Journal of Scientific Research & Reports
3(14): 1828-1842, 2014; Article no. JSRR.2014.14.001

SCIENCEDOMAIN *international*
www.sciencedomain.org

Variability of the Precipitation and Its Connections with Dry Years in the Central Anatolia, Turkey

Osman Yildiz[1*]

[1]*Kırıkkale University, Engineering Faculty, Civil Engineering Department, Hydraulics Division 71451 Kırıkkale, Turkey.*

Author's contribution

This whole work was carried out by the author OY.

Original Research Article

Received 26th March 2014
Accepted 28th May 2014
Published 9th June 2014

ABSTRACT

This study presents an evaluation of the variability of the precipitation and its connections with dry years in the Central Anatolia of Turkey, a semiarid region subjected to frequent and widespread drought events. The statistical parameters of major historical drought events in the region are determined. Annual and seasonal Box-plots of precipitations are used to determine the drought characteristics in the region. The spatial maps of precipitation deficits during the selected drought years are utilized for the assessment of areal impacts of droughts across the region. The hydrological response to droughts is investigated with the use of surface water data including streamflows and reservoir storages. The results of the study indicate that regional drought analysis can provide very useful information for drought mitigation and sustainable water resources management in the Central Anatolia Region.

Keywords: Drought; semiarid region; box-plots; surface water; The Central Anatolia.

1. INTRODUCTION

Wilhite and Buchanan-Smith [1] defined drought as an insidious natural hazard that results from a deficiency of precipitation from expected or normal level with adverse effects on the

**Corresponding author: E-mail: osmanyildiz@kku.edu.tr;*

demands of human activities and the environment. Valuable information can be obtained from regional drought analysis to be utilized for various objectives including drought mitigation and sustainable water resources planning and management (see Dracup et al. [2], Mishra and Singh [3-4]).

Located in a semiarid region, Turkey experiences frequent drought events. The climate of the country is mainly characterized by the Mediterranean macroclimate resulting from the seasonal alternation of frontal depressions with polar air masses and subtropical high pressures with subsiding maritime tropical and continental tropical air masses. Continental tropical airstreams from the northern African and Arabian deserts particularly dominate throughout the summer causing generally long-lasting warm (hot) and dry conditions over the country, except the Black Sea and the northeastern regions. The country is generally characterized by high topography with increasing elevations from the coasts to inner regions and from west to east. With a mean altitude of 1100 m a.m.s.l more than 55% of the country is located above 1000 m a.m.s.l, while only 17.5% of it varies from sea level to 500 m. Annual average rainfall in the country is about 630 mm ranging from about 300 mm over the continental central Anatolia to more than 1000 mm along the Eastern and Western Black Sea, and Western Mediterranean coasts. Approximately 67% of the annual rainfall occurs during winter (December-February) and spring (March-May), and about 23% and 10% of it occurs during autumn (September-November) and summer (June-August), respectively. Sudden decreases in precipitations in the African Sahel and the subtropics during the 1960s affected the Eastern Mediterranean Basin and Turkey as well in the 1970s, especially, during winter months. Severe and widespread droughts occurred over the country during 1932, 1955-1956, 1973, 1977, 1984, 1989-1991, 1999-2001 periods as reported by Türkeş [5] and Komuscu [6].

The objective of this study is to present an evaluation of the variability of the precipitation and its connections with dry years in the Central Anatolia of Turkey, so that useful information can be obtained for drought mitigation and water resource management purposes within the region. For this purpose, both annual and seasonal statistical parameters of the historical droughts in 1956, 1973, 1984, 1989, 1993 and 2004 are taken into consideration. The Box-plots of precipitations are used to determine the drought characteristics over the region. The spatial maps of precipitation deficits for the selected drought years are utilized for the assessment of areal impacts of droughts. Also, drought effects on surface waters including streamflows and reservoirs are investigated.

2. REVIEW OF PREVIOUS DROUGHT RESEARCHES

Several studies on regional drought analysis are presented in the literature. Recently, Shin and Salas [7] proposed a method for analyzing and quantifying the spatial and temporal patterns of meteorological droughts based on annual precipitation data by using neural networks. Kim et al. [8] investigated the temporal and spatial characteristics of droughts in the Conchos River basin, Mexico, with the drought intensity-areal extent-frequency curve obtained from the Palmer Drought Severity Index. Sırdaş and Şen [9] presented a spatial and temporal drought analysis in the Trakya region of Turkey with the Standardized Precipitation Index (SPI) method and the run analysis. Vicente-Serrano and López-Moreno [10] used the SPI at different time scales to compare with surface hydrological variables in a big closed basin located in the central Spanish Pyrenees. Mishra and Desai [11] developed quantitative relationships between drought severity, area and frequency using SPI values for different time scales in Kansabati catchment, India. Vicente-Serrano [12] analyzed the evolution of droughts in the Iberian Peninsula employing the SPI method at 12-month temporal scale. Yıldız [13,14] applied SPI method to investigate frequency, intensity and areal extent of selected historical droughts in the Central Anatolia and the Hirfanlı Dam Basin, Turkey. Burke and Brown [15] developed tools to assess regional drought events based on limited periods of record and applied them to regional climate model output to examine potential future changes in drought due to increased greenhouse gases over United Kingdom. Núñez et al. [16] presented a regional frequency analysis method based on L-moments for estimating and mapping return periods of severe droughts in the arid and semiarid region of Chile.

3. MATERIALS AND METHODS

The region under study is geographically located at 30-39^{o}E longitudes and 37-40.5^{o}N latitudes with a land surface area of about 150,000 km^2 which corresponds to 20% surface area of Turkey (Fig. 1). Approximately with a 17 million population the region has 13 cities including the capital city of Ankara. The region is generally characterized by highlands and wide ranging plateaus with an average altitude of 1150 m. The northern Anatolian mountain ranges in the north and the Taurus mountain ranges in the south have a significant influence on the climate of the region acting as a barrier against humid air masses from coastal regions. The region has a typical dry climate with a mean temperature of about 10^{o}C and a mean annual precipitation of about 400 mm. It receives the lowest amount of rainfall as compared with other regions in the country. Convective and frontal rainfall systems are dominant over the region.

Two major water resources of the country, the Kızılırmak and Sakarya rivers originate in the region with long term annual average flow rates of 184 m^3/s and 134 m^3/s, respectively, at their outlets to the Black Sea. The major dam reservoirs across the region are illustrated in Fig. 1.

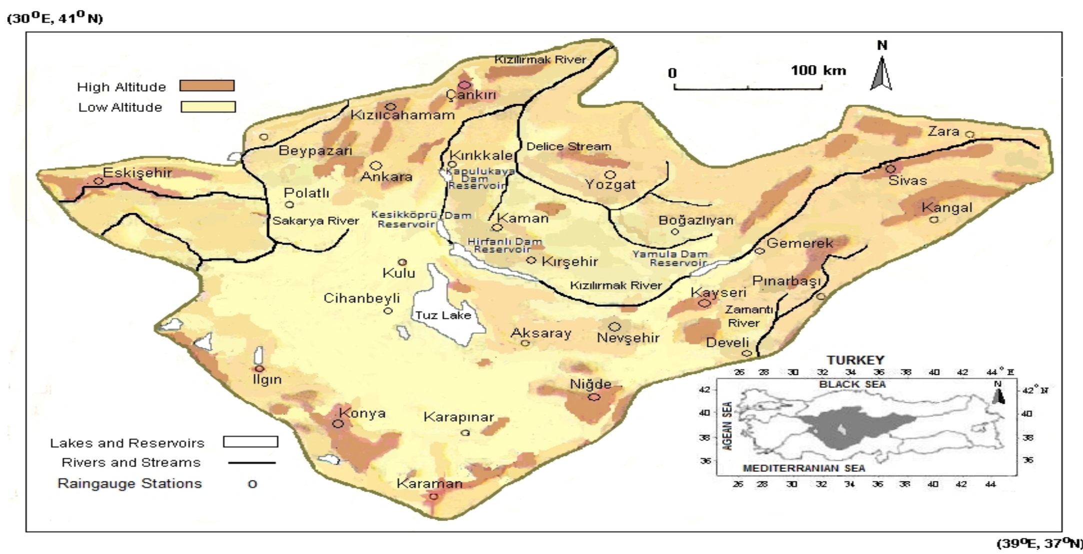

Fig. 1. The study region with meteorology stations and major reservoirs

The characteristics of reservoirs on the Kızılırmak River operated for different purposes are presented in Table 1 below.

Table 1. Characteristics of major reservoirs on the Kızılırmak River

Name	Reservoir Area(km²)	Reservoir Volume (hm³)	Purpose	Hydropower Capacity (MW)	Irrigation Land Area (ha)
Yamula	85.3	2025	Hydropower, irrigation	100	104,000
Hirfanlı	263	5980	Hydropower, flood control	128	-
Kesikköprü	6.5	95	Hydropower, irrigation	76	11,860
Kapulukaya	20.7	282	Hydropower, domestic water supply	54	-

Agriculture is among the major economic sectors in the region where almost one-third of the country's cereal is produced annually. Also, a significant amount of potato and sugar beet across the region are produced. Droughts can cause substantial crop failures in the region. For example, droughts occurred during the periods of 1953-1954, 1956, 1961, 1964, 1969, 1973, 1977, 1984, 1989, 1993-1994, and 1999-2001 resulted in up to 25% decreases in annual cereal production across the region according to Turkish State Statistics Institute [17].

Fig. 2 depicts the temporal evolution of normalized values of spatially averaged annual precipitation between 1950 and 2007 in the Central Anatolia. Here, the major drought events which had severe impacts on agriculture and water resource systems within the region can be easily distinguished. Here, the region seems to be influenced by frequent droughts of various intensities in almost every decade. This is obviously an indication of semiarid characteristic of the region under study.

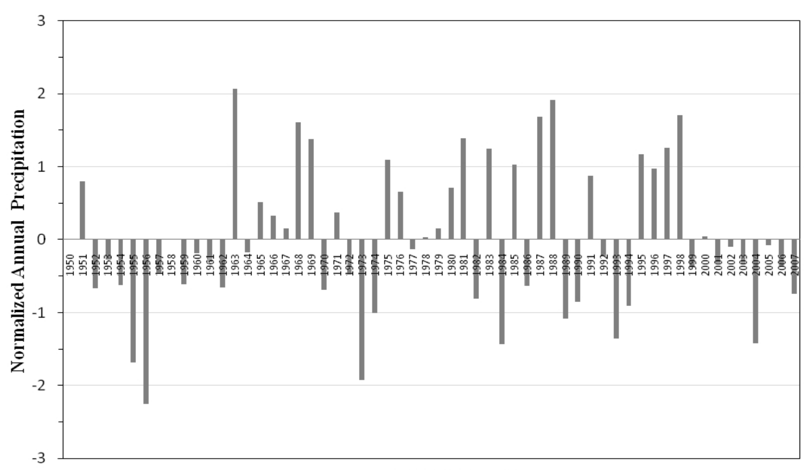

Fig. 2. Normalized values of spatially averaged annual precipitations

The drought frequencies in the region were determined by the spectral analysis of spatially averaged annual precipitations. The variation of spectral density with frequency (cycles/year or cpy) is depicted in Fig. 3 which shows that relatively low frequency droughts (with about 10 to12 years of drought periods) are more dominant in the region. Also, high frequency droughts that occur in every 2 to 6 years seem to prevail over the region.

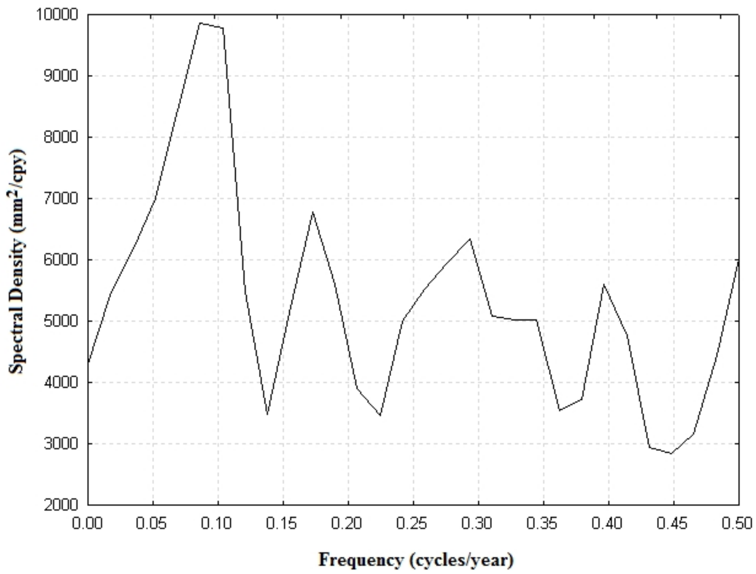

Fig. 3. The spectral analysis of spatially averaged annual precipitations

The influence of droughts on surface waters in the region was assessed using the available streamflow and reservoir storage data. The hydrological response of streamflows recorded at the inlet of the Hirfanlı reservoir to droughts is shown in Fig. 4 where significant decreases in annual flows can be detected during the droughts of 1950s, 1960s, 1970s, 1990s and 2000s.

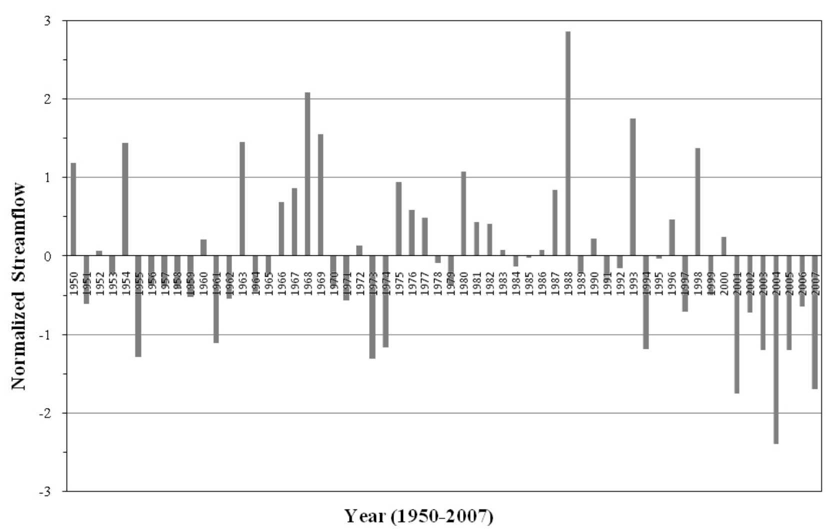

Fig. 4. Normalized annual inflows to the Hirfanlı reservoir

The monthly storage data of the Hirfanlı reservoir between 1980 and 2007 were employed to evaluate the drought effects on reservoir storages (Fig. 5). Here, the hydrological response of reservoir storages to droughts seems to be relatively slow as compared with that of streamflows. In fact, this is in accordance with the results obtained by Yıldız [14] who found that streamflows are more accurately determined by 3-6 month cumulative precipitation, while reservoir storages are more accurately determined by 6-12 month cumulative precipitation in the Central Anatolia region.

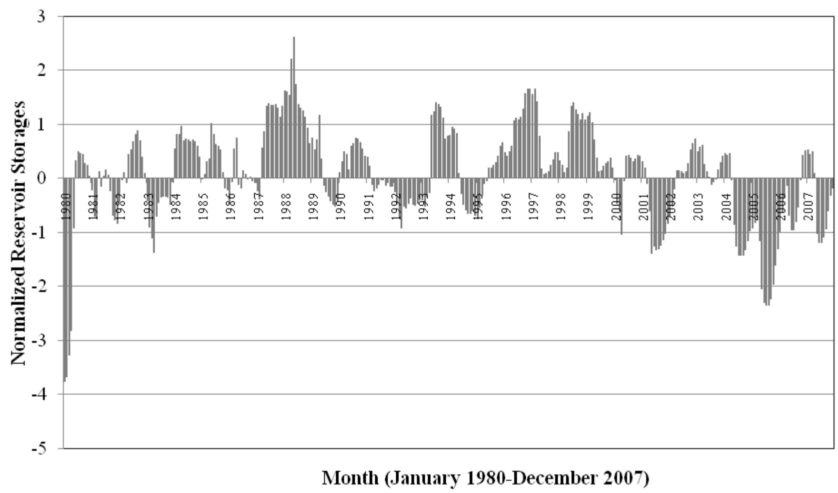

Fig. 5. Normalized monthly storages of the Hirfanlı reservoir.

In this study, the precipitation data between 1950 and 2007 obtained from 27 meteorology stations across the region (see Fig. 1) were utilized for the statistical analysis. The monthly data were acquired from the Turkish State Meteorology Directorate (www.dmi.gov.tr). A summary of geographical information and precipitation statistics for the meteorology stations is given in Table 2.

Table 2. Information on the meteorology stations used in the study

		Geographical Info			Annual Precipitation Statistics		
Index No	Station Name	Altitude (m)	Latitude (°)	Longitude (°)	Mean (mm)	Std. Dev. (mm)	Skewness
1	Aksaray	965	38.23	34.05	335.7	67.7	0.11
2	Ankara	891	39.57	32.53	395.6	78.5	0.33
3	Beypazarı	682	40.10	31.55	392.8	73.2	0.00
4	Boğazlıyan	1066	39.12	35.15	370.6	80.1	0.47
5	Cihanbeyli	969	38.39	32.56	311.4	68.6	0.26
6	Çankırı	751	40.36	33.37	401.9	71.3	-0.42
7	Develi	1180	38.23	35.30	365.0	61.9	-0.04
8	Eskişehir	787	39.78	30.57	371.4	63.6	-0.09
9	Gemerek	1173	39.11	36.04	393.1	62.3	0.33
10	Ilgın	1034	38.17	31.55	425.6	75.9	-0.18
11	Kaman	1075	39.22	33.43	444.9	90.9	0.21
12	Kangal	1545	39.14	37.23	409.2	87.0	0.35

Table 2 Continued…..

13	Karaman	1025	37.11	33.13	326.9	67.0	0.59
14	Karapınar	1004	37.43	33.33	284.7	59.5	0.38
15	Kayseri	1093	38.44	35.29	381.4	74.7	0.63
16	Kırıkkale	747	39.51	33.31	368.0	77.9	0.84
17	Kırşehir	1007	39.09	34.10	378.0	66.6	0.22
18	Kızılcahamam	1033	40.28	32.39	549.0	121.9	0.21
19	Konya	1031	37.52	32.29	314.3	74.5	0.55
20	Kulu	1010	39.06	33.00	372.4	75.8	0.21
21	Nevşehir	1260	38.35	34.40	401.9	77.6	0.16
22	Niğde	1211	37.58	34.41	328.3	66.5	-0.29
23	Pınarbaşı	1500	38.43	36.24	420.9	78.8	0.02
24	Polatlı	885	39.35	32.09	353.8	65.7	0.35
25	Sivas	1285	39.45	37.01	425.9	71.6	-0.09
26	Yozgat	1298	39.49	34.48	567.5	102.4	0.30
27	Zara	1348	39.54	37.45	515.1	115.5	-0.73

4. RESULTS AND DISCUSSION

The annual precipitations and their standard normal variates for the selected drought years (i.e., 1956, 1973, 1984, 1989, 1993 and 2004) are given in Table 3. The regional averages (RA) of annual precipitations were first obtained by the Thiessen polygons method and their standard normal variates were calculated afterwards. Here, the standard normal variate is only employed as a general drought assessment parameter not as an index which aims to classify the severity of a drought into classes.

The Box-plots of the annual and seasonal (i.e., winter, autumn, spring and summer) precipitation data for each station and the regional averages are given in Figs. 6 to 10. The values for the selected drought years also are shown on the same figures for comparison. The seasonal variabiliy of precipitations enable to better evaluate the temporal evolution of drought and the impact of drought on water resources and agriculture as well.

The spatial maps of precipitation deficits expressed as a percentage of the mean annual precipitation for the selected drought years are shown in Fig. 11. Here, the areal distribution of annual precipitation deficits across the region can be observed visually.

The evaluation of annual and seasonal precipitation data reveals that, in the 1950s, the region was affected by a 6 year drought period from 1952 to 1957 (please refer to Fig. 2). It was shown that the drought of 1956 was among the most extreme and wide spread droughts occurred in the study region. In fact, with the lowest regional average annual standard normal variate (i.e., z value) more than half of the stations had their annual z values lower than -1.5 (see Table 3) during this year. Also, Fig. 11(a) displays that almost the whole region was influenced by significant decreases in precipitations up to 50%. As the seasonal Box-plots display the drought of 1956 was mostly due to precipitation anomalies in spring, summer and autumn. The hydrological response of surface flows in the region to droughts is quite apparent in Fig. 4, which displays that the annual inflows to the Hirfanlı dam reservoir were lower than the normal levels between 1955 and 1959 (i.e., five years in a row). This shows that the streamflows are quite sensitive to precipitation deficits in the study area as an indication of its semiarid characteristics.

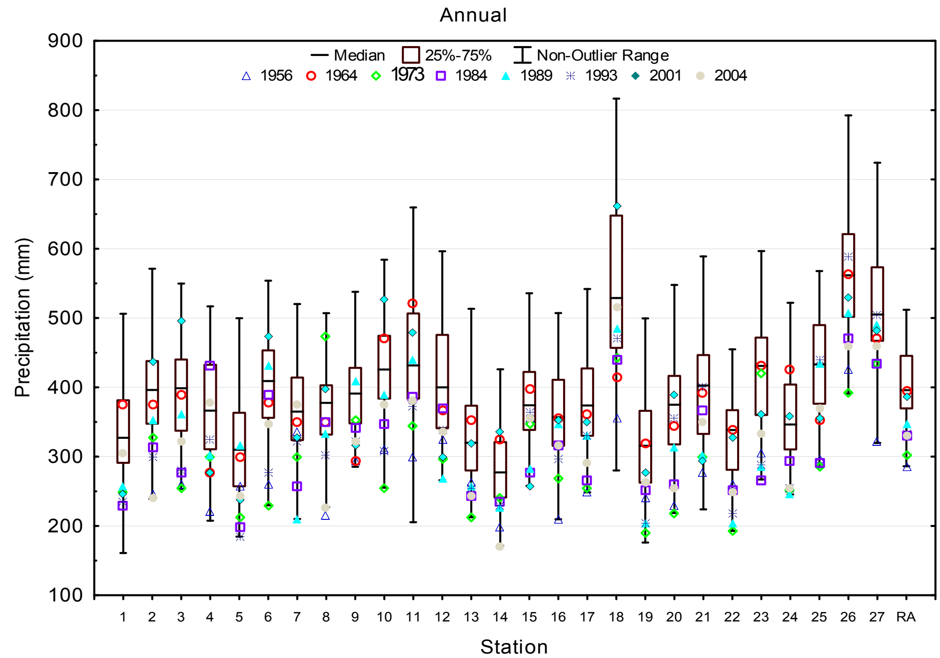

Fig. 6. Box-plots for annual precipitations between 1950 and 2007

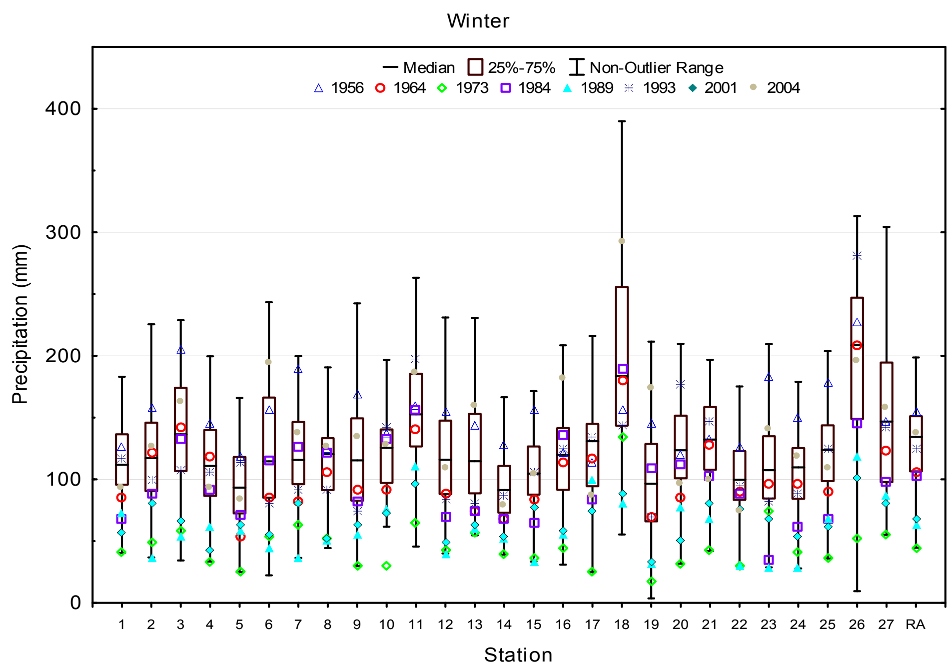

Fig. 7. Box-plots for winter (December-February) precipitations between 1950 and 2007

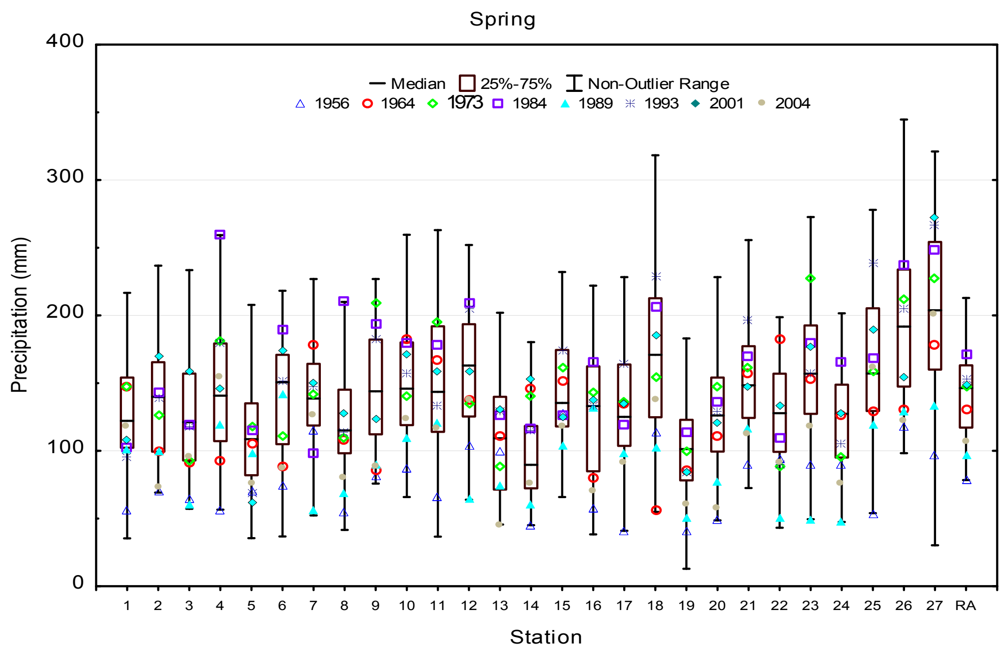

Fig. 8. Box-plots for spring (March-May) precipitations between 1950 and 2007

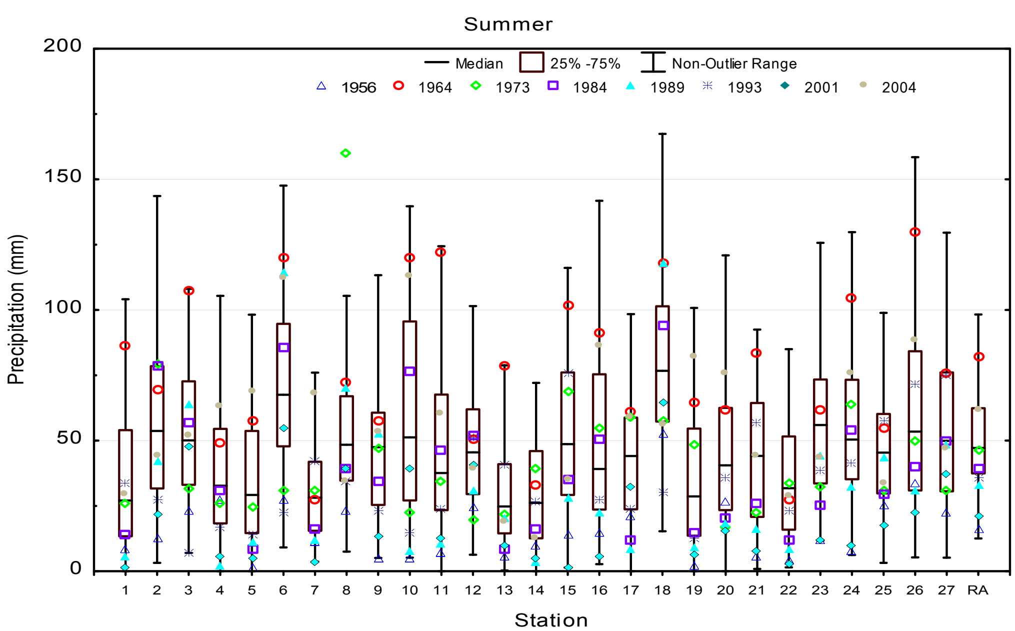

Fig. 9. Box-plots for summer (June-August) precipitations between 1950 and 2007

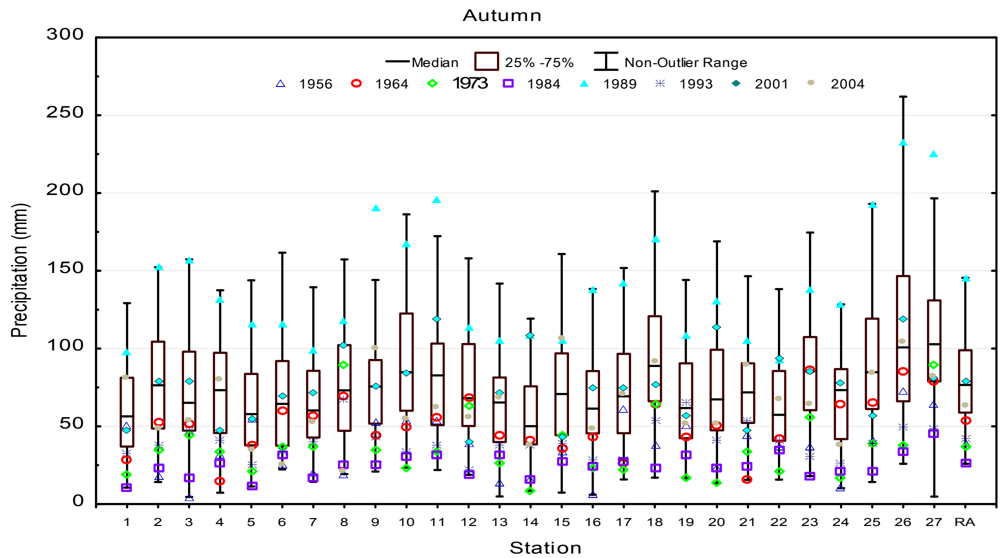

Fig. 10. Box-plots for autumn (Sept.-November) precipitations between 1950 and 2007

As Fig. 2 indicates the region was subject to a 3 year drought period from 1972 to 1974. In 1973, the annual precipitations at most stations were much lower than the long term averages and, therefore, almost the entire region was again under the influence of extreme drought conditions. As shown in Fig. 11(b) the annual precipitation deficits over the region were up to 45%. Referring to Figs. 7 and 10, the drought of 1973 mainly resulted from relatively low precipitations in winter and autumn. The regional water resources were obviously stressed by the droughts in 1973 and 1974, since significant decreases in the annual inflows to the Hirfanlı reservoir were recorded during these years (Fig. 4).

Referring to the annual and seasonal precipitation Box-plots, the drought of 1984 was mainly caused by below normal precipitations in autumn (see Fig. 8). In fact, almost half of the stations had precipitation deficits up to 40% during this year as shown in Fig. 11(c). This drought, however, seemed to have a slight impact on surface waters in the region as shown in Figs 4 and 5, due mainly to the wet period in the previous year (Fig. 2).

A relatively moderate to severe type of drought in 1989 prevailed over the region as a result of low precipitations during winter, spring and summer seasons. The majority of the stations received below normal precipitations, especially those located at the south of the region as shown in Fig. 11(d). Actually, the region was still under the influence of drought through 1990 with a relatively lower intensity though (Fig. 2). On the other hand, as shown in Fig. 4, the drought impact on the surface flows in 1989 seemed to be lessened by above normal precipitations during the previous years. Referring to Fig. 5 the Hirfanlı reservoir seemed to respond quickly to winter and spring precipitation deficits and the storage levels declined afterwards.

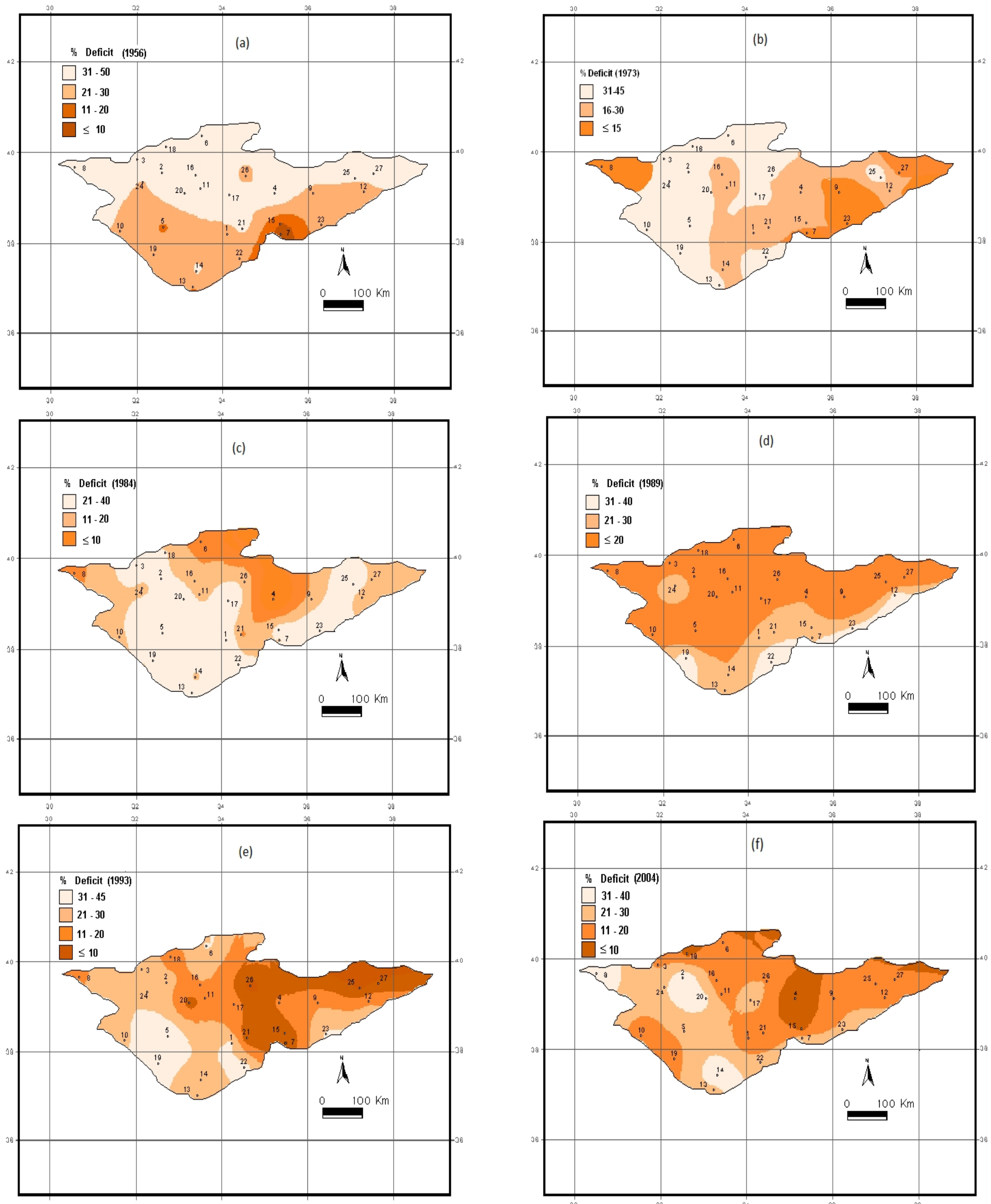

Fig. 11. Spatial maps of precipitation deficits for the selected drought years (a: 1956, b:1973, c:1984, d:1989, e:1993, f: 2004)

Table 3. The annual precipitations and standard normal variates for the selected drought years

		Precipitation (mm)						Standard normal variate (z)					
Index no	**Station name**	**1956**	**1973**	**1984**	**1989**	**1993**	**2004**	**1956**	**1973**	**1984**	**1989**	**1993**	**2004**
1	Aksaray	253.5	247.8	228.8	257.3	236.0	303.7	-1.21	-1.30	-1.58	-1.16	-1.47	-0.47
2	Ankara	247.5	328.3	313.9	351.7	300.3	239.1	-1.89	-0.86	-1.04	-0.56	-1.21	-1.99
3	Beypazarı	260.1	253.4	276.3	361.7	280.6	321.9	-1.81	-1.90	-1.59	-0.42	-1.53	-0.97
4	Boğazlıyan	221.9	300.2	432.2	302.3	325.0	378.5	-1.86	-0.88	0.77	-0.85	-0.57	0.10
5	Cihanbeyli	257.2	213.2	197.1	315.4	184.6	242.9	-0.79	-1.43	-1.67	0.06	-1.85	-1.00
6	Çankırı	261.0	229.8	389.6	431.7	276.3	346.2	-1.98	-2.41	-0.17	0.42	-1.76	-0.78
7	Develi	335.2	298.7	256.4	210.1	321.8	375.5	-0.48	-1.07	-1.76	-2.50	-0.70	0.17
8	Eskişehir	215.8	473.2	350.0	331.9	302.7	227.1	-2.45	1.60	-0.34	-0.62	-1.08	-2.27
9	Gemerek	294.7	353.1	341.5	410.0	321.7	321.8	-1.58	-0.64	-0.83	0.27	-1.15	-1.14
10	Ilgın	310.5	255.3	347.9	388.2	306.8	376.1	-1.52	-2.24	-1.02	-0.49	-1.57	-0.65
11	Kaman	298.9	343.0	386.0	439.4	371.9	379.4	-1.61	-1.12	-0.65	-0.06	-0.80	-0.72
12	Kangal	323.7	295.3	368.3	267.2	337.4	336.3	-0.98	-1.31	-0.47	-1.63	-0.83	-0.84
13	Karaman	264.0	212.6	242.2	256.5	255.6	242.1	-0.94	-1.70	-1.26	-1.05	-1.06	-1.26
14	Karapınar	197.9	241.0	234.1	227.2	228.3	171.6	-1.46	-0.73	-0.85	-0.97	-0.95	-1.90
15	Kayseri	354.4	347.7	275.8	281.4	364.1	354.4	-0.36	-0.45	-1.41	-1.34	-0.23	-0.36
16	Kırıkkale	209.7	269.4	316.0	346.3	296.7	315.8	-2.03	-1.27	-0.67	-0.28	-0.92	-0.67
17	Kırşehir	248.5	254.2	266.7	329.0	330.1	290.2	-1.95	-1.86	-1.67	-0.74	-0.72	-1.32
18	Kızılcahamam	356.9	443.6	438.8	484.8	470.6	515.6	-1.58	-0.86	-0.90	-0.53	-0.64	-0.27
19	Konya	241.0	191.3	250.7	202.6	203.6	262.5	-0.98	-1.65	-0.85	-1.50	-1.49	-0.70
20	Kulu	230.2	218.7	260.5	312.6	355.8	254.5	-1.88	-2.03	-1.48	-0.79	-0.22	-1.56
21	Nevşehir	277.1	299.2	367.9	302.8	400.9	350.3	-1.61	-1.32	-0.44	-1.28	-0.01	-0.67
22	Niğde	259.7	192.9	251.8	203.2	216.6	250.1	-1.03	-2.04	-1.15	-1.88	-1.68	-1.18
23	Pınarbaşı	306.4	421.2	267.1	285.3	289.0	334.0	-1.45	0.00	-1.95	-1.72	-1.67	-1.10
24	Polatlı	254.9	252.6	294.0	245.5	253.2	253.8	-1.51	-1.54	-0.91	-1.65	-1.53	-1.52
25	Sivas	295.5	284.8	290.4	433.7	438.8	368.9	-1.82	-1.97	-1.89	0.11	0.18	-0.80
26	Yozgat	426.2	391.0	471.4	508.5	588.4	460.5	-1.38	-1.72	-0.94	-0.58	0.20	-1.05
27	Zara	321.6	434.8	433.9	491.5	504.7	458.9	-1.67	-0.70	-0.70	-0.20	-0.09	-0.49
	RA	286.3	303.0	329.1	347.2	332.9	329.6	-2.25	-1.93	-1.43	-1.09	-1.36	-1.42

Almost the entire region was affected by the drought of 1993 because of significant decreases in precipitations in summer and autumn (Figs. 9 and 10). As shown in Fig. 11(e) the precipitation deficit ranged from 20 to 40% over more than half of the region. The analysis of the monthly precipitation data suggest that high streamflows during 1993 were actually resulted from above normal precipitations beginning by the autumn of 1992 through the summer of 1993. Therefore, the decreases in streamflows due to the drought in 1993 seemed to take place later in 1994. The Hirfanlı dam reservoir was actually below normal levels for about 24 months before the spring of 1993. The drought effects of 1993 and 1994 on the reservoir storages appeared after the spring of 1994 and lasted for about a year.

The region was actually under the impact of about a 7-8 year drought period from the end of 2000 to 2009. According to the precipitation statistics in Table 3, the drought of 2004 was caused by record low precipitations since 1973 across the region, especially during spring and autumn seasons (see the Box-plots in Figs. 8 and 10). As shown in Fig. 11(f) the precipitation deficits were relatively high (up to 40%) in the western and partially the southern parts of the region. The hydrological response to low precipitations was apparent during the entire drought period. Actually, the streamflows were significantly low during the drought of 2004 (Fig. 4). The influence of droughts on reservoir storages was more visible in the 2000s. In fact, the Hirfanlı reservoir was below normal levels for more than 2 years after the spring of 2004 (Fig. 5).

5. SUMMARY AND CONCLUSION

This study presented an evaluation of precipitation varaiability and its connections with dry years years in the Central Anatolia region, Turkey. The study region is actually characterized as a semiarid region and subject to frequent droughts which affect regional water resources and cause substantial agricultural and economic losses. The droughts of 1956, 1973, 1984, 1989, 1993 and 2004 were selected for statistical analysis to obtain useful information for drought mitigation and water resource management purposes within the region. The Box-plots of annual and seasonal precipitations were utilized for determining the regional drought characteristics. The spatial maps of precipitation deficits for the selected drought years were utilized for assessing the areal impacts of droughts. The hydrological responses to droughts were also investigated using streamflow and reservoir storage data in the region.

The evaluation of annual and seasonal precipitation data indicated that the Central Anatolia is usually under the influence of frequent droughts with varying intensity and spatial characteristics. The spectral analysis of spatially averaged annual precipitations revealed that the region is more dominated by relatively low frequency droughts (with about 10-12 years of periods). It was also shown that relatively high frequency droughts occur in the region (with 2-6 years of periods). The evaluation of study results indicated that the selected droughts were of relatively high intensity and wide spread.

The precipitation deficits or decreases during the drought periods were as high as 30-50% across the region. The annual and seasonal Box-plots of precipitations displayed that the region received significantly low precipitations, especially in the 1950s and 1970s during which more than half of the region was under the influence of extreme droughts. The droughts in the recent decade had obviously significant impacts on the hydrological system in the region. Actually, the region was affected by a drought lasted about 7-8 year between 2000 and 2009 during which extremely low precipitations were recorded since 1973. The evaluation of hydrological response to precipitation deficits showed that the surface water resources are affected from droughts at different time scales. In other words, the drought effects on streamflows and reservoirs take place within 3-6 months and 6-12 months, respectively.

Overall, the study results suggest that useful information on regional droughts can be obtained by relatively simple methods. The evaluation of precipitation varaiability and its connections with dry years in the Central Anatolia enabled to determine the general characteristics of droughts and their impacts on regional water resources. The results of the study presented, analyzed and discussed in this paper can provide valuable guides for drought mitigation and sustainable water resources planning and management purposes in the Central Anatolia. Further studies can be conducted to better understand the impact of droughts on other surface water systems and groundwater as well in the region.

ACKNOWLEDGMENTS

This research is funded by the Kırıkkale University Scientific Projects Unit with project number BAP 2008/53. The author wishes to thank the university administration for its financial support.

COMPETING INTERESTS

The author has declared that no competing interests exist.

REFERENCES

1. Wilhite DA, Buchanan-Smith M. Drought and water crisis: science, technology, and management issues, Edited by Donald A. Wilhite, Taylor & Francis Group. 2005;406.
2. Dracup JA, Lee KS, Paulson Jr. EG. On the definition of droughts. Water Resources Research. 1980;16(2):297-302.
3. Mishra AK, Singh VP. A review of drought concepts. Journal of Hydrology. 2010;391(1–2):202-216.
4. Mishra AK, Singh VP. Drought modeling–A review. Journal of Hydrology. 2011;403(1–2): 157-175.
5. Türkeş M. Spatial and temporal analysis of annual rainfall variations in Turkey. International Journal of Climatology. 1996;16:1057-1076.
6. Komuscu AÜ. An analysis of recent drought conditions in Turkey in relation to circulation patterns. Drought Network News. 2001;13(2-3):5-6.
7. Shin HS, Salas JD. Regional drought analysis based on neural networks. Journal of Hydrologic Engineering. 2000;5(2):145-155.
8. Kim Tae-W, Valdés JB, Aparicio J. Frequency and spatial characteristics of droughts in the Conchos River basin, Mexico. IWRA Water International. 2002;27(3):420-430.
9. Sırdaş S, Şen Z. Spatio-temporal drought analysis in the Trakya region, Turkey. Hydrological Sciences Journal. 2003;48(5):809-820.
10. Vicente-Serrano SM, López-Moreno JI. Hydrological response to different time scales of climatological drought: An evaluation of the standardized precipitation index in a mountainous Mediterranean basin. Hydrology and Earth System Sciences. 2005;9:523-533.
11. Mishra AK, Desai VR. Spatial and temporal drought analysis in the Kansabati River Basin, India. Int J River Basin Management. 2005;3(1):31–41.
12. Vicente-Serrano SM. Spatial and temporal analysis of droughts in the Iberian Peninsula. Hydrological Sciences Journal. 2006;51(1):83-97.

13. Yıldız O. Investigating frequency and spatial characteristics of droughts in the Central Anatolian region, Turkey, International Congress River Basin Management Antalya, Turkey. 2007;2:235-243.
14. Yıldız O. Assessing temporal and spatial characteristics of droughts in the Hirfanlı Dam basin, Turkey. Scientific Research and Essays. 2009;4(4):249-255.
15. Burke EJ, Brown SJ. Regional drought over the UK and changes in the future. Journal of Hydrology. 2010;394:471–485.
16. Núñez JH, Verbist K, Wallis JR, Schaefer MG, Morales L, Cornelis WM. Regional frequency analysis for mapping drought events in north-central Chile. Journal of Hydrology. 2011;405:352–366.
17. Turkish State Statistics Institute. Agricultural Status, Production, Cost, Price; 2002. Available: http://www.die.gov.tr/

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=560&id=22&aid=4858