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Effects of the latest drought on the alluvial aquifer of a semiarid region in northeastern Brazil

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Abstract. Climate change has modified global and local water cycle patterns inducing more intense and severe drought events. In the Ceará state (Northeast Brazil), a semiarid region very vulnerable to droughts, groundwater acts as a strategic reserve to ensure water security for small rural communities. Well drilling jointly with the building of dams and cisterns are the main policy performed by the public authority to cope with the droughts. This study performed a preliminary qualitative analysis to investigate the effects of dam building in the piezometric level of an alluvial aquifer in the Ceará state during the most recent drought (2012–2016). The micro-basins of the Algodão and Forquilha creek were selected as study area, in which the alluvial aquifer has been monitored by Funceme since 2010. The alluvial aquifer was extensively exploited for local agriculture before the drought (2012–2016) due to public policies of well drilling (2001–2002). During the most recent drought, the construction of new dams, coupled with reduced rainfall, compromised the recharge of the alluvial aquifer. We evaluate these effects through the groundwater level. The results revealed a continuous drawdown of groundwater in the monitored wells. Since 2017 the piezometric level started to rise, however, the graphs reveal a different behavior of the piezometric levels monitored after the latest drought, with sudden changes between the periods of recharge and drawdown of the alluvial aquifer. Field diagnostics with local stakeholders revealed how the latest drought changed the dynamics of the activities developed by the rural communities. Before the drought the aquifer supplied the local agriculture. The drought has affected the recharge of the alluvial aquifer and compromised local agriculture. Local stakeholders have adapted, and agriculture has been replaced by livestock. The heterogeneity of this environment and of its water users requires efficient management policies adapted for the local physical and socioeconomic conditions to avoid overexploitation and maintain the recharge of the alluvial aquifer. These policies at the local scale can be the identification of local actors who are willing to develop their own management of surface and groundwater resources.

Keywords. Alluvial aquifer; drought; local scale; public policies

1 Introduction

Climate change has modified global and local water cycle patterns inducing more intense and severe drought events (IPCC, 2021). This scenario is intensified in semiarid regions, where rainfall distribution is irregular and frequent drought events occur (Nunes Carvalho et al., 2022), leaving these regions very vulnerable. In the Ceará state about 75 % of its territory corresponds to crystalline. And in the semiarid region the precipitation is less than 500 mm (Vasconcelos Junior et al., 2021). In this scenario, groundwater acts as a strategic reserve to ensure water security for small rural communities, especially alluvial aquifer. The alluvial aquifer is characterized by its porosity, good potential for water stor-

age, follow drainages, good quality water, and generally low cost access. This resource is important to ensure water supply, especially in periods of multi-year drought (Burte et al., 2009).

To face the recurrent droughts, the Ceará's state public authority increased the building of small dams and cisterns and also was noticeable an increase in the groundwater demand for domestic supply.

The objective of this work was to perform a qualitative analysis of the effects of the latest drought with a focus in the dam building and reduction of aquifer recharge, especially for the period of 2012 to 2016, on the piezometric level of the alluvial aquifer monitored by Funceme in the Forquilha and Algodão Watershed (Fig. 1).

Research area context

The micro-basins of the Forquilha and Algodão creek were selected as study area. We called the Experimental and Representative basin of Funceme. The area is in the semiarid region of the Ceará state. The geology is represented by a crystalline basement and alluvial sediments follow the main creek. We called the Experimental and Representative basin of Funceme. The area is in the semiarid region of the Ceará state. The geology is represented by a crystalline basement and alluvial sediments follow the main creek.

The network gauges and the alluvial aquifer have been monitored by Funceme since 2010 (Fig. 1). Nowadays, we are monitoring 43 points (Fig. 1a): 20 wells in the alluvial aquifer, 13 wells in crystalline aquifer and 10 reservoirs. On these points we get water level, pH, temperature, and electric conductivity measures.

Several hydrological studies were already developed in the region, notably the research related to the alluvial aquifer developed by Burte (2008).

Figure 2 shows the photo monitoring in one reservoir. We take pictures every 15 d to follow water surface variation. In this case it is also important to note that infiltration through the dam wall occurs in this reservoir, supplying the downstream alluvial aquifer.

Public studies (governmental reports, thesis) till 2020 reveal 117 wells in Forquilha and Algodão Watershed (Fig. 1b), demonstrating that this alluvial aquifer (Fig. 1) has a great importance for multiple uses (Fig. 4), e.g. local agricultural development and the water supply for domestic activities (Burte, 2008). The alluvial aquifer increased the resilience of these communities. However, a preliminary field diagnostic observed (Fig. 3) conflicts between upstream and downstream in the basin as the aquifer needs the river streamflow to be recharged, but the dams are preventing this. These conflicts have already been reported by Burte (2008).

2 Methodology

We collected data of the number of wells with state and federal institutions. In the physical context, we worked on groundwater level data, from wells which Funceme monitors since 2010. The piezometric level of alluvial aquifer monitored allowed us to visualize the variation of groundwater level.

In the social context, we made preliminary field diagnostics with local stakeholders to understand how the decrease in aquifer recharge has changed local productive activities. The field diagnostics was performed through some interviews and workshops.

3 Results

As a result of the droughts, the main policy performed by the public authority to cope with the droughts was building of small dams and cisterns. In addition, new wells have been constructed as well as reactivated to ensure water supply. As the alluvial aquifer is recharged directly by the river flow, and the water flow is dammed, groundwater recharge is compromised.

Figure 1b shows that there are approximately 117 wells drilled in the area, 70 wells drilled in alluvial aquifer and 47 drilled in crystalline aquifer. The infrastructure projects encouraged the use of the alluvial aquifer, as this water is easily accessible and low cost, and boosted irrigated agriculture. The increase in the of number families and the development of local economics were the effects reported by stakeholders (Fig. 3).

The survey of groundwater uses of the alluvial aquifer indicated that 62.86 % of the wells are used for irrigation. Secondly, 29.52 % of the wells are used for multiple uses, 6.67 % for domestic supply and and less than 1 % for industrial supply.

The precipitation reduction and the dam construction have significantly compromised the recharge of the alluvial aquifer. The stakeholders interviewed in this territory report that irrigated agriculture has decreased, and was replaced with livestock. Between the years 2001 and 2002, 59 wells were drilled in the alluvial aquifer due to public projects. On the other hand, between the years 2016 and 2018, the state drilled 23 wells in the crystalline aquifer to face the drought. The state continues to drill wells but has invested in wells that catch water from the crystalline aquifer.

When we analyze the data of the piezometric level of the alluvial aquifer monitored by Funceme, we observe that the recharge and drawdown periods are different before the drought (2012) and after the drought in 2017. Therefore, the groundwater level configuration has changed. We can see sharper peaks which show a match with rainy periods in Ceará State (February to May).

From June 2014 until February 2017, the groundwater level has been drawdown. After that, the piezometric level

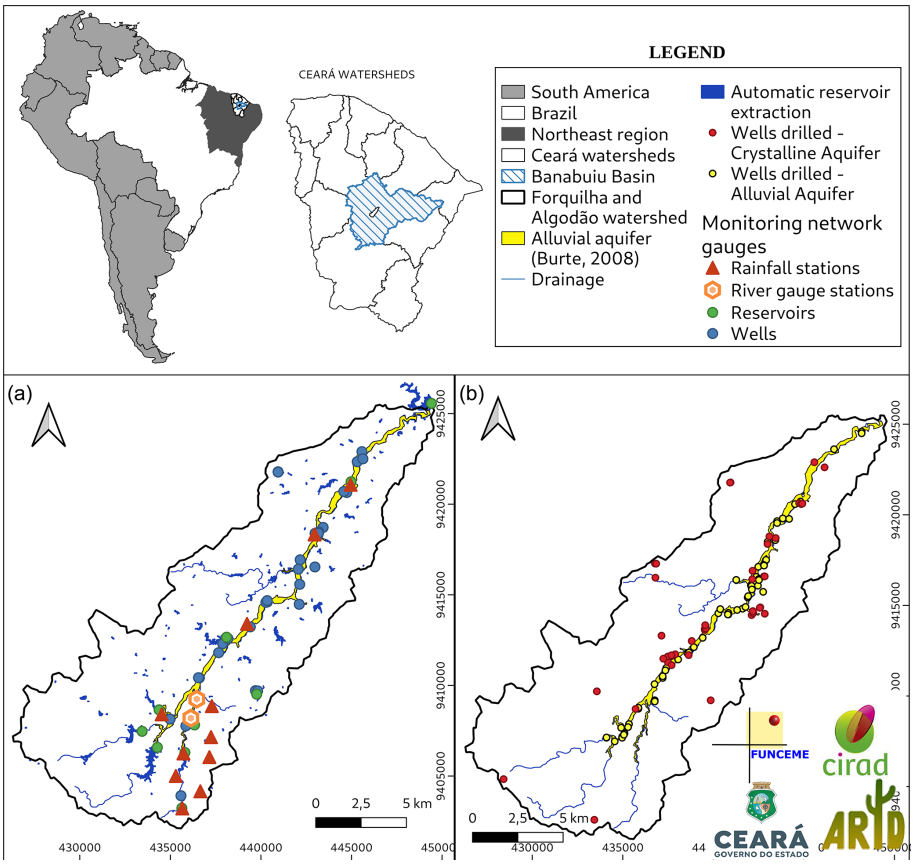

Figure 1. Monitoring network gauges **(a)** and wells drilled in alluvial and crystalline aquifer **(b)** in Forquilha and Algodão watershed.

Figure 2. Monitoring of a reservoir by photos.

Figure 3. Field diagnostics with local stakeholders.

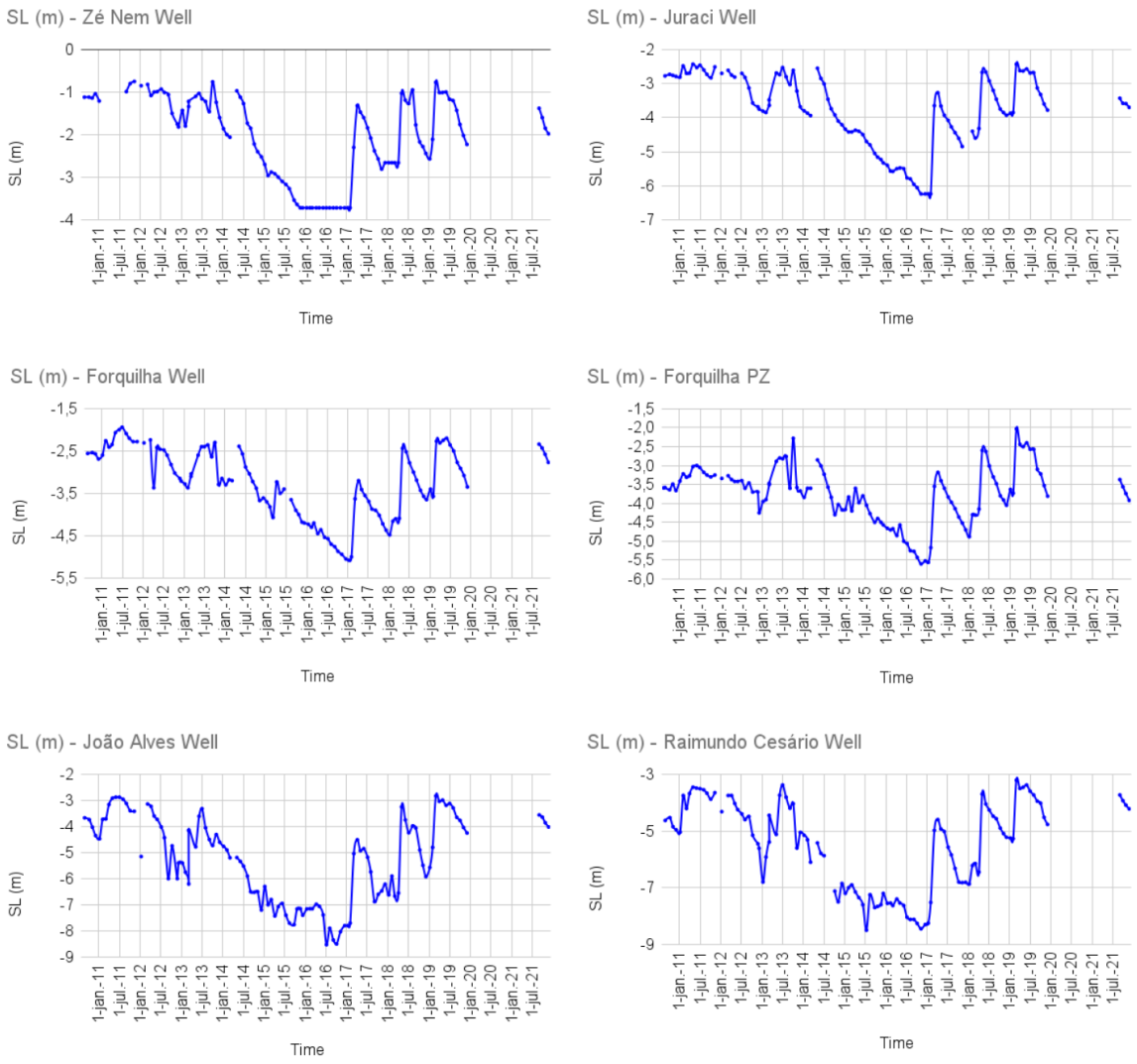

Figure 4. Groundwater level of the wells monitored in Forquilha and Algodão watershed. SL: Static Level.

has started to rise. However, the monitoring reveals a different pattern of the piezometric levels after the latest drought. With sudden changes between the periods of recharge and drawdown of the aquifer (Fig. 4).

The justification for the lack of data between February 2020 and July 2021 is the pandemic of COVID-19.

4 Conclusions

We can conclude that the precipitation reduction and the dams affect the recharge of the alluvial aquifer. This behavior has been observed through the groundwater level.

Specifically on the alluvial aquifer, continuous monitoring on a daily or sub-daily scale is needed, as they are smaller, heterogeneous, and shallow and can be quickly recharged. The heterogeneity of this environment and its water users requires efficient management policies suitable to physical and socioeconomic local conditions. These policies can be to develop a system of territorial intelligence, seeking to engage actors willing to manage local surface and underground water resources. Integration among actors in order to promote local governance and increase the resilience of diffuse communities, through Citizen Science.

Data availability. Data can be made available upon request directly to the authors.

Author contributions. RdSA, SSL, HG and RVR wrote the original draft manuscript; RdSA and RVR reviewed and edited the manuscript; RdSA, SSL, GM and HG performed the measurements; RdSA, SSL, GM, HG, ESPRM, RVR and ABSE built the methodology and the conceptualization.

Competing interests. The contact author has declared that none of the authors has any competing interests.

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