Chapter 42

Impacts of extreme events in the submedium of the São Francisco river basin

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ABSTRACT
The Submiddle San Francisco River Basin (SSFB), located in the semi-arid region, is subject to adverse hydrological conditions, increasing the levels of vulnerability of the local population to climatic phenomena and favoring natural disasters such floods and severe droughts and the risk of water shortages in its reservoirs. This critical scenario has been worsened due to climate change. In most cases, the impacts related to the occurrence of such phenomena can be amplified due to the lack of planning and structure. In this context, the objective of this study was to identify the impacts associated with climate change on the SSFRB. To identify critical climatic periods, the Standardized Precipitation Index (SPI) was used during the period 1970-2014. It was observed that despite the existence of wetter years, there was a negative trend of precipitation over the studied period. Despite the occurrence of these events, drought episodes were more frequent, mainly from the 1990s onwards, with emphasis on the years 1993 and 2012, classified as extremely dry. These extreme events, which have been intensified in recent decades, cause severe social, economic and environmental impacts, intensifying social conflicts. Public policies should be the priority for the prevention and minimization of these impacts, such as revitalization of the basin, protection of springs, sanitation of municipalities, erosion control, establish flood prevention, protection of the floodable areas, reduction of losses in water distribution, rational use of water resources, among other measures.

Keywords: Rio São Francisco, climate change, impacts, conflicts, multiple uses.

1 INTRODUCTION

The semi-arid region of Brazil is experiencing a drama of scarcity of its water sources and the risk of water shortages through its reservoirs. This critical scenario has been aggravated due to the high rates of evapotranspiration and the irregular distribution of precipitation that is marked by its sand-time variability, allowing the occurrence of prolonged periods of droughts, and accentuating water deficits (Oliveira, 2019; p. 8).

Despite the problems inherent to water scarcity, the region's main source of fresh water is the São Francisco River Basin (BHSF), which accounts for 73% of the northeastern surface water supply and where large water reservoirs managed by the São Francisco Hydroelectric Company (CHESF) are installed. The hydropower generation policy adopted by CHESF, with the construction of several dams (Três Marias, Sobradinho, Itaparica, Moxotó, Paulo Afonso and Xingó), substantially altered the natural regime of the São Francisco River, mainly with the formation of Sobradinho Lake in the 1970s (Araújo e Sá, 2008, p. 1).

The BHSF area is characterized by the large irregularity of rainfall. About 54% of the territory of the basin is located in the semi-arid, with a record of critical periods of drought. These characteristics increase

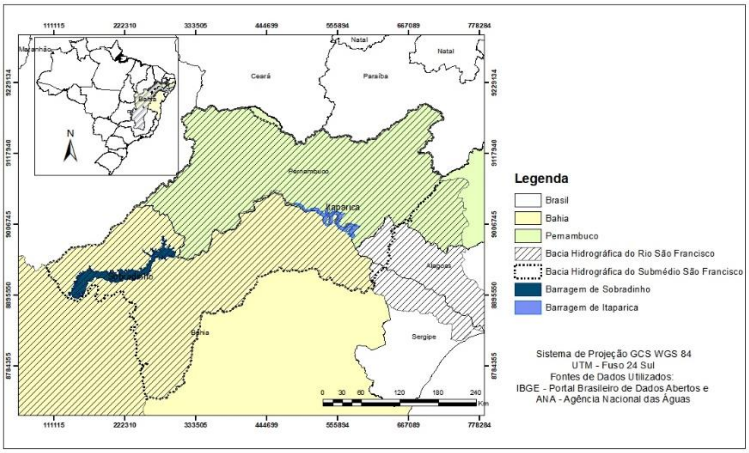
the levels of vulnerability of the local population to climatic phenomena, and demand appropriate solutions for water management (Science and Climate, 2018; p. 1). In this sense, one of the major challenges for the management of the waters (BHSF), is in the management of the sobradinho and itaparica water reservoirs inserted in the Sub-medium region of the basin. This region is considered extremely dry and in recent years have suffered from the decrease in the volume of water available for electricity production. Moreover, with the increase in population and growth of agriculture, the problems inherent to inadequate management of land use intensified around these reservoirs, compromising the quantity and quality of water (Oliveira, 2019; p. 27). In the SUB-Middle region of BHSF, the scarcity of water, in addition to affecting the electricity sector, affects the multiple uses of water offered by the reservoir, such as the agricultural sector, which uses about 70% of the total water in the Submédio region.

In addition to ecological problems, there are also social problems. There is no equity in access to water in this region and so-called "isolated" populations still do not have quality drinking water for human consumption, even if it is on the river or riverside or on the road. Access is still limited to supply isolated populations, especially those that depend on reservoir water (Oliveira, 2019; p. 27). In most cases, the impacts related to the occurrence of such phenomena can be amplified due to the lack of planning and structure (Oliveira *et al*., 2021; p. 1). In this context, the aim of this study was to identify the impacts associated with climate change in BHSF.

2 MATERIALS AND METHODS

The São Francisco Submédio (SMSF), is located between the states of Pernambuco and Bahia, representing about 17% of the basin area and approximately 440 km long, housing 83 municipalities. In this stretch of São Francisco stand out the dams of Paulo Afonso I, II, III and IV, Xingó, Itaparica and Moxotó (CBHSF, 2015). From the climatic point of view, the SMSF area is characterized by the great irregularity of rainfall and presents as the main rainy season the months of January to April (SOBRAL *et al.* , 2018).

Figure 1 - Delimitation of the BHSF Submedium.



Oliveira (2019).

To identify critical climatic periods, the Standardized Precipitation Index (SPI) was used during the period between 1970 and 2014. The monthly precipitated totals of 22 regional rainfall stations located in the BHSF were provided by the National Water Agency (ANA), observing the historical data series with the lowest number of failures, whose series have a long period of records, totaling 44 years (1970-2014).

3 RESULTS AND DISCUSSION

Since the SMSF is located in the middle of the semiarid region, it should be noted that it is a vulnerable territory and subject to critical periods of prolonged droughts, which presents several geographical zones and different aridity indexes (CBHSF, 2004). The frequent and prolonged droughts in the region have been responsible for the exodus of part of its population. However, the irrigation centers located in the SMSF have acted as labor fixers and stand out at the national level as a region of great employment and income opportunities, mainly due to irrigated fruit growing (Moura *et al.*, 2006), mainly mango and grape, whose destination of 90% of production is the external market.

The climatic behavior of the SMSF is characterized by the great variability, especially of precipitation. The region is also marked by extreme drought events, which can last an average of between 7 and 10 months. These characteristics increase the levels of vulnerability of the local population to climatic phenomena, and demand appropriate solutions for water management (SOBRAL et al., 2018).

The spatial-temporal variability of precipitation in the SMSF is directly conditioned to the intensity and occurrence of two meteorological systems the Intertropical Convergence Zone (ITIC) and the High Levels Cyclonic Vortexes (VCAN). These systems operate at different times of the year, being observed more specifically between the months of February to May (ITC), and the VCAN's occur in spring, summer and autumn, in the period from October to April, with maximum frequency in January (Mello *et al.*, 1996). Since the SMSF is located in the middle of the semiarid region, it should be noted that it is a vulnerable territory and subject to critical periods of prolonged droughts, which presents several geographical zones and different aridity indexes (CBHSF, 2004).

According to a report by the IPCC (2007), it was observed that there is an increase in extreme events, both in the rainy season and in the dry season. The frequency of extreme events increased over most terrestrial areas, in a manner consistent with the warming and observed increases in atmospheric water vapor. The most of the climate forecasts are very worrying, as everything indicates that with the increase in global warming, precipitation in certain regions, as in the case of SMSF, will decrease, as well as its flow, causing great damage to society, such as diseases, lack of water and food, harming the hydroelectric sector, which is currently the basis of our electrical system (Santana et al., 2011, p. 14). For semi-arid regions, projections indicate that the climate will tend to become more arid, aggravating drought episodes and increasing desertification processes (Dias e Pessoa, 2020; p. 1).

The construction and filling of accumulation reservoirs in the SMSF led to significant evaporation of the reservoirs (Pereira *et al.* , 2009). Since 2013, the SMSF has been facing adverse hydrological

conditions, with below average precipitation and flows, with consequences on the storage levels of reservoirs located in the basin, which has led to actions to make the minimum effluent flows of the Sobradinho and Xingó reservoirs more flexible. From April 2013 to May 2017, it was authorized to reduce the minimum inflows of Sobradinho from 1,300 m³/s to 550 m³/s through a series of Resolutions published by ANA. Recently the Sobradinho reservoir experienced the largest drought in its history, reaching its lowest level in almost 40 years (Agência Brasil, 2015). To maintain a good water capacity, the dam depends mainly on the rain at the source of the São Francisco River, located in the North of Minas Gerais. If it doesn't rain there, not enough water gets into the reservoir. Silva (2018) detected regions of the Sobradinho reservoir, maintaining a reduction of approximately 19 km in length, a worrying result, since flood regions are historically used for agricultural planting. In addition, irrigation regions are observed perpetuating, even in extreme periods of drought in the semi-arid region.

Oliveira (2019) points out that from the identification of critical periods that occurred in the SMSF, it was observed that despite the existence of wetter years, there was a negative trend of precipitation over the period studied (1970 - 2014) Assisi (2016) found an important change in the precipitation pattern, with an increase in the occurrence of dry years to the detriment of rainy years. Despite the occurrence of these events, drought episodes were more frequent, especially since the 1990s, especially in 1993 and 2012, classified as extremely dry. Thus, the production of hydroelectric power in the region would be unfeasible in years of drought from 2030 (De Jong *et al.* , 2018).

An increase of 3 ºC or more in the average temperature would make even drier the sites that already suffer from water deficit in the semi-arid. In addition, the high evaporation potential, combined with the increase in temperature, would cause a fall in the water level of lakes, dams and reservoirs. A frequency of consecutive dry days and heat waves would accelerate soil degradation, making subsistence agriculture unfeasible and threatening the survival of communities in the region (Nobre, 2012). The drought event that began between 2012 and 2017 had intensity and impacts not observed for decades, causing significant agricultural losses, damage to small producers, destructuring large areas of agricultural land, with great damage to the population (Pontes, 2018; p. 91). The drought also harms the communities surrounding the Sobradinho dam, which are being supplied with water trucks (Agência Brasil, 2015; p. 1).

Among the threats identified in BHSF, Siqueira Filho et al. (2015) highlight that the natural recharge capacity of the dams depends fundamentally on the main rivers in the Cerrado, which today are threatened by agroindustry, especially cattle and soybeans. Bhsf's 2016-2025 Water Resources Plan raised other problems in the basin, such as deforestation, susceptibility to geological and geomorphological risks, erosion, eutrophication and toxic contamination of surface water and vulnerability to groundwater pollution, susceptibility to desertification in the Sub-Middle and Lower San Francisco (CBHSF, 2016).

The current panorama of surface water quality in BHSF presents important regional differentiations, either by the distribution of polluting sources of different typologies, or by natural conditions (climatic, hydrological, geological) and anthropic interventions that imply changes in flow and, consequently, of the

conditions of dilution of polluting loads (CBHSF, 2016). The strong anthropic pressure around dams in the semi-arid area of BHSF as a result of water availability is one of the most likely causes of increased vulnerability to extreme rainfall events (Santos et al., 2013; p. 1205).

The management of water resources in SMSF has always been surrounded by challenges. In addition to natural climatic conditions, with high temperatures, high rate of evapotranspiration and soil that favors the formation of intermittent rivers, water storage inefficiently and often concentrated, intensifies social conflicts (Marengo et al., 2011; Nobre et al., 2011; Medeiros et al., 2018;). The conflicts in the basin are mainly related to the multiplicity of these uses and the increase in demand (Martins et al., 2011). Currently, the BHSF committee divides conflicts in those dependent on water resource management and quantitative-qualitative conflicts over water use (CBHSF, 2015).

4 CONCLUSION

The use of SPI allowed the identification of changes in precipitation behavior patterns. From the 1980s on, there was an important change in the precipitation pattern of the SMSF, since the dry years began to predominate, worsening in the 1990s, characterizing a point of inversion. If this trend is consolidated, the pressure on water resources in this basin will increase.

The SMSF stimulates the growth and social and economic development of the region, contributing to the fulfillment of multiple uses. Seeking solutions for adequate monitoring and management of the basin's water resources should be a priority of the management agencies, since the knowledge of the temporal and spatial distribution of daily rainfall in the country has a relevant impact for an effective evaluation of water availability, among other available natural resources, especially in regions where water scarcity has always been present. Climate changes associated with constant changes in land use and occupation are associated with water availability, so they are of great importance in conflict mediation.

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