

METEOROLOGICAL CONDITIONS AS A DRIVER OF WATER QUALITY IN NORTHEAST BRAZIL

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1) INTRODUCTION

Water quality refers to physical, chemical and biological conditions suitable for a particular purpose like human consumption. Monitoring water quality is necessary to understand hazards for human health or aquatic organisms. Chlorophyll-a is widely used in water quality monitoring programs as it provides information on the algal biomass, the trophic state index, the risk for human health, and the quality of an aquatic environment (WHO, 2003; Zounemat-Kermani, 2014; Liu et al. 2020). Chlorophyll-a is an algal biomolecule involved in the photosynthesis process which is in direct relationship with biological activity and amount. It is highly sensitive to environmental conditions, such as temperature. Thus, understanding how climatic conditions influence chlorophyll-a concentration is relevant for water quality studies.

Climatic extreme events are defined as events in which a given variable exceeds a certain threshold. Extreme events are defined based on the statistical distribution of a given variable for a specific location. Although the concept of extreme events is widely used in climate sciences, it is not commonly used to describe water quality, despite the fact that extreme values of water quality indicators are key to understanding hazards to human health. Analyzing extreme events in water quality can be a powerful tool to understand trends and patterns associated with changes in water quality.

This study aims to define extreme events in water quality and explore their relationship with climate in the Northeast of Brazil. We report on chlorophyll-a concentration, a major indicator of water quality, along with climatic and hydrological data from reservoirs from the state of Ceará.

2) MATERIAL AND METHODS

Ceará is in the northeast region of Brazil, between the coordinates (2°30'00" - 8°52'00" South and 37°14'00" - 41°30'00" West). The climate in this state ranges from tropical savannah (Aw) and arid-steppe-hot (BSh) type according to the Köppen-Geiger classification (Peel et al. 2007, Köppen 1936). We used a dataset of water quality of 158 water reservoirs monitored from 2008 to 2019, given by the Fundação Cearense de Meteorologia e Recursos Hídricos (FUNCEME, available at: <http://www.hidro.ce.gov.br>). We considered chlorophyll-a (n=3863) as a proxy of water quality. We considered two thresholds to evaluate the temporal variation of water quality: the World Health Organization guideline (chlorophyll $\leq 50\mu\text{g/L}$; WHO, 2003), and a

statistical limit of extreme events. Extreme events of chlorophyll-a were defined as events exceeding the percentile 90% of every chlorophyll-a concentration measurement (for this dataset extreme event of chlorophyll-a $\geq 141.0 \mu\text{g/L}$).

Box and whisker plots were drawn to visualize the repartition of chlorophyll data for each year, and the distribution position regarding the two limits defined above. Boxes represent the interquartile distance (IQD, 25th–75th percentiles), and the median value (50th percentile) is indicated by a dark blackline inside boxes. Values under the 0.01 percentile or above the 99.9 one (horizontal bars outside boxes) are outliers (little rhombuses). Frequency of occurrence of extreme events was normalized by the total number of observations in each year.

The annual accumulated precipitation was directly obtained from the FUNCEME website. The annual potential evaporation was calculated thanks to the Thornthwaite method (Thornthwaite, 1948) using as parameters the monthly mean temperatures of Ceará. The index of the water level anomaly was created using the data of daily water volume from each reservoir. The data was then normalized to obtain an index representing the global annual stored volume of water in Ceará (a water level anomaly > 0 meaning the stored water this year is above the median of water storage). We used the Pearson's r coefficient and computed the p -value to assess the existence of a correlation between variables.

3) RESULTS AND DISCUSSION

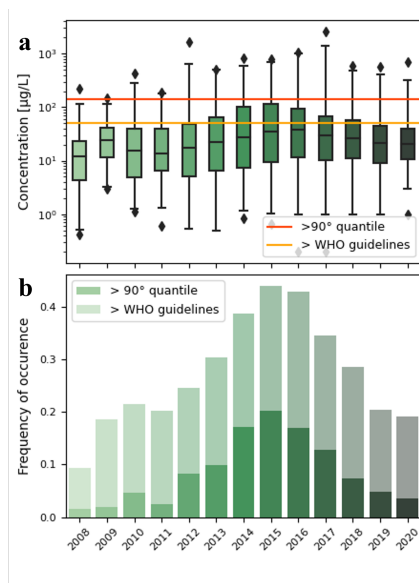


Figure 1: Temporal variation of Chlorophyll-a

Chlorophyll-a presented a temporal trend with a consistent period of increase from 2008 to 2015 and a period of decrease thereafter (Fig 1a). Along the whole range of years, concentrations ranged from $<10 \mu\text{g/L}$ to $>1000 \mu\text{g/L}$, and for the years 2014, 2015 and 2016 the 75th percentile exceeded $100 \mu\text{g/L}$. The frequency of extreme events also showed an important temporal variation, being 13-time inferior in 2008 than in 2015 (Fig 1b). 2015 and 2016 were the worst years in terms of water quality, as inadequate values of chlorophyll-a account for 40% of total observations according to the WHO threshold, and had the highest frequency of extreme events. The observed tendency suggests that large scale climatic conditions may drive interannual variation.

We observed that as mean annual precipitation increased, the probability to find chlorophyll-a extreme events decreased (Fig 2a). Similarly, the frequency of chlorophyll-a extreme events decreased with increasing water level, but this relationship presented a higher and more significant statistical correlation (Fig 2b). Water level was driven by the balance of precipitation minus evapotranspiration (Fig. 2c), while the streamflow could be considered as a second order driver. Water level has been linked to algal bloom formations (extreme high chlorophyll-a concentrations). Here, by using chlorophyll-a extreme events, we quantified the probability of occurrence of low water quality using the precipitation as a proxy of the water level and quality. For example, the cumulative percentage of precipitation (Fig 2d) suggested that 20% of years ($<600\text{mm/m}^2$) have a $>10\%$ frequency of extreme events (Fig. 2a).

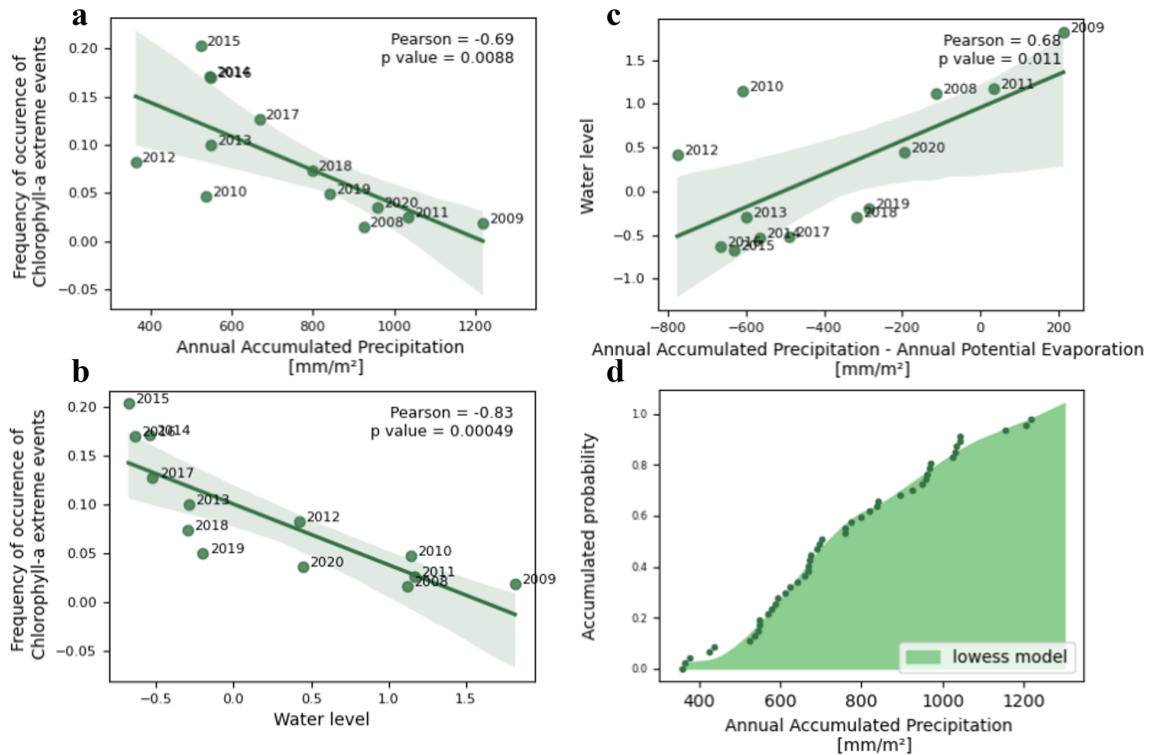


Figure 2: Relationship between chlorophyll a extreme events, precipitation and reservoirs water level: a) correlation between frequency of extreme events of chlorophyll-a and the annual accumulated precipitation; b) correlation between frequency of extreme events of chlorophyll-a and the water level; c) correlation between water level and difference between the annual accumulated precipitation and the annual potential evaporation; d) Accumulated probability of annual accumulated precipitation.

3) CONCLUSION

This study suggests that water quality is lower in dry years, and thus potentially aggravating access to water suitable for human consumption in the state of Ceará in Brazil. The extreme event analysis for chlorophyll-a brings focus on an important descriptor of water quality and complements other efforts to predict the impact of climate on human health.

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