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Full Length Research Paper

Importance of annual and seasonal precipitation variations for the sustainable use of rangelands in semi arid regions with high altitude

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Precipitation is one of the most important factors which can determine the type and productivity of rangeland vegetation in arid and semi arid regions. In the present study, a widely used drought analysis index, Standard Precipitation Index (SPI), was used considering an eighty–year precipitation data set belonging to Erzurum province. Data was analysed in order to estimate the length, magnitude and severity of drought period in Erzurum province. According to the results of the present study, it was found that long term average precipitation was normal or close to normal in 56 years (70%), 11 years (13.75%) were moderately dry, one year (1.25%) was severely dry while the number of moderately, severely and extremely wet years was 3 (3.75%), 7 (8.75%) and 2 (2.5%) respectively.

Key words: Precipitation, standard precipitation index, drought, rangeland.

INTRODUCTION

Rangelands consist of an important part of surface area of both Turkey and the world and are significant source values for not only being forage reserves but also contributing to water reserves and providing recreational areas, biodiversity and nature conservation and ecological balance.

Precipitation which is an important element for plant development is also vitally important for the productivity of rangelands especially those in arid and semi arid regions. Climatic changes which are accelerated by the alterations in the atmosphere can result in the differences in the productivity of rangelands as in all plant productions (Herbel and Pieper, 1991; Pittock, 1995).

Not only the amount of precipitation but also its seasonal distribution is important for the productivity of rangelands (Le Houerou, 1984). In the rangelands dominated by cool season grassy plants, autumn and winter precipitation is especially important (Hanson and Lewis, 1978; Herbel and Gibbens, 1989; Vallentine, 1990; Te Krony and Egli, 1991; Hafercamp et al., 1993; Koç, 1995, 2001). This is because precipitation in spring and summer adds moisture only to upper soil layers (Smoliak, 1956; Rickart and Murdock, 1963; Jensen, 1989) and only some short living plants use this moisture supply (Borman et al., 1992). In addition, autumn and winter precipitation is important for breaking dormancy appearing in summer and allowing the development of shooting (Ogden, 1980; McDonald et al., 1996). There-fore, determination of the effects of rain-fall in different seasons on the productivity of rangelands can provide great benefits.

Water shortage caused by drought events which can be defined as obtaining lower precipitation amount compared to long term averages have adverse effects on humans, livestock and vegetations. Type, total productivity, forage quality and vegetation cover of rangelands as well as yield losses can be affected by droughts (Snyman and Fouche, 1993; Moldenhauer, 1998; Peterson et al., 1992).

In addition to its direct effect on productivity of rangelands, precipitation can affect agricultural activities. In the periods when precipitation is low, plant production in range-lands is reduced (Holechek et al., 2004). On dry and sunny days, animals can not utilize rangelands efficiently due to high air temperature (Tuvaansuren and Bayarbaatar, 2003).

In addition changes in climate can have negative

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Table 1. Drought classification of standard precipitation index (SPI).

SPI values	Categories
>2	Extremely wet
1.5 - 1.99	Severely wet
1.0 - 1.49	Moderately wet
-0.99 - 0.99	Normal or close to normal
-1 to - 1.49	Moderate dry
-1.5 - 1.99	Severely dry
<-2	Extremely dry

effects on animal health (Batima et al., 2006). Negative impact of drought on vegetation can be more severe in the rangelands under bad conditions than those under good conditions and plants in rangelands can not meet their physiological needs in the periods when precipitation is low.

This condition can cause productivity of rangelands to decrease immediately. In addition, if overgrazing takes place before a dry period, nutrient reserve of vegetation can be adversely affected and plants can suffer from physiological stress. If the magnitude of dry period increases, carrying capacity of rangeland can decrease (Thurow et al., 1999). Due to significant level of deterioration on the surfaces of rangelands, albedo of these surfaces can change and this can change cloud formation and precipitation reduction (Charney et al., 1975).

Prediction of the fluctuations in climatic elements can be useful for the preparation of future feeding programmes for animals. In addition, rangeland management and improvement programmes can best be applied if the trends in climatic elements can be predicted.

The aim of the present study is to determine the effects of precipitation trends on rangelands and livestock breeding based on rangelands suggesting some solution proposals as to how production programming should be by considering the effects of long term precipitation trends on primary production. With this aim, SPI index was used considering an eighty year (1929 – 2008) precipitation data set. With the help of annual and seasonal SPI series, water shortage from precipitation was evaluated in Erzurum and some solution proposals were suggested.

DATA AND METHODOLOGY

Precipitation values were obtained from the meteorological station in the city, which began operation in 1929. Totally, an eighty year measurement period (1929 - 2008) was chosen which is known to be suitable for climatologic studies. Standard Precipitation Index (SPI), which is one of the most widely used indices for the analysis and monitoring of precipitation and drought analysis, is method is a very easy to use method since it utilizes only precipitation values as a variable. Only means and standard deviations of precipitation values are used in the formula below for the calculation of standard precipitation series.

$$SPI = (Xi - X_{mean}) / \sigma$$

Where X_{mean} is average of annual precipitation values, σ is their standard deviation. While negative values show precipitation deficiency, positive values show precipitation excesses. Drought classification shown in Table 1 was used for the evaluation of SPI series (McKee et al., 1993).

Deficiency in precipitation can be determined by using this method, where precipitation values measured in certain periods can be used for the calculation of index values 3, 6, 12, 24 of 48 – moth periods over at least 30 years (McKee et al., 1993).

RESULTS AND DISCUSSION

When eighty-year precipitation data was considered, it was seen that mean annual precipitation was 434.6 mm. In 16 years of the period (20%), precipitation was found to be close to the long term average value, in 27 years (33.8%), this value was above long term average. It was also found that in about half of the period (37 years; 46.3%), precipitation was lower than the long term average. A downward trend in precipitation can be seen especially after 1944 and from this year onward in only thirteen years, precipitation was above long term average. Values were generally close to the mean values after 1970. From this year, only one year was highly above mean value. Mean annual precipitation until 1946 was found to be 542.4 mm while this value showed a downward trend until 1968 which is the midpoint of the period reducing to 467.0 mm. Mean precipitation measured in the first half of the period (467.0 mm) is higher than that recorded in the latter half showing a decreasing trend and reaching down to 402.3 mm. (Figure 1).

When considered long term variations of SPI (Figure 2), in 56 years (70%) of eighty years annual mean precipitation was normal or close to normal; in 11 years (13.75%) moderate dry was seen, in one year (1.25%) severe dry was prevalent; and the number of moderate, severely and extremely wet years was found to be 3 (3.75%), 7 (8.75%) and 2 (2.5%), respectively. According to SPI model, total of nine years were found to be of severely and extremely wet, eight of which were seen in the first 40 years of the period while in the second part only one year 1979 was severely wet (Figure 2).

When considering the seasonal variation of precipitation, it can be seen that the highest long term average precipitation is seen in autumn with 114.4 mm while the lowest mean is seen in winter months with 54.3 mm. Long term average of spring months is (March, April and May) 105.0 mm and in 34 years of the period, spring precipitation is above the long term average. As in the annual precipitation, it is also valid for the spring precipitation that over the latter part of the period a clear decrease began to be seen. Of the 34 years when precipitation is above normal, only 14 are in the latter half of the period. Downward trend in spring precipitation

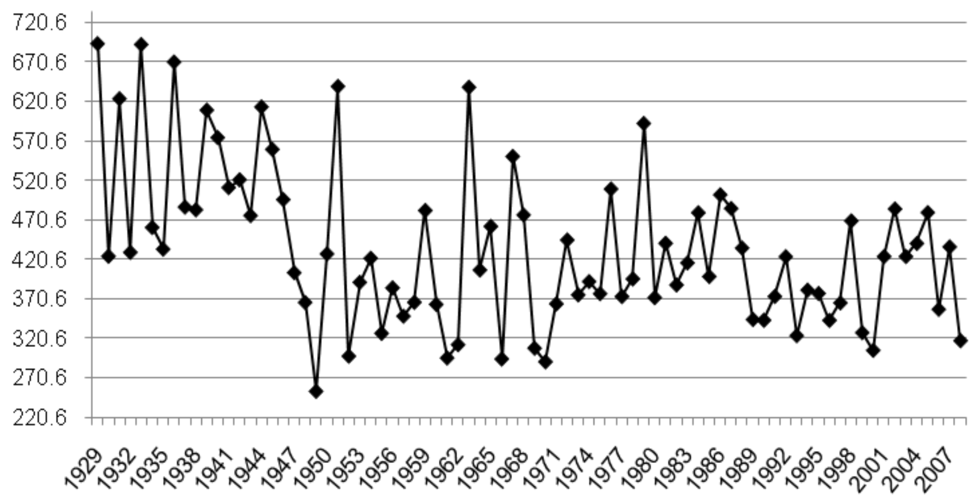

Figure 1. Long term (1929-2008) mean precipitation values.

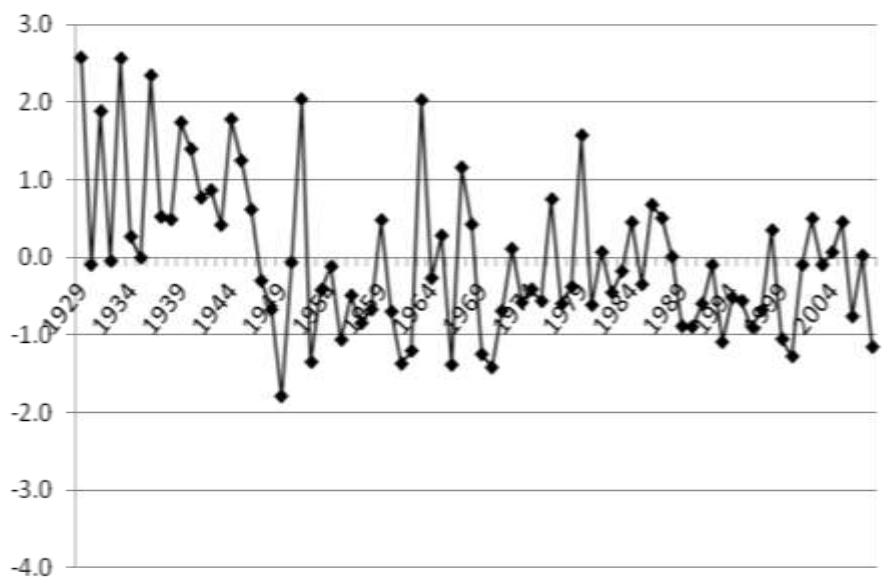

Figure 2. Yearly SPI for long term (1929-2008) mean precipitation values.

have ceased and an increasing trend began to be seen over the last five years. In the period after 2004, spring precipitation is above long term spring means (Figure 3). When SPI values were considered, total of 8 (10%) years were found to be extremely and severely wet, 3 (3.75%) years were moderately wet, while the number of years accepted to be normal or close to normal was found to be 58 (72.5%). The remaining 11 years were found to be severely or moderately dry.

Mean spring precipitation showed a downward trend; beginning from 1946, values were below long term averages until 1996. After 1996 values began to increase and in only three years of the last twelve years, spring precipitation was slightly below the normal while in the remaining years, spring mean precipitation was highly above the normal (Figure 4).

The number of years when summer precipitation was above long term average 34 was determined to be 34. A downward trend seen in annual means was also seen in summer values. During the first half of the eight–year study period, the number of years summer means were above long term average was 22 while in the second half this number was only 12 (Figure 5). If we evaluate mean precipitation series according to SPI method, the number of years which can be accepted as severely or extremely wet; moderately wet; normal or close to normal and moderately dry was found to be 7 (8.75%), 3 (3.75%), 60 (75.0%) and 10 (12.5%), respectively. Long term average of summer precipitation was above long term average precipitation until 1940 and after that time, this value was

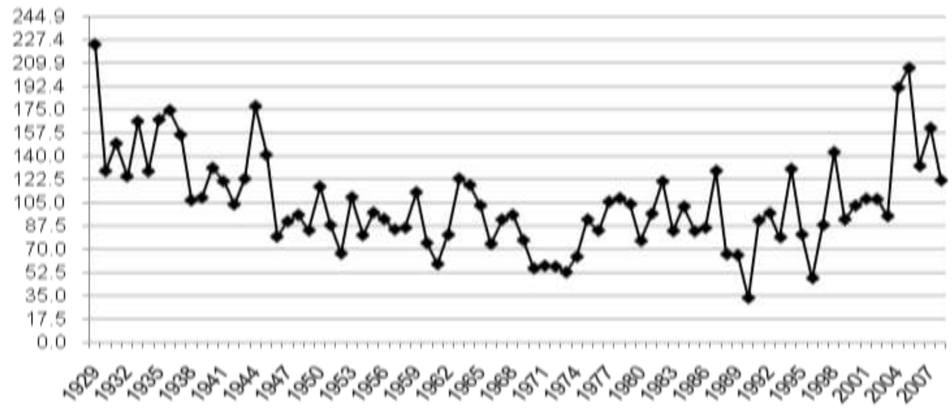

Figure 3. Long term (1929-2008) spring mean precipitation values

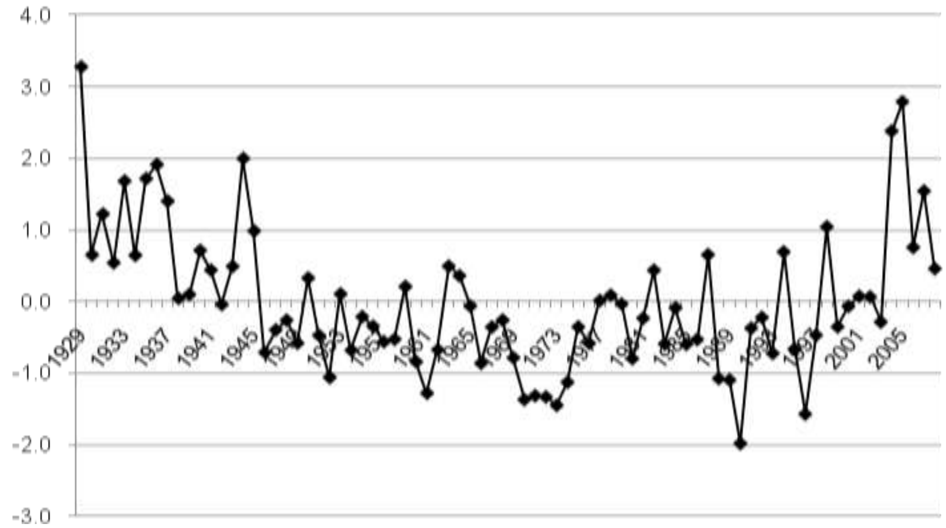

Figure 4. Spring SPI for long term (1929-2008) mean precipitation values.

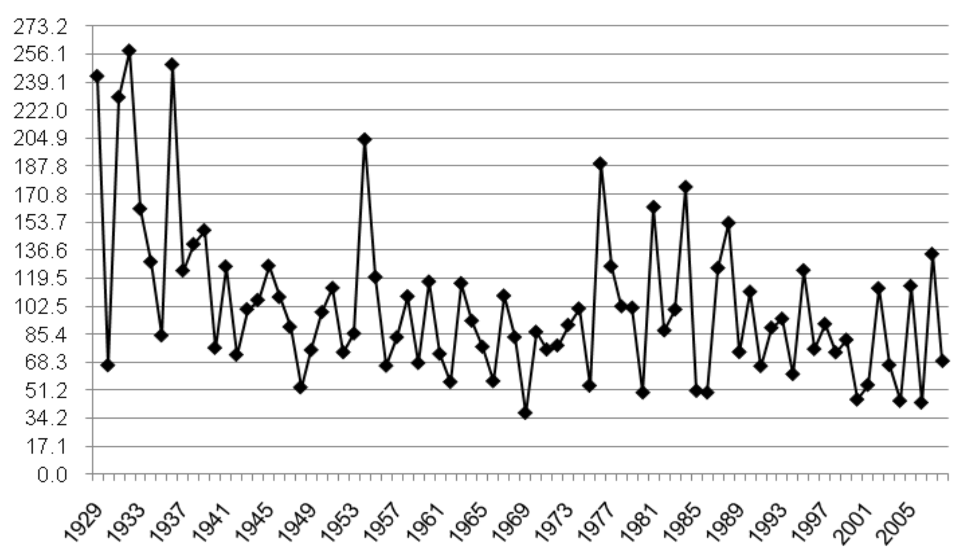

Figure 5. Long term (1929-2008) summer mean precipitation values.

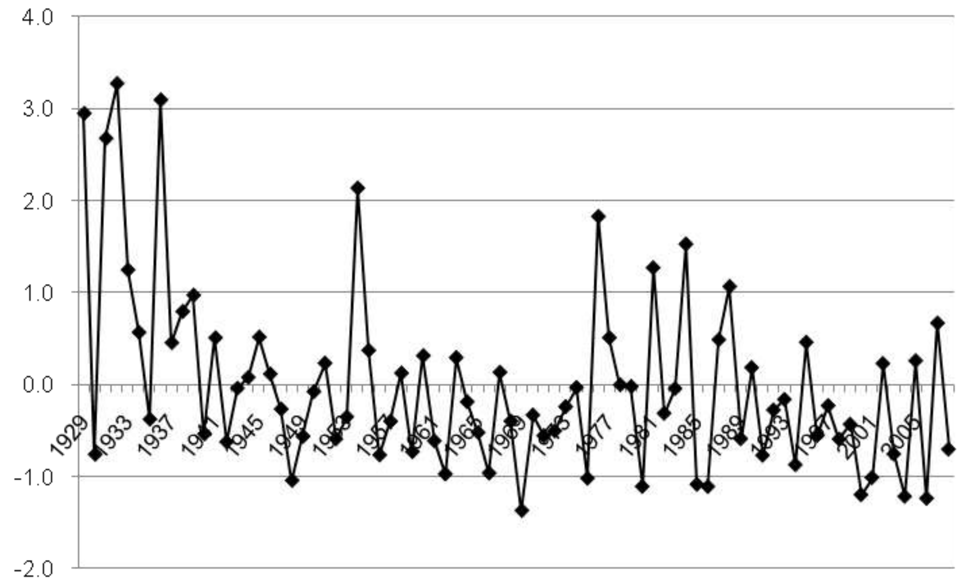

Figure 6. Summer SPI for long term (1929-2008) mean precipitation values.

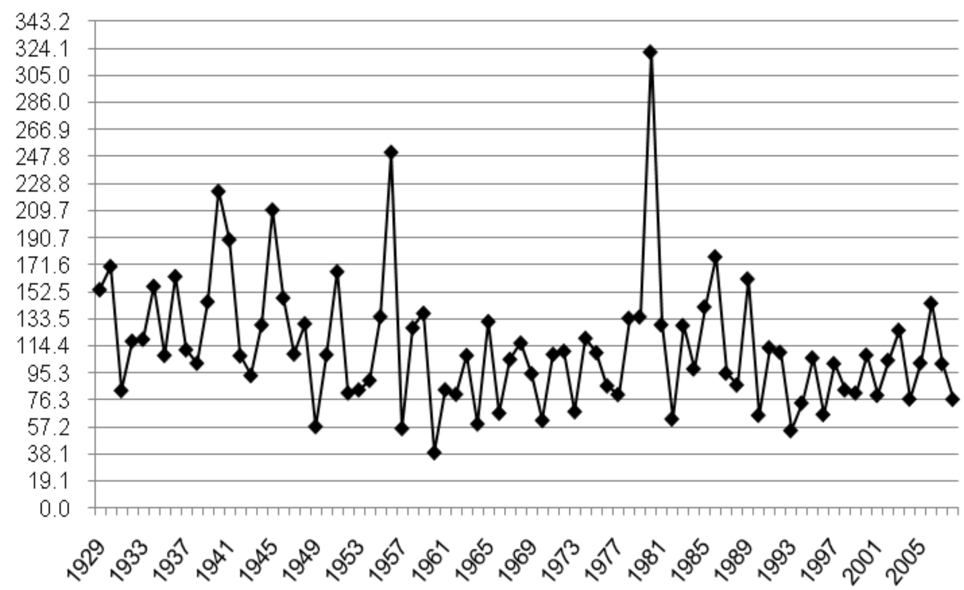

Figure 7. Long term (1929-2008) autumn mean precipitation values.

lower than or close to long term average. Only five years had values well above long term average precipitation (Figure 6).

According to long term precipitation values, mean autumn precipitation was higher than the normal in the first half of the period while in the second half the trend was downward. Total of 20 years in the first half of the period had higher autumn precipitation values than the normal while in the second half this number was only 11 (Figure 7). When considering the index values of autumn mean precipitation, it can be stated that 5 (6.25%) years were severely or extremely wet and 5 (6.25%) years were moderately wet. According to mean autumn precipitation, 59 years (73.75%) were normal or close to normal and the number of moderately or severely dry years was found to be 11 (13.75%). Downward trend was seen in this season as in spring and summer and the values above long term average autumn precipitation until 1957 was close to normal. After that date, only 5 years had autumn precipitation values above long term average (Figure 8).

Study area gets the lowest precipitation amount in

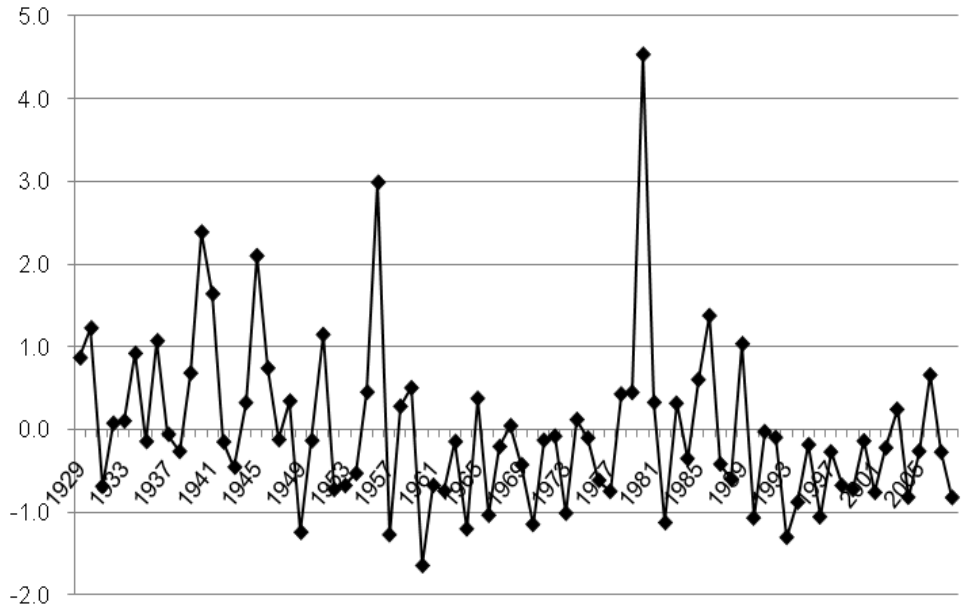

Figure 8. Autumn SPI for long term (1929-2008) mean precipitation values.

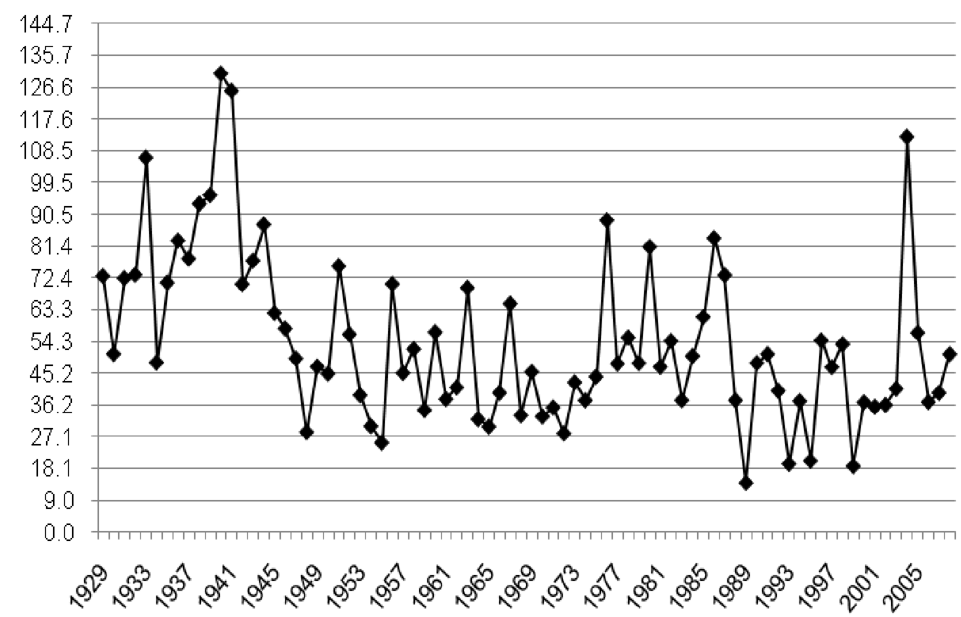

Figure 9. Long term (1929-2008) winter mean precipitation values.

winter. Downward trend is seen in this season again. The number of years when precipitation was above normal is 22 in the first half of the period and this number is 10 in the second half, two of which was seen in the last twenty years (Figure 9). When considered the SPI index values of winter mean precipitation, it can be seen that 6 (7.5%) years were severely or extremely wet and 5 (6.25 %) years were moderately wet, 60 years (75.0%) were normal or close to normal and the number of moderately or severely dry years was found to be 9 (11.25%). Winter precipitation values were generally above 21 normal, until 1944 and after that date, mean values were close to normal. Only 10 years had higher mean values than normal after 1944 whereas in a 15–year period before that date only in two years mean winter values were lower than the long term mean (Figure 10).

As in the long term average annual precipitation, seasonal values were also lower than the long term average values for a few years after the periods when this value was above normal. In the period after 1990,

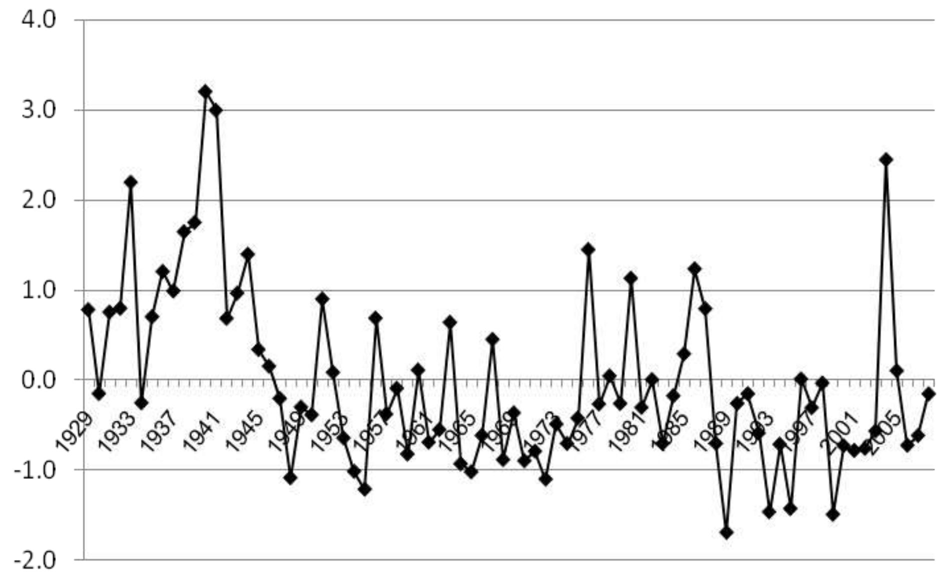

Figure 10. Winter SPI for long term (1929 - 2008) mean precipitation values.

precipitation in all seasons showed close values to normal with the exception of spring when precipitation was above normal from 2004 onwards.

The most important factor effective on the type and yield of rangelands located in high and arid and semi arid regions is precipitation. Seasonal distribution of precipitation can significantly affect rangeland vegetations (Holechek et al., 2004). Winter precipitation in especially high elevated regions is important for plant root development and productivity while spring precipitations have importance for the yield of rangeland vegetation (Koç, 2001). In the regions with low precipitation means, reduced amount of precipitation can affect plant yield more than the reduction in the regions with high precipitation (Klages, 1942). When considering the magnitude of drought which can be defined as the period between beginning and ending points of drought (McKee et al., 1993), it can be stated that in general, immediately after the years with precipitation became higher than long term average, lower precipitation amounts are seen but this amount is not much lower than long term average (close to normal). On the other hand, if precipitation was measured far lower than long term average in a given year, precipitation amount in the following year was seldom close to or above normal (long term average). It was clearly seen in the present study that precipitation was lower than long term averages in a few years following the year with low precipitation. In especially a period after 1946, a drought period of one, two or three years was observed after each year with higher precipitation than long term average. In the period after 1946, only the year 1951 had precipitation value considerably higher than long term average. When considering the values in the period after 1965, it can be stated that as the number of years with higher precipitation than long term average increases, the number of the years with lower precipitation than long term average also increases. A three–year period with lower precipitation than normal was seen after the years 1967 and 1968 when precipitation was higher than long term averages. After the period between 1986 and 1988 when precipitation was higher than normal, a nine–year period when precipitation means were lower than long term average values was experienced. After two years of higher than normal precipitation means in 2004 and 2005, precipitation was close to or lower than long term average precipitation. Precipitation means were found to be lower than long term average after the years when precipitation was close to or higher than long term average. From this point of view, in 2007 precipitation was close to long term average while in 2008 precipitation was lower than long term average values and in 2009 precipitation was close to normal (437.1 mm). Considering these points, it can be predicted that precipitation in 2010 will be lower than long term average.

It was stated by Koç (2001) that precipitations in autumn are vitally important for rangelands in arid and semi arid regions at high elevations to develop and give high yield in the following year and therefore, possible drought in this period can cause significant yield losses. As the consequence of the SPI assessment, if an estimation of precipitation deficiency is seen in autumn and winter months, beginning of grazing periods in spring should be well-adjusted in order not to reduce yields in the following year. Under such a condition, development process of vegetation should be followed and grazing in suitable and sustainable density should be performed beginning with maturity period of rangeland. When long term variations in precipitation values are considered, it can be seen that rangeland vegetations can be adversely affected by drought lasting for two or more years while the years with normal or higher than normal precipitation after one year of drought period can have less unfavourable effects on vegetation (Holechek et al., 2004). If these conditions are considered, it can be estimated that dry periods lasting for at least two years can decrease the yield in rangelands. Therefore, if these conditions and the ideas about the repetition frequency of these conditions can be detected using long term precipitation series, yield losses after long dry periods can be estimated and some measures for the removal of food or forage shortage in rangelands can be taken. In addition, in dry years rangeland vegetation should be grazed at suitable levels and if needed little or no grazing should be considered. It was stated that in dry years, light or moderate grazing can have as favourable effects on yield as no grazing (Ganskopp and Bedell, 1981). Sometimes more favourable effects have been observed (Weaver and Albertson, 1936). On the contrary, excessive grazing in dry years can have very unfavourable effects on the yield and land cover of vegetation in the same and following year (Pieper and Donart, 1975).

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