Understanding Surface Water-Groundwater Interactions on the Left Bank of the Niger River for Sustainable Dam Management in a Sahelian Context (Niamey,Niger)

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ABSTRACT

Gaining a thorough understanding of the interactions between groundwater and surface water is essential for the effective management of significant river systems, especially in semi-arid areas like the Niger River basin. With the construction of the Kandadji dam upstream from Niamey, we anticipate major changes in the flow patterns of the river, which could disrupt the hydrological balance between the Niger River and the nearby alluvial aquifers. Nevertheless, the details of these interactions are not well understood along the river's left bank. This research is designed to achieve three main objectives: (i) to describe the spatial and temporal patterns of groundwater-surface water exchanges, (ii) to measure their individual contributions to the river's discharge, and (iii) to evaluate how these interactions might change due to the hydrological impacts of the dam. To address these goals, the study employs a hyper-resolution hydrological modeling technique aimed at capturing the intricate processes that influence water exchanges between the Niger River and the alluvial aquifer system. In particular, the physically based, fully integrated model ParFlow coupled with the common land model is implemented. This modeling framework enables the explicit simulation of surface-subsurface interactions by simultaneously resolving overland flow, variably saturated groundwater flow, and land-atmosphere-exchanges. This model has been calibrated and validated using existing field data, such as river discharge measurements, and piezometric levels. By utilizing high-resolution spatial discretization, we can pinpoint specific recharge and discharge areas along the left bank. Initial findings suggest that groundwater inputs are crucial for maintaining the Niger River's baseflow in the dry season, especially in areas with strong hydraulic connectivity between the river and the alluvial aquifer. The model highlights strong spatial heterogeneity in exchange processes, with alternating gaining and losing river sections depending on seasonal dynamics and local hydrogeological conditions. These changes could have big effects on the availability of water and the stability of ecosystems. This research illustrates the significance of high-resolution, integrated modeling techniques for a comprehensive understanding of groundwater-surface water interactions in extensive African river systems. For the Kandadji dam, it is important to know more about these exchanges so that we can predict how they will affect the water cycle, support flexible water management, and make sure that both people and river ecosystems can continue to use the water. The results give decision-makers useful information and help fill a big gap in knowledge about the Niger River Basin.

Keywords: Niger River; Kandadji Dam; ParFlow-CLM; High-resolution modeling; River-aquifer exchange.