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Estimating Multi-sectoral Water Withdrawals Through Machine Learning for Attribution in an Ungauged Terminal Lake Basin in Central Asia

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Many terminal lakes in Central Asia have witnessed concerning rates of shrinkage in recent decades. These lakes are particularly sensitive to both climate change and human water withdrawals. Although human water withdrawals are acknowledged as a major factor influencing long-term lake changes, previous studies often fail to distinguish the specific contributions of different sectors such as irrigation, livestock, industry, and domestic water usage. This knowledge gap is largely due to the absence of observed multi-sectoral water withdrawals. Recognizing the value of machine learning methods in predicting water withdrawals through complex, non-linear relationships between water uses and potential explanatory factors, we developed an innovative approach that integrates a hydrological model and a machine learning-based water use model. This methodology was applied to simulate the long-term changes in the area of Ebinur Lake, a large terminal lake in Central Asia. Water withdrawals estimated by Random Forest based on meteorological (temperature and precipitation) and socio-economic data (e.g., population, multi-sectoral GDP, per capita income, etc.) and allocated by irrigated area and population were extracted from the river route in the hydrological model which in turn affects the inflow into the lake. Finally, integrated model simulations were validated using remotely sensed lake areas and streamflow data from mountain hydrologic stations. Several experiments, including and excluding different sectoral water uses, were conducted to isolate factors influencing lake dynamics. The results indicated irrigation water withdrawal not only caused lake shrinkage, but also increased seasonal variability, thereby increasing the uncertainty of water supply to lake ecosystems. The proposed modelling approach provided a framework for quantifying the responses of terminal lake area changes to different sectoral water withdrawals in arid basins, especially in the absence of specific water withdrawal data.