Scientific Research Publishing

Atmospheric and Climate Sciences, 2024, 14, 118-127
https://www.scirp.org/journal/acs
ISSN Online: 2160-0422
ISSN Print: 2160-0414

# Levant Drought Occurrence, Lebanon Case

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**How to cite this paper:** Jomaa, I., Choker, M., Haj, N.E., Saab, M.T.A., Funaro, M. and Mereu, S. (2024) Levant Drought Occurrence, Lebanon Case. *Atmospheric and Climate Sciences*, **14**, 118-127.
https://doi.org/10.4236/acs.2024.141007

**Received:** October 29, 2023
**Accepted:** January 16, 2024
**Published:** January 19, 2024





## Abstract

Rainfall data is probably one of the longest-recorded climatic parameters in Lebanon. On the central coast of Lebanon, the Beirut weather station started collecting rainfall data in 1876. However, the recorded data is not available at one data provider source. Published data is found in historical documents but it reaches the early 1970s and then appears a data gap till 1990. Still the data is available, but it might be found to be saved privately. This study investigated the SPI variability on annual time scale between the years 1876 and 2021. The SPI was computed using R-Stat software to compare every year between 1876 and 2021. The majority (about 70% of the years) of the years are near normal in the precipitation rate. The Standardized Precipitation Index (SPI) demonstrated a normal distribution of years. Dry and wet years constitute about 15% of the total 146 years (1876-2021). Extremely dry years might appear in two consecutive years between 50 to 60 years count. After 1991, there were no wet years it was only near normal and few dry years. The last 30 years showed a trend of increasing drought years without any occurrence of wet years. This study demonstrated the importance of keeping records of at least rainfall data and it must be recorded on a daily basis or intensity on time. It is highly important on a managerial basis and for water security reasons to understand the drought event occurrence and investigate the changes in rainfall rates. Climate change scenarios always forecast a decrease in rainfall rates which will not appear without such studies.

## Keywords

Climate Change, Standardized Precipitation Index (SPI), Beirut, Rainfall Gages

## 1. Introduction

Reports claim that drought frequency has been increasing in the Levant and Me-

diterranean regions over the twentieth century [1]. IPCC reports that the number of drought months in the Mediterranean has doubled since 1900. Climate change future scenarios are also expecting more frequent and severe droughts [2].

Among the main causes of drought in the Levant are climate change, deforestation, overgrazing, overexploitation of resources, etc. Climate change is causing temperatures to rise and precipitation patterns to become more variable. These facts are aggravating the harm of drought events.

The increasing frequency of drought events, over the Levant, is a serious socioeconomic threat. Drought events impact agriculture production, increase water scarcity, raise the risk of forest fires, enhance the progress of desertification and intensify economic losses (e.g., [3] [4]). It is essential to forecast and monitor drought events. Previous drought events need to be analyzed and displayed for a better understanding of the linked circumstances.

Groundwater aquifers are not being replenished because of soil erosion, deforestation and overgrazing. Deforestation makes soils more vulnerable to erosion and exposed to high rates of evaporation. Overgrazing decreases organic matter in soils causes soils to reduce water holding and subjected to erosion and further effects of drought.

Meteorological drought is caused by the deficit of rainfall. Hydrological and agricultural droughts are affected by the life span of the occurrence of the meteorological drought. Long-term average rainfall records demonstrate a general climatic trend of a region and determine the changes in the climate.

Levant countries are vulnerable to drought as they are experiencing water scarcity. In Lebanon, as a levant country, agriculture, water supply and natural ecosystems might experience devasting impact in more frequent drought events.

Data on Climate parameters, in Lebanon, remain sporadic and cover a limited portion of the country and are sometimes unreliable [5]. In the 20$^{th}$ century, there were 129 manual rain recording locations over Lebanon between the years 1921 to 1970. However, these rain recording locations were installed on different years in the mentioned 49 years.

Lebanon's largest agriculture land area, Bekaa Valley, resides under semi-arid to arid climate that makes precipitation integral socioeconomically. Any negative deviation of precipitation disrupts crop growth and causes natural and ecosystem disasters. However, drought is not well monitored and studied in Lebanon. The length and the frequency of drought events remain weakly investigated.

Long term precipitation records are an indispensable part of analyzing the climate of a region. The Standardized Precipitation Index (SPI) is a widely used drought index that measures the precipitation deficit or surplus relative to the long-term climate conditions of a specific region. The SPI is one of the important indices to study and monitor drought events. SPI is used to measure the departure of precipitation from the long-term average. The SPI is a dimensionless number, with values ranging from −2 to +2. Values less than −1 indicate

drought conditions, while values greater than 1 indicate wet conditions.

In the Mediterranean region, the negative SPI has been increasing over the past century with increasing frequency of drought events [6]. The duration of drought events showed an increase in the Mediterranean [7]. Thus, drought is becoming more common, likely due to climate change temperature rising and erratic precipitation scenarios [7] [8] [9] [10].

The Levant, especially Lebanon, is facing climate change, population growth and instability. Drought events cause harder difficulties to overcome such challenges. Monitoring drought is indispensable for any plan. The SPI is rarely studied over Lebanon which makes it necessary to investigate such index on any possibly existing data, especially in the long term.

The Second National Communication report of the Ministry of Environment expects to have 9 to 18 days longer drought periods by the year 2040 and 2090 respectively [11]. The period between 1998 and 2012 was among the driest periods of the past 900 years in the Levant area [1].

Understanding the temporal variability of precipitation in Lebanon, as part of the levant, this study aims to analyze the precipitation behavior over the period between 1876 and 2021. This study provided the frequency and period of drought occurrence, using precipitation data gathered from different sources for Beirut city which reflects the drought situation for all Lebanon. The purpose of this work is to investigate the length of continuous drought events or the possible occurrence of drought years and how it will be possible for Lebanon to manage water resources following the prevailing wet and dry years.

## 2. Materials and Methods

Lebanon is a country located in the Levant part of the Middle East at the coordinates 33.8547˚N and 35.8623˚E. Historical rainfall data of Lebanon was gathered from various sources, published documentation and private communications[1] [12] [13] [14]. The Department of Irrigation and AgroMeteorology (DIAM) of the Lebanese Agriculture Research Institute (LARI) has provided the records of the last decade [e.g., [15]].

SPI depends only on precipitation records. It monitors precipitation anomalies to assess drought conditions and aid water recourse management. SPI quantifies and monitors precipitation deficits or surpluses over various time scales. SPI could be computed for different temporal resolutions on a short-term scale (1 - 3 months), medium-term (6 - 12 months) and long-term (24 - 36 months). SPI is dimensionless which enables comparison among regions and of different periods, identifying drought severity.

SPI (Standardized Precipitation Index) was computed for 146 years of the period between 1876 and 2021 for Beirut Weather Station at 33.82˚N and 35.48˚E of 19 m elevation (World Meteorological Organization-WMO listed).

Computing SPI, using R stat, was to search frequency and occurrence of wet

[1]For the years 1970-1990: Nadim Farajalla, Director, Climate Change and Environment, Issam Fares Institute, AUB.

and dry time segments over Beirut which reflects all Lebanon. SPI was computed yearly for the whole period from 1876 to 2021 using the following equation [16].

$$\mathrm{SPI} = \left(\mathrm{X} - \mathrm{Xm}\right) / \ \sigma$$

where SPI is the Standardized Precipitation Index

X = Precipitation of one year recorded at the station

Xm = Average precipitation overall the studied period

σ = Standard Deviation

Positive and negative SPI values indicate wet and dry weather conditions respectively. The magnitude of the value indicates the severity of the deviation from the long-term precipitation average (**Table 1**).

## 3. Results and Discussions

Lebanon is a country of 10,452 km$^2$ located at the Eastern shore of the Mediterranean Sea with about 200 km of coastal length. The whole country is affected by humidity diverting through the Mediterranean Sea. The distribution of various precipitation rates is mostly related to the topography and geomorphology of the Lebanese territory (Jomaa et al., 2019). Any result obtained from the rain gauge or point data rainfall reading in any location will reflect the situation overall in Lebanon. If a rain gauge shows the dry year the whole country will have similar circumstances. Beirut weather station, which is used for this study assessment, is located at the central part of the Lebanese shoreline. The rain gauge at this location of Beirut is considered representative of the whole country, as an indication of a dry or wet year.

The lowest precipitation recorded in Beirut between the years 1876 and 2021 was 270 mm in 1932, while the highest was 1600 mm in the year 1969. The SPI drought index classified the dry and wet years in the 146 years between 1876 and 2001. The SPI index showed a normal distribution (**Figure 1**).

Within this 146-year period, it was found that the years of extremely dry, severely dry, moderately dry, near normal, moderately wet, very wet and extremely wet are 5, 4, 14, 99, 13, 6 and 5 respectively (**Table 2**). Normal years constituted about 70% of a century and a half of time. The frequency of normal years showed

**Table 1.** Climate classification according to the SPI values.

| SPI Value | Class |
|---|---|
| SPI ≥ 2.00 | Extremely Wet |
| 1.50 ≤ SPI < 2.00 | Severely Wet |
| 1.00 ≤ SPI < 1.50 | Moderately Wet |
| −1.00 ≤ SPI < 1.00 | Near Normal |
| −1.50 ≤ SPI < −1.00 | Moderate Drought |
| −2.00 ≤ SPI < −1.50 | Severe Drought |
| SPI < −2.00 | Extreme drought |

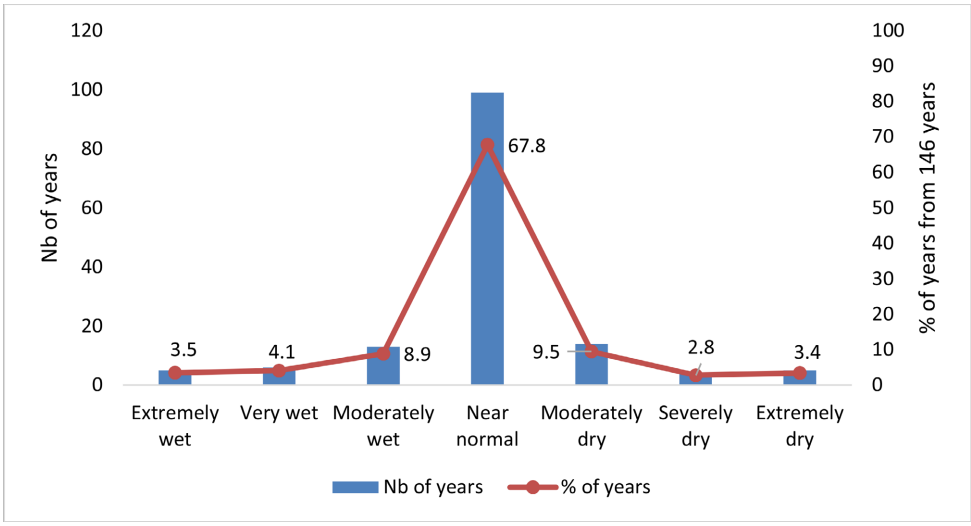


**Figure 1.** Percentage of years per SPI class.

**Table 2.** Classification of the 146 years following the SPI values.

| SPI Class | Nb of years | Years |
|---|---|---|
| Extremely wet | 5 | 1883, 1897, 1918, 1948, 1975 |
| Very wet | 6 | 1893, 1911, 1938, 1968, 1969, 1991 |
| Moderately wet | 13 | 1877, 1896, 1902, 1907, 1912, 1926, 1929, 1935, 1943, 1944, 1949, 1953, 1963 |
| Near normal | 99 | 1876, 1878, 1879, 1880, 1881, 1882, 1884, 1885, 1886, 1887, 1888, 1890, 1891, 1892, 1894, 1899, 1900, 1903, 1904, 1905, 1906, 1908, 1909, 1910, 1913, 1914, 1915, 1916, 1917, 1919, 1920, 1921, 1922, 1923, 1924, 1927, 1928, 1931, 1934, 1936, 1937, 1939, 1940, 1942, 1945, 1946, 1947, 1950, 1951, 1952, 1954, 1955, 1957, 1959, 1961, 1962, 1964, 1965, 1966, 1967, 1970, 1971, 1973, 1974, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1986, 1987, 1988, 1992, 1994, 1995, 1996, 1997, 1998, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2011, 2012, 2014, 2015, 2016, 2017, 2018, 2019, 2020 |
| Moderately dry | 14 | 1889, 1895, 1898, 1901, 1925, 1930, 1941, 1956, 1958, 1960, 1983, 1984, 2013, 2021 |
| Severely dry | 4 | 1972, 1985, 1993, 2010 |
| Extremely dry | 5 | 1932, 1933, 1989, 1990, 1999 |

yearly repetition, i.e., each year is normal between 1876 and 2021 but it had irregular years (Figure 2). The irregular years are distributed almost equally between the drier (23 years) and wetter ones (24 years). The frequency of near-normal years is almost equal over the whole period of the 146 years. Between the year 2000 and 2021, there are 18 normal out of 21 years. After the year 2000, there were three irregular dry years that are 2010 (severely dry), 2013, and 2021 (moderately dry). None of the 20 years was wetter than normal between the

year 2000 and 2021.

Consecutive years of extremely dry were the years 1932 and 1933, then the years 1989 and 1990. The time difference between these two consecutive years was 56 years (frequency of drought years also found by Mahfouz et al., 2016). Between 50 to 60 years, the levant area could experience two consecutive extremely dry years (Figure 3). Another extremely dry year came after 1990 in 9 years, i.e., 1999. The other consecutive severely dry year was 2010, i.e., 11 years after. The years 2013 and 2021 were moderately dry.

In 15 to 30 years, there could be one extremely wet year. Every 15 years, there will be two to three years above average. After the year 1975, there was only the year 1991 above normal. After 1991, the years were normal and lean toward the dry portion of the SPI classification (Figure 4). Up till 1991, the largest timelapse is 16 years to reach one year above normal. Thirty years after 1991, between 1991 and 2021, there was no year above the normal SPI classification.

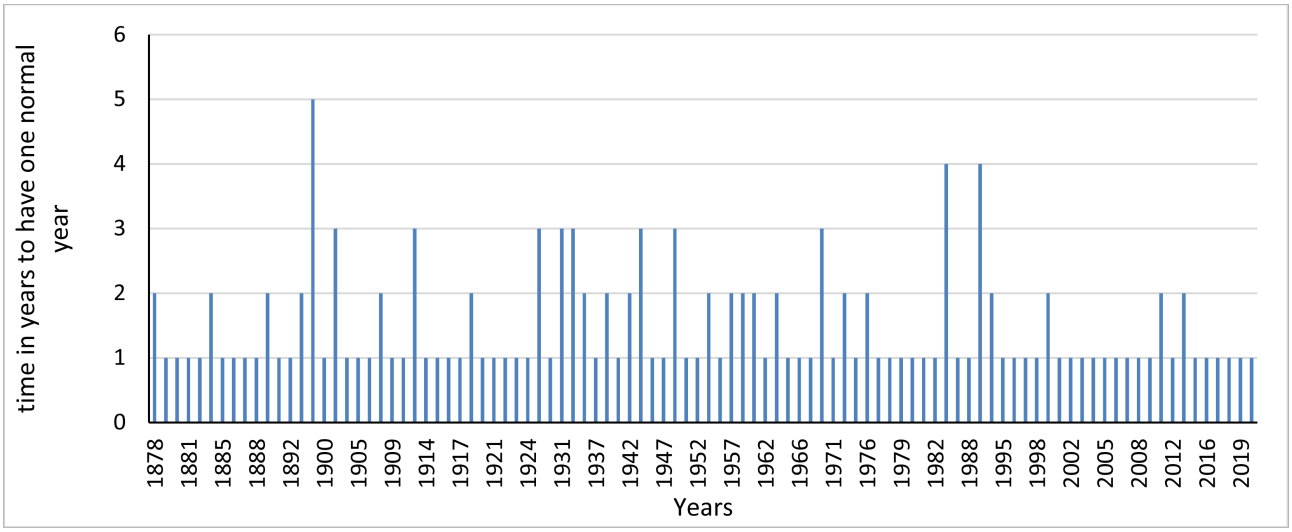


Figure 2. The occurrence of near normal years.

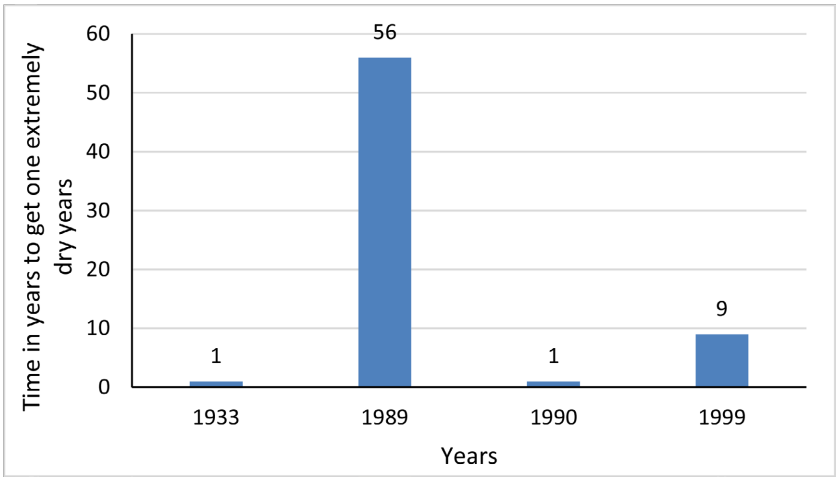


Figure 3. Dry years occur throughout the whole period of a century and a half of precipitation data.

The trend of getting one wet year shows less frequency. It took longer (like 16 years) to get one wet year between the years 1975 and 1991 (Figure 5). As mentioned earlier there is no wet year after 1991. Thus, the occurrence of a wet it already took longer than 30 years by the year 2021 and has not arrived yet.

The longest period of wet years happened in the first quarter of the last century. In 1903, the coming 24 consecutive years were wet (Figure 6). The trend of consecutive wet years has been declining since then. Thus, the frequency of getting dry years is increasing.

The standardized Precipitation Index is computed for the whole period from 1876 till 2021 (Figure 7). It is obvious that the last decades have shown a drier period.

## 4. Conclusions

Data of rainfall in Lebanon remains sporadic and it is difficult to have the data from one secured source. Historical rainfall records are mostly available by calendar year. This study is based on calendar year of data analysis (calendar year 2021

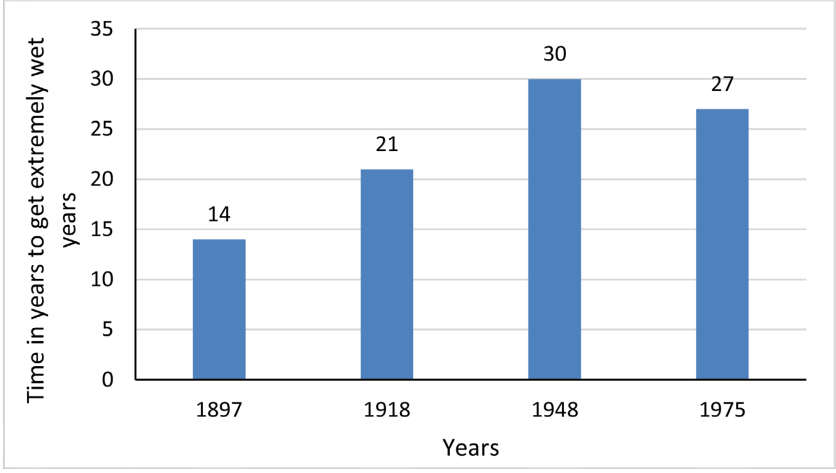


Figure 4. Extremely wet years occurrence.

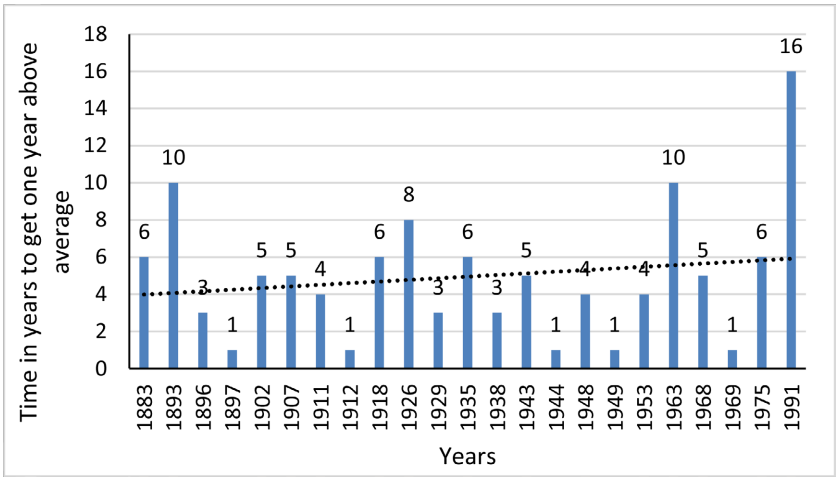


Figure 5. Time lapse to get one year above near normal.

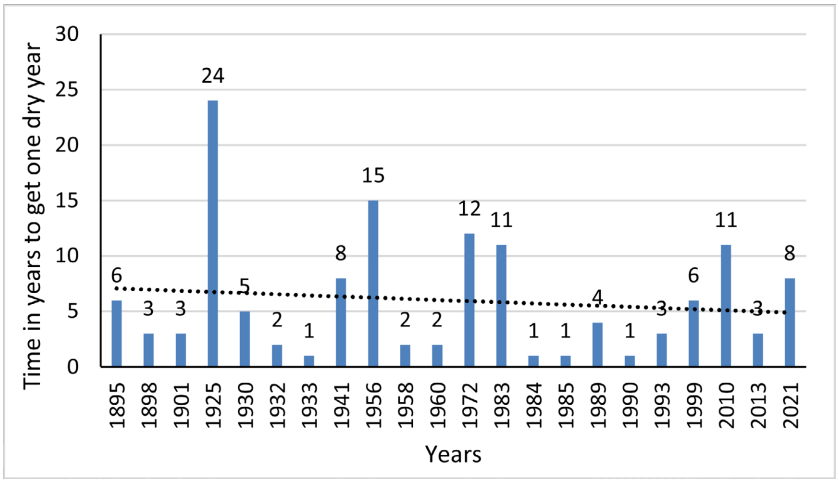


**Figure 6.** The frequency of getting dry year.

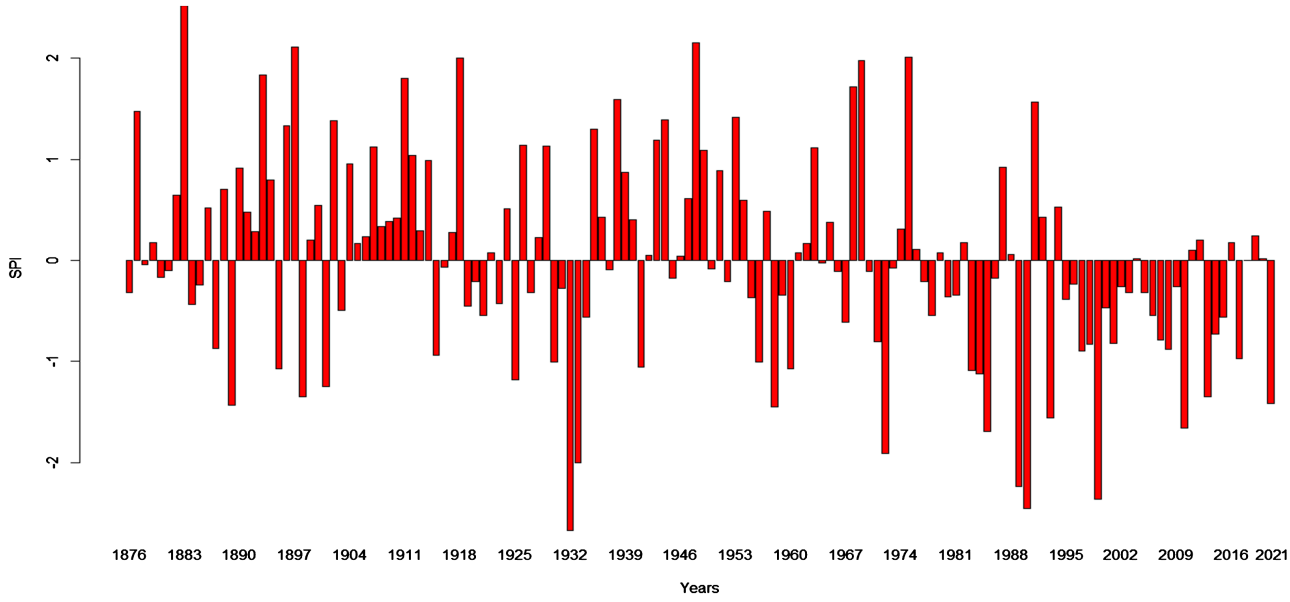


**Figure 7.** SPI for the whole period from 1876 till 2021.

01 January to 31 December). A calendar year has data from two consecutive rainy seasons (January to May and September to December). Analyzing rainfall rates in a region would be easily studied once recorded as one rainy season (September till May) than having a calendar year. It would be logical to compare rainy seasons with each other while comparing calendar years would hide the variability. A rainy season is a result of atmospheric pressure movement over the entire earth thus it would be much easier to comprehend the variability of rainfall rates within rainy seasons in contrast to calendar year rain. This needs to be considered while collecting rainfall data. Monthly rainfall data would be of higher possibility of preparing comprehensive analysis. Nonetheless, rainfall records for a long period of time are highly important to comprehend the trend of drought in a region. SPI index reflects drought and wet years occurrence in an area making its use highly valuable for water resources management.

In Lebanon, following the SPI classification extreme drought events occur only five years (five times) out of almost century and a half. Drought conditions of SPI (severely dry and extremely dry) happen almost 10 times out of 146 years. In parallel, the very and extremely wet events occur similarly in almost 10 years. In other words, the distribution of dry and wet events seems normal with a small percentage on both sides (either dry or wet) of the normal years.

After the year 1991, there was no year above the normal year (wet year) with 20% of the years being either moderate or very dry. It could not be considered as a sign of rainfall rate changes with 80% of normal rainy years. However, it did not happen before to have 30 consecutive years without having any wet years. The drought trend is showing an increase in occurrence with fewer wet years and more dry years.

Recording rainfall rates are an integral part of understanding anomalies of drought. The rainfall rates must be recorded at least daily. The yearly comparison should be based on the rainy season and not on the calendar year. One rainy season is an altogether confined event which is comparable to another confined event (another rainy season). Historical recording of rainfall data is hardly available in calendar year which makes it difficult to choose detailed analysis.

This study showed the importance of such analysis to comprehend the climate variability and spot dry conditions. Through such analysis, the changes in the occurrence of dry events will be detected for management purposes.

## Acknowledgements

This article was made possible through the generous support and funding provided by the EU prima-funded project "ACQUAOUNT". We would like to express our heartfelt gratitude to the project team and all those involved for their contributions, which have been instrumental in the successful completion of our research. We are thankful to Nadim Farajalla, Director, Climate Change and Environment, Issam Fares Institute, AUB for assuring rainfall data for the years 1970-1990.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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