteorological, hydrological and agricultural drought together.

There are many other studies that examine the relations between the NAO, ENSO and precipitation, temperature in Turkey (Karabörk 2007, Karabörk and Kahya 2003, Kahya and Karabörk 2001) finding significant correlations. The results of these studies conclude that there is a relation between the weather patterns and the oscillations.

In this study SPI, SRI and SEI are determined for several different monthly time periods. The ADI is calculated after a principal component analysis with or without time lags (1 - 12 months) to determine aggregated index values. SPI, SRI and SEI values are used with 3 months lag periods from 1 - 12 months lag in order to test the effect of these indexes on ADI.

DATA AND METHODOLOGY

The study area is the Çamlidere Dam basin that supplies most of the domestic water to the city of Ankara in Turkey where the total supplied water is about 800 000 m^3/day. The location of the basin and the Ankara city is shown in Figure 2. The study area lies in the zone "D" of zones that are defined by Unal and Karaca (2003).

The data used in the study is the monthly records of precipitation, runoff and air temperature. Snow measurements within the basin are also included in order to analyze the snow depth trends. There are two runoff stations data; one of them is recorded by the State Hydraulic Works (DSI) in Çamlıdere basin and the other is recorded by the Ministry of Agriculture and Rural Affairs (MARA) in Guvenc basin that is close to the study area for the period 1988 - 2006. The precipitation data were recorded by the State Meteorological Service (DMI) in Ankara, Esenboğa and Kizilcahamam stations as shown in Figure 2. These three stations are in or near the settlement areas where they can not represent the study area alone. So another precipitation data from Guvenc basin that was recorded by MARA is also included in the study. High correlation coefficient (0.80) between Esenboga and Ankara stations were obtained, so the Ankara station data were omitted in the calculation of the precipitation for Çamlıdere basin to prevent redundancy. The temperature data is obtained from DMI for the study period (1988 - 2006). The temperature lapse rate was calculated and the station data were distributed to basin with the calculated lapse rate (0.33°C

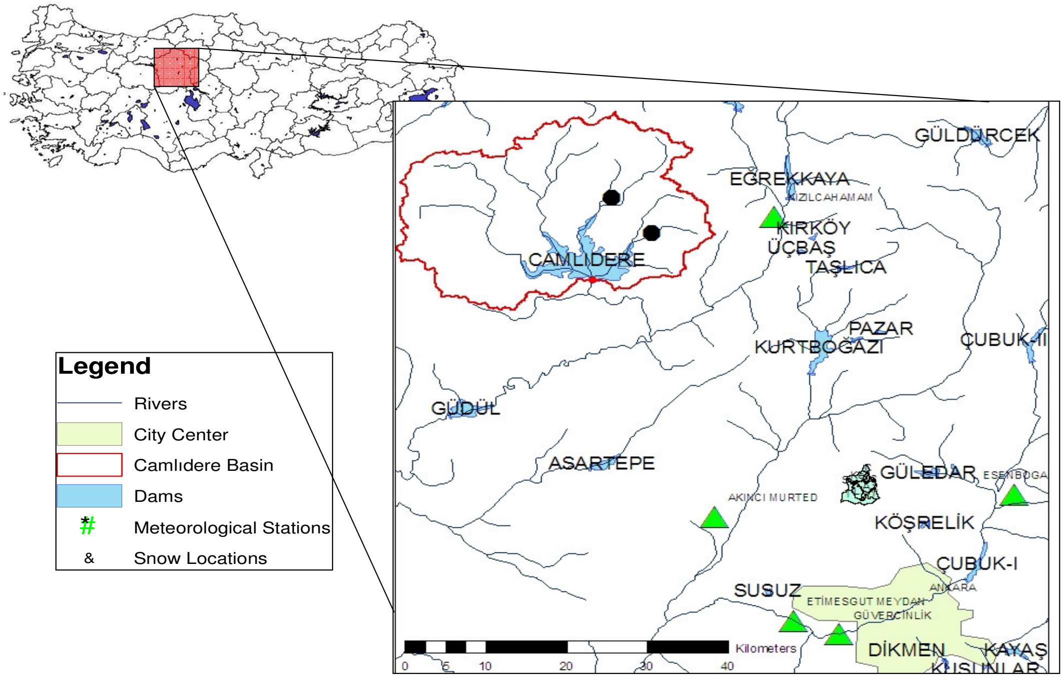

Figure 2. The basin and the stations.

per 100 meters). The temperature data were used for determining potential evapotranspiration value for the basin. The NAO index values are supplied from the Climatic Research Unit, whereas the ENSO index values are taken from Climate Prediction Centre. There are four different indices used which were named as SPI, SRI, SEI and ADI indices in the study. The index data for SPI, SRI and SEI derived from precipitation, runoff and air temperature are plotted and depicted in Figure 3.

SPI index

First, a time series of the precipitation value of interest is generated. Then, a frequency distribution is selected and a statistical fit to the data is determined. The cumulative distribution is formed from the fitted frequency distribution. The percentile for the particular time series element of interest, usually the latest one, is selected from the cumulative distribution. For "ties" (multiple instances of the same value), the upper value is used (probability of non-exceedance). For any other theoretical probability distribution, the analogous point on its associated cumulative frequency distribution can be determined. For the normal distribution, these are exactly the same as units of standard deviations. The Standardized Precipitation Index can be thought of as the number of standard deviations that the precipitation value of interest would be away from the mean, for an equivalent normal distribution and adequate choice of fitted theoretical distribution for the actual data. In effect, the method consists of a transformation of one frequency distribution to another frequency distribution, in this case the widely used normal, or Gaussian, distribution". The SPI is calculated by taking the difference precipitation from the mean for a time period and division by the standard deviation of the whole recorded precipitation. The precipitation data was assumed as normally distributed (Mckee et al., 1993). The precipitation data can also be expressed with Gamma or Log Normal 3 distributions (Shukla and Wood, 2008). Mckee et al. (1993) suggested a methodology to calculate the SPI with selecting a j months set of aggregated precipitation data to determine a set of time scales where j is 3, 6,12,24,48 months. The dataset reorganized in a moving sense that a new series is formed from the previous j months. These dataset are fitted to gamma function to get the probability of precipitation for the recorded data. The probability of a precipitation value is determined with an estimate of the inverse normal for calculating the precipitation for a normally distributed probability density with a mean of zero and standard deviation of unity (Mckee et al., 1993). This value is called as SPI for the particular precipitation data value. The advantage of the SPI is that after normalization both wet and dry periods can be expressed with SPI.

Mckee et al. (1993) defined drought event for time period j where SPI is continuously negative and SPI reaches -1.0 or less. The defined categories of SPI for the drought severity definition are given in Table 1.

SRI index

The definition of the severity of hydrological droughts is important for several management issues like reservoir management and water quality assessments. SRI is an important index for the definition of runoff drought. The calculation of SRI is similar to the calculation of SPI (Shukla and Wood, 2008).

SEI index

The potential evapotranspiration is determined by the interaction of several factors such as water demands, temperature and humidity. Also the basin characteristics affect the evapotranspiration but the potential evapotranspiration can be used as an indicator of soil moisture droughts which is also called agricultural drought. Because of its difficulties in measurement, there is no potential evapotranspiration measurement in the basin. The potential evapotranspiration (PET) is calculated with the well known

Table 1. Drought categorization values (Mckee et al., 1993).

SPI Values	Drought category
0 to -0.99	mild drought
-1.00 to -1.49	moderate drought
-1.50 to -1.99	severe drought
< -2.00	extreme drought

Thornthwaite's (Thornthwaite 1948) scheme as;

$$PET = 16N_m * \left(\frac{10T}{I}\right)^a mm \qquad (1)$$

Where; T is the mean monthly temperature (MMT) (℃), and I is the heat index and calculated with the formula

$$I = \sum_{1}^{12}\left(\frac{Ti}{5}\right)^{1.5} \qquad (2)$$

Where air temperature is summed over a 12-month period to a power of 1.5 and

$$a = 6.7*10^{-7}*I^3 - 7.7*10^{-5}*I^2 + 1.8*10^{-2}*I + 0.49 \qquad (3)$$

The MMT values that have a negative value are assigned to zero. After the analysis of the potential evapotranspiration values, it was seen that the data can be expressed by normal distribution.

There might be the need for other types of indexes for the different definition of drought, but these three indexes which can be determined easily are very important for the definition of hydrometeorological drought. The hydrometeorological drought starts with meteorological drought with a deviation from normal precipitation. Then the agricultural drought and hydrological drought comes after a water deficit in precipitation. There is a continuous link between these three droughts. Normally within the hydrological cycle, if the potential evapotranspiration decreases then the probability of having precipitation may decrease. If there is not enough soil moisture to support the groundwater, then there may be a decrease in runoff values depending also on the basin characteristics. So we need one multivariate index to define the hydrometeorological drought so that it can represent the interaction in a basin. The ADI is an important index that can define the hydrometeorological drought.

Times series for the three indices were formed for the basin to show the effect of the time period for 3, 6 and 12 month time intervals (Figure 3). The 12 Month period index graph (Figure 3c) is better for identifying wet and dry periods specifically. It can be seen from these graphs that up to the end of 2005, the SRI did not deviate from SPI largely. But after this time period, although there is an increasing trend in SPI, the SRI trend continues downward. This result also shows the need for the definition of the hydrometeorological index. Although with just looking to SPI, one can think that the trend is upward, but because of the deterioration of groundwater and recharge, SRI can not respond immediately to SPI. In a basin, runoff gives 1 - 2 month(s) later response to the precipitation. Also in some periods, especially in winter, there is a 2 - 3 months lag time response of runoff to precipitation because of the snow accumulation and melting.

ADI index

Keyantash and Dracup (2004) suggested the ADI and calculated for three diverse climate divisions in California. The ADI combines all physical forms of drought with the selection of variables related to different drought type. The Principal Component Analysis (PCA) was used for the construction ADI with the available indices (SPI, SRI and SEI). The eigenvectors as unit vectors are derived through PCA. The first principal component which explains the largest fraction of variance of information is selected and used for the calculation of ADI. The data is used to determine the sets of averaging periods to determine a set of time scales of period j months. Keyantash and Dracup (2004) used the normal distribution function to standardize the data but in this study, gamma distribution was selected for the calculation of SPI and SRI after trial of several probability distribution functions. After the calculation of ADI, the values are used in order to identify the correlations between ENSO and NAO indices. The analysis approach is applied to identify the correlation with ENSO and NAO with ADI starting lag-0 to lag-7. The rank correlation (Spearman) which is a robust measure of the connection between a data pair (Wilks, 1995) is applied for lag-n prior 12 month index of ENSO-NAO and the respective 12 month ADI for different dryness and wetness severity. The significance of the correlations is tested for ± 95% confidence levels. Flowchart of the methodology is depicted in Figure 4.

ANALYSIS OF RESULTS

Index studies

As mentioned earlier, each of the index shows different type of drought. In some periods although effect of a hydrological drought is not observed, one can observe the effect of agricultural drought. The analysis showed that there is a high correlation between two month prior amount of SPI (2 month lag period) and the respective amount of SRI. The correlation coefficient for 1 month and 2 month lag is about 0.669 and 0.641 respectively. Application of the significance test for the relation shows that the correlation between SRI and SPI is significant at 95% confidence level. When the last portion of the Figure 3c representing 12 month indices is examined, the SPI shows that the drought is not so severe (≥-1), but the SRI shows that there is a severe drought in terms of runoff (≤-2.5), so ADI was calculated to define the severity of drought and wetness. The correlation matrices are used in order to calculate the Principal Components (PCs). The PCA for different time periods (1, 3, 6, 9, 12 months) of the SPI, SRI and SEI showed that the explained variance is highest in 3 and 6 months. The calculated explained variances for different time periods resulting from first principal component (PC1) are given in Table 2. The PC1 accounts for 66% of the total variance for the index values. The PC1 can be accepted as an indicator of the general relation between SPI, SRI and SEI.

The Eigenvectors which show the relationship between PCs and the original index data are derived from PCA. The calculated eigenvectors for the PC1 for three indices (SPI, SRI and SEI) and two time periods (3 and 6 months) are shown in Table 3. Since explained variance

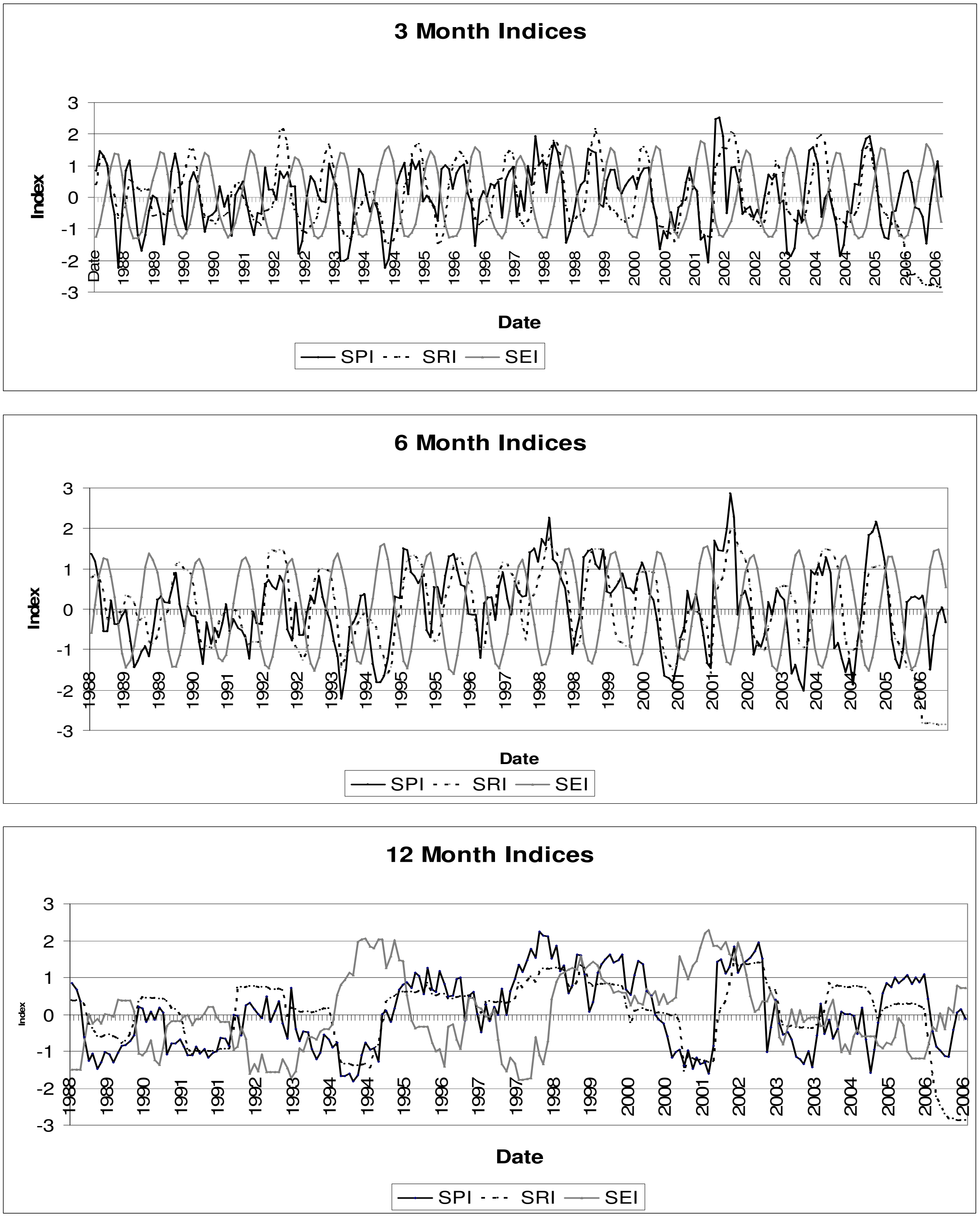

Figure 3. Graphs of SPI, SRI and SEI values for 3 month time period (a) and 6 month time period (b) and 12 month time period (c).

in 3 and 6 months periods is not different from each other, the calculated eigenvectors show the same difference. The SPI and SRI is proportional to PC1 (positive sign) and SEI (negative sign) is inversely proportional to PC1.

The ADI was calculated with the determined eigenvectors by multiplying values of vectors with index value as discussed in ADI section. The determined values of ADI are plotted together with other 3 indices and depicted in Figures 5a - b with 6 and 12 month time

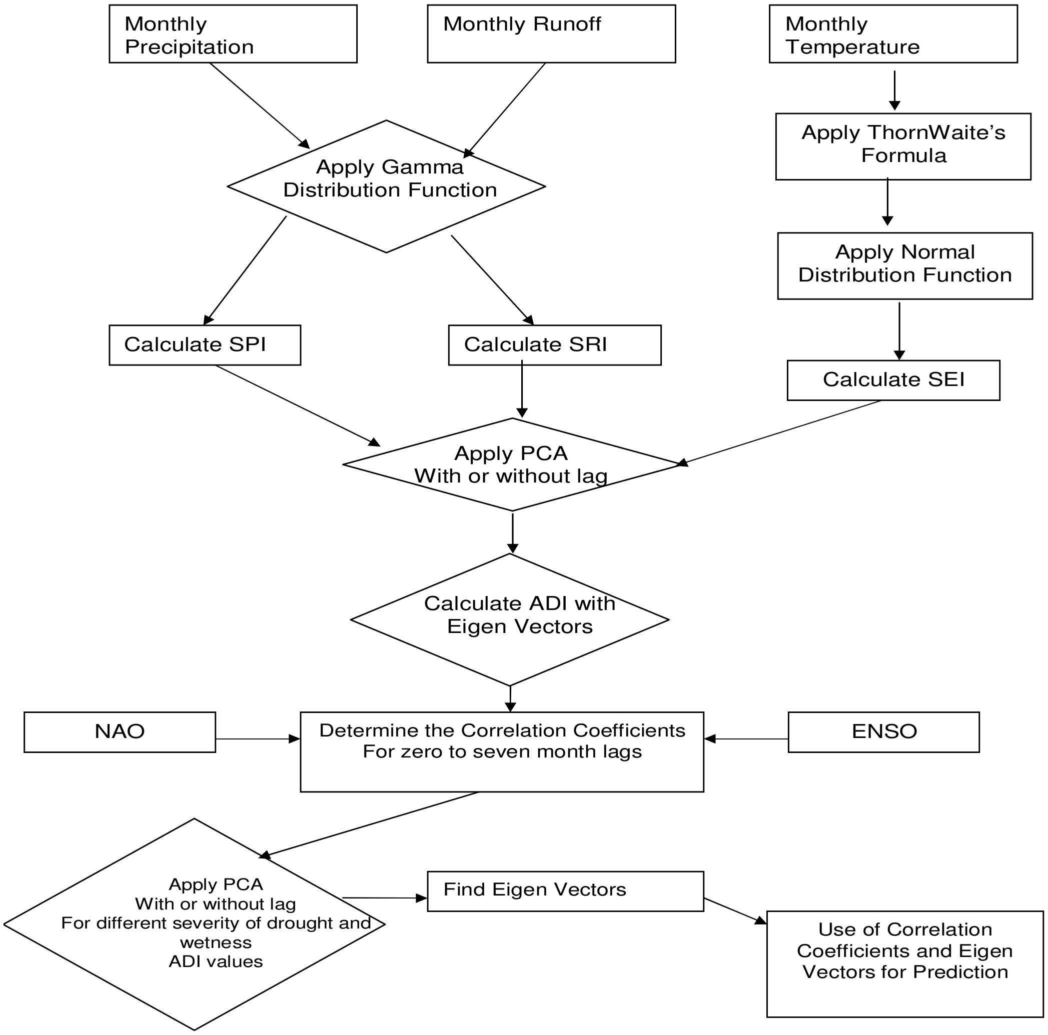

Figure 4. Flowchart of the methodology.

Table 2. The calculated explained variance for PC1.

Time Period	Explained Variance % for PC1
1- Month	56.547
3- Month	64.871
6- Month	66.114
9- Month	60.063
12- Month	58.175

Table 3. The calculated eigenvectors for PC1.

Time period	SPI	SRI	SEI
3 Month	0.616	0.548	-0.565
6 Month	0.631	0.569	-0.527

periods. There is two much fluctuations in 6 month period index values, so 12 month period is better to visualize dry or wet period(Figure 6). The periods turn wet to dry or dry to wet. Also the duration of the wet and dry period changes from time to time. Longer wet periods (period of 1995-2000) mean an increase in the number of flood events (Figure 7). Longer dry periods (1993-1995) indicate an increase in the drought events. When we look from the dry period side as the duration gets longer, the severity of the drought event gets much worse which means that the water users feel much worse the drought

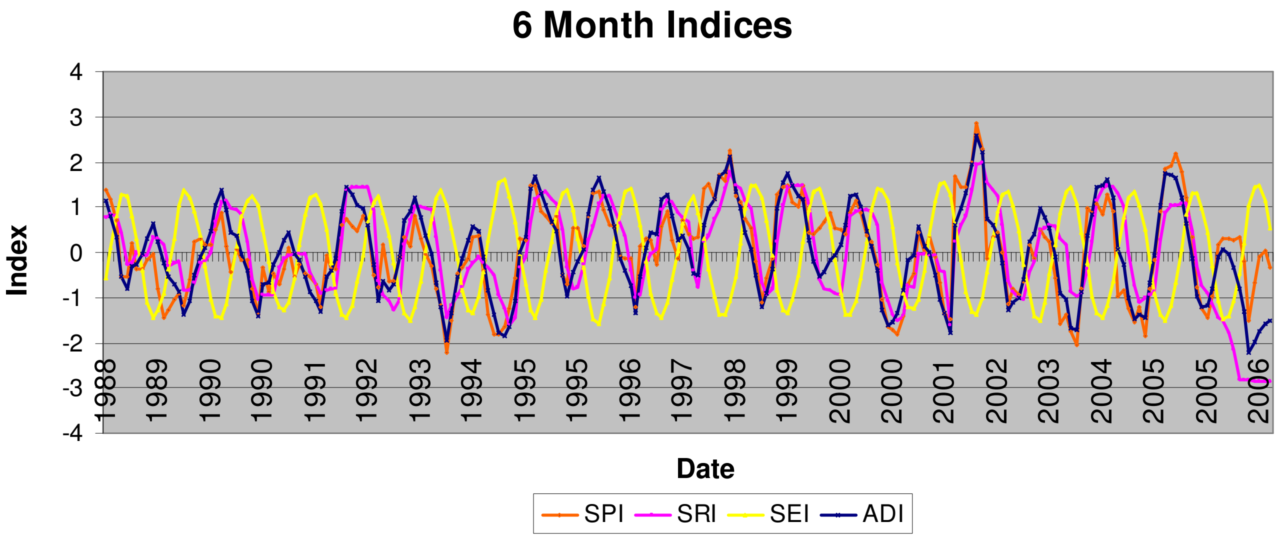

Figure 5a. 6 month SPI, SRI, SEI and ADI Index Graphs.

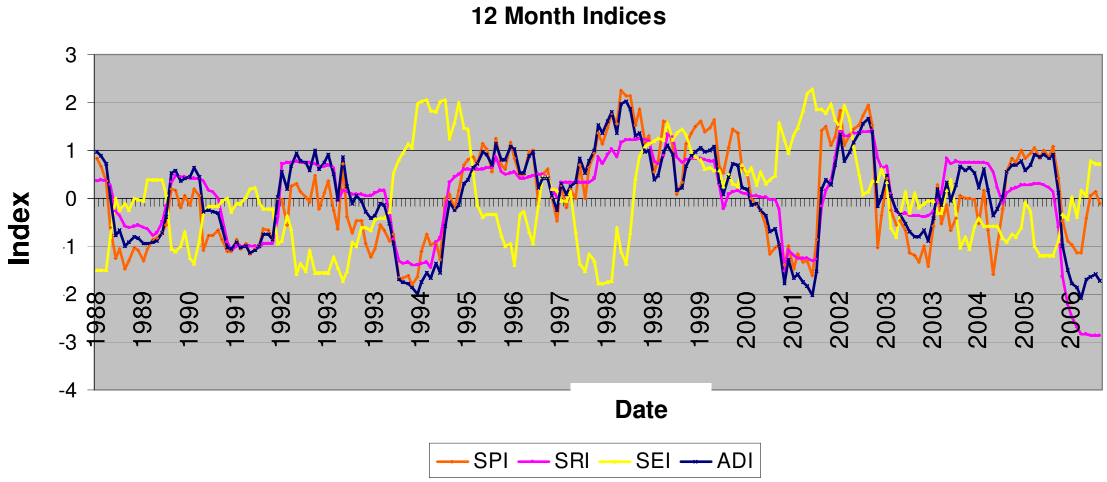

Figure 5b. 12 month SPI, SRI, SEI and ADI index graphs.

effect if the water budget can not be managed properly

Wet or dry periods

The calculation of ADI can help the water managers for proper decision for the maximum use of the water in the system. The wet periods are the periods where the number of flood events can increase or the periods that excess water is released from the spillways. There are two other dams (Çubuk and Kurtbogazı dams, refer to Figure 2) which also supply domestic water to Ankara city. The storage capacity of these two dams is not enough to store all the discharge in the river. The water that is released from these two dams, 22 million m^3 and 92 million m^3 respectively, was plotted on the ADI graph to see the effect of the wet period and to check the usability of the ADI. As it can be seen from Figure 7, ADI shows that the period is wet in nearly all of the released water event periods. The amount of the released water is directly related with the aggregated index value and the duration of the wet period. For example, the most damaging flood events were recorded in nearly whole of the west and north of Turkey in 1998 which is the year of the biggest ADI value. The graph also supports that the ADI values can be used in water management issues properly as a decision support tool.

The severity of the drought is also directly related with the duration of the drought event. As it can be seen from Figure 7, there are 5 major drought events and three of them (1994-1995, 2000-2001, 2006) are larger in terms of index values. The occurred drought events were also

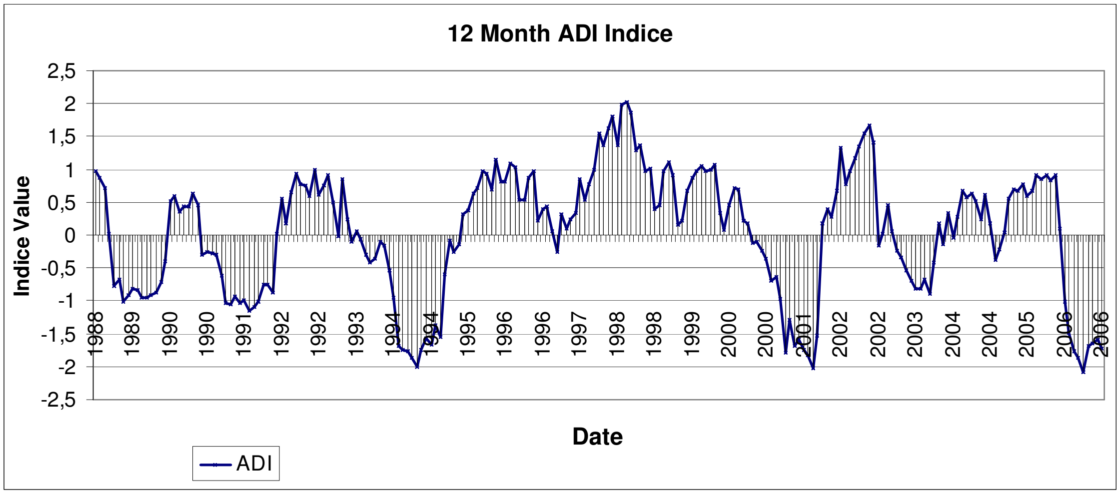

Figure 6. Graph of the 12 month ADI.

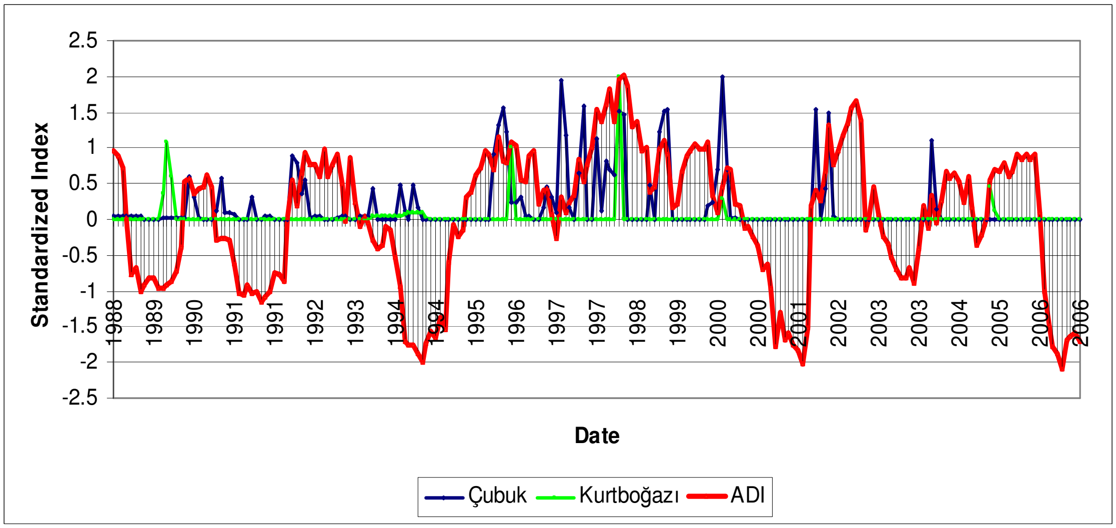

Figure 7. Graphs of ADI with excess water released from Cubuk II and Kurtbogazi dams.

checked from different literatures (Table 4) in order to compare with the ADI values determined in the study. The observed severe drought events that are in the study period were tabulated and shown in Table 4. There are different periods mentioned in the sources, but the 1989 - 1994 periods is common in three of these references. After a comparison with recorded drought event and the ADI values, it can be stated that the ADI shows the drought events properly. There are also some wet periods (1990 - 1991 - 1992) in the 1989 - 1994 periods. The drought periods show the event for the whole Turkey not focused in the study area. In order to check whether the same drought years apply to the study area or not, the measured snow depths are collected. The snow measurements were started in 1992 and there are some gaps in the measurements. The gaps were filled with the nearby station values after a regression analysis. The recorded measurements derived from two locations as

Table 4. Recorded drought periods and references.

Drought Period (Turkey)	Severe Drought Years(Figure 7)
1987-1995[1]	1989
1982-1994[2]	1991
1989-1994[3]	1994
1999-2006***	2001-2003-2006

References : [1] Akkemik et al., 2005. [2] Kalaycı and Kahya. 2006. [3] Yağcı. 2008

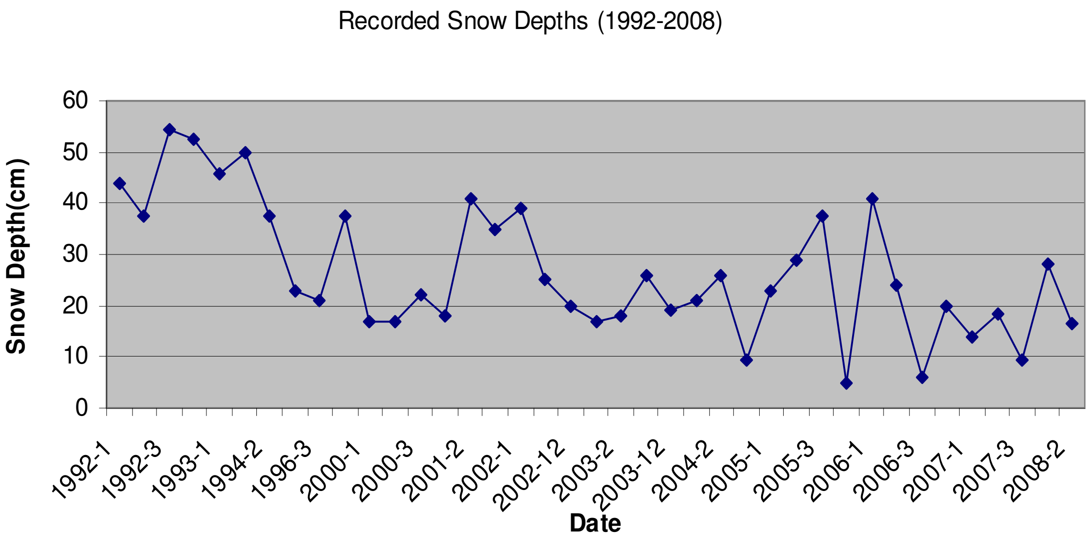

Figure 8. Recorded snow depths in Çamlıdere basin.

shown in Figure 2 are plotted and shown in Figure 8. It was determined that snow depth is below the normal value in these periods and there is a downward trend which also supports that these periods are dry. Therefore these results also support that the ADI values covering precipitation, runoff and evaporation as well the snow depth records can be used as a tool for the decision support system in water management as well.

Effect of climate indices NAO and ENSO on ADI

There are two studies (Kahya and Karabörk, 2001; Karabörk and Kahya, 2003) which show the probability of existing relation of ENSO index with the runoff and precipitation changes. The reference studies focus on the country wide correlation, not the basin wide correlation, and have found no significant correlations between NSO and precipitation and runoff in Turkey. The results of Karabörk and Kahya (2003) showed that NAO index series has simultaneous negative correlations with the seasonal fall precipitation series. This also supports the study of a relation between NAO and precipitation indices. Karabörk (2007) applied a trend analysis to identify the relation between NAO indices and the Surface Humidity Index (SHI). As it can be seen from Table 5, there is some correlation between SHI and NAOI values (-0.333 - 0.199). Especially the correlation coefficient in spring and fall term for the region D (Central Anatolia) is high which also results for significant relation of NAO and temperature and precipitation values. It was also suggested that NAO can be considered to challenge the ENSO phenomena (Marshall et al., 2001). The past studies showed that the ENSO effect on Turkey's general climatology is much weaker than the North Atlantic (Karabörk, 2007). The mentioned studies performed in the past were focused on the seasonal effect of NAO and ENSO, where they did not take into account the severity of drought and wetness for a prolonged period.

Table 5. Correlation coefficients that are calculated between seasonally averaged NAOI and SHI (Karabork et al., 2007).

Region	Winter	Spring	Summer	Fall
A	-0.133	-0.199	0.031	-0.275
B	0.004	-0.229	0.047	-0.270
C	0.148	0.102	-0.154	-0.017
D	0.199	-0.333	-0.116	-0.245
E	N/A	0.052	-0.134	-0.208
F	0.108	-0.223	-0.036	-0.153
G	-0.051	-0.094	0.081	-0.216

In this study, the correlations between the ADI, ENSO, and NAO indices have been examined in a basin scale. Non-parametric Spearman's Rho correlation coefficient is applied in the study for the advantages of non-parametric techniques with being distribution free of the data and robust to outliers. Several correlation analyses were performed with the 3 month and 12 month accumulated values of ADI and 12 month averaged NAO and ENSO indices. The correlation studies were also extended with lag-zero up to 7 month lags (Table 6) for the use of indices in the prediction of the drought or wetness periods. The results are summarized in Table 7 by sub-grouping the selected ADI values. The study focused on the severity of the wetness and drought by grouping the ADI values with 0.5 increments starting from 0 to -1.5 and 1.5. The idea is to see if there is a significant effect of NAO and ENSO on the drought and wetness periods by considering the drought and wetness severity. The tabulated results (Table 7) show significant (at 95%

Table 6. Correlation coefficients for ADI vs. NAO & ENSO indices with 12 month values for different monthly time lags.

Indices	**ADI < 0.0**							
	Lag0	**Lag1**	**Lag2**	**Lag3**	**Lag4**	**Lag5**	**Lag6**	**Lag7**
NAO	0.288	0.271	0.301	0.308	0.298	0.293	0.305	0.256
ENSO	-0.114	-0.145	-0.161	-0.158	-0.148	-0.126	-0.103	-0.075
ADI < -0.5								
NAO	0.312	0.31	0.329	0.32	0.294	0.295	0.286	0.247
ENSO	0.103	0.087	0.069	0.07	0.077	0.085	0.103	0.138
ADI <-1.0								
NAO	0.281	0.296	0.387	0.513	0.541	0.584	0.577	0.543
ENSO	0.012	0.003	-0.026	-0.021	0.002	0.024	0.054	0.08
ADI < -1.5								
NAO	-0.019	-0.064	0.024	0.12	0.083	0.221	0.473	0.213
ENSO	-0.122	-0.122	-0.1	-0.034	0.014	0.031	0.047	0.069
ADI > 0.0								
NAO	-0.096	-0.07	-0.049	-0.054	-0.069	-0.069	-0.049	-0.03
ENSO	-0.332	-0.353	-0.352	-0.332	-0.304	-0.255	-0.213	-0.163
ADI > 0.5								
NAO	-0.12	-0.093	-0.087	-0.105	-0.142	-0.184	-0.217	-0.23
ENSO	-0.346	-0.347	-0.33	-0.297	-0.244	-0.192	-0.135	-0.073
ADI >1.0								
NAO	0.186	0.213	0.084	-0.024	0.004	-0.146	-0.477	-0.602
ENSO	-0.779	-0.754	-0.677	-0.567	-0.460	-0.335	-0.207	-0.103
ADI > 1.5								
NAO	-0.181	-0.371	-0.33	-0.054	0.18	-0.058	-0.571	-0.441
ENSO	-0.781	-0.873	-0.865	-0.853	-0.854	-0.874	-0.922	-0.908

Table 7. Summarized results of correlation study of ADI vs. NAO & ENSO indices.

Dry and Wet Periods (maximum Correlations)	
ADI (Dry period)	**NAO vs ADI Correlation Coefficients**
ADI<0	0.308
ADI<-0.5	0.329
ADI<-1.0	0.584
ADI<-1.5	0.473
ADI (Wet Period)	**ENSO vs ADI Correlation Coefficients**
ADI>0	-0.353
ADI>0.5	-0.347
ADI>1.0	-0.779
ADI>1.5	-0.922

confidence level) correlations between ADI, ENSO and NAO indices. Especially the relation of ENSO index with ADI index in wet periods is high in the periods where ADI>1.0. The correlations for the values of 0<ADI<0.5 and 0>ADI>-0.5 are not so strong. The result does not change with 1-month lag of the ENSO index values. For both ENSO and NAO indices, the correlation with ADI in moderate and severe periods of drought and wetness, the correlation coefficient is above 0.55 which can be used as a forecast tool of ADI for future time periods, especially for reservoir operation and flood management.

The NAO and ENSO indices have different influences on ADI index values. In dry periods, the influence of NAO is very strong and has a positive correlation where as in wet periods, the influence of ENSO is much stronger and has a negative correlation. The influence of ENSO on ADI during dry months can be observed with no time lag (zero) or 1-month lag which is meaningful. Any increase in precipitation above normal could lead to increase in the wetness of the basin. For the NAO, it is a little different

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result as an excess in runoff but may be in groundwater recharge. After the recharge to groundwater, 4 - 6 month later, the influence can be observed in the runoff. A study of PCA was done in order to see the effect of ENSO and NAO indices on ADI index values. The time series of ENSO, NAO and ADI were considered together (including all time lags) as a composed vector for which a PCA was done. The analysis was made separately for dry and wet months/periods. The analysis reveals that with highly correlated values of ENSO and NAO with ADI values, high percentage of total variance (80%) can be explained by the relation. These two results also can be used in the drought and flood management plans for the study area as well similar areas in Central Anatolia with similar basin characteristics.

Conclusion

The hydrometeorological drought index, ADI was applied for the identification of wet and dry periods. In water management, the manager must have a plan for decision making. This index can be used as a tool by explaining the meteorological, hydrological and agricultural drought together.

In order to test the results of ADI, the excess water released from the spillway of dams are checked and the analysis showed that the ADI can be used for both wet and dry periods. In wet periods, diversion of water to other dams or groundwater storage can be tried in order to maximize the use of the water in the system by calculating the index with the latest available information. The groundwater must be included in the further studies for the basin. The explained variance is about 65%, which is high enough to support the index value calculation methodology. There is a relatively good correlation (0.60) between the SPI and SRI with 1 - 2 months lag time. This relationship can be used for the prediction of the possible runoff due to precipitation in the basin.

Also the correlation of ADI with ENSO and NAO in moderate and severe periods of drought and wetness is above 0.55 which can be used as a forecast tool of ADI for future. Especially the variance can be explained up to 80% with the values of ENSO, NAO and ADI values in moderate and severe periods of drought. The results of the analysis can be used in order to predict the possible precipitation or runoff with the known 1-6 month early values of ENSO and NAO indices. All of the study concludes that the runoff can be predicted by the precipitation and temperature values and can be supported with ENSO and NAO indices in order to maintain a drought or flood management plan for a decision support system.

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