DROUGHT CHARACTERIZATION IN THE ITAPARICA RESERVOIR, SÃO FRANCISCO BASIN, BRAZIL, USING PRECIPITATION AND TWS-GRACE BASED INDICES

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Caractérisation de la sécheresse à l'aide d'indices basés sur les précipitations et de TWS-GRACE dans le réservoir d'Itaparica, bassin de São Francisco, Brésil

Mots-clés : stockage total d'eau, indice de gravité de la sécheresse, analyse des séries temporelles
Keywords: Total Water Storage, Drought Severity Index, time series analysis

Introduction

Climate change alters water cycle processes, causing changes in precipitation patterns that will lead to extreme events on global and regional scales. Drought, as a natural phenomenon caused by water flux imbalance, leads to the persistence of water scarcity in the context of global warming, impacting human consumption, agricultural irrigation, and the stability of ecological systems. Over the last decade, drought events have occurred more frequently, resulting in a decrease in river flow, reservoir volume, lake levels, groundwater levels, and soil moisture. Furthermore, the reduction in stored water volume in reservoirs directly impacts water security and water resource management. Climate data information support is necessary to better understand the mechanisms influencing extreme events. Drought can be characterized and classified using indices, where different types of data, parameters, and mathematical models are used for their development and applications. The Standardized Precipitation Index (SPI) proposed McKee *et al.* (1993) is widely used for drought characterization, with its multiscale nature providing insights from meteorological to hydrological scales. In this context, remote sensing (RS) products complement in-situ observations and overcome obstacles regarding data availability. Recently, Total Water Storage (TWS) has been calculated using the GRACE mission, providing an alternative approach to monitoring the global and regional water cycle. The use of TWS-GRACE as an indicator of water availability has resulted in the creation of new drought indices or improvements to existing ones, such as the Drought Severity Index (DSI-GRACE) proposed by Zhao *et al.* (2017). The objective of this research is to characterize drought using precipitation and TWS-GRACE-based drought indices and correlate them with the volume of the Itaparica reservoir in the São Francisco River.

1. Data and methods

The SFW is the largest basin in the Brazilian semiarid region, covering 639.219 km² of drainage area. Its main river has an average flow of 2.850 m³ and a length of 2.700 km. The reservoir of Itaparica is in the lower-middle portion of the SFW, with extensions of 149 km, area of 828 km² and capacities of 10,7 billion m³, respectively. Monthly GRACE solutions of mass concentration processed by the Center for Space Research were utilized. In total, monthly solutions from April 2002 to December 2022 (RL06M v.02) were used. Precipitation data from the most current version of the monthly global precipitation dataset of the Climatic Research Unit (CRU TS v.4.07) were also used. We used data from January 1992 to December 2022, encompassing the entire study area. Reservoir volume observational data were obtained from the National Electric Energy Operator (ONS) and cover the period from April 2002 to December 2023, with gapless documented monthly information. The methodological structure and workflow applied in this research encompass the following steps: (i) data acquisition, where all data used were obtained freely, (ii) pre-processing for database creation and filling gaps in the time series of the TWS variable, (iii) DSI-GRACE, SPI – 12 and 36 months drought index processing, (iv) statistical analysis using Spearman correlation, maxima and minima analysis, and scatter plots, followed by the examination of results, including drought event characteristics and statistical responses of the data.

2. Results and discussion

Figure 1 presents the results of the indices (A) DSI e (B) SPI -12, 36 correlated with the reservoir volume. The negative slope coefficients obtained from the regression equations indicate a decline throughout the time series, where the reservoir volume collapses from 2013 to 2018. The beginning of the dry period is identified in different periods in the three indices, where the DSI identifies it in November 2014, the SPI-12 and 36 identify the beginning of the dry period in January 2012 and 2013 respectively, the SPI-12 presents fluctuations throughout the time series, this behavior is related to a rapid response to climate variability triggering a meteorological drought. However, DSI and SPI-36 better represent the behavior of the reservoir volume, presenting constant dry values between 2014-2019 within the drought classification limit. These results corroborate studies referring to the last period of drought in northeastern Brazil. Climatic factors such as the Inter-Tropical Convergence Zone, Madden-Julian Oscillation, El-Nino-Southern Oscillation events, and sea surface temperature in the Atlantic directly influenced the occurrence of the latest drought event observed between 2012 and 2018, as documented in various studies (Mutti *et al.,* 2022; Cunha *et al.,* 2019).

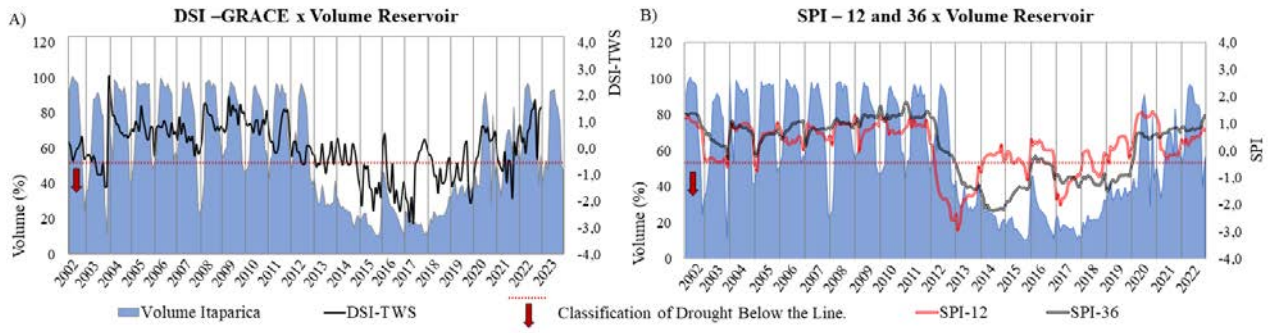

Figure 1. Reservoir volume in Itaparica, (A) Time series of DSI-TWS and (B) Time series of SPI – 12 and 36 months.

Despite being from distinct datasets, both variables exhibit similar seasonalities over the years. As non-parametric and independent variables with a coefficient of variation greater than 30%, the Spearman rank correlation (σ) was calculated for the results of the drought index and the volume. The obtained results were (σ) = 0.62, (σ) = 0.49 and (σ) = 0.75 in relation to the reservoir volume with DSI-GRACE, SPI-12 and spi-36 respectively. The SPI-36 and DSI-GRACE presented similar results, with a correlation of (σ) = 0.65. The correlations were significant at the 5% level, thus accepting the alternative hypothesis that there is a real strong correlation between the indices.

Conclusion

The crucial role of reservoirs in the SFW is highlighted by their contribution to providing potable water, supporting agricultural irrigation, generating hydroelectric power, and assisting in flood mitigation. Given the frequent occurrence of droughts in the region, it is essential to study and quantify these events to guide strategic decisions. The utilization of observations from the GRACE mission has proven to be a viable alternative for assessing and monitoring reservoir water availability, enabling the identification of specific drought patterns and enhancing water resource management.

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