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Estimating Drought Index Using Standardized Precipitation Index from 1901 to 2015, Turkey[#]

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Abstract: Complete administration and decision making in the subject of water resources needs dependable forecast for drought region, duration and severity. The major objective of this study is to determine drought features which are significant for drought awareness and management using rainfall data for 115 years (1901-2015) by compute Standardized Precipitation Index (SPI) values in different time scales (1, 3, 6 and 12 months), where the SPI is used for Drought Early Warning. The drought index is founded on monthly precipitation, SPI calculated over the Turkey region 38.9637 °N and 35.2433° E, at time scales of 1, 3, 6 and 12 months for the period 1901–2015. Trends in SPI values denote that the ratio of Turkey experiencing extreme and/or severe drought provisions has different considerably through these years.

Keywords: *Standardized Precipitation Index (SPI), Drought Index, Precipitation, Turkey.*

Introduction

Drought is one of the most devastating natural disasters in the world and affects more people than floods and any another natural disaster because of the bigger spatial influence, and is analyzed in planning and management of water resources studies (Berhanu F & JM, 2013; Loukas & Vasiliades, 2004; Wilhite, 2000). Drought risk management includes risk, weakness and effect valuation, a drought early warning system (DEWS; observing and predicting), readiness and alleviation of affects, the drought caused by the merged of severe rainfall and severe high temperature is more strict, causing maximal hurt to agriculture. (Bandyopadhyay, Bhuiyan, & Saha, 2016; He, Lü, Wu, Zhao, & Liu, 2011; Sivakumar et al., 2014). There are several different types to estimate drought index, including the standardized precipitation index (SPI), the Palmer drought severity index (PDSI), the precipitation anomaly, Crop Moisture Index (CMI), Surface Water Supply Index (SWSI), Effective Drought Index (EDI), Percent of Normal Index (PNI), NDVI based indices, *Z*-index and the Standardized Precipitation-Evapotranspiration Index (SPEI) (Angelidis, Maris, Kotsovinos, & Hrissanthou, 2012; Xu, Lin, Huang, Zhang, & Ran, 2011; Zhai et al., 2010).

Standardized Precipitation Index (SPI) used as a most popular drought index to give a best description of wetness and dryness and identifies the significance of time scales in analyzing of water availability and water consumption (McKee et al., 1993), in addition to it is a successful tool in the assessment of the intensity and duration of drought events. This standardization permits the SPI to determine the scarcity of the current drought situation in addition to the possible precipitation essential to end the existing drought (Wu, Svoboda, Hayes, Wilhite, & Wen, 2007; Yusof, Hui-Mean, Suhaila, Yusop, & Ching-Yee, 2014). The development of the SPI, that needs only data on precipitation, founded on the hypothesis that the deficit in precipitation at varying intervals or periods affects groundwater, reservoir storage, stream flow, snowpack and soil moisture. Therefore, primarily computed the SPI for the time scales of 1-, 3-, 6-, 9-, and 12-months consistent with the U.S. National Drought Mitigation Center (NDMC), nonetheless the index is flexible regarding the period selected. So, the SPI is especially appropriate to contrast drought conditions between various time periods and areas with varied climatic conditions (Tsakiris et al., 2007; Wu, Hayes, Wilhite, & Svoboda, 2005). Consequently, the SPI provides a macroscopic understanding of the effect of the shortfall of precipitation upon to all stated above water resources, which is very tricky to be assessed otherwise. A

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[#] *This paper has been presented in Alblakes3 2017, Elbasan-Albania* drought event happens at the time when the value of SPI is continuously negative. The event finishes when the SPI becomes positive. Table 1 presents a drought classification founded on SPI.

Turkey is periled to drought risks rather frequently. Spatial and temporal analyses of drought dangers in Turkey have not hitherto been finished, nevertheless for example, severe drought intervals in 1804, 1876 and 1928 produced the damage of crops and animals and the immigration of farmers to other districts. In specific, drought in 1876 affected the loss of more than 200,000 persons due to food crisis and disease increases (Ceylan, 2009). All portions of Turkey are suffering dry meteorological conditions, especially; parts regions in the Central Anatolia region undergoing drought involve Aksaray, Nevsehir, Nigde, northern parts of the Konya zone, Polatli and Ankara (http://www.world-grain). The purposes of this study are applying the SPI for determining dry/wet conditions (drought index) using four different time periods of the precipitation data set (1-, 3-, 6-, and 12-months).

Impacts of Drought

The influences of drought are widespread and have destructive impacts on the environment, the economic and the society as a whole. Water consumption is portion and parcel of almost every human activity in addition to the life of plants and animals. Several direct effects are deficiency of agricultural crops, incidence of forest, prairie, lower water levels in reservoirs, lakes and ponds, besides decreased stream flow in rivers and groundwater depletion. Increase in fires, mortality rate of animals and fish types as well as drought is associated with insect invasion, plant diseases, and wind erosion. Various indirect influences are decline in incomes of farmers and agricultural corporations, rise in food prices, crime rates, joblessness and immigration producing severe hydrological imbalances that negatively impact earth resources and production techniques (Alston & Kent, 2004; Bond, Lake, & Arthington, 2008; Ceylan, 2009; DaMatta & Ramalho, 2006; Türkeş, 2010).

Materials and Method

Study Area

Total area of Turkey is 783,562 km^2 which it straddles the Sea of Marmara; divides southeastern Europe from southwestern Asia. The geographic coordinates of Turkey are 39°00'N latitude and 35°00'E longitude. Though Turkey is located in a geographical location where climatic conditions are very moderate, there are important differences in climatic conditions from one area to the other. Whereas the coastal regions enjoy milder climates, the inland Anatolia plateau encounters a dryer climate with hot summers and cold winters with limited rainfall. In Istanbul and around the Sea of Marmara the climate is moderate. In winter 4 degrees Celsius and summer 27 degrees Celsius. In Western Turkey there is a mild Mediterranean climate with average temperatures of 9°C in winter and 29°C in summer. Rainfall is low and there is more snow. The climate in the Black Sea area is wet, warm and humid. In Eastern Anatolia and South-Eastern Anatolia there is a long hard winter, where year after year snow falls from November until the end of April. Figure 1 shows the Meteorological drought Map for 2013 of study area.

Method

The precipitation and temperature data were collected over a period of 115 years (1901–2015) of monthly data for Turkey from *Climate Data API* website, *SPSS 24* was used for *Statistical analysis and graphing*, and *Easy Fit spi_sl_6* program software was used to calculate standardized precipitation index (SPI) on time scale conditions of 1, 3, 6 and 12 months, where SPI has been used to determine the precipitation deficit. As said by McKee et al. (1993), the index has a natural distribution, thus it can be utilized for evaluating both dry and wet periods. A wet period in relation to the SPI may be described, for a time scale *i*, SPI is incessantly positive and reaches a value of +1 or higher, while dry period in relation to SPI is continuously negative and reaches a value of -1 or higher, SPI is based on the probability of precipitation for any required time scale as presented in Table 1. This table additionally includes the equivalent probabilities of happening of each severity, result from naturally from the Normal probability density function. The SPI is calculated by dividing the difference between the standardized seasonal precipitation and its long-term seasonal average by the standard deviation, shown in the equation below:

$$SPIi = (Pi - P)/\delta$$

Where, SPIi symbolize drought index, Pi represent precipitation values in period i, P is the mean precipitation, and δ is the standard deviation of precipitation.

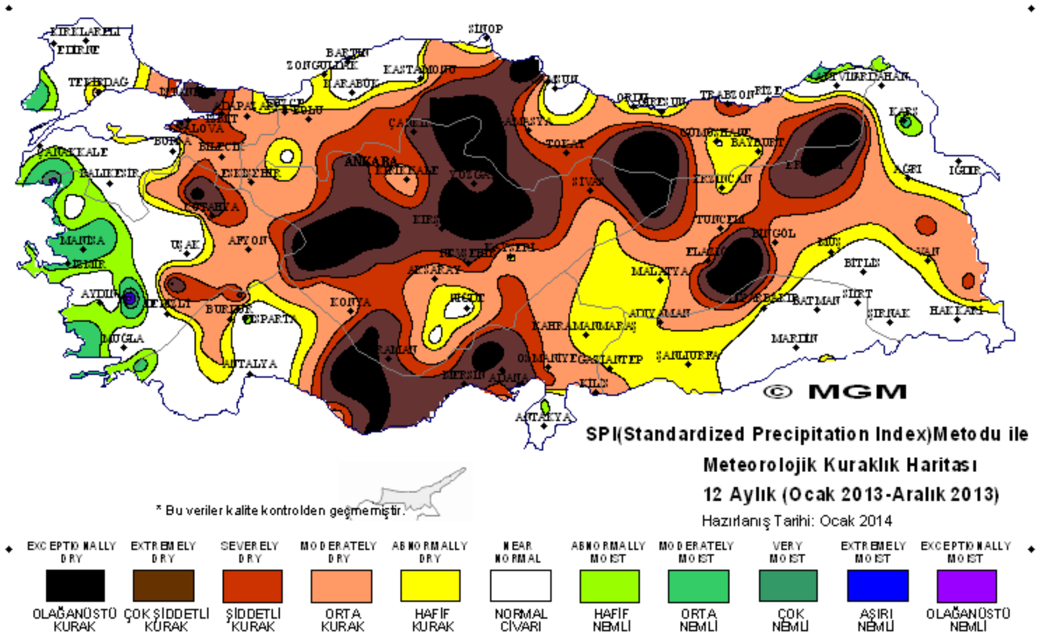

Figure 1: Study Area with (SPI) Meteorological drought Map of Turkey 2013 (Emre, 2014)

Table 1. Drought classification by SPI value and corresponding event probabilities

Category	SPI Value	Probability (%)
Extremely wet	≥2.00	2.3
Severely wet	1.50-1.99	4.4
Moderately wet	1.00-1.49	9.2
Near normal	-0.99-0.99	68.2
Moderately drought	-1.00 to -1.49	9.2
Severely drought	2.00 to -1.50	4.4
Extremely drought	≤-2.00	2.3

Results and Discussions

Figures 2, 3, 4 and 5 indicate different time series (1, 3, 6, and 12 monthly) local illustrative of SPI for the Turkey region was computed, using the average monthly precipitation. The time series of 1-month SPI (Fig. 2) presented that the region felt frequent moderate, severe and extreme droughts (SPI<−1) for all months of the year (Table 1). Frequency assessment of the annual lowest monthly SPI, appeared the most extreme 1-month SPI (SPI=−3.81) happened in February 1914, (SPI=-3.04) in November 1926, (SPI=3.05) in October 1964, (SPI=-3.8) in December 1972, (SPI=-3.12) in September 1984, (SPI=-3.23, -3.11) in February and April 1989 respectively, (SPI=-2.91) December 2006 and (SPI=-3.04) in November 2010 and had a return period of 12, 38, 8, 12, 5, 17 and 4 years respectively, where probability of occurrence depending on values of SPI is approximately equal to 3.07% of years . Very humid intervals (SPI >2) with possibly severe flooding occurred in 1.1% of years in 1902, 1908, 1921, 1922, 1929, 1934, 1956, 1966, 1968, 1996, 1997, 1999, 2011 and 2014 shown in Figure 2.

Whereas the time series of 3-month SPI shown in (Figure 3), the frequency measurement of the annual minimal monthly SPI, showed the most extreme drought 3-month SPI (SPI= -2.94, -3.65 and -3.97) happened in February, march and April 1989 respectively, (SPI= -3.29) in January 1973 and (SPI= -3.11) in November 1926 and had a return period of 10 and 47 years, where probability of extreme drought occurrence depending on values of SPI is approximately about 3.07% of years . Very humid intervals (Extreme wet, SPI >2) with possibly severe flooding occurred in 1.4% of years in 1909, 1921, 1936, 1938, 1939, 1942, 1963, 1972, 1989, 1997, 1998, 2002, 2011 and 2014 as shown in Figure 3.

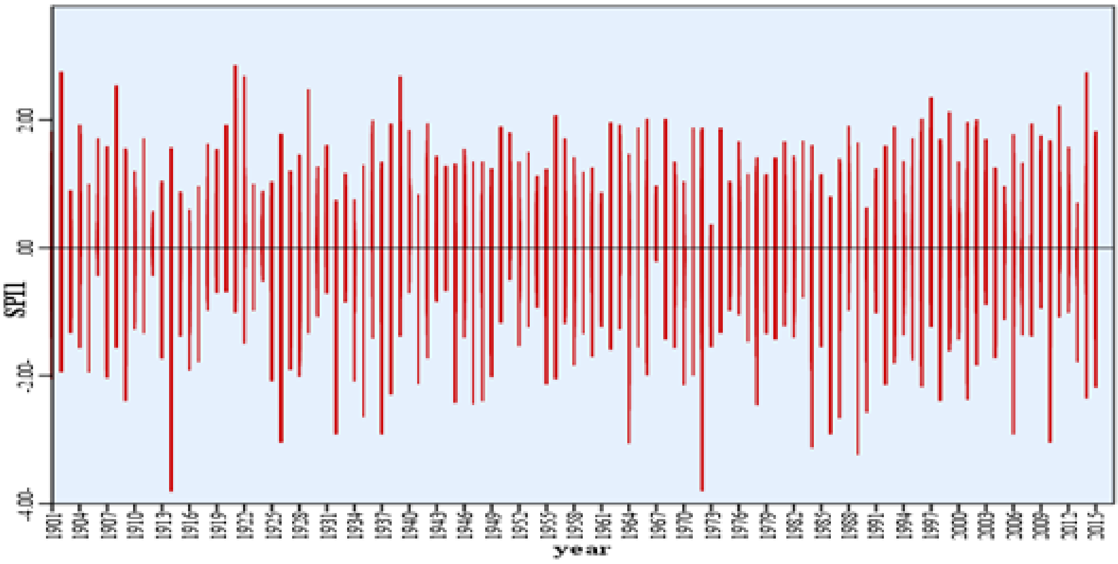

Figure 2. Mean SPI values for the 1_month time scale.

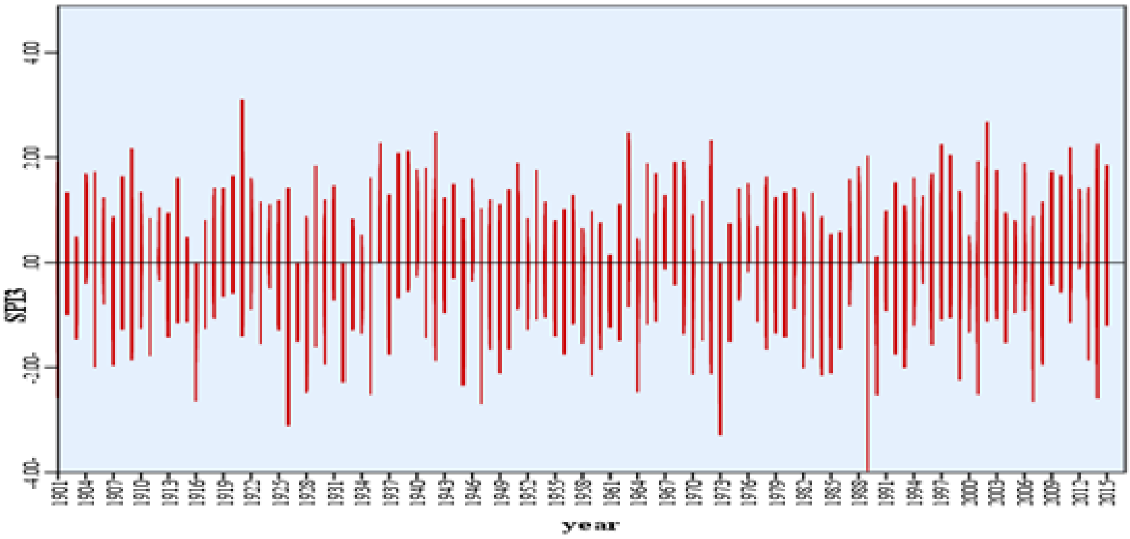

Figure 3. Mean SPI values for the 3_month time scale.

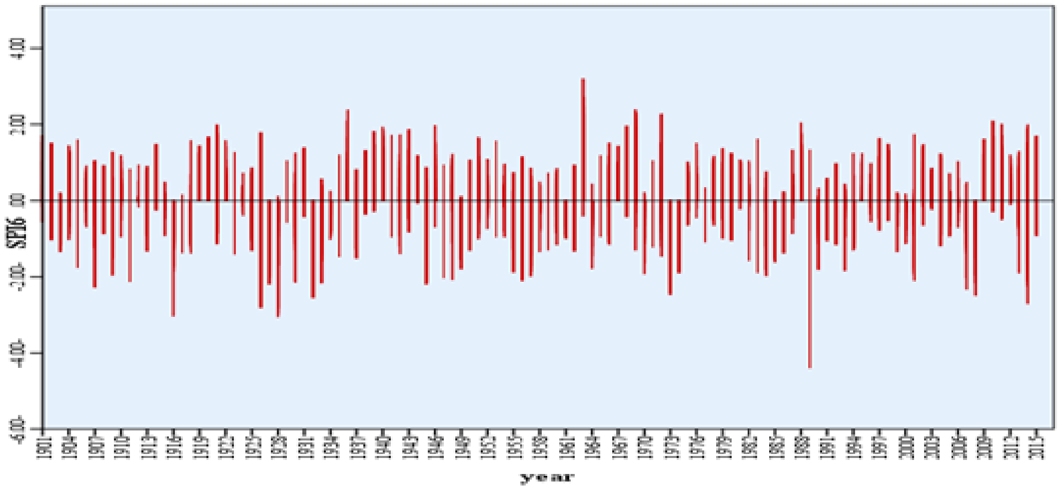

Figure 4. Mean SPI values for the 6_month time scale.

Figure 4 represent 6-month time periods, Where extreme drought values occurred in the 2014, 2008, 2007, 2001, 1989, 1973, 1956, 1948, 1947, 1945, 1933, 1932, 1930, 1928, 1927, 1926, 1916, 1911 and

1907 years, at different return periods by occurrence probability about 2.69% of years, with maximum value of (SPI = -4.39) in June 1989, whereas the highest wet value of (SPI = 3.2) in May 1963, with the flood occurrence probability about 1.31% of years.

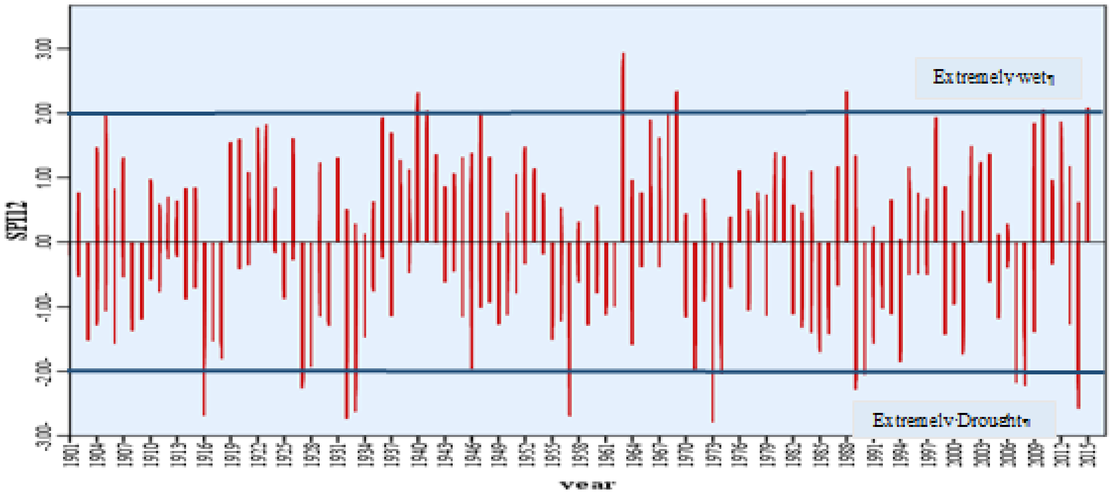

Figure 5. Mean SPI values for the 12_month time scale.

The series for 12 months appears the severest drought had been in the October 1973 (SPI= -2.78) and in the December 1932 (SPI= -2.73) with other most important droughts in the 2014, 1957, 1992, 1933 and 1916. It also looks indicates that the 2008, 2007, 1990, 1989, 1974 and 1927 had drought index (SPI <-2), if united, would be more dangerous than anyone of the others as shown in figure 5, with the drought occurrence probability about 2.34% of years, While most wet periods occurred in the 1963 beginning from May to December with maximum value of SPI = 2.93 in November, and others in 2015, 2010, 1988, 1969, 1963,1947, 1941 and 1940 with SPI value greater than 2.

Figure 6 shows the relation between times with rainfall during study years, where the maximum value of rainfall rate occurred in 2001, 1962 by rate 139 mm.

Whereas figure 7 shows relation between temperature and rainfall, the liner regression equation is Y (Rainfall) = 74.16 – 2.42 *X (Temperature) with R^2 = 0.5, Where the decreasing in temperature causes increasing in rainfall.

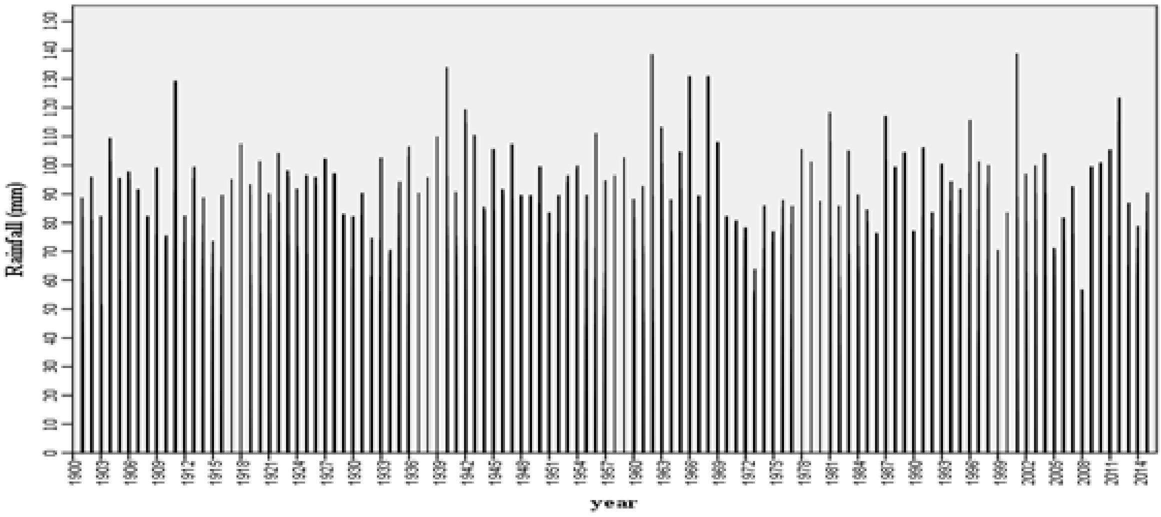

Figure 6. Relation between Time and Rainfall.

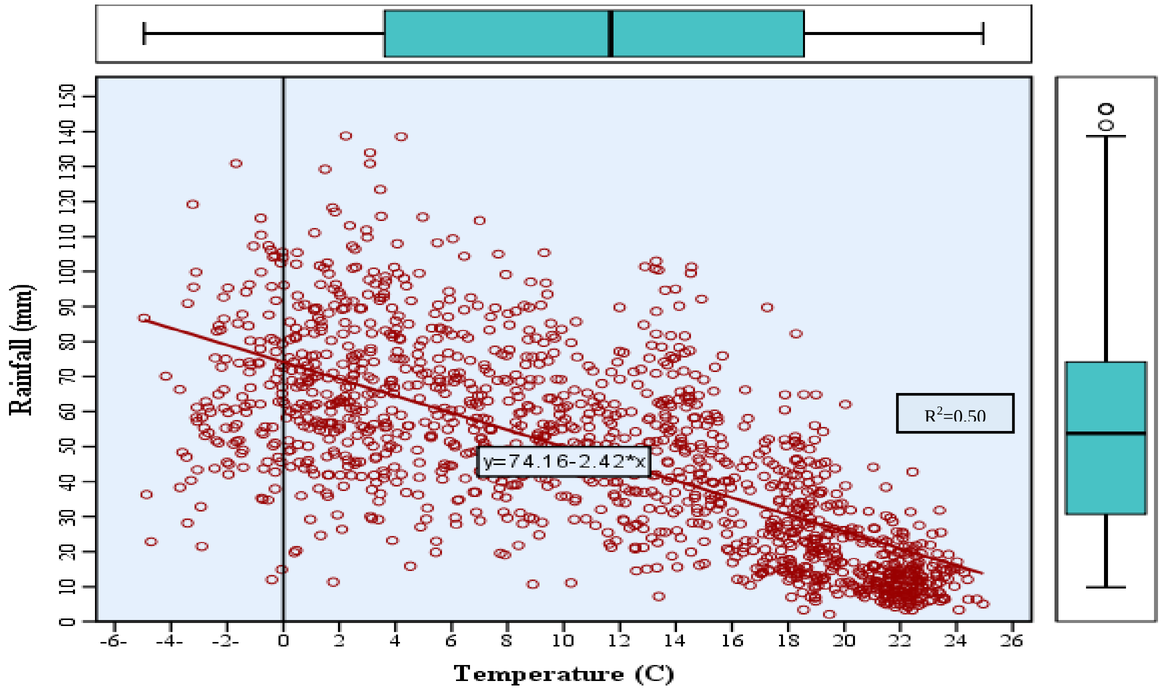

Figure 7. Relation between Temperature and Rainfall

Conclusion

Standardized Precipitation index can be achieved for various periods scales (1-, 3-, 6-, 12-month). This would allow evaluating trends and forms of droughts at different time and spatial scales. Extreme droughts happened numerous times was identified. The presence of such severe droughts in the past record increases worry over the probability of a like drought happening in the future that may be dangerously influenced urban water equip and irrigation of agricultural. The principal feature of the SPI is its flexibility to monitor various timescales. This property makes it an important tool for all water resource administrators concerned in either short- or long- period moisture provides.

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