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Using the SPI to Analyze Spatial and Temporal Patterns of Drought in Turkey

Ali Umran Komuscu
Turkish State Meteorological Service

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Introduction

Drought is a natural phenomenon that has significant economic, social, and environmental impacts. Drought differs from other natural hazards in that its onset and end are difficult to determine. It develops slowly, and its impacts may remain for years after termination of the event. No single definition of drought exists that applies to all circumstances, but most definitions of drought are based on an expression of deficiency of precipitation resulting in water shortage for some activity related to use of water (Wilhite and Glantz, 1985; Dracup et al., 1980). Water resources planners usually rely on quantitative indices to decide whether or not a drought exists. Consequences of drought are usually defined by the impacts that human use systems place on water supply. Drought impacts are usually first apparent in agriculture but gradually move to other water-dependent sectors. Recovery time for water stored in surface and subsurface systems can be quite long under severe drought conditions.

Risk of drought is still a major concern in parts of Turkey where precipitation amounts are low and extremely variable. The combination of rainfall deficiency and other climatic factors, especially high temperature, creates a serious risk of drought in the central and southeastern parts of the country, where agriculture is the main economic sector (Komuscu, 1998). The impacts of drought in the low and variable rainfall regions of the country can be widespread, affecting such diverse sectors as agriculture, irrigation, and energy. In particular, the southeastern Anatolian region, which is the host of the Southeastern Anatolian Project (GAP), may face a serious threat from persisting drought conditions. Moreover,

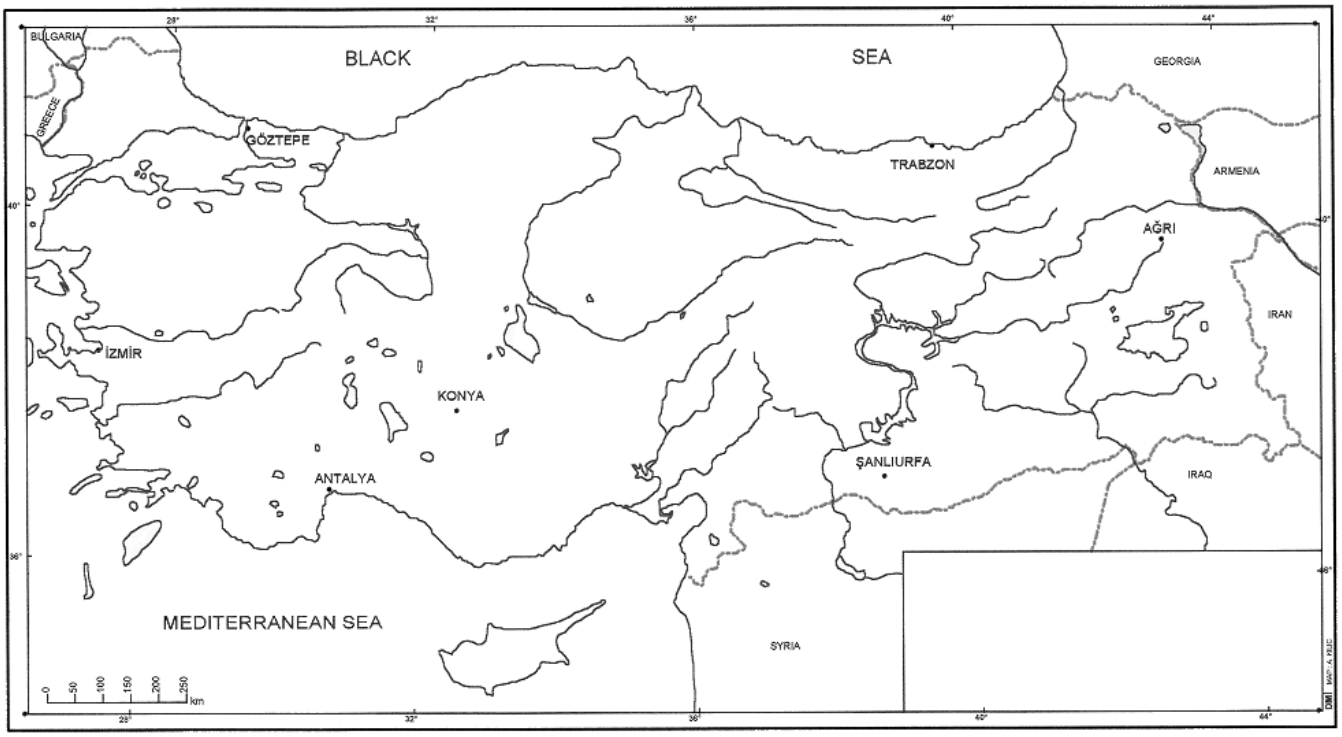

Figure 1. Geographical distribution of the stations selected for the SPI analysis.

the project includes large-scale irrigation, which stimulates higher competition among the water-dependent sectors.

Use of the SPI for drought analysis and monitoring

The impact of rainfall deficiency on water resources varies markedly on a temporal scale for different water storage components of the hydrologic system. While soil moisture responds to precipitation anomalies on a relatively short scale, groundwater, streamflow, and reservoir storage reflect longer-term precipitation anomalies. McKee et al. (1993) developed the Standardized Precipitation Index (SPI) to quantify the precipitation deficit for multiple time scales, reflecting the impact of precipitation deficiency on the availability of various water supplies. They calculated the SPI for 3-, 6-, 12-, 24-, and 48-month scales to reflect the temporal behavior of the impact. The SPI provides a quick and handy approach to drought analysis. Other advantages of this approach are its relative simplicity and minimal data requirements.

Methodology

The SPI is calculated by taking the difference of the precipitation from the mean for a particular time scale, then dividing it by the standard deviation:

$$SPI = \frac{x_i - \bar{x}_i}{\sigma}$$

The calculations become more complicated when the SPI is normalized to reflect the variable behavior of the precipitation for time scales shorter than 12 months. The normalized series of SPI values represent wetter and drier climates in the same way. McKee et al. (1994) defined the criteria for a drought event for all of the time scales and classified the SPI to define various drought intensities (Table 1).

The SPI is a relatively new index, and it has not been widely applied or tested. In this study, we tested the SPI for different climatic regions and investigated its potential use as a tool for monitoring drought in Turkey.

SPI values	Drought category
0 to -0.99	mild drought
-1.00 to -1.49	moderate drought
-1.50 to -1.99	severe drought
-2.0	extreme drought

Table 1. SPI categories.

Analysis and Results

SPI values have been computed for 40 stations, but only 7 stations representing the different climatic regions across the country will be presented here for 3-, 6-, 12-, and 24-month scales, covering 1940-97 (Figure 1). Figure 2 shows time series of the SPI values computed for Konya station for the 3-, 6-, 12-, and 24-month time scales. Konya is located in the central Anatolian region of Turkey, where the annual rainfall is around 300 mm. The most striking characteristic of the drought is the change in drought frequency as the time scale changes (shown in Figure 2). On longer time scales, drought becomes less frequent but lasts longer. At the 3-month scale, drought frequency increases but its duration decreases. In other words, on shorter time scales, drought becomes more frequent but lasts for shorter periods. Another interesting point shown by Figure 2 is that the SPI responds quickly to wet and dry periods, which means that each new month has a large influence on the period sum of precipitation. This also means more droughts of shorter duration. On the other hand, as the time scale increases, the index responds more slowly. In other words, as the time scale increases, each new month has less impact on the total, which is indicative of fewer droughts of longer duration. Both cases (more droughts but shorter duration, fewer droughts but longer duration) can be interpreted differently for different water resources. For example, soil moisture in the Konya region can be more sensitive to a 3-month drought, but it may take more time to see the effect of drought on underground water resources of the region.

Long-term series of the 3-month SPI values are presented for the 7 stations in Figure 3. It is interest-

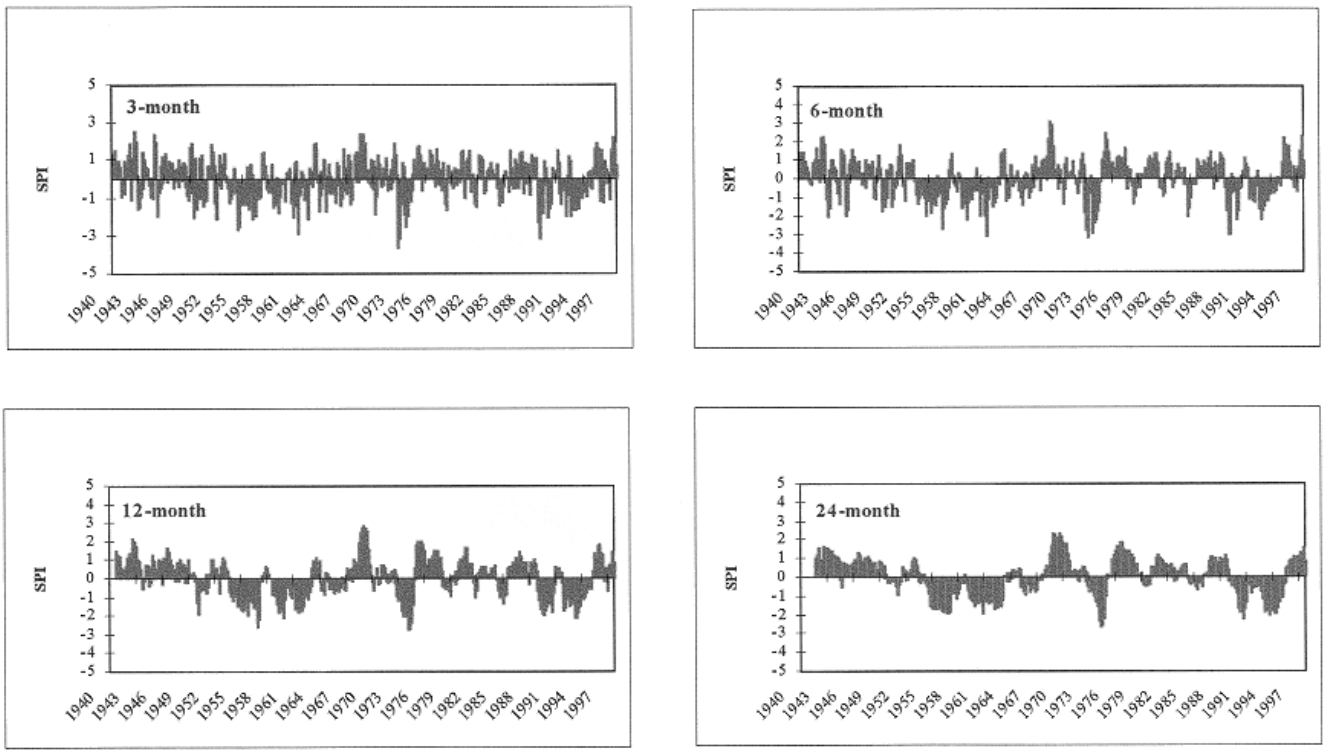

Figure 2. SPI values at varying time scales for Konya station.

ing to note that almost all regions suffer from drought to some degree, but not all the regions experience well-defined droughts during the same periods. In other words, temporal distribution and frequency of the dry periods varies markedly among the regions. Although the dry spans are more persistent and continuous in the coastal stations, the eastern Anatolian station experiences drought at a lower frequency. When we move to 6-month and 12-month SPI time series, the dry spans defined previously expand and occur at lower frequencies (Figures 4 and 5). It is interesting to note that as the time scale increases, drought occurs at higher frequencies at the coastal stations while the inner stations experience longer-duration droughts at lower frequencies, indicating that seasonal droughts are more common in the coastal areas while the interior parts of the country suffer from prolonged droughts. Sanliurfa, the southeastern Anatolian station, differs from the other locations in the sense that it suffers from short-duration but frequently occurring droughts, which may lead to serious adverse impacts for the agricultural activities in the region. Sanliurfa is in the center of the Southeastern Anatolian Project (GAP), which is a massive agricultural and water resources development program within the Turkish portions of the Euphrates and Tigris river basins. The region receives very little rainfall in the summer, creating very dry conditions coupled with high temperatures. Therefore, one of the goals of the project is the irrigation of large areas to reduce the impact of severe droughts.

Table 2 shows the time category of the drought events observed in each station for 3-, 6-, and 12-month time scales. Geographical variations in the time category of droughts present interesting patterns. On a 3-month scale, the coastal stations suffer from mild droughts more often than the interior stations, with the exception of the Sanliurfa station. Interestingly, the coastal stations suffer from severe drought more often than do the interior stations. These similar trends continue on the larger time

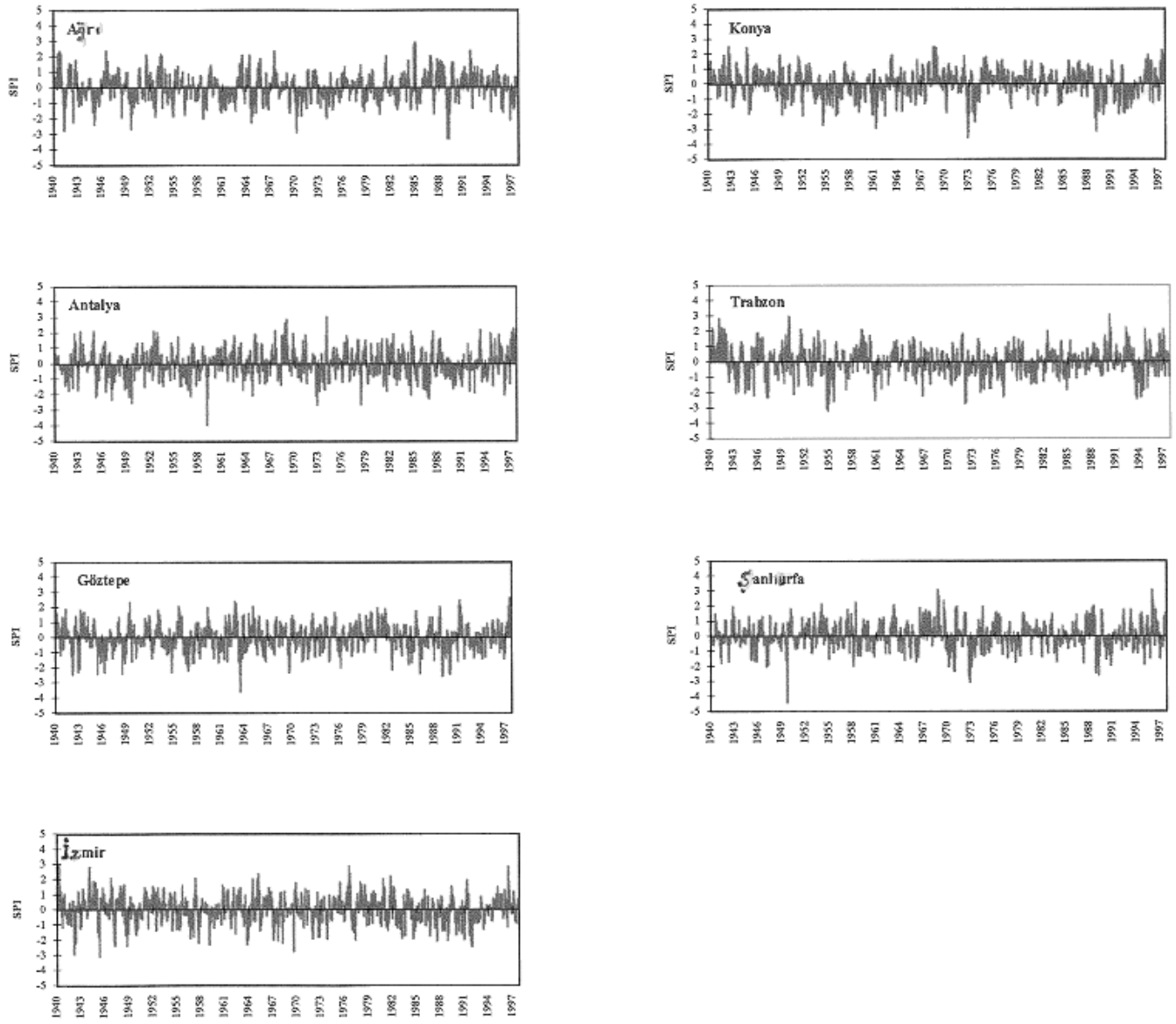

Figure 3. Three-month SPI values for selected stations.

scales. Severe droughts, however, become more common on the 6-month scale in the central parts of the country where rainfall is very low. On the other hand, two Black Sea stations, Trabzon and Göztepe, have the most frequent drought events on a 12-month scale in almost all drought categories. This indicates that coastal parts of the country are affected by both short- and long-duration droughts at different levels while the interior stations are under the influence of long-lasting mild droughts. The most interesting results are observed in the Sanliurfa station, located in the center of the GAP. This station is affected mainly by mild droughts. It is not affected by severe droughts as much as the coastal stations are, although it receives less rainfall.

In this study, we presented a brief drought analysis using the SPI and demonstrated its potential use for drought analysis with minimal data requirements. It is our view that development of a drought monitoring system, based largely on meteorological and climatic information, can be a great help for early assessment of drought impacts in Turkey. In this

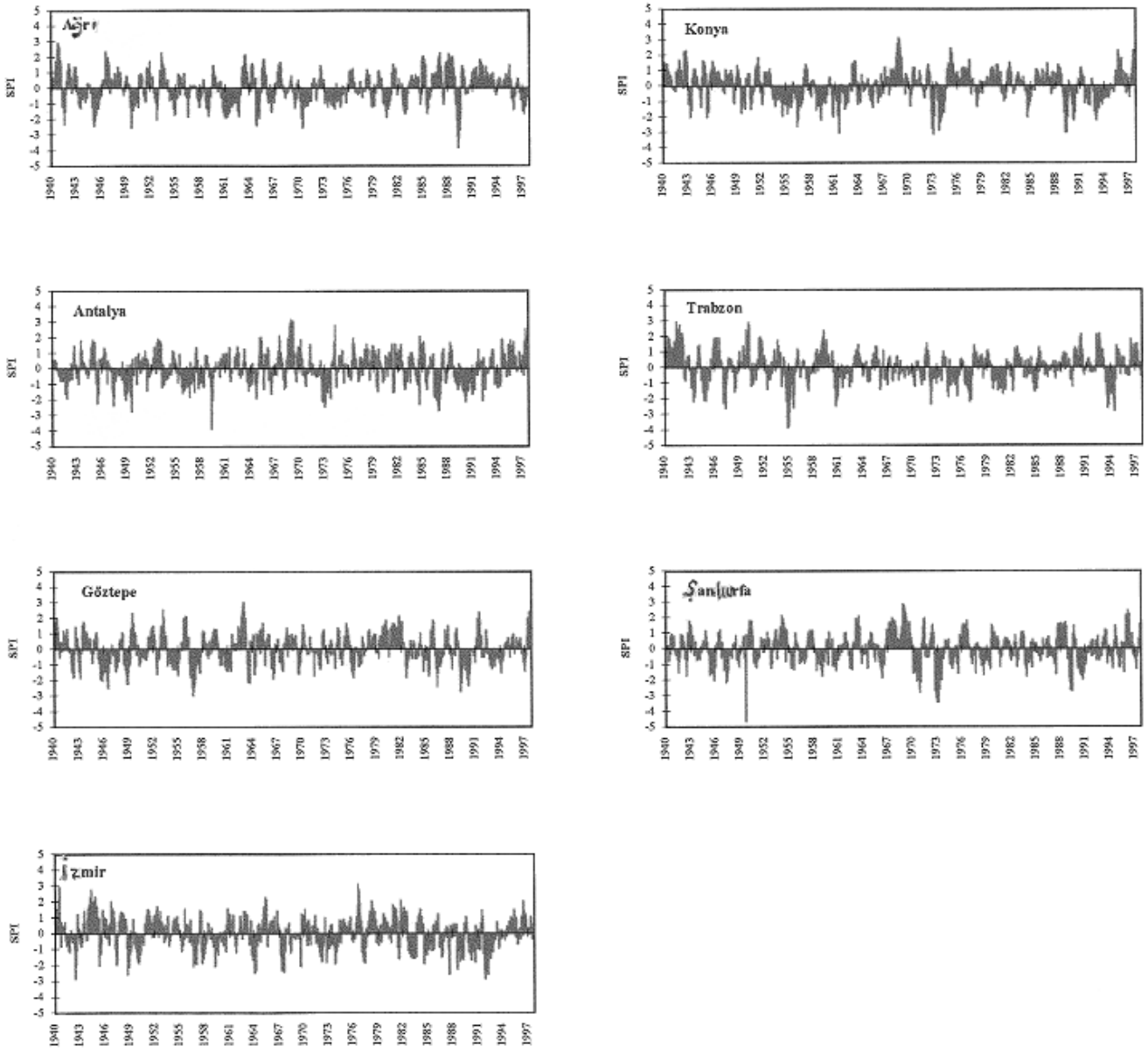

Figure 4. Six-month SPI values for selected stations.

sense, the SPI can be a valuable tool for monitoring climatic conditions, particularly in drought-prone areas of the country.

Dr. Ali Umran Komuscu
Turkish State Meteorological Service
Research Department
Kalaba 06120
Ankara, Turkey

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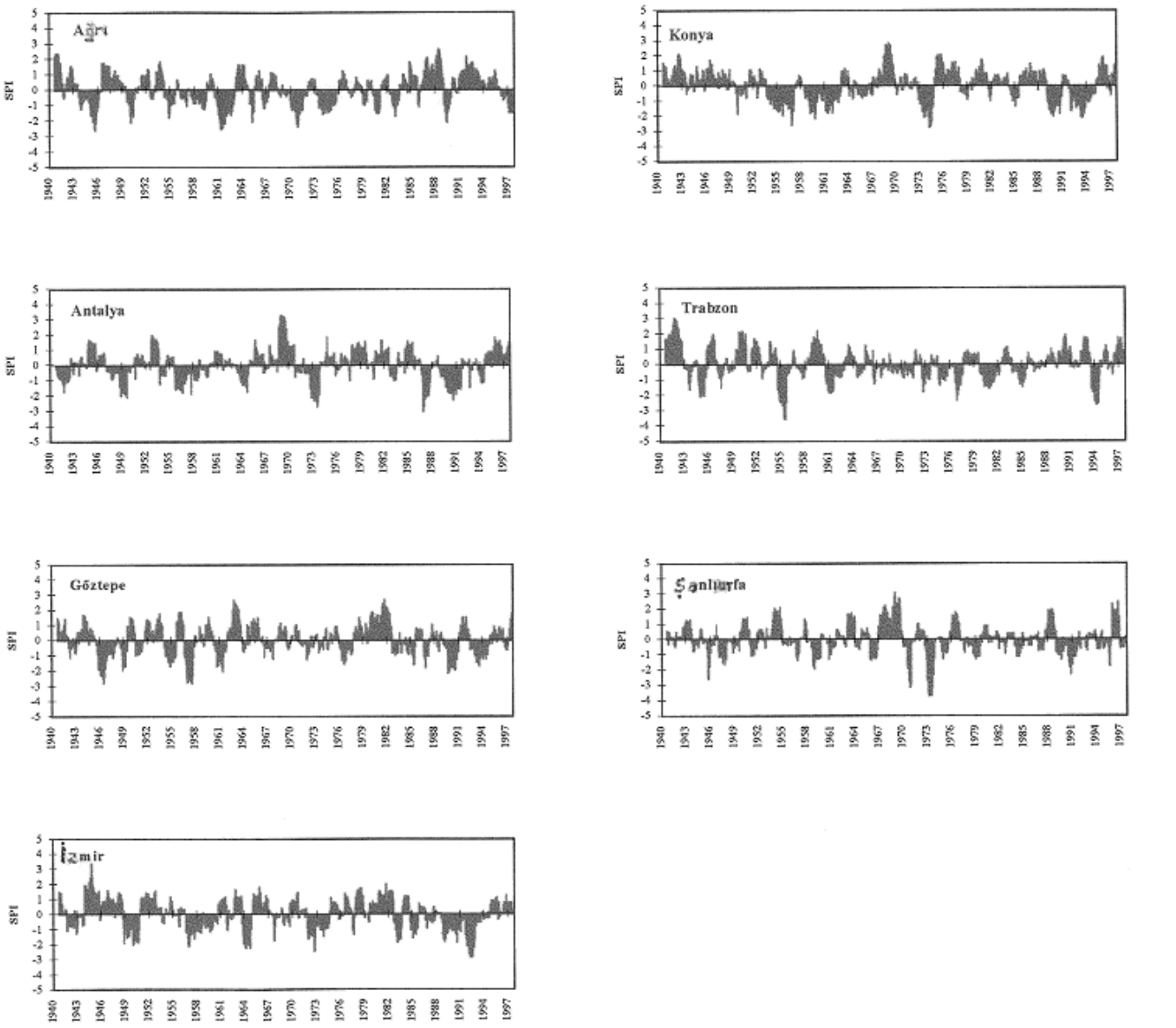

Figure 5. Twelve-month SPI values for selected stations.

AĞRI

SPI	Drought category	Time (%) (3 mo.)	Time (%) (6 mo.)	Time (%) (12 mo.)
0 to -0.99	mild	32.2	31.8	31.3
-1.00 to -1.49	moderate	10.8	10.8	10.3
-1.50 to -1.99	severe	3.9	3.9	4.6
≤-2.0	very severe	1.8	2.1	2.6

ANTALYA

SPI	Drought category	Time (%) (3 mo.)	Time (%) (6 mo.)	Time (%) (12 mo.)
0 to -0.99	mild	33.8	34.7	32.4
-1.00 to -1.49	moderate	9.2	8.1	5.7
-1.50 to -1.99	severe	3.6	4.2	6.2
≤-2.0	very severe	2.6	2.7	2.7

GÖZTEPE

SPI	Drought category	Time (%) (3 mo.)	Time (%) (6 mo.)	Time (%) (12 mo.)
0 to -0.99	mild	32.8	34.1	35.3
-1.00 to -1.49	moderate	10.3	10.1	7.1
-1.50 to -1.99	severe	3.1	4.3	4.5
≤-2.0	very severe	3.0	2.0	2.9

İZMİR

SPI	Drought category	Time (%) (3 mo.)	Time (%) (6 mo.)	Time (%) (12 mo.)
0 to -0.99	mild	32.7	31.8	29.2
-1.00 to -1.49	moderate	8.7	8.8	10.0
-1.50 to -1.99	severe	3.6	5.2	5.1
≤-2.0	very severe	2.7	2.9	2.4

KONYA

SPI	Drought category	Time (%) (3 mo.)	Time (%) (6 mo.)	Time (%) (12 mo.)
0 to -0.99	mild	31.7	30.5	28.1
-1.00 to -1.49	moderate	8.6	9.2	9.2
-1.50 to -1.99	severe	4.1	3.6	6.2
≤-2.0	very severe	3.0	3.4	2.3

TRABZON

SPI	Drought category	Time (%) (3 mo.)	Time (%) (6 mo.)	Time (%) (12 mo.)
0 to -0.99	mild	34.4	36.1	39.8
-1.00 to -1.49	moderate	7.6	6.9	5.6
-1.50 to -1.99	severe	3.7	3.9	4.2
≤-2.0	very severe	3.3	3.1	3.2

SANLIURFA

SPI	Drought category	Time (%) (3 mo.)	Time (%) (6 mo.)	Time (%) (12 mo.)
0 to -0.99	mild	37.7	34.0	39.1
-1.00 to -1.49	moderate	7.5	7.9	9.3
-1.50 to -1.99	severe	4.0	3.3	2.1
≤-2.0	very severe	1.7	2.9	2.0

Table 2. Time category of the drought events for 3-, 6-, and 12-month time scales for the selected stations.