*Research Article*

# Standardized Precipitation Index (SPI) For The Characterization Of Meteorological Droughts In The Town Of Guanare, Portuguesa State, Venezuela

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**Abstract::** The objective of this study was to characterize the meteorological drought in the town of Guanare, Portuguesa state. The information used for the study was obtained from the meteorological data record, from the monthly precipitation series of the Aeropuerto-Guanare meteorological station of the Portuguese state for the period 1982-2015. The Standardized Precipitation Index (SPI) was used for a monthly scale of the period under study, which allowed the identification and description of the drought phenomenon, specifying its intensity, duration, magnitude and frequency of occurrence. According to the SPI values obtained, it was obtained that the level of extreme drought intensity in the locality during the 1982-2015 period was very low, not exceeding 2% and being rare with extremely strong magnitudes. These meteorological drought events occurred coincidentally for the period evaluated between the months of December and March; while the months of highest humidity were between the months of May, June and July. By virtue of the results obtained, it is important to take into account the vulnerability to drought events of the social, water and agricultural sectors of the area.

**Keybords:** drought index, severity, meteorological drought, standardized precipitation index.

## 1. Introduction

The phenomenon of drought is caused by a decrease in precipitation below the average that occurs in a given area and that extends over a long period of time, which can range from one season to several years, and that causes a deficit in the supply of water. water resource for an activity, a group or an environmental sector (Campos, 2014). When this phenomenon lasts for a season or for a longer period of time, and precipitation is insufficient to respond to the water demands of society and the environment, drought should be considered as a relative and not an absolute state (OMM, 2012). Historically, drought has been one of the hydrometeorological disasters that most affects agricultural activity, well-being and the food sovereignty of society. Generally, the effects of a drought are exacerbated by increased demands for drinking water, irrigation for agriculture, and other uses. The phenomenon of drought usually generates impacts on water users, progressively generating meteorological and hydrological deficits that produce agricultural and socioeconomic droughts (Sene, 2010).

For their analysis, droughts have been grouped into various categories, such as meteorological, hydrological, agricultural, water supply and underground, which refer both to the moment in which a deficit in precipitation is observed and in the period for the perception of its effects on the different sectors (Pereira et al., 2009). Among the available indices, the Standardized Precipitation Index (SPI) is the most appropriate to monitor such types of droughts, proposed by McKee et al. (1993) and widely used in characterization studies of droughts in hydrological basins. Several studies have analyzed the spatio-temporal evolution of RLS at different time scales; as well as to identify trends and periodicities of dry and wet events in time series through dry / wet indices. Among the most outstanding studies regarding the study of meteorological droughts, are the contributions of Paredes et al, (2008); Paredes and Guevara (2010); Gocic and Trajkovic (2014); Esquivel et al. (2019); Modaresi et al (2020) and Parra et al. (2018).

In the particular case of Venezuela, throughout history the national territory has gone through events of intense drought, product of the late onset of the rainy season, as reported by the studies developed by Olivares et al. (2016); Quiroz et al. (2016) and Olivares (2017). This situation has caused a decrease in water levels in most of the water reserves, generating water rationing in several regions, affecting the agricultural sector and food production in the country to a greater extent. The Guanare municipality of the Portuguese state is of great interest due to the great development of rainfed crops such as rice, corn, sesame and sorghum among others; as well as for its water reserves of great importance for agricultural and human consumption.

In this sense, the society and the agricultural economy that develops in Venezuela are highly vulnerable to the occurrence of drought events, for which it is vitally important to have a better understanding of the variations in precipitation, their trends and future scenarios. The effects of climate change can be minimized if the most susceptible areas are known, given their intensity and periodicity, to deal with it through preventive measures (Colotti et al., 2013). That is why the objective of this study was to characterize the meteorological drought in the town of Guanare, Portuguesa state; by means of the Standardized Precipitation Index (SPI), which will allow the phenomenon to be properly identified and described, specifying intensity, duration, magnitude and frequency of occurrence.

## 2. Materials and methods

### 2.1 Study zone

The town of the Guanare municipality is located northwest of the Portuguese state, between 08º 52´ 36” and 09º 26 ^ 44” north latitude and 69º 25´ 50” west longitude. It limits to the north with the Municipality of José Vicente de Unda and the State of Lara; to the south with the San Genaro de Boconoito and Papelón Municipalities; to the east with the Ospino Municipality and to the West with the San Genaro de Boconoito and Sucre Municipalities. The climate is tropical savanna, with an average temperature of 28 ºC that attenuates in the high areas and an average annual rainfall of 1,400 to 1,800mm. The information used for the study was obtained from the meteorological data record, from the monthly precipitation series of the Aeropuerto-Guanare meteorological station of the Portuguese state for the period 1982-2015.

### 2.2 Determination of the standardized precipitation index (SPI)

The Standardized Precipitation Index (SPI), developed by Mckee, et al., Was used. (1993), for a monthly scale for the period 1982-2015; in order to characterize the meteorological droughts in the locality under study. Its application requires the use of historical series of monthly precipitation and offers the advantage of manipulating various time scales, making it possible to identify the impacts of drought in short, medium and long term periods; it also allows to conveniently identify and describe the phenomenon, specifying its intensity, magnitude and duration.

For each month, the monthly accumulated value was determined, thus obtaining 12 sub-series in each station. The parameters α and ß of the Gamma Theoretical Probability Distribution (GTPD) associated with each of these 12 accumulated precipitation sub-series were estimated. The probability density function of the GTPD is given by equation 1:

$$f(x,\alpha,\beta)=\frac{1}{\beta^{\alpha}\Gamma(\alpha)}x^{\alpha-1}e^{-\frac{x}{\beta}} \qquad (1)$$

Where $f(x,\alpha,\beta)$: is the Gamma probability density function, $(x)$: is the monthly accumulated rainfall expressed in mm; $(\alpha\ y\ \beta)$: are the scale and shape parameters of the distribution, respectively and Γ: Gamma distribution. On the other hand, the probability that the monthly accumulated, in a subseries, is less than or equal to the existing record, is represented as $F(x)$and is estimated according to equation 2:

$$F(x)=\int_0^x f(x,\alpha,\beta)dx \qquad (2)$$

To estimate the parameters α and ß of equation 1, the methodology proposed by Campos (2005) was used, which is summarized below: first, a dimensionless auxiliary variable (A) is calculated for each monthly subseries (A), defined in Equation 3:

$$A=\ln(\bar{x})-\frac{\sum_1^{\acute{n}}\ln x_i}{\acute{n}} \qquad (3)$$

Where $\ln(x_i)$ is the natural logarithm of the accumulated record, n´ represents the number of non-null records, and is the arithmetic mean of the monthly subseries expressed in mm. From the previous step, 12 auxiliary variables are obtained, A. Subsequently, the estimation of the parameters α and ß of each subseries is carried out by applying equations 4 and 5.

$$\alpha=\frac{1+\sqrt{1+\frac{4}{3}A}}{4A} \qquad (4)$$

$$\beta = \frac{\bar{X}}{\alpha} \qquad (5)$$

The null records in the monthly subseries make it impossible to calculate the auxiliary variable A (the natural logarithm of zero tends to infinity), therefore, the Mixed Gamma Function (MGF) proposed by Thom (1971) and Wu et al. (2005) as follows in equation 6:

$$H\ (X) = q + pF(X) \qquad (6)$$

Where $(q)$ is the probability that a null value occurs in the subseries, $(p = 1 - q)$ is the probability that a null value does not occur in the subseries, and $H(X)$ is the probability of not exceeding the record. Once the 12 series of Gamma probabilities were obtained, the corresponding Z value or SPI value was estimated, in a standardized normal distribution with zero mean and standard deviation equal to 1.

### 2.2.1 SPI intensity categorization

McKee et al. (1993) used the classification system shown in the table of SPI values shown in Table 1, to define the different intensities of drought according to the different SPI values. These categories refer to the phenomenon of meteorological drought (those whose SPI value is negative) and, therefore, correspond to short-term dry events, but they do not constitute an aridity condition (Colotti et al. 2013).

**Table 1:** SPI Classification

| SPI | CATEGORY |
|---|---|
| 2,0 and more | Extremely humid |
| 1,5 to 1,9 | Very humid |
| 1,0 to 1,49 | Moderately humid |
| -0,99 to 0,99 | Normal or approximately normal |
| -1,0 to -1,49 | Moderately dry |
| -1,5 to -1,99 | Severely dry |
| -2 and less | Extremely dry |

Source: McKee et al. 1993.

### 2.2.2 Determination of the magnitude, duration and frequency of occurrence of the drought

To calculate the magnitude of the dry period during any given year, in a given season, a variant of the original method proposed by Edwards and Mckee (1997) was used where the monthly SPIs were accumulated whose magnitude was equal to or less than -1, and when the SPI was greater than -1 was replaced by a zero. Under this approach, an SPI value> -1 indicates a normal or wet condition (equation 7).

$$MS = -\sum_{I=1}^{12} SPI_i \text{ if and only if } SPI_i < 0 \qquad (7)$$

Where $(MS)$: represents the magnitude of the drought for the evaluated period, $(SPI)$: is the SPI index for monthly accumulated rainfall series. Table 2 shows the categories of the magnitude of the drought.

**Table 2:** Magnitude of the drought

| MS | CATEGORY |
|---|---|
| 0,1-0,99 | Normal |
| 1-1,99 | Mild |
| 2-2,99 | Little strong |
| 3-3,99 | Strong |
| 4-4,99 | Very strong |
| >5 | Extremely strong |

Source: Hernández, 2008.

According to McKee et al. (1993) continuously negative SPI values reaching the value (-1) or lower, are considered a significant dry sequence related to a sufficiently important water deficiency, while positive values are identified with the normal or humid category. The frequency of occurrence was determined by the number of drought cases that occur during a given period, thus establishing the empirical probability that a drought of a given magnitude will occur. The R Studio program was used to carry out all the calculations.

## 3. Results and Discussion

### 3.1 Drought intensity

Figure 1 shows the general results of monthly SPI calculated for the period 1982-2015 for the town of Guanare, observing extreme drought events with very little frequency of occurrence and visualizing a predominant behavior in the area, normal or approximately normal. regarding drought. It is noted that the driest months generally span from December to March; however, the wet SPI values are mostly focused on the months of May to July.

Table 3 shows that 72.3% of the reported indices are in the normal or approximately normal category, with a moderately dry drought of 9.07%, a severe drought intensity of 2.70% and an extreme intensity of barely 1.96%. This behavior found coincides with that reported by Paredes et al. (2014), who established that region 4 of the study unit located in the upper basin of the Boconó river in the Portuguese state, was the wettest of all the units evaluated. Likewise, these authors refer to the existence of a positive rainfall gradient in an east-west direction, which generates rainfall in the headwaters of the Guanare and Portuguesa rivers.

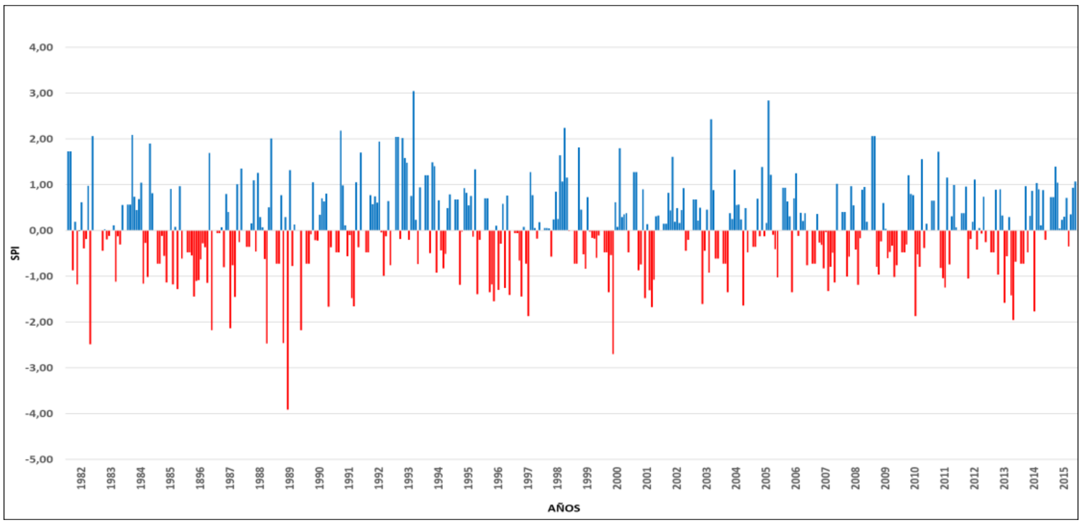


**Figure 1:** Course of the monthly SPI for the period 1982-2015, in the town of Guanare, Portuguesa state.

**Table 3:** Intensity of the drought in the town of Guanare, Portuguesa state; for the period 1982-2015.

| SPI | CATEGORY | % |
|---|---|---|
| 2,0 and more | Extremely humid | 3,19 |
| 1,5 to 1,9 | Very humid | 3,19 |
| 1,0 to 1,49 | Moderately humid | 7,60 |
| -0,99 to 0,99 | Normal or approximately normal | 72,30 |
| -1,0 to -1,49 | Moderately dry | 9,07 |
| -1,5 to -1,99 | Severely dry | 2,70 |
| -2 and less | Extremely dry | 1,96 |

### 3.2 Drought magnitude

In relation to the severity of drought events, Figure 2 shows the magnitude values obtained through the SPI values obtained, where it is evidenced that more than 85% of the years studied presented magnitude values of 2% or more, translating in a magnitude of drought ranging from a mild level to an extremely strong level. This situation makes it possible to establish that the drought episodes in the area under study are few recurrent, but they offer to be of great magnitude.

Figure 3 shows the results in the frequency of occurrences of drought events, denoting a distribution of 35.29% for the extremely strong frequency, represented in 12 years of the total period studied. In this sense, authors such as Loaiza et al (2015) established that these extremely strong magnitudes are associated with durations of several consecutive temporal groupings of extreme and severe intensities. As can be seen, the strong and weak frequencies appeared in a 17.65% frequency of occurrences for each one. Parra et al. (2016) in a study on the Meteorological Drought in Localities of the Llanos de Venezuela, pointed out that these frequencies of occurrences are associated with temporary durations of one month, and may have a high intensity. Finally, the results show a very strong frequency level with 14.71% and a mild and normal frequency level of 15% between the two.

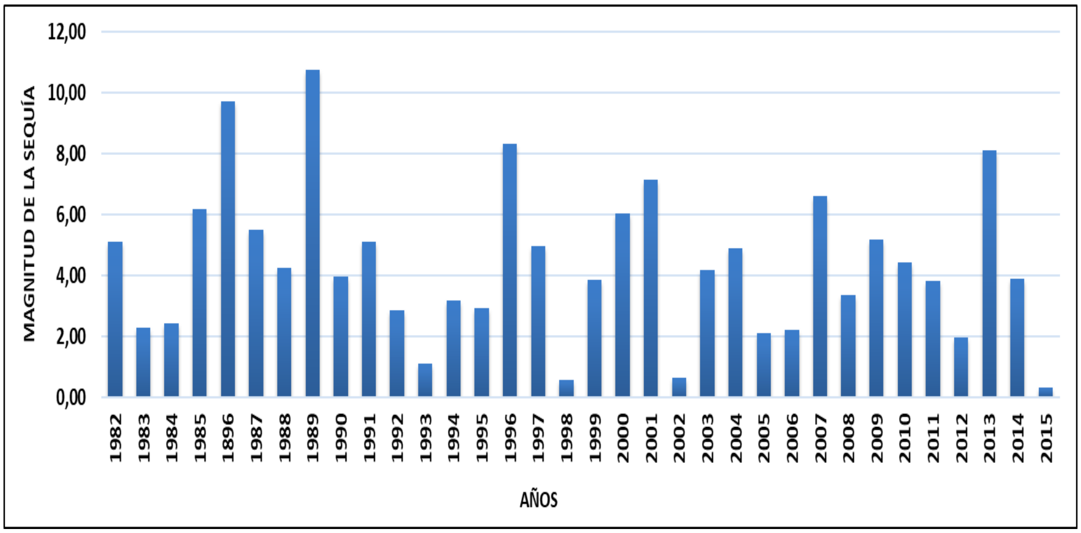


**Figure 2:** Distribution of the magnitudes of droughts for the town of Guanare, Portuguesa state; during the period 1982-2015.

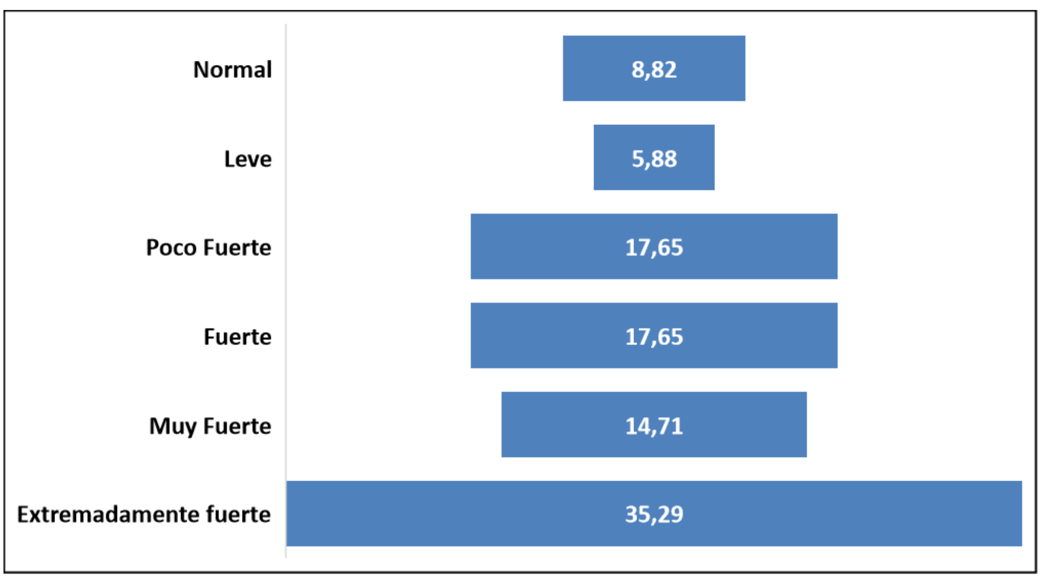


**Figure 3:** Frequency of occurrence of drought events according to the magnitude classes (monthly SPI) for the town of Guanare, Portuguesa state; in the period 1982-2015.

### 3.3 Duration of peak magnitudes of droughts

Table 4 shows the three maximum magnitudes of drought detected in the Guanare locality for the period 1982-2015, observing that the greatest magnitude of drought occurred in 1989 with a value of 10.78 and an annual precipitation level. 1,258 mm, distributed in 7 of the 12 months of the year. Likewise, the second maximum magnitude reflects a value of 9.75 for all months in 1986 except for the month of November, with an annual price estimate of 1,137 mm; and finally in 1996 a third maximum magnitude of drought of 8.33 was evidenced between the months of March-April, July, August, October and December; with an annual level of precipitation of 1,178 mm.

**Table 4:** Duration of the maximum magnitudes detected in the town of Guanare, Portuguesa state; for the period 1982-2015.

| **MAGNITUDE** | **DURATION** | | **TOTAL RAIN** |
|---|---|---|---|
| | **Period** | **Year** | **Annual** |
| **9,75** | January-October, December | 1986 | 1.137 |
| **10,78** | January-February, April, June, August, November-December | 1989 | 1.258 |
| **8,33** | March-May, July, August, October, December | 1996 | 1.178 |

### 4. Final thoughts

The Standardized Precipitation Index (SPI) applied to the town of Guanare, Portuguesa state; allowed a characterization of meteorological droughts in terms of intensity, magnitude and duration of these events. The results of this research showed that the level of extreme drought intensity in the locality during the 1982-2015 period was very low, not exceeding 2% and being rare with extremely strong magnitudes. On the other hand, it should be noted that these meteorological drought events occurred coincidentally for the period evaluated between the months of December and March; while the months of highest humidity were between the months of May, June and July. Finally, by virtue of the results obtained, it is important to take into account the vulnerability to drought events of the social, water and agricultural sectors of the area.

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