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Assessment of sustainable water use and water stress in India using census-based statistical data

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India which has the second largest population in the world and the largest in freshwater consumption faces severe freshwater scarcity. The primary drivers of water scarcity include increasing water demand and declining freshwater availability. Large-scale assessments using distributed hydrological models have become an important tool to quantify the impacts of global climate change and water use changes on water resources sustainability. The current large-scale assessments, however, need improvement in accounting for the industrial, and environmental water demands as most of such assessments may not include proper estimates of these water demands.

The present study aims to develop a large-scale assessment framework to estimate sustainable water use and water footprint in India via combined use of a global earth system model and a census-based statistical data. The modelling is carried out for the period 1991–1999 at a spatial resolution of 50 km x 50 km and a monthly temporal resolution scale. As a measure of deficiency in water supply relative to the water demand, the Water Stress Index (WSI) is defined as the ratio of total water withdrawal to total available water. The total available water is modelled as the sum of surface and sub-surface runoff using the Community Land Model, CLM 4.0, developed by the National Centre for Atmospheric Research (NCAR) of the US. The total water withdrawal is defined as the sum of the irrigation, industrial, domestic and environmental water uses. The demand for these water uses is modelled using census-based statistical data collected from various national and state governmental organisations in India. Moreover, the amount of non-renewable groundwater abstraction, which is defined as the excess groundwater abstraction over groundwater recharge, is modelled using available groundwater recharge and withdrawal datasets within the country.

The modelled surface runoff is calibrated with the discharge observations from six river basins of India. Model results show good performance indices (R-squared = 0.82, RMSE = 17.27, NSE = 0.58). The modelled water withdrawals estimated from census-based statistical data are superior in accuracy to the FAO (Food and Agricultural Organization) estimates. The modelling of these water withdrawals is carried out at the national level and are distributed to state-level based on the data collected at the state-level. The verification of the model performance at the state-level also shows good agreement with the observed values. The study further identifies that most of the states in India face severe water stress (WSI>0.4) at least one month in a year, except for the northeastern part of India. The estimates of non-renewable groundwater abstraction show severe groundwater depletion in the northwestern parts of India (Gujarat and Rajasthan), consistent with the existing estimates from GRACE satellite observations.

Keywords: Sustainable water use, water scarcity, water stress, environmental water demand