Unveiling Contamination Pathways: Investigating River-Aquifer Interactions in São Paulo, Brazil

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Abstract: In recent years, there has been a growing interest in characterizing the interactions between surface and groundwater, particularly due to their crucial role in managing river systems and assessing contamination risks. However, in Brazil, despite various local studies, a comprehensive analysis of these interactions has not been thoroughly explored due to challenges in accessing groundwater data and limited information on water bodies. In this study, we propose a simple methodology to analyze river-aquifer interactions in the state of São Paulo, Brazil, using the hydraulic gradient between the water table and the nearest river. To conduct our analysis, we utilized well data obtained from the Brazilian Geological Survey, spanning from 1970 onwards. We compared the water level of each well with the corresponding nearest river point. To ensure connectivity between the analyzed points, we imposed two criteria: the distance between each well and the nearest river was limited to 200 m, and the depth of each well was restricted to 100 m. Additionally, we considered only rivers that had at least one well every 10 km in length. Our results demonstrated that a minimum of 459 rivers in São Paulo potentially contribute to the underlying aquifers using data from approximately 1000 wells. The conducted sensitivity analyses validate the consistency of these results. These findings provide valuable insights for the integrated management of surface and groundwater systems, as these identified points may serve as potential contamination pathways to the underlying aquifers.

Keywords: SW-GW interaction, hydrological connectivity, groundwater sustainability, groundwater contamination, groundwater management.

INTRODUCTION

River-aquifer interactions are pivotal in ecohydrology and biogeochemistry as they play a crucial role in assessing groundwater recharge rates (Wendland et al., 2009) and understanding contamination (Krause et al., 2010). In this study, we introduce a methodology to investigate river-aquifer interactions by examining the hydraulic gradient between groundwater data and the nearest river.

DATA AND METHODS

We utilized well data obtained from the Brazilian Geological Survey, from 1970 onwards. The ANA (2016) database was employed to identify the nearest river point for each well. To obtain elevation points, we utilized SRTM products and the empirical equations by Bieger et al. (2015). Thus, if most of the analyzed points in the river had water levels above those in adjacent wells, it was considered that the river potentially drains into the underlying aquifers. To ensure connectivity between the analyzed points, we imposed similar conditions to Jasechko et al. (2021).

RESULTS AND DISCUSSION

The findings of our study reveal that a total of 459 rivers in São Paulo potentially drain into the underlying aquifers, which suggests the existence of potential contamination pathways to the aquifer. The sensitivity analyses confirmed the consistency and reliability of the data. This finding highlights the increased vulnerability of the aquifer in these specific areas, emphasizing the importance of monitoring and managing potential contamination risks.

Figure 01 - Rivers that potentially drain into the underlying aquifers in São Paulo, Brazil.
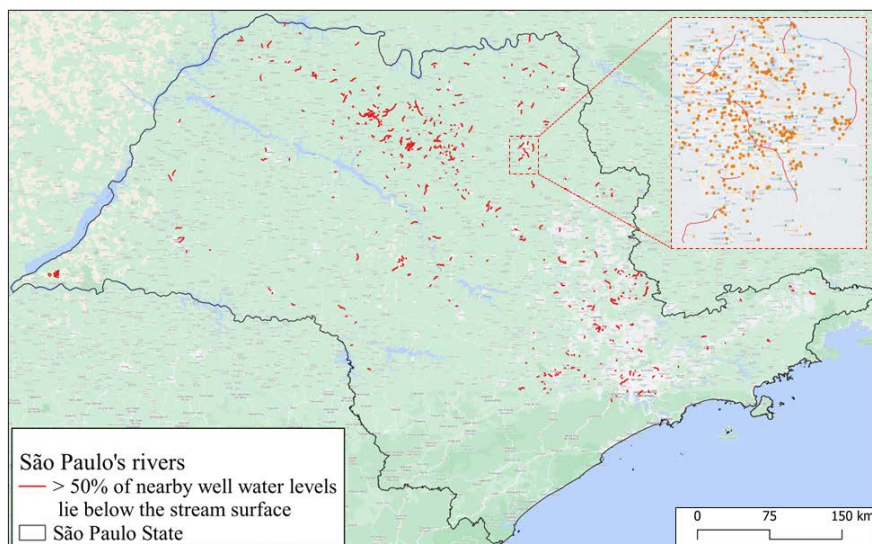
REFERENCES

ANA - National Water and Sanitation Agency. (2016). Corpos Hídricos Superficiais.

BIEGER, K.; RATHJENS, H.; ALLEN, P. M.; ARNOLD, J. G. (2015). Development and evaluation of Bankfull hydraulic geometry relationships for the physiographic regions of the United States. Journal of the American Water Resources Association, 51(3), pp. 842–858.

JASECHKO, S.; SEYBOLD, H.; PERRONE, D., FAN, Y.; KIRCHNER, J. W. (2021). Widespread potential loss of streamflow into underlying aquifers across the USA. Nature 591(7850), pp. 391–395.

KRAUSE, S., HANNAH, D. M., FLECKENSTEIN, J. H., HEPPELL, C. M., KAESER, D., PICKUP, R., PINAY, G., ROBERTSON, A. L.; WOOD, P. J. (2010). Inter-disciplinary perspectives on processes in the Hyporheic Zone. Ecohydrology, 4(4), pp. 481–499.

RABELO, J. L.; WENDLAND, E. (2009). Assessment of groundwater recharge and water fluxes of the Guarani aquifer system, Brazil. Hydrogeology Journal, 17(7), pp. 1733–1748.