World Academy of Science, Engineering and Technology
International Journal of Marine and Environmental Sciences
Vol:14, No:11, 2020

Estimation of the Drought Index Based on the Climatic Projections of Precipitation of the Uruguay River Basin

José Leandro Melgar Néris, Claudinéia Brazil, Luciane Teresa Salvi, Isabel Cristina Damin

Abstract**—**The impact the climate change is not recent, the main variable in the hydrological cycle is the sequence and shortage of a drought, which has a significant impact on the socioeconomic, agricultural and environmental spheres. This study aims to characterize and quantify, based on precipitation climatic projections, the rainy and dry events in the region of the Uruguay River Basin, through the Standardized Precipitation Index (SPI). The database is the image that is part of the Intercomparison of Model Models, Phase 5 (CMIP5), which provides condition prediction models, organized according to the Representative Routes of Concentration (CPR). Compared to the normal set of climates in the Uruguay River Watershed through precipitation projections, seasonal precipitation increases for all proposed scenarios, with a low climate trend. From the data of this research, the idea is that this article can be used to support research and the responsible bodies can use it as a subsidy for mitigation measures in other hydrographic basins.

Keywords**—**Drought index, climatic projections, precipitation of the Uruguay River Basin, Standardized Precipitation Index.

I. Introduction

THE effects of climate change are becoming more and more present today. It is argued that among the elements that cause this phenomenon, there is a significant increase in the emission of gases responsible for the greenhouse effect, related to anthropogenic activities, such as burning, deforestation and emissions of industrial gases without adequate controls [1].

Escalating change is now available, so it is important to take steps to minimize its effects [2]. If the population does not act effectively to contain the concentration of greenhouse gases in the atmosphere over the next two decades, the increase in average global temperature can exceed 4 °C by 2100, which will put the Earth in an irreversible process of warming, with unpredictable consequences.

In Brazil, both the El Niño and La Niña phenomena have caused climate change throughout the territory and also in a very heterogeneous way. According to [3], the entire southern region of Brazil experiences abundant precipitation, intense rains and elevations in temperature levels due to El Niño and La Niña manifestations, this same region is affected by severe droughts.

The scarcity of precipitation can cause drought, which is a complex meteorological phenomenon, with social influences often aggravated by human action, due to air pollution, fires, irregular industrial growth, among others. The occurrence of this climatic anomaly in several regions of the globe shows the vulnerability of humans to this climatic risk [4].

Several indicators can be developed to quantify, standardize and compare drought with the historical data of the study region, the SPI is currently one of the most used tools [5]. This indicator quantifies the deficit or the excess of precipitation at different time scales. "Characteristic that makes this index a valuable method for all studies of water availability, whether short or long term" [7].

According to the Diagnosis of the Region of the Uruguay River Basin [15], the analyzed region, Uruguay River Basin, comprises almost 50% of the territories of the states of Santa Catarina and Rio Grande Sul. This region presents an approximate area of 175,000 km^2, with a reasonable diversity of natural landscape, form of occupation and use of the soils, economic, socio-cultural aspects, as well as environmental issues.

The Diagnosis of the Uruguay River Basin Region states that in the Uruguay River Basin there are several causes for environmental damage and economic problems [15], among them the lack of planning instruments regulate and monitor the use of natural resources, such as land occupation, proper use of water and preservation of forested areas.

The observation of the precipitation data must be done in a very careful way, so that it is not a source of several errors when interpolated or extrapolated, this treatment is necessary, since the measurements are punctual in space.

Knowledge of the flow of water in and out is extremely important for various sectors such as agriculture and power generation [8]

A. Goals

The objective of this work is to characterize and quantify, based on precipitation climatic projections, the dry and rainy events in the region of the Uruguay River basin, through SPI. From the collected data, it is intended to analyze the possible variations on the water potential of the basin and eventual damages due to the lack of water that can impact the hydroelectric of the region, which depend on the flows of the rivers for its operation.

Specific objectives:

a) Use the climatic projections of the models belonging to the Coupled Model Intercomparison Project Phase 5 (CMIP5) to present an analysis of the impacts of climate

Claudineia Brazil is with the College Dom Bosco, Brazil (e-mail: neiabrazil@gmail.com).

change on the pluviometric regime in the Uruguay River Basin;

b) Extract and organize the precipitation database of the Uruguay River Basin;

c) Calculate the standard drought index of the Uruguay River Basin.

II. Material and Methods

The evaluation of the precipitation and drought estimation was carried out in the Uruguay River Basin, which extends between the parallels of 27º and 34º south latitudeS and the meridians of 49º30' and 58º5' W. According to the National Water Agency [11], the hydrographic region of Uruguay has great importance for the country due to the agroindustrial activities developed and its hydroelectric potential.

Fig. 1 Location Uruguay River Basin in RS [8]

The Uruguay River is 2,200 kilometers long and originates from the confluence of the Pelotas and Canoas rivers. In this section, the river takes the east-west direction, dividing the states of Rio Grande do Sul and Santa Catarina. The watershed has, in Brazilian territory, 174,533 km² of area, equivalent to 2% of the national territory. Its Brazilian portion is in the southern region, comprising 45,000 km^2 of the State of Santa Catarina and 130,000 km^2 in the State of Rio Grande do Sul. It is bordered to the north and northeast by Serra Geral, to the south by the border with the Eastern Republic of Uruguay, east by the Central Depression Riograndense and the west by Argentina [9].

The climate of the Uruguay River Basin is temperate, with a regular intra-annual distribution of rainfall, but with some increase from May to September, coinciding with winter. The average annual precipitation is 1,784 mm; the periods of greatest drought in the Uruguay Basin are associated to periods of very low rainfall occurrence [10].

The standard monthly precipitation index should be calculated taking into account the monthly precipitation of the current year (P), the monthly mean precipitation ($\overline{\mathbf{P}}$) and the standard deviation of the monthly precipitation (Sp) of the climatological rainfall series.

The equation that determines the SPI value is shown as:

$$\text{SPI} = \frac{P - \overline{\mathbf{P}}}{Sp} \tag{1}$$

TABLE I
SPI Values and Drought Categories [5]

SPI VALUES	DRY CATEGORY
≥ 2,00	Extremely Humid
1,5 a 1,99	Very Humid
1,0 a 1,49	Moderately Humid
- 0,99 a 0,99	Near Normal
- 1,0 a - 1,49	Moderately Dry
- 1,50 a - 1,99	Severely Dry
≤ - 2,0	Extremely Dry

In the analysis of the SPI values found and the severity class of this index, it is considered that the drought event begins when the SPI becomes negative and ends when it returns to positive values. Thus, according to [6], the values of the positive SPI results show higher than the median or average precipitation and the negative values show lower precipitations, being thus used for both dry climates and humid climates.

The database that was used in this research is part of the CMIP5, which provides models of climate projections. These models are organized according to the CPR. They are calculated based on the number of radiation reflection, i.e. the ability to dissipate heat in each of the scenarios. "The projection scale goes from 2.6 (optimistic scenario) to 8.5 (pessimistic scenario), the current scenario is 2.2" [12].

In this research, the RCP 8.5 method was used. (Pessimistic scenario), the increase in radiation value would be four times higher. According to [12]: "The most worrying of all cases, it would be characterized by the constant increase in the radiation rate, caused by the growth in the emission of greenhouse gases and in a higher concentration".

For the comparison of the climatic projections, these were divided into three intervals: Interval - 1 (2026 - 2050), Interval - 2 (2051 - 2075) and Interval - 3 (2076 - 2100). Seasonal precipitation analysis was performed for each of these intervals separately, differentiating for the seasons of spring, summer, autumn and winter.

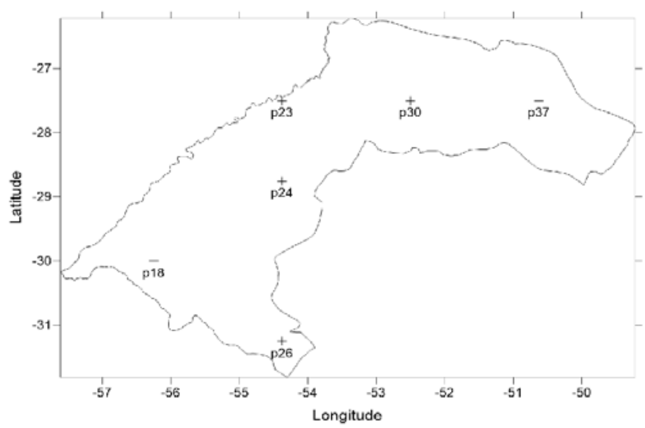

Fig. 2 Pluviometric stations analyzed in the Uruguay River Basin

Fig. 2 shows the location of the pluviometric stations within the Uruguay River Basin, defined by the GrADS system, which works with binary data matrices, where the variables can have up to four dimensions such as longitude, latitude, vertical levels and time. The defined points were for p18, p23, p24, p26, p30, p37.

The climatic norm of Brazil (1961-1990) is defined by the World Meteorological Organization (WMO), using average values calculated for the relatively long and uniform period, comprising at least three consecutive decades, and normal climatological patterns as averages of climatological data calculated for consecutive periods of 30 years [13].

III. Results

The information was provided in grid points using the Grid Analysis and Display System (GrADS) software, for the extraction of the monthly values of solar radiation. According to [14], GrADS is a grid data visualization and analysis system, which works with binary data matrices, and its variables can have up to four dimensions such as longitude, latitude, vertical levels and time.

The positive SPI values show that the differentiation behavior is higher than the average and the values show that the rainfall is lower than the average, consequently determining whether the climate is dry or humid.

In Fig. 3, which refers to station 18, located between the sub-basins of Ibicuí and Quaraí, it was shown that in February and April the climate will be moderately humid and in August the climate will be very humid. In the case of June, the climate will tend to approach moderately dry. The other months remain with the climate close to normal.

In the case of Fig. 4, which refers to station 23, located between the sub-basins of Santa Rosa and Ijuí, there will be moderately humid weather in January and February. In August, the climate will reach extremely humid. In other months they remain with the climate close to normal.

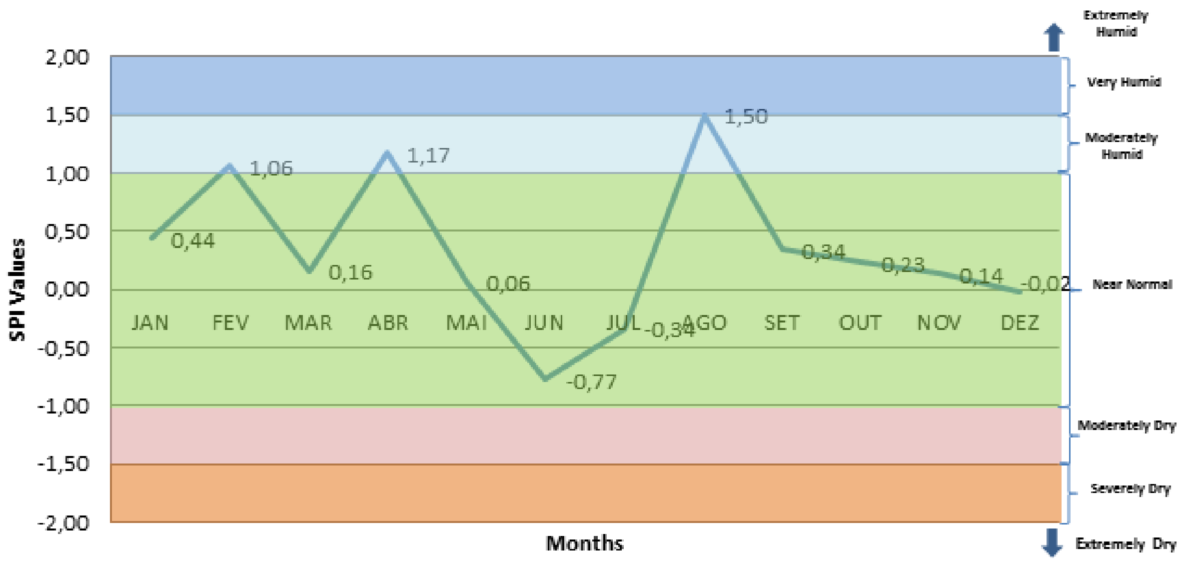

Fig. 3 SPI for Pluviometric Station 18 (2026-2100).

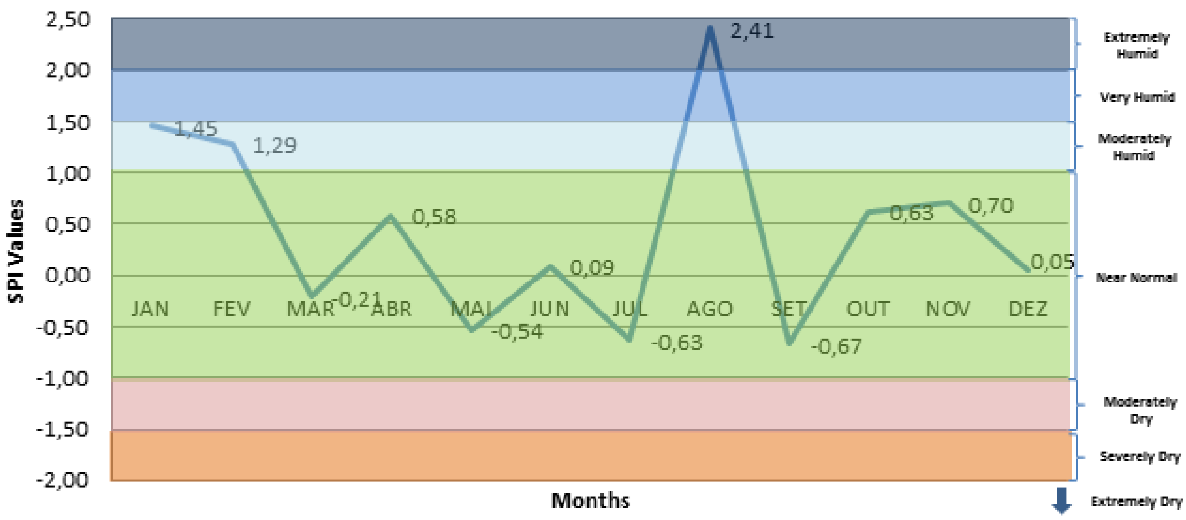

Fig. 4 SPI for Pluviometric Station 23 (2026-2100)

In Fig. 5, which refers to station 24, located between the sub-basins of Piratinim and Ijuí, January almost reaches the moderately humid climate different from February that reaches this index. August will have a very humid climate and in the case of September there will be moderately dry weather. According to [14] the State of Rio Grande do Sul, because despite having a favorable climatic characteristic, with an average annual rainfall of 1,547 mm (normal pattern 1931-1960), has been facing drought periods during the last years. In other months they remain with the climate close to normal even though there are variances between them.

Fig. 6, which refers to station 26, located between Santa Maria and Negro sub-basins, shows that the climate starts moderately humid in January and afterwards the remaining months will remain close to normal, highlighting only January. Analyzing the results, it is observed that September presents conditions that indicate an extremely humid scenario.

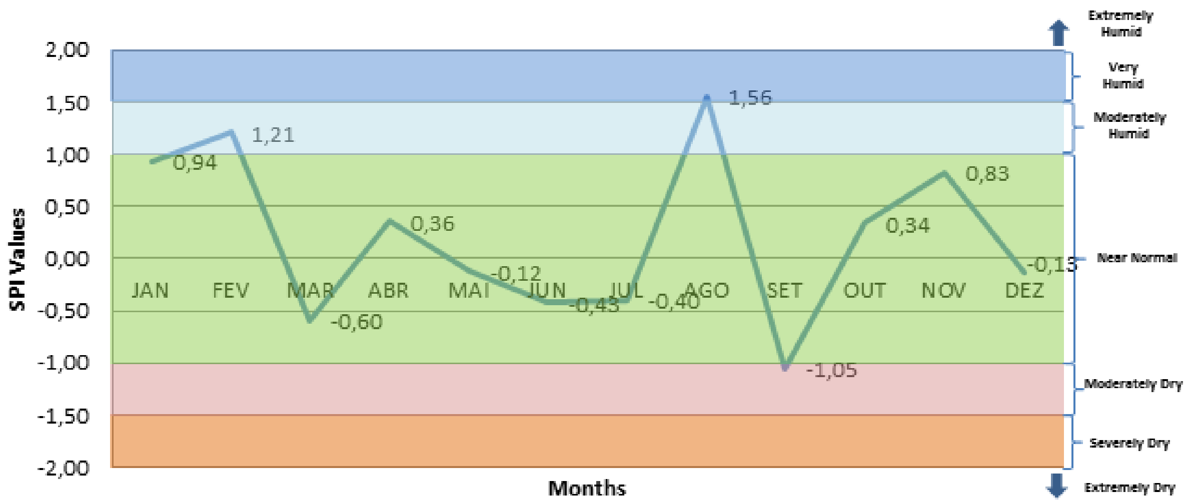

Fig. 5 SPI for Pluviometric Station 24 (2026-2100).

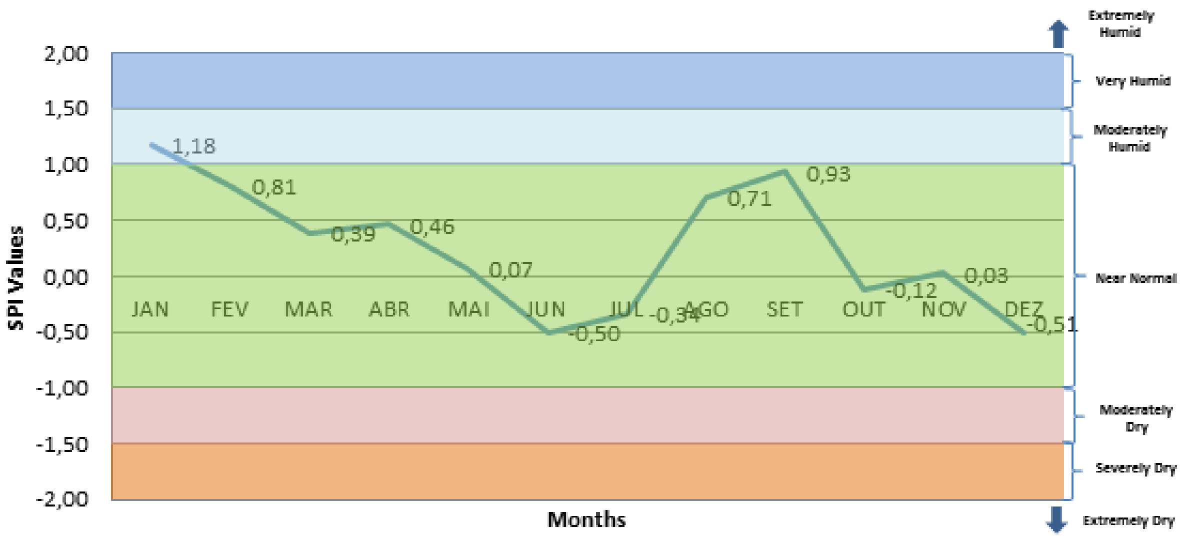

Fig. 6 SPI for Pluviometric Station 26 (2026-2100)

According to Fig. 7, which refers to station 30, located between the sub-basins of Passo Fundo and Várzea, the climate in January reaches the extremely humid point, in August it will be moderately humid, in the other months the stable climate is within normal climatology.

According to Fig. 8, which refers to station 37, located in the sub-basin of Apuaê Inhandava, in January and June it will be very humid, April and August with a tendency for moderate humidity, but within normal climatological conditions, as in other months.

IV. Conclusion

The objective of this work was to characterize and quantify rainfall and rainfall events in the Uruguay River Basin, using the SPI, based on precipitation climatic projections. Comparing the climatic norm of the stations defined in the Uruguay River Basin through the precipitation projections, we can see the increase of seasonal precipitations for all the proposed scenarios. These results served as a complement to characterize and quantify the dry and rainy events.

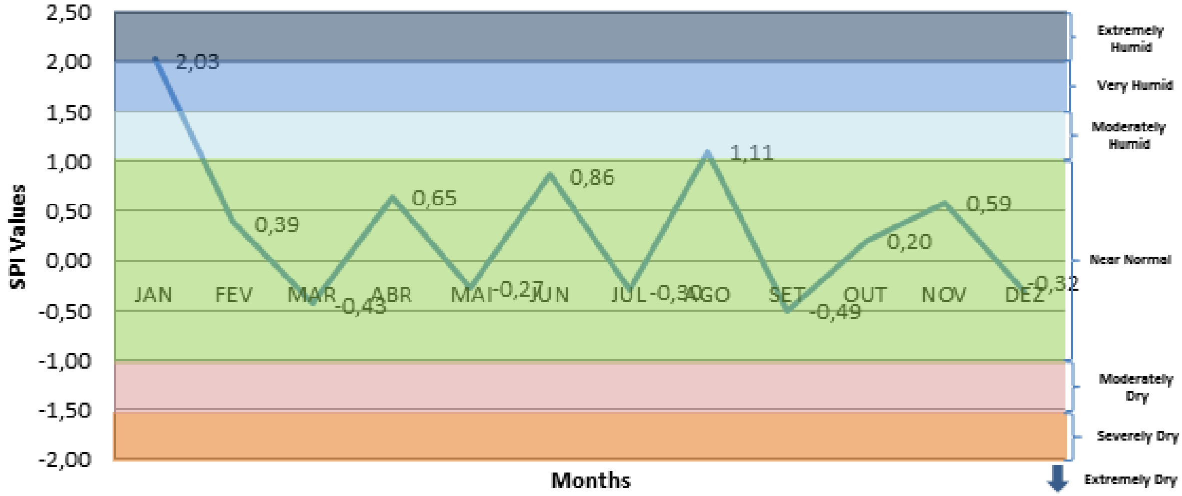

Fig. 7 SPI for Pluviometric Station 30 (2026-2100)

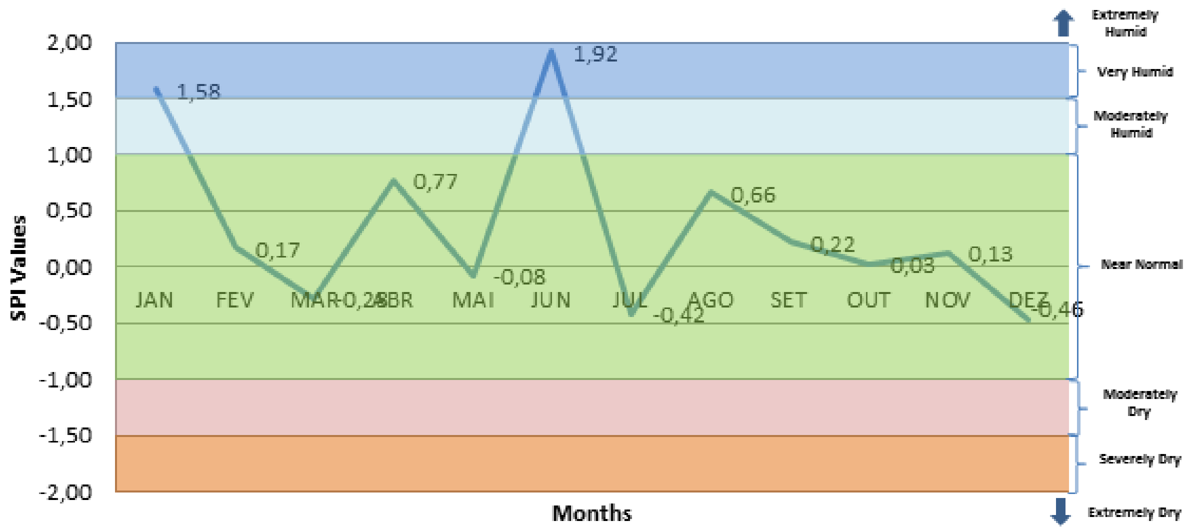

Fig. 8 SPI for Pluviometric Station 37 (2026-2100)

The results obtained for SPI (2026-2100) indicated that in the majority of the analyzes, there will be a climate close to normal and tendencies to humid climates, that is, increase of precipitation in the Uruguay River Basin for all pluviometric stations chosen for this study. Of note is the pluviometric station 30, where it reached an extremely humid climate index in January, and at station 24, in September it had a moderately dry climate.

With the prediction of this study concerning the volume of precipitation, bringing a hydrological improvement to the Region of the River Basin of Uruguay, offers an optimistic scenario for the already existing hydroelectric plants and the future projects for the construction of new hydroelectric plants.

The importance of precipitation also reflects in agriculture and livestock. Fertile soil with good water availability is crucial to obtain good results to ensure productivity, such as: rice, potatoes, garlic, apples.

Due to the information in the results found, where it indicates that there will be an increase in precipitation, it is extremely important that local managers make investments for drainage in urban and rural areas. Flow control should be efficient so that they do not suffer from floods, maintaining public health, basic sanitation, population safety and the local economy.

Climate change and drought rates can indicate environmental damage, define the water future of a region, affect agriculture and livestock, and bring disruption to hydroelectric power plants and the population. From the data of this research, the information may serve as a subsidy for the definition of mitigating measures, if necessary, and the basis for future studies in other river basins.

REFERENCES

[1] Nobre, C. A.; Sampaio, G.; Salazar, L. 2007. Climate change and the Amazon. Science and Culture, São Paulo, v. 59, n.3. Available At: <http://cienciaecultura.bvs.br/scielo.php?pid=S0009-67252007000300012&script=sci_arttext&tlng=en>. Accessed on: 19 Aug. 2017.
[2] Toledo, B. Climate Observatory brings together Brazilian IPCC scientists to discuss conclusions and projections of the new report. 2014. Available at: <http://www.observatoriodoclima.eco.br/observatorio-do-clima-reune-cientias-brasilicos-do-ipcc-para-discutir-conclusoes-e-projecoes-do-novo-relatorio/ >. Accessed on: 07 Sep. 2017.
[3] CPTEC/INPE - Center for Time Forecasting and Climate Studies, National Institute of Spacial Research. 2011. Available at: <http://www.cptec.inpe.br/>. Accessed on: 06 Nov. 2017.
[4] Wilhite, D. A.; Glantz, M. H. Understanding the drought phenomenon: The role definitions. In: Wilhite D. A.; Easterling, W.E.; Wood, D. W. Planning for a reduction of societal vulnerability. Boulder: Westview Press, p.11-14, 1987
[5] McKee, T. B.; Doesken, N.J.; Kleist, J. 1993. The relationship of drought frequency and duration to time scales. Eighth Conference on Applied Climatology. American Meteorological Society, p. 179-184, 1993.
[6] Blain, G. C. Statistical considerations related to six monthly air temperature series of the Department of Agriculture and Supply of the State of São Paulo. Brazilian Journal of Meteorology, São José dos Campos, v.26, p.279-296, 2011.
[7] Hayes, M. J. et al. Monitoring the 1996 drought using the Standardized Precipitation Index. Bulletin of the American Meteorological Society, v.80, n.3, p.429-438, 1999.
[8] Brazil. Decree No. 5,163, July 30, 2004, Regulates the sale of electric energy, the process of granting concessions and authorizations for the generation of electric energy, and other measures. Available at: <http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2004/decreto/d5163.HTM>. Accessed on: 20 Aug. 2017.
[9] Andreolli, I. Forecasting of real-time flow in the Uruguay River based on the weather forecast. Dissertation (Master's). IPH, UFRGS, Porto Alegre, 2003.
[10] Brazil. Ministry of the Environment. Notebook of the Hydrographic Region of Uruguay. 2006. Available at: <http://mma.gov.br/estruturas/161/_publicacao/161_publicacao03032011023025.pdf>. Accessed on: 27 Aug. 2017.
[11] ANA - National Agency of Waters. Hydrographic Region of Uruguay. Available at: <http://www2.ana.gov.br/Paginas/portais/bacias/uruguai.aspx>. Accessed on: 27 Aug. 2017.
[12] MAP, Ministry of Agriculture, Livestock and Supply. Trend and projection of the air temperature for the State of Goiás. Embrapa Rice and Beans. Santo Antônio de Goiás - GO, Brazil. 2018.
[13] INMET, National Institute of Metereology. Norma Climatológicas of Brazil. Available at: <<http://www.inmet.gov.br/portal/index.php?r=clima/normaisclimatologicas>. Accessed on: 16 Apr. 2018.
[14] Souza, E. B. GrADS - Grid Analysis and Display System Fundamentals and Basic Programming. Federal University of Pará, 2004. Available at: <http://www.dca.iag.usp.br/www/material/ritaynoue/aca522/referencias/apostilagrads.pdf>. Accessed on: 27 Aug. 2017.
[15] Andreolli, I. Forecasting of real-time flow in the Uruguay River based on the weather forecast. Dissertation (Master's). IPH, UFRGS, Porto Alegre, 2003.