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Gradient Boosting for Forecasting Groundwater Levels from Sparse Data Sets in an Alluvial Aquifer Subjected to Heavy Pumping and Flooding

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In most catchments, there is usually inadequate information to build an accurate three-dimensional representation of the sediment type and associated hydraulic properties. This makes it challenging to build a physics-based groundwater flow model that accurately replicates measured fluctuations in the groundwater level, and it also results in considerable uncertainty in forecasting the groundwater level under various climate scenarios. However, in many catchments in Australia, and around the world, there are 100 year-long rainfall and streamflow records. Good groundwater level data sets often date from mid last century, when advances in pumping technology enable high volume groundwater extractions to support irrigated agriculture. For the lower Murrumbidgee alluvial aquifer in Australia, which covers an area of 33,000 km^2, we demonstrate that it is possible to train the gradient boosting algorithm to predict the annual change in the groundwater level to within a few centimetres.

The lower Murrumbidgee aquifer, which is up to 300 m thick, is an important but highly stressed aquifer system in Australia. Annually the groundwater level fluctuates many metres due to groundwater withdrawals and occasional flooding. Some portions of the alluvial aquifer are unconfined and other portions semi-confined. Under current groundwater pumping conditions, groundwater levels decline in the semi-confined portions of the aquifer during extended periods of below average rainfall. In other portions of the catchment, there have been periods of groundwater level rise due to deep drainage beneath irrigated crops.

Despite the catchment size, groundwater levels throughout the region are driven by four primary processes: ongoing river leakage, pumping, deep drainage and occasional flooding. Combined with knowledge of the hydrogeological setting, we successfully used just rainfall, streamflow and annual groundwater withdrawal records to build a gradient boosting model to predict where the groundwater level will rise and fall, in both space and time. Under existing annual pumping rates, the gradient boosting model forecasts that the groundwater level will fall many metres if the catchment has a period of below average rainfall as occurred from 1917 to 1949. This fall in the groundwater level will trigger groundwater access restrictions in some portions of the aquifer.