GIS-based Approaches for Quantifying Water Resources in Boreal Regions: Aquifers, Water Cycle and Groundwater Dependent Ecosystems

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ABSTRACT

Quantifying the water resources stored in shallow aquifers and their hydrological exchanges with surface waters is critical to better evaluate the sensitivity of groundwater resources and groundwater dependent ecosystems (GDEs) face to climate change and human impacts. Yet, the evaluation of water resources is challenging in vast and remote areas such as Northern Quebec, where pre-existing data is sparse and the access to the land is limited. Fitting in this context, this study focuses on the development of GIS-based approaches to evaluate components of the water cycle over more than 180,000 km^2 encompassing vast boreal watersheds of the James Bay basin (Canada). A multi-criteria analysis (MCA) based on geological and hydrogeological data was coupled to geometric calculations to evaluate the volume of shallow granular aquifers (≈ 40 km^3) and to identify areas where groundwater protection should be prioritized. Remote sensing and geochemical data (stable isotopes [δ^2H-$\delta^{18}O$] and electrical conductivity of water) were subsequently used in mass balances and mixing equations to estimate the groundwater contribution to river discharge. The monitored rivers showed systematic seasonal variations in discharge and isotopic compositions. The calculations suggest that river flow is mainly a mix of rainfall (50-69%) and snowmelt (26-46%) with evaporation over inflow ratios of 3-13%, while the groundwater contribution is generally below 19%. Time-series of land surface temperature (LST) from Landsat thermal imagery are also analyzed to highlight seasonal changes in the monitored watersheds. These images are used to delineate groundwater discharge areas where LST remain cold and stable during the warm period. The data offers unprecedented insights on the evaluation of shallow groundwater resources and their ecological functions in boreal watersheds of the James Bay area. Ultimately, the results will help better protecting aquifers and GDEs face to increasing human pressures and better predicting their response to climate change.