IMPORTANCE OF WETTING AND DROUGHT CYCLES IN PLAIN AREAS
CASE STUDY: ARRECIFES RIVER

Bacchiega, J.D.; Lopardo, M.C. y Barrionuevo, H. D.
Instituto Nacional del Agua
Au. Ezeiza Cañuelas km 1.62. Tel/Fax 011-44804500. dbacchiega@gmail.com

Cycles of wetting and drying produces in lowland areas consequences that directly affect their economic activities. The individual analysis of these issues leads, often, to solutions that can be effective for one cycle and counterproductive for the other. In this framework, a comprehensive watershed study allows to define and quantify the major problems, guide the implementation of structural measures and establish guidelines for structural solutions aimed at mitigating both problems.

In this paper we analyze the results of a comprehensive study of the watershed property of the pampas of Argentina, where both farming and urban life are affected by alternating cycles of moisture and on. We have evaluated various drought indices allowing to characterize the behavior change and its direct impact on the normal development of activities in the basin.

KEYWORDS: wetting and drought cycles, integral basin studies, Pampa region

INTRODUCTION AND PURPOSE

This work aims to highlight the general importance of the study of wetting and drying cycles in the climate of plain regions. Each region has climatic cycles of wetting and drying with different severities. Particularly in lowland areas of high agricultural activity, these cycles can produce consequences that directly affect economic activity in the region.

The premise of this problem must be contained within a comprehensive study of watershed study. In general when watershed studies are conducted, they have an eco-environmental point of view or a hydraulic-hydrological. It is to highlight the importance of integrated river basin studies with not only the above aspects but also economic, agricultural, social, hydrogeology, infrastructures between others.

Many of the actions that are performed in the emergency during periods of excess water are countrary to dry periods and vice versa. That is why there is a need for studies that include both periods and establish work aimed at improving the overall problems.

Finally, we made an application of the methodology to a case study linked to a basin located in the plain Pampeana in Argentina.

INTRODUCTION AND PURPOSE

The methodology used is based on the fabrication and characterization of wetting and drying cycles from different drought index. To use these indexes, basic weather data rates are needed as rainfall, monthly and annual and temperatures (minimum, maximum and average, both annual and monthly).

From the variety of drought indexes can be found in the literature, we have considered those who have been most widely used worldwide. The indexes used are:

- Decils indexes
- Estándar Precipitation Index
- Percentage of average rainfall
- Lang rainfall index

Deciles indexes are based on a classification of cumulative annual rainfall. To do this, the art is to be performed a statistical analysis of series of accumulated rainfall by distributing percentiles. This index has the practical utility of expressing the degree of rainfall in a given period within the frequency distribution without specifying the amount of rain.

To obtain this index an order should be made of the monthly precipitation data into deciles. Subsequently, it divides the distribution of occurrences of records of long-term precipitation in tenths of the distribution. Each of these categories is a decil. The first decil is the amount of rain exceeded by the lowest 10% of the occurrences of precipitation. The second decil is the precipitation amount not exceeded by the lowest 20% of the occurrences and so on. These deciles continue until the amount of rainfall identified by the tenth decile is the largest amount of precipitation in the long-term record. By definition, the fifth decil is the median, and the amount of precipitation that does not exceed 50% of the occurrences of the registration period. The deciles can classify the climate of a region as indicated in the table below.

Table Nº 1 – Classification by deciles index

0-10%	Extreme Drought
10-20%	Severe Drought
20-30%	Moderate Drought
30-40%	Mild Drought
40-50%	Incipient Drought

50-60%	Incipient Wetness
60-70%	Light Moisture
70-80%	Moderate Humidity
80-90%	Severe Moisture
90-100%	Extreme Moisture

The **Standard Precipitation Index** (**SPI**) helps to improve the early detection of drought and monitoring it. The SPI is a probability index that considers only precipitation of the study region. An index based on the probability of recording a given amount of precipitation, these probabilities are standardized so that when the index gives a null it indicates the average rainfall, which, when the index is negative corresponds to a period of drought, while positive where the period is wet.

A key feature SPI is the flexibility of the measures of drought on different time scales. Because droughts are a great variation in the length, it is important to detect and monitor them in a variety of scales. Short-term droughts are measured by meteorological instruments and are defined according to specific regional climate. On the other hand, important droughts to agriculture are in deficit of soil moisture and drought and periods of three to six months can make a big impact. The longest drought (months to years) can have significant impacts on surface water reservoirs and groundwater. SPI values are derived by comparing the total accumulated precipitation for a particular season or region during a specific time interval with the average cumulative rainfall for the same interval, this is done for the greater number of data available climate record. The values range from 2.00 or higher (extremely wet) to -2.00 or less (extremely dry) with near-normal conditions in a range of 0.99 to -0.99 (Table 2)

Table Nº 2 – Classification using standard precipitation index (SPI)

Extremely wet	**> 2.00**
Severely wet	**1.5< <1.99**
Moderately wet	**1< <1.49**
Almost normal	**-0.99< <0.99**
Moderately dry	**-1.49< <-1**
Severely dry	**-1.99< <-1.5**
Extremely dry	**<-2.0**

Drought is defined when the SPI is continuously negative and reaches a value of -1.00 or less, and continues until the SPI becomes positive. The duration of the drought is defined by the interval between the beginning and end of the period. The magnitude of drought is measured by adding the values of SPI during the months of drought.

This index can be obtained from the following expression:

$$I = \frac{(Pa - Pp)}{100}$$

Where P is the annual precipitation (in mm) and Pp is the average rainfall of record, preferably 70 years (in mm).

The **percentage of the average rainfall** is an index that refers to the relationship between the accumulated rainfall in a period of time and the average annual precipitation for a region expressed as a percent. The historical annual average precipitation is called normal rainfall and is derived from average annual rainfall occurred over a period of not less than 30 years.

This index is obtained from the following expression:

$$I = \frac{Pa - Pp}{Pa} * 100$$

In which, P is the annual precipitation (in mm) and Pp is the average annual rainfall in the serie. The percentage values estimated for each year indicate the deficit (negative values) and over (positive values) in annual precipitation occurred. Percentage values close to zero correspond to values near the historical average. The following table shows the value of the index.

Table N º 3 - Assessment percentage of average rainfall rate

Range of percentages values	Drought category
Between -20 y -30%	Mild Drought
Between -30 y -40%	Moderate Drought
Between -40 y -50%	Strong Drought
Between -50 y -60%	Acute Drought
Less than -60%	Intense Drought

The **Lang rainfall index** characterizes the climate of a region from the relationship between mean annual precipitation and mean annual temperature. The calculation expression is provided below:

$$I = \frac{P}{T}$$

Where P is the average annual rainfall (in mm) and T is the mean annual temperature (degrees Celsius). From the value of the index can classify the climate of the region under study according to the following table.

Table No. 4 - Assessment of Lang rainfall index

I_L	Climate Zones
>160	Wet
160-100	Humid temperate
100-60	Warm températe
60-40	Semi-arid
0-40	Arid

APPLICATION OF METHODOLOGY TO PLAIN BASIN

The pilot basin considered for the implementation of explicit methodology for the source area of the Arrecifes River, located in the Province of Buenos Aires, Argentina. This basin has an area of approximately 10,900 km2 and is composed of 11 municipalities: General López, Constitución, Colón, Pergamino, Ramallo, General Arenales, Junín, Rojas, Salto, Chacabuco, San Antonio de Areco, Baradero, Arrecifes, Capitán Sarmiento y San Pedro. All this region constitutes an area of high production value in terms of farming and agriculture and livestock.

The following figure shows the political map of the basin.

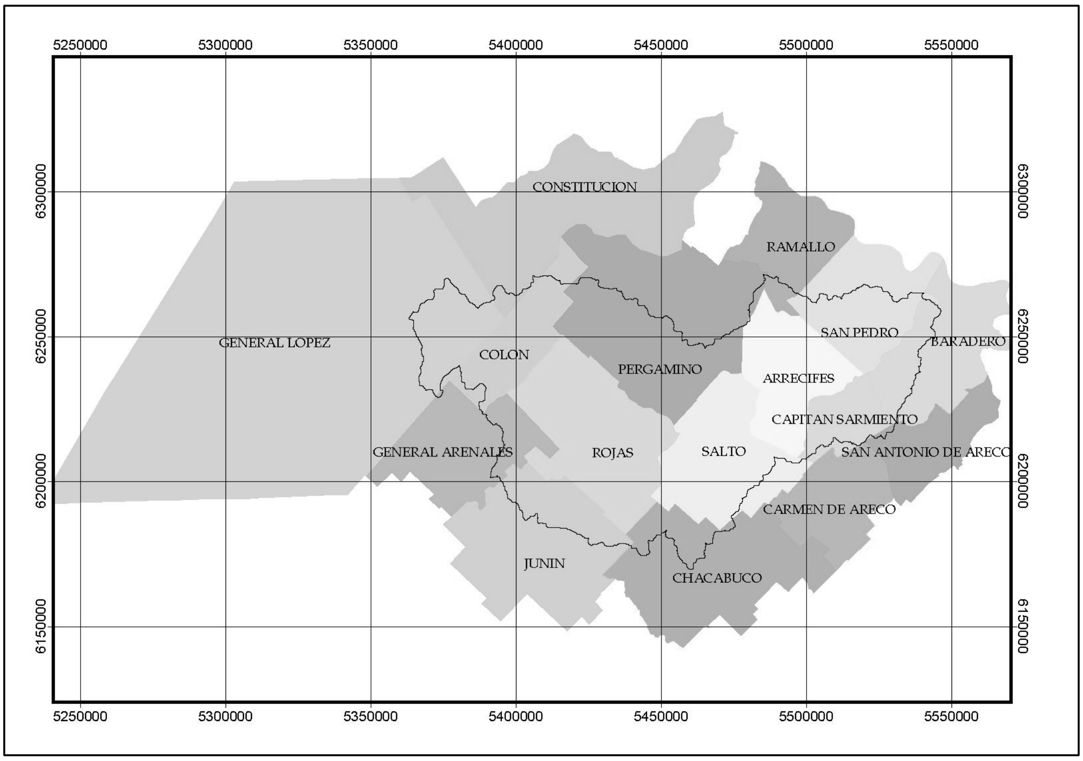

Figure 1.- Political map of the basin

Arrecifes River Basin is a plain basin with gentle slopes and a well-defined drainage network. The average rainfall in the basin is about 900 to 1000 mm per year and the climate is temperate-humid region. For the analysis of various indexes of drought has received sufficient information from both phenomena available to the INTA (National Institute of Agricultural Technology) in the city of Pergamino, Junín, Salto and San Pedro, and can thus characterize the basin in its entirety.

RESULTS ANALYSIS

In 2007 and particularly in 2008 precipitation in the Arrecifes basin was very low. As shown in Figure No. 2, the precipitation in 2008, monthly and annual, was considerably less than the average rainfall of the season for the series 1910-2005. This situation caused serious problems in farming produce an increase in the number of wells pumping and greatly increasing the demand for water for irrigation. This demand for irrigation was due to a need to maintain minimum agriculture returns that could be economically sustainable.

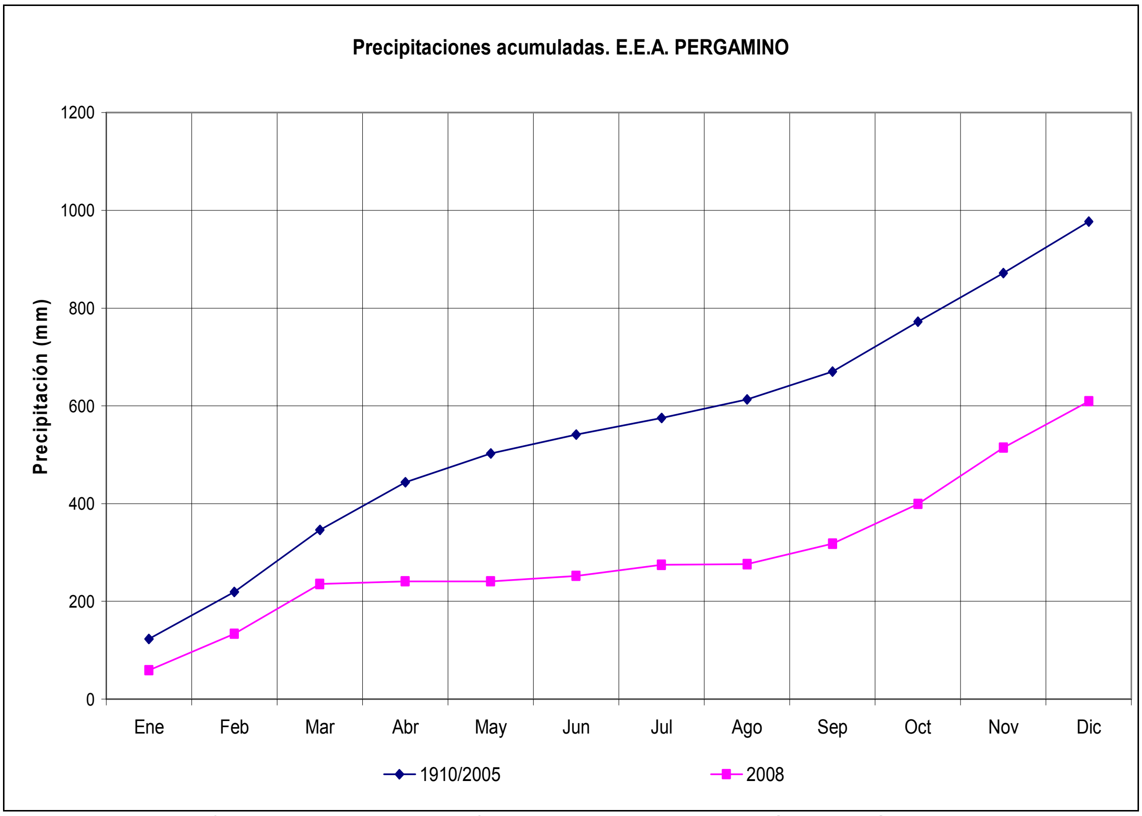

Figure N° 2. – Hydrological deficit in 2008. Pergamino Station. Source: INTA

From this problem arises the need to scrutinize the periods of drought and the potential solution of the consequences in a comprehensive study where a water surplus basin where usually turn of relevant quantities.

As noted above were used weather data collected from 4 stations in the basin, which are located so that from the consideration of the same basin can be characterized as a whole. The stations are considered in the towns of Pergamino, Salto, Junín and San Pedro. From the same data were calculated various indices proposed in the methodology, which allows understand the behavior of the climate in the region.

Figures 3 through 6 show the results obtained by applying the rate of deciles for the four seasons analyzed. In figures 7 to 10 the results obtained for the standard precipitation index (SPI). In Figures 11 to 14 present the results for the percentage rate of average rainfall. Finally in Figures 15 through 17 show the result of the implementation of Lang rainfall index only stations in the town of Pergamino, Junín and San Pedro, could not be calculated for Salto station because it does not record data temperature.

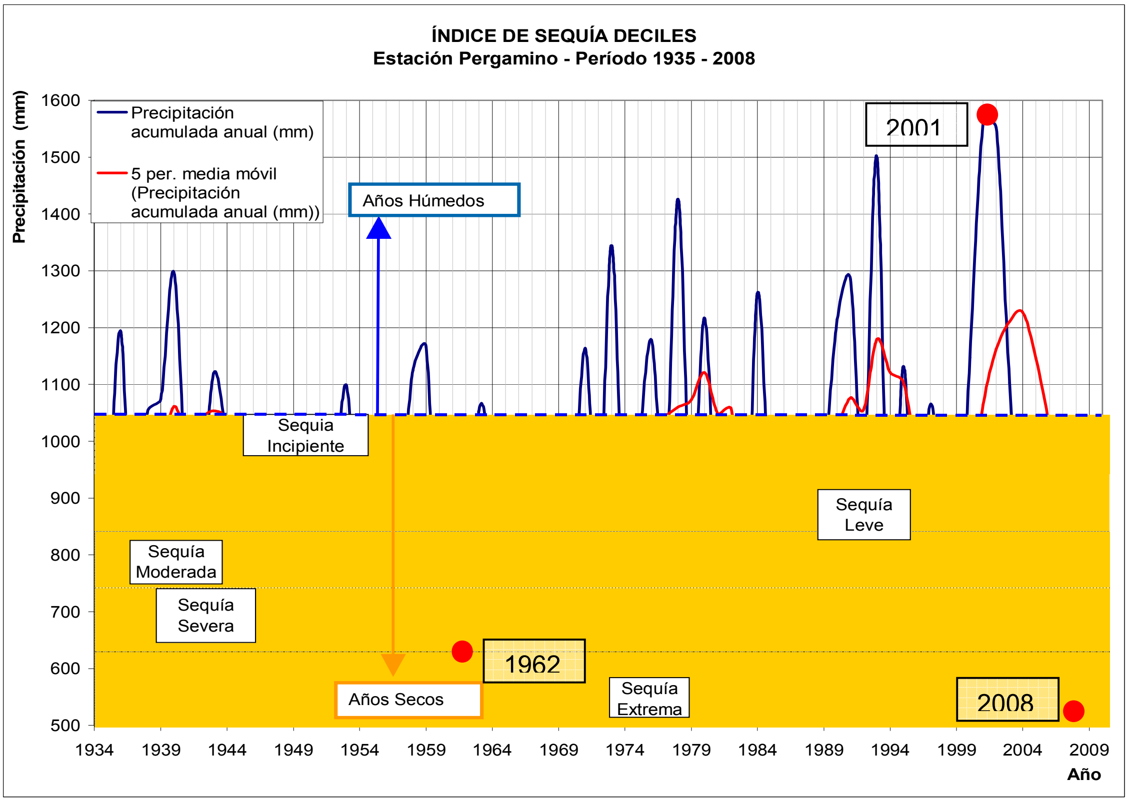

Figure 3 – Deciles indexes – Pergamino Station

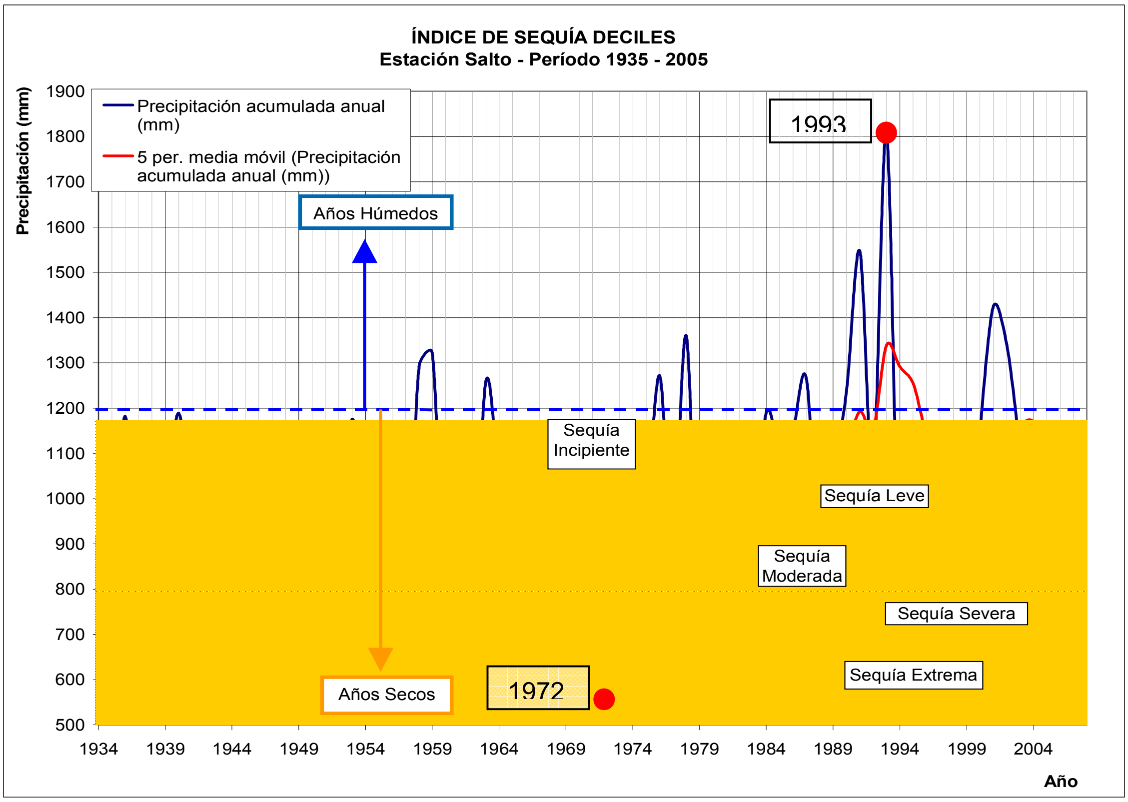

Figura 4 – Deciles indexes –Salto Station

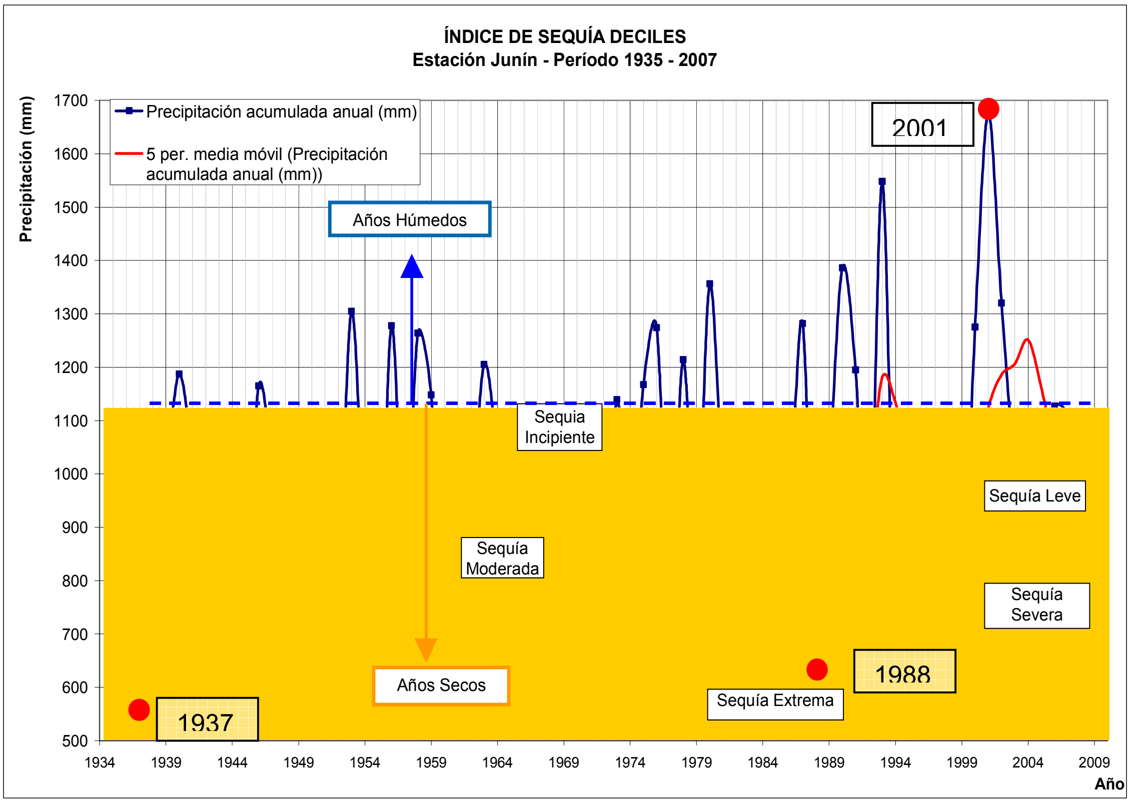

Figura 5 – Deciles indexes – Junín Station

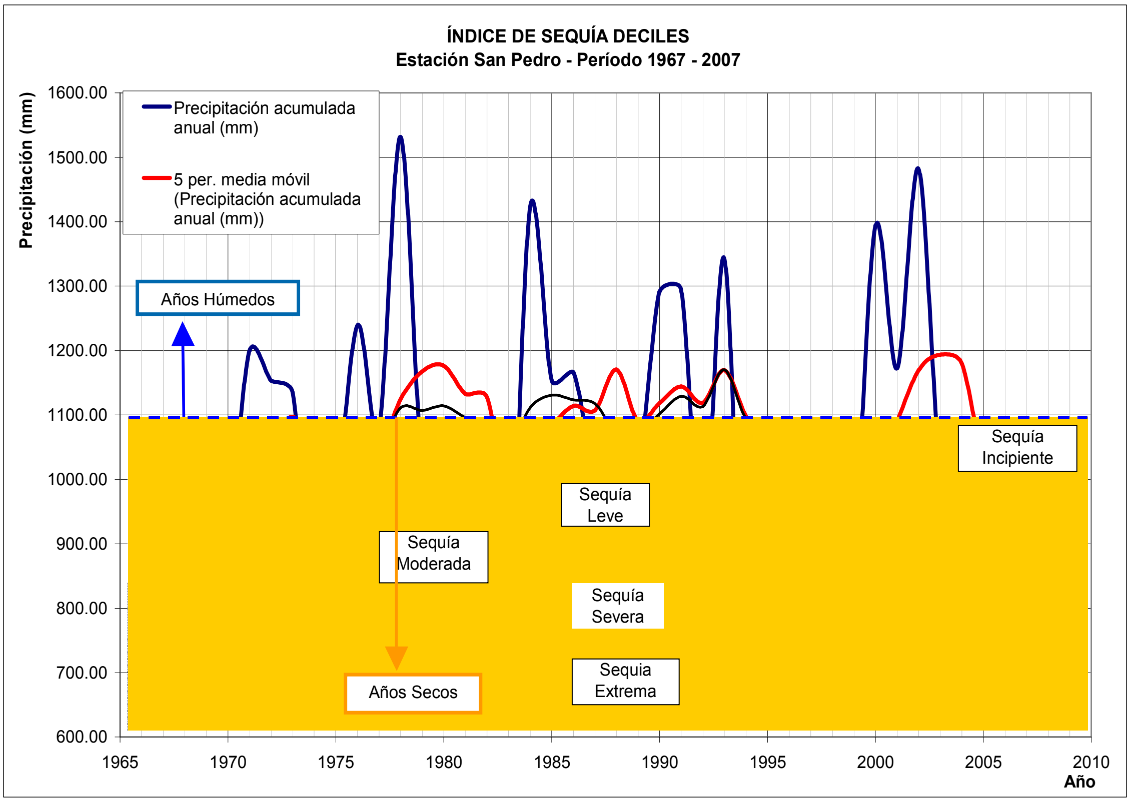

Figura 6– Deciles indexes –San Pedro Station

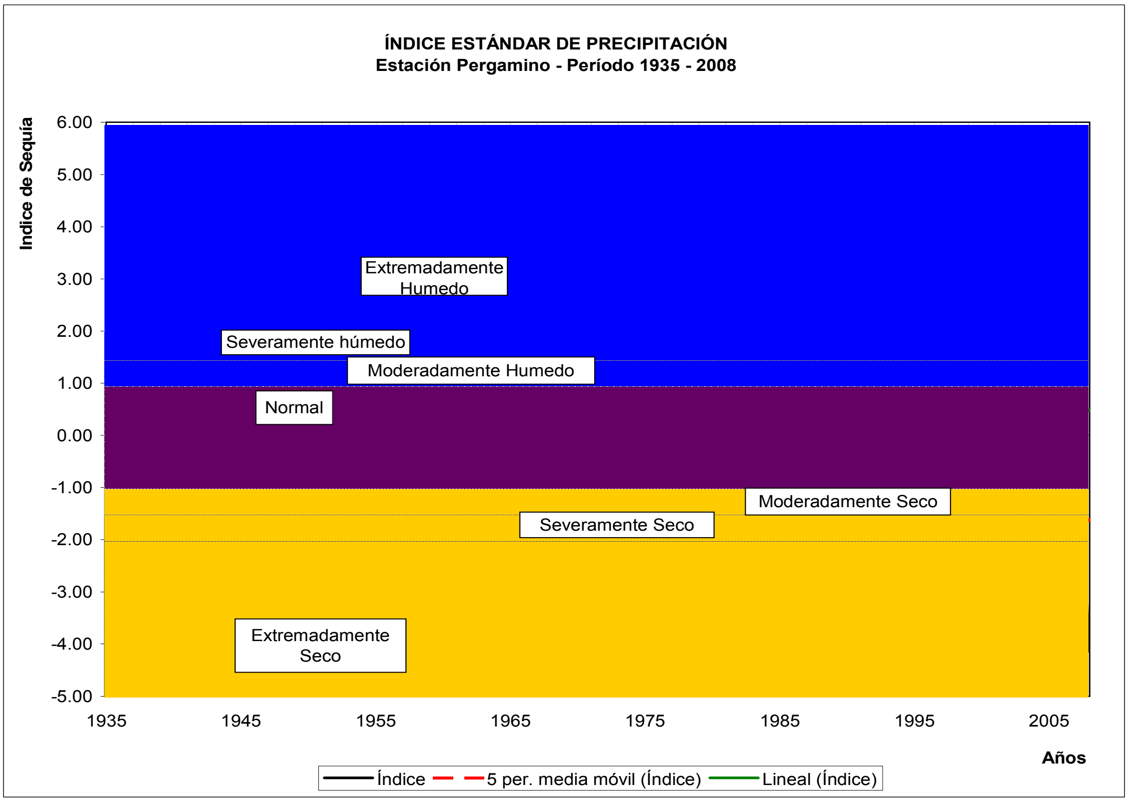

Figura 7 – Standar Precipitacion index –Pergamino Station

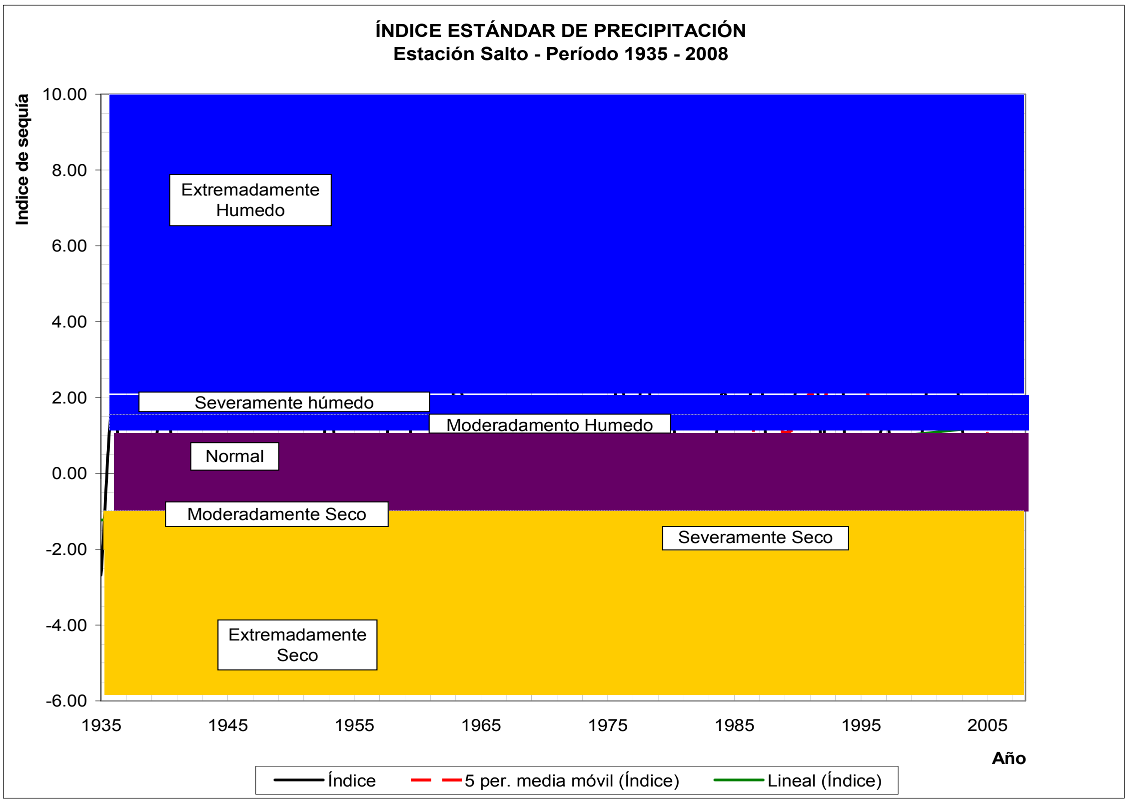

Figura 8 – Standar Precipitacion index – Salto Station

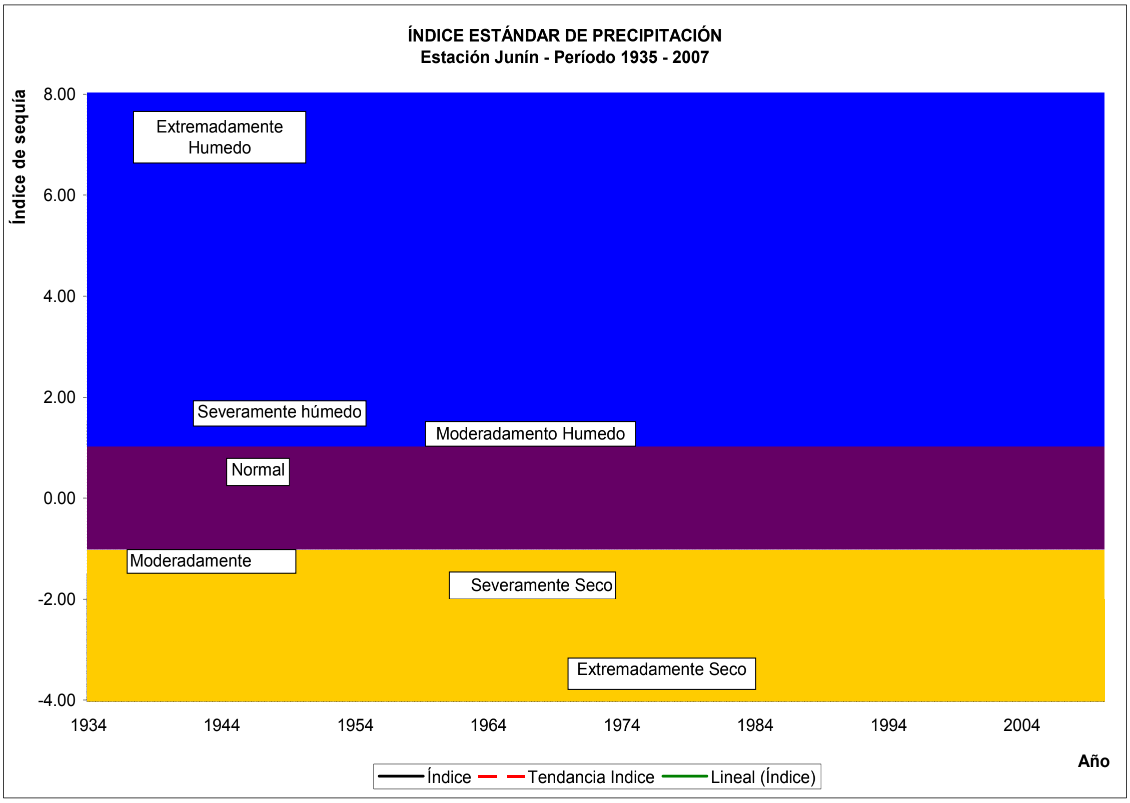

Figura 9 – Standar Precipitacion index – Junín Station

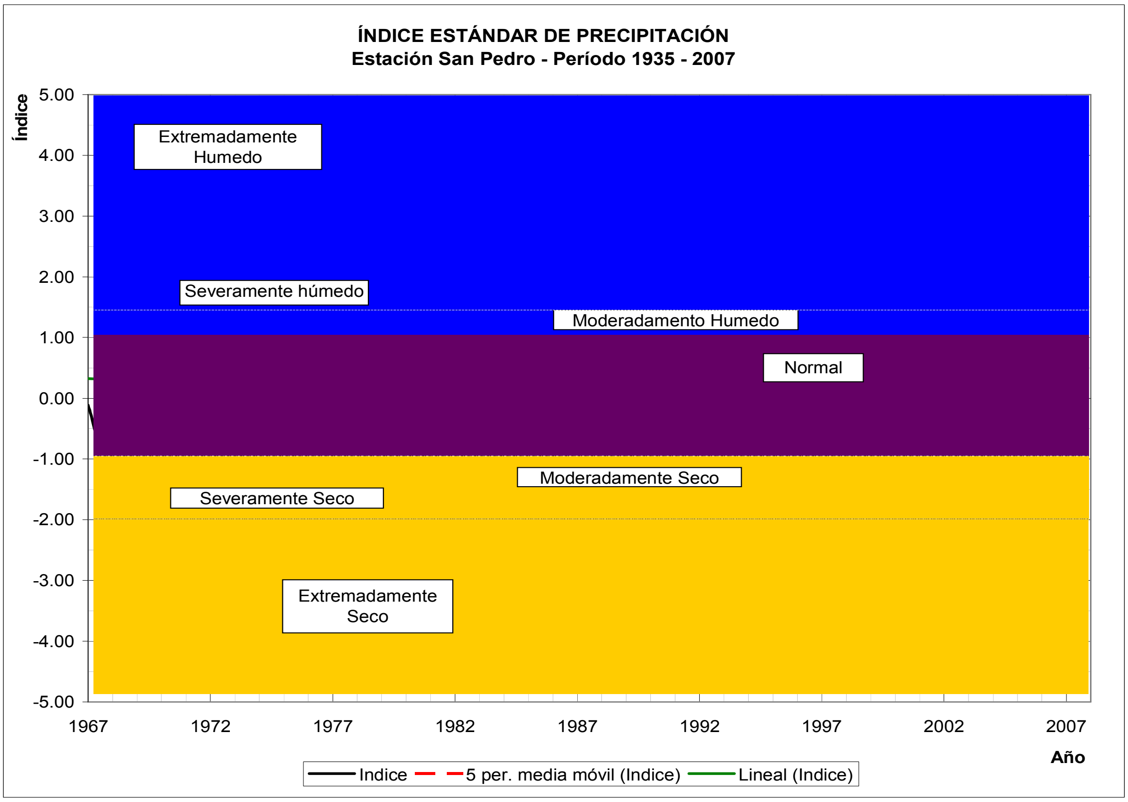

Figura 10 – Standar Precipitacion index – San Pedro Station

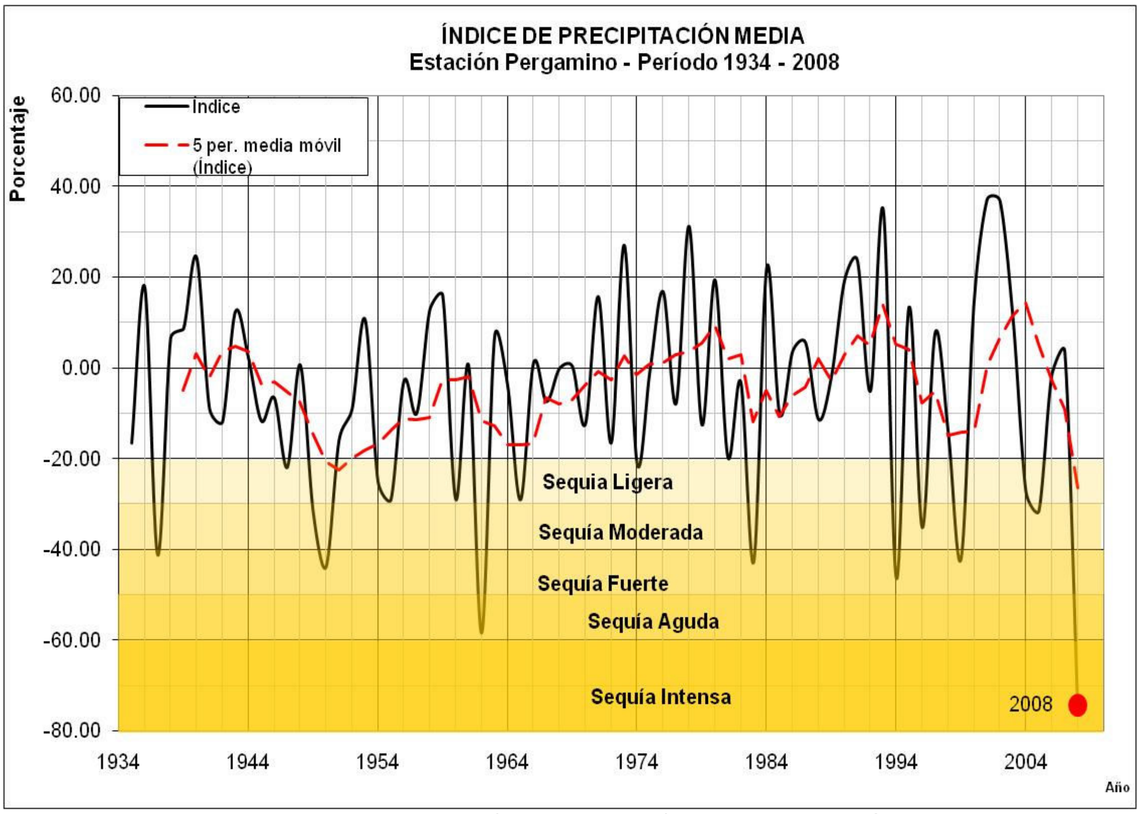

Figure 11 – Percentage of average rainfall – Pergamino Station

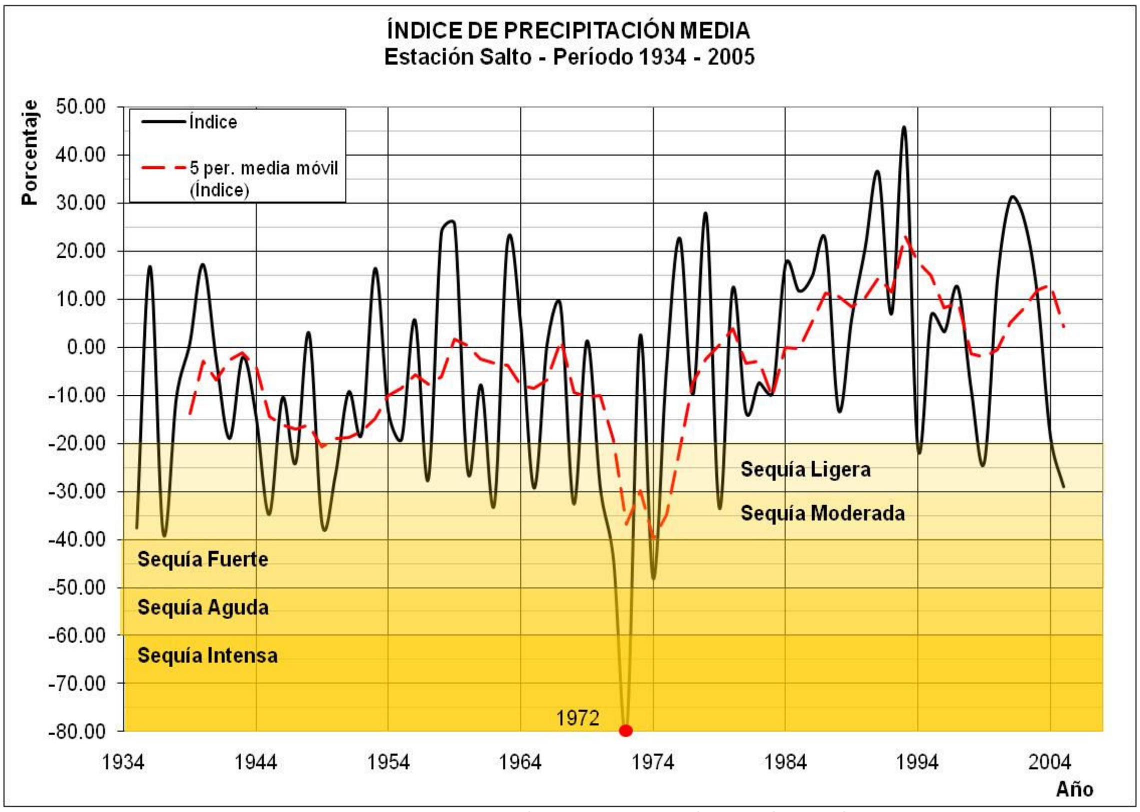

Figure 12 – Percentage of average rainfall – Salto Station

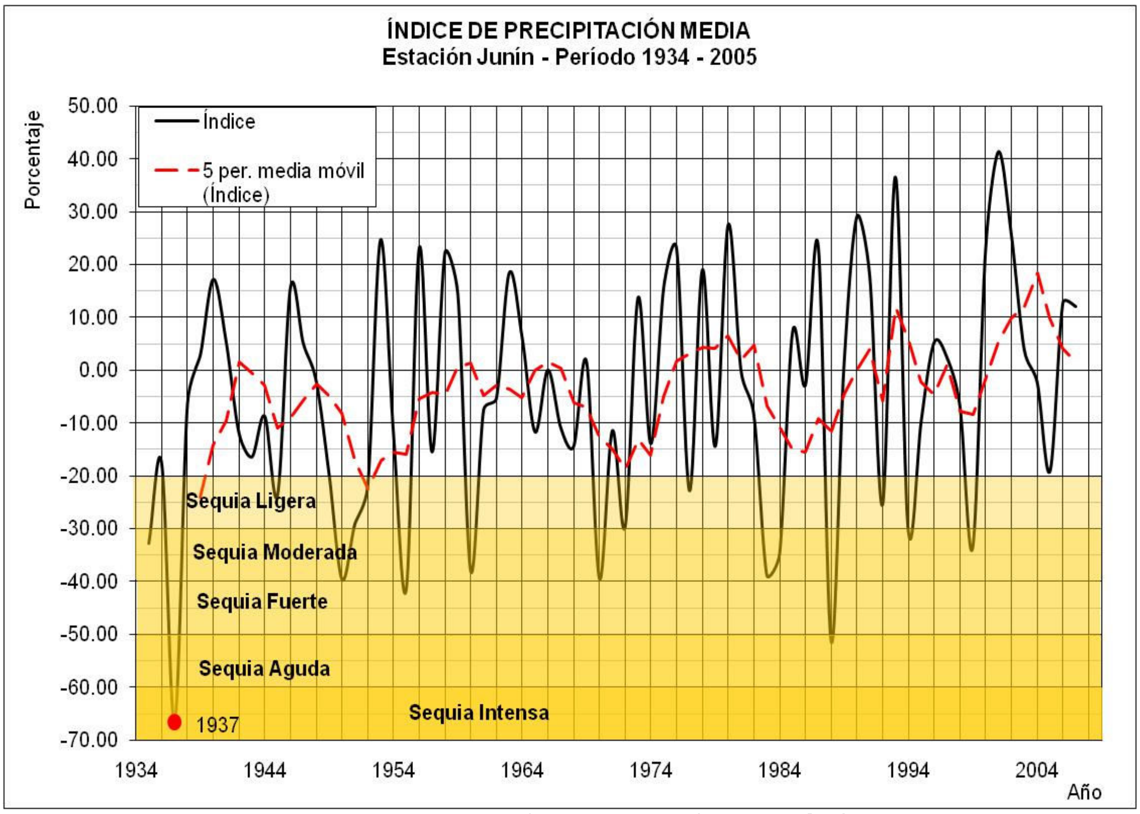

Figure 13 – Percentage of average rainfall – Junín Station

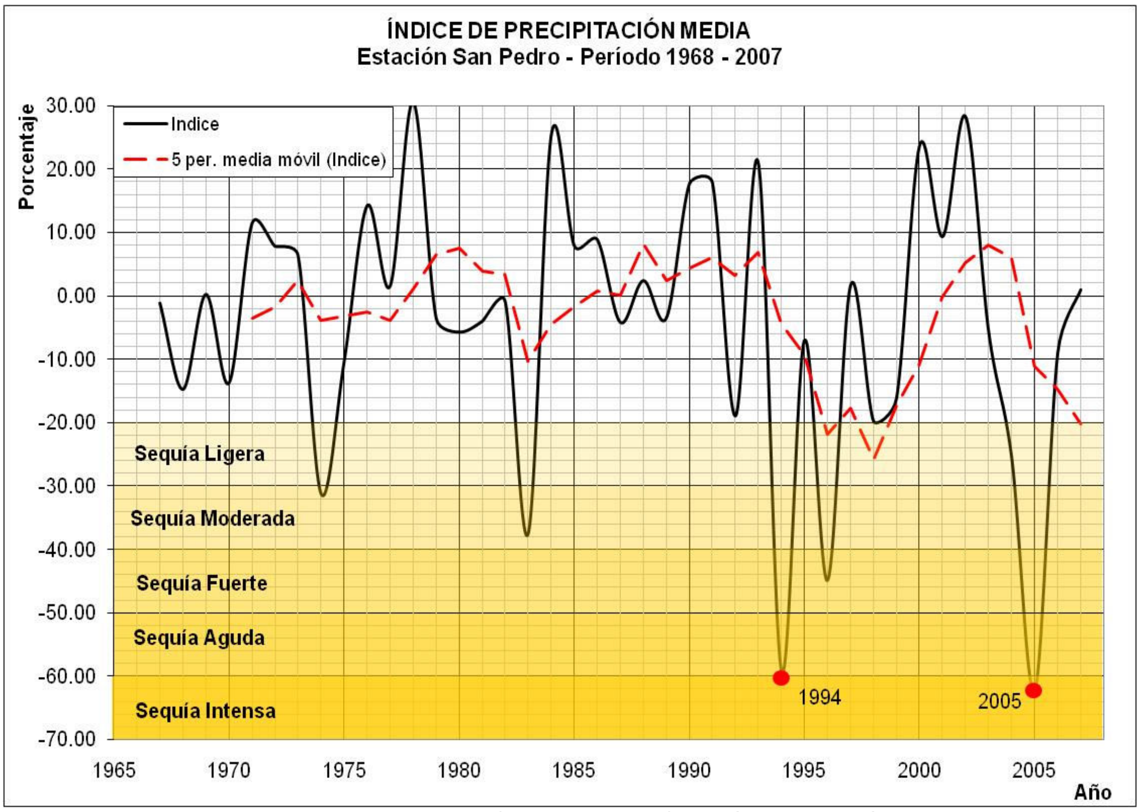

Figure 14 – Percentage of average rainfall – San Pedro Station

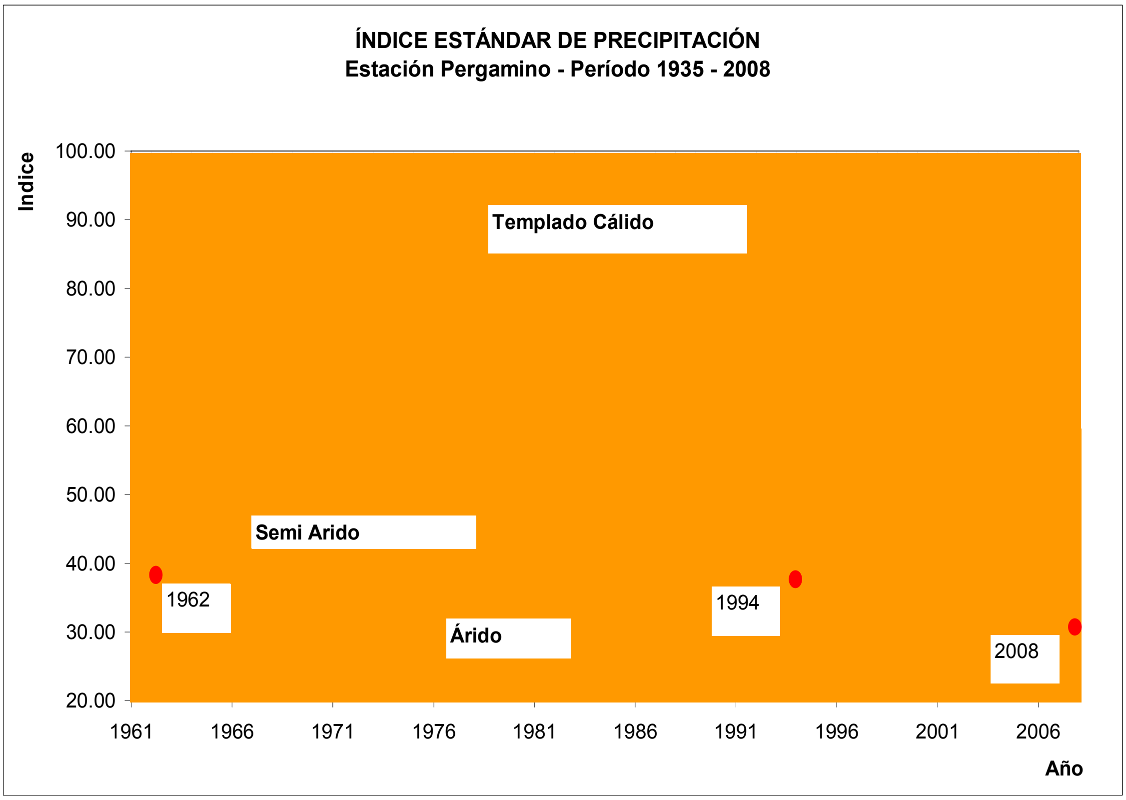

Figure 16 – Lang rainfall index – Pergamino Station

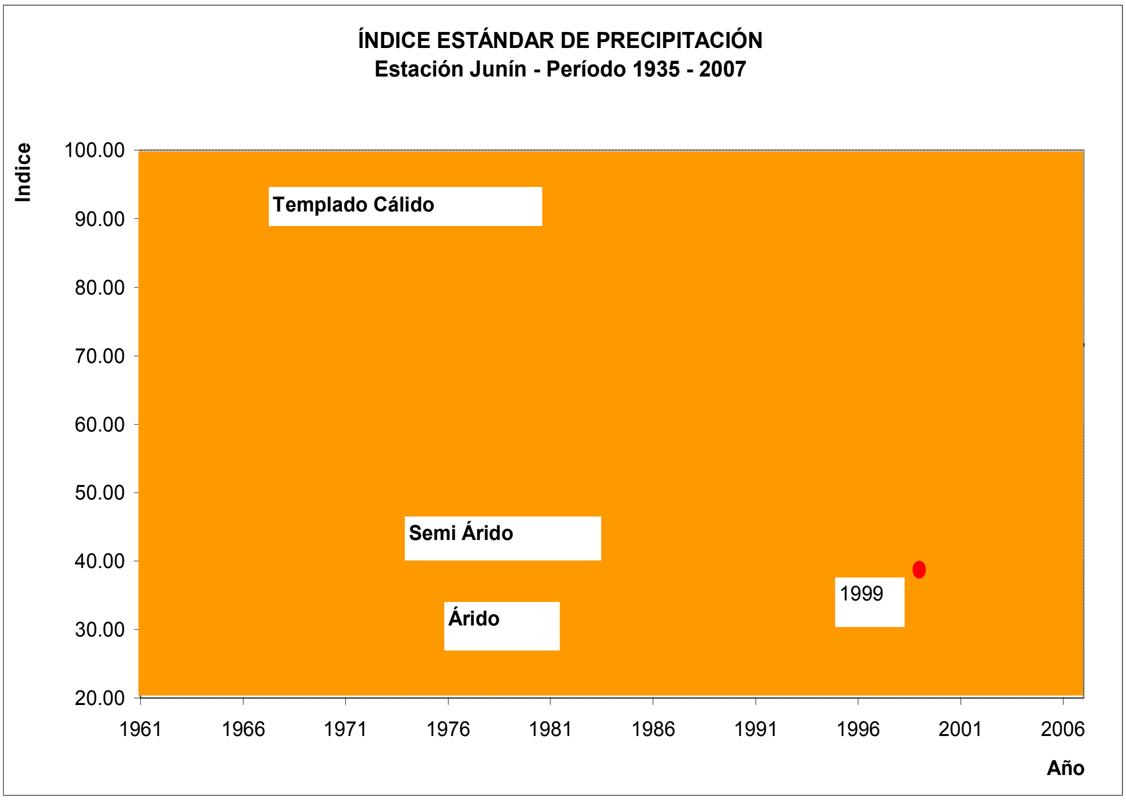

Figure 17 – Lang rainfall index – Junín Station

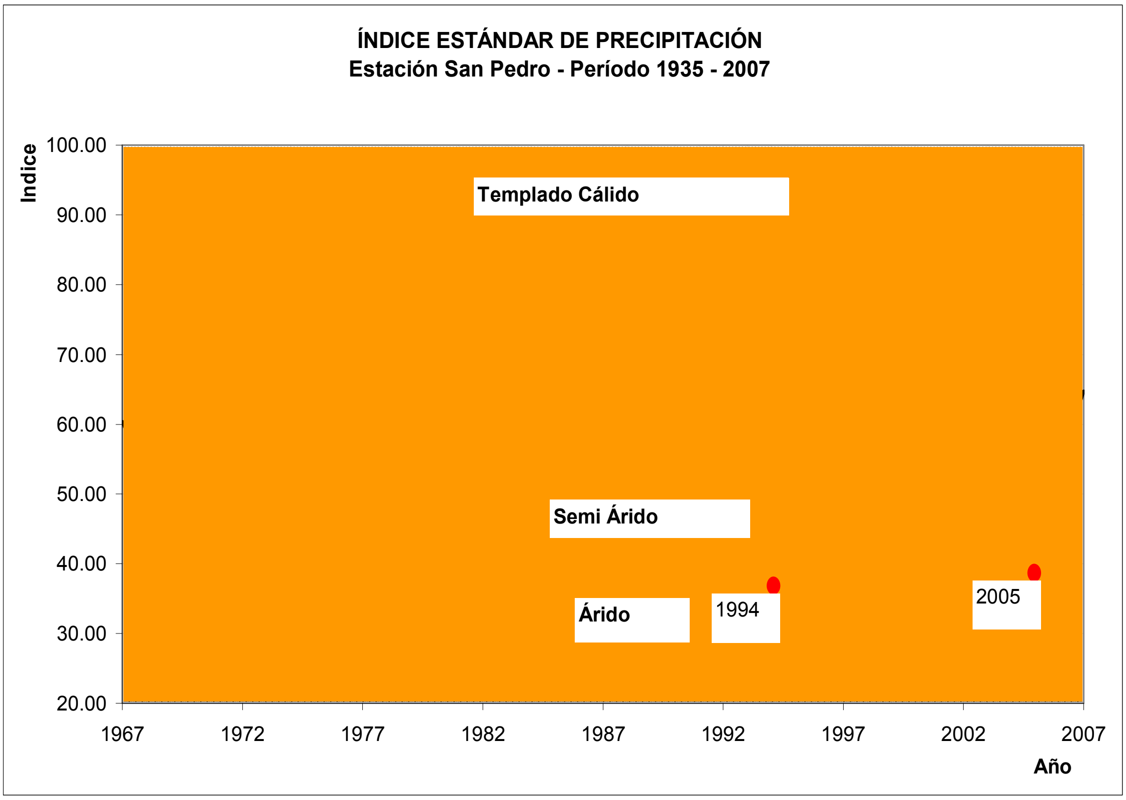

Figure 18 – Lang rainfall index – San Pedro Station

From the analysis of drought indices discussed above have drawn the following observations:

- The year 2008 was, according to the station in Pergamino, the driest year of the series, consider it as "extreme drought". No data are available from other stations this year, but according to information gathered from local newspapers and local people's own condition could be extrapolated to the entire basin. In a locality could not be regarded as extreme but if you can ensure that it has been a year of severe drought.

- In the last decade has seen several years with varying degrees of mild to severe drought, particularly the years 2004, 2005 and 2006. The degrees of drought are different depending on the area and season considered, but all agree that were dry years.

- To the town of Junín, the driest year, excluding 2008, was in 1937, coinciding with severe droughts in the rest of the stations in the region.

- As you can see all the records and indexes analyzed, there are no marked dry periods, except 2004 and 2008. There are only dry years, of which only some may be regarded as extreme. Most years the record can be considered as wet feature that is evident in the high productivity of the region.

- From the observation of the indexes can be said that there is a trend towards greater number of wet years has been increasing over the years, even considering the dry period from 2004 to 2008. This condition of increased humidity, corresponds to the greater involvement caused by overflowing streams.

CONCLUSIONS

Of the analysis emerges clearly that the behavior of a basin hydrometeorological causes alternating cycles of wetting and drying, tend to prevail in the basin study, the first during the years of existing records. Indeed, if considered as an indicator, for example, the average precipitation rate in the four analyzed stations would have an incidence of around 25% of droughts over the total period of record. This percentage tends to change if we consider as a parameter the standard precipitation index, which gives an incidence of dry periods reaching up to 40%, but cycles always prevail over the dry moist.

Also of note is that effectively the last 40 years, there was an increased frequency of wet years, during which the incidence of drought years decreased to 20% on average.

REEFERENCES

Barros V.; Clarke, Robin; Silva Dias, Pedro; (2006). El Cambio Climático en la Cuenca del Plata, capítulo VII, pag.95-97 . Publicación CIMA-CONICET. Proyecto IAI SGP II 057

Burgos & Vidal (1951). Cálculo de la Evapotranspiración Potencial y Balance Hídrico, según Thornthwaite. Meteoros, Año I N°1, Servicio Meteorológico Nacional, Argentina.

Thornthwaite, C.W.; Mather, J.R.(1967) Instrucciones y tablas para el cómputo de la evapotranspiración potencial y el balance hídrico. Reproducción del Instituto de Suelos y Agrotecnia, INTA, Argentina.

Valiente, O , (2001) Sequía: Definiciones , Tipologías y Métodos de Cuantificación; Investigaciones geográficas Nº 26, pp 56-80; Insituto Universitario de Geografía, Universidad de Alicante, España.