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Hydrometeorological Monitoring and Alert System Applied to the Monitoring of the Paraíba do Sul River Basin

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Highlights:

- Extreme events are occurring more frequently and with greater intensity, causing significant economic, social, and environmental damage;
- Monitoring, warning, and alert systems are important for taking action to prevent or reduce risks and to prepare for an effective response;
- The developed tool is essential for the efficient and sustainable management of river basins, providing continuous monitoring, accurate forecasts, and alert issuance.

Keywords: river basin; extreme events; monitoring and alert.

INTRODUCTION

In recent years, several sectors of the economy have been suffering more intensely from the consequences of climatic events, especially those of hydrometeorological origin, such as atmospheric microbursts, torrential rains, heat waves, tropical cyclones, and others. According to UNSIDR, more than 90% of major disasters between 1995 and 2015 were related to climatic and meteorological events (UNSIDR, 2015). In 2021, Brazil experienced its worst drought in 91 years, which mainly affected the Southeast and Central-West regions. Water reservoirs reached less than 30% of their capacity, and there was water rationing in some cities.

Such atmospheric disturbances have consequences, such as floods, destruction of homes, increased resource consumption, and interruption of basic services for long periods. Among the basic services that can be affected by climatic events, sanitation services stand out. The provision of sanitation services depends not only on the infrastructure built, maintained, and operated by the service provider but also on the conditions of the watershed where the municipality is located, from which water is drawn, and sewage is discharged. These conditions, which involve land use, climate, geology, and ecosystems, determine the quality and quantity of the water. This concept is widely discussed in the context of the legal framework for basic sanitation in Brazil, highlighting the interdependence between sanitation infrastructure and sustainable watershed management.

In watershed management and decision-making, obtaining hydrometeorological data and numerical models' simulations have been widely used to monitor and understand natural processes and phenomena related to water resources (Zhang & Wang, 2013; Ribeiro et al., 2022). These data help manage and optimize water and sewage treatment, assist sanitation operators in managing resources more efficiently, predict variations in water availability and demand due to changes in climatic conditions (rain or drought), minimize the risk of flooding or water shortages, inform about heavy rains to detect water contamination risks due to landslides or floods, among other things.

Due to the observation that extreme events are occurring more frequently and with greater intensity (Avila-Diaz et al., 2020; Zhang et al., 2007; IPCC 2018; Giorgi et al., 2019), causing significant economic, social, and environmental damage and, above all, affecting vulnerable populations, it has become necessary to apply measures for more efficient and effective risk management (Silva, 2016). In this context, monitoring, warning, and emergency alert systems have emerged, providing information for individuals or companies exposed to a threat to take timely actions to avoid or reduce risks and prepare for an effective response (Peixoto, 2013).

The use of Monitoring, Warning, and Alert Systems as tools for monitoring weather, climate, and hydrological aspects has low implementation costs, offers ease of use even for users with little knowledge of the involved technologies, provides coherent results, and helps mitigate the consequences of natural disasters (Oriollo et al., 2014). The results obtained can be a differential for guiding decision-makers in the company regarding hydrometeorological risk management in watersheds, through solutions aimed at application in areas of operational, personnel, and commercial safety, and maintaining effective communication channels with key local actors, such as municipalities and state agencies (Ribeiro et al., 2022).

Given this context, this project aims to evaluate the Paraíba do Sul River basin by consolidating various monitoring and forecasting inputs so that decision-makers can access the necessary information for diagnosing and forecasting river basins within a single tool. This is intended to increase productivity and optimize the operational activities of sanitation companies.

The Paraíba do Sul river basin has a drainage area of about 55,500 km², distributed across the states of São Paulo, Rio de Janeiro, and Minas Gerais in Brazil. The basin is responsible for draining one of the country's most developed regions, composed of the Vale do Paraíba, part of Minas Gerais (Zona da Mata Mineira), and half of the state of Rio de Janeiro, encompassing 184 municipalities. Approximately 14.5 million people rely on the waters of the Paraíba do Sul River basin, of which 7.8 million inhabitants are in the metropolitan region of Rio de Janeiro, supplied by water diverted through the Lajes/Guandu system (CEIVAP, 2024).

METHODOLOGY

The evaluated Monitoring and Alert System (SMAC), version 2.0, is an advanced digital tool for hydrometeorological information, featuring various functionalities for climate monitoring and analysis to provide strategic information for decision-making related to environmental conditions.

Developed by Climatempo, it is available online with a user-friendly interface and quick access to all functionalities. The tool includes maps, tables, and graphs. It was designed to contain information for all of South America and is customizable for registering different geometries for monitoring (lines, points, and areas), such as river basin.

For the operation of the meteorological alert system, the availability of various collected data is ensured, including:

- Real-time data: from meteorological and hydrological station network of public domain, automatic and conventional, provided by the National Institute of Meteorology (INMET), the National Center for Monitoring and Alerts of Natural Disasters (Cemaden), and the National Water Agency (ANA), with data for flow rate, river level, precipitation and other variables; Lightning data; Wildfire data from different satellites, public and private meteorological radar data, satellite data, and others;
- Short-term forecasting (next hour) based on real-time data monitoring and nowcasting models;
- Numerical weather prediction models for different time horizons and risk for some variables, such as wildfires;
- Issuance of imminent alerts based on interest thresholds for meteorological variables
- Access to historical climate data for comparative analyses and trend identification.

The Monitoring and Alert System integrates all the information listed above, providing interactive maps that show risk areas and the evolution of meteorological and hydrological conditions. For this study, the geometry of the river basin, the municipalities belonging to it, and the main hydraulic structures (Paraibuna, Santa Branca, Jaguari, Funil, Santa Cecília, Pereira Passos) were registered on the platform. In addition, several strategic monitoring points were established to track hydrological and meteorological variables using the inputs available on the platform.

RESULTS AND CONCLUSIONS

The developed tool is essential for the efficient and sustainable management of river basins. Specifically, in the studied basin, it was possible to monitor in real-time three meteorological radars, 7 automatic meteorological stations, 5 conventional meteorological stations, numerous rain gauges and flow stations, in addition to accurate weather forecast data for various variables. It provides continuous monitoring, accurate forecasts, alert issuance, and decision-making support, significantly contributing to disaster mitigation and the proper management of water resources. With reliable and up-to-date data, this type of tool aids in environmental protection, enhances safety for populations, and offers more effective water management, an asset for sanitation companies.

The main benefits include:

i. Continuous and real-time monitoring with updated data, allowing for constant surveillance of the basin;

ii. Accurate weather forecasts that help anticipate events that could cause floods, aiming at the planning of control operations, infrastructure maintenance, and other preventive actions;

iii. Early alert issuance for risk areas, facilitating the mobilization of resources and the implementation of protective measures;

iv. Use of interactive maps to identify critical and vulnerable areas within the basin;

v. Analysis of hydrological trends and patterns over time, helping in risk assessment and the implementation of preventive measures.

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