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Analyzing the Relationship between Electrical Consumption by Pumping and Water Induced Land Deformation to Understand Water Security

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Monitoring water security remains a significant challenge due to the complexity of the water cycle and the socio-hydrological drivers behind water consumption. Effective monitoring requires data on water use and availability, which are often difficult to obtain in large urban or semi-urban areas with limited resources and lacking hydrological instrumentation. Emerging technologies, such as Earth observation systems and indirect hydrological indicators such as energy for water pumping can help estimate water use and availability. In urban socio-hydrological systems dependent on groundwater, energy consumption for pumping provides information about water use, while water-induced land surface deformation can serve as a proxy for water availability due to its relationship to groundwater level changes. This study analyzes the trends and relationship between energy consumption for groundwater pumping and land surface deformation to characterize water security, defined as the sustainable balance between water use and availability. The study focuses on Cochabamba, Bolivia, a rapidly growing metropolis facing unique water management challenges and land deformation (i.e. subsidence in some areas and uplift in others) due to groundwater overexploitation and incomplete water infrastructure. Using Small Baseline Subset (SBAS) and Regression analysis, we estimated trends in these variables from 2018 to 2022 across an extensive network of groundwater wells. We identified four trends in pumping energy consumption (increasing, decreasing, no significant change, and no consumption) and three trends in land surface deformation (uplifting, subsidence, and no significant deformation). By combining these trends, we formulated four potential scenarios to characterize water security from wells to the regional level: Water Security, Unsustainable Water Security, Water Insecurity, and Recoverable Water Insecurity. The findings reveal a predominant domestic use and an increasing trend in pumping energy consumption across wells. Most wells exhibit a state of Water Insecurity characterized by the combination of subsidence and increasing energy consumption. The study highlights the potential of combining energy consumption and land surface deformation data as accessible and scalable tools for water security monitoring in resource-constrained regions. Understanding these trends can help to develop targeted management strategies and prevent water depletion in growing urban populations.