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Incorporating land use change adjustments into basin-scale groundwater recharge estimates in the Murray-Darling Basin

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Abstract:

Groundwater is central to water security and groundwater-dependent ecosystems. Since long-term, basin-scale recharge is not directly measurable, it is estimated from indirect methods such as water-balance models, numerical modelling, and environmental tracers. The Chloride Mass Balance (CMB) method is widely used due to its simplicity and cost-effectiveness, providing reliable point-scale recharge estimates. However, upscaling these estimates to a basin-wide scale is challenging due to spatial variability in factors such as rainfall, soil properties and vegetation cover. A key limitation of CMB estimations is the uncertainty introduced by historical land use changes, which can significantly alter recharge rates via changes in infiltration and evapotranspiration. The clearing of native perennial vegetation for agriculture often increases recharge rates, but the time required for aquifers to reach hydrologic equilibrium varies, leading to potential underestimates of long-term recharge estimates using the CMB method.

This study estimates groundwater recharge in the Murray-Darling Basin, Australia, involving the following steps: (i) estimating point recharge using the chloride mass balance method; (ii) generating a multiple regression model based on spatial covariates such as rainfall, NDVI and clay content; (iii) applying regression kriging for upscaling the recharge estimates; (iv) Incorporating a novel adjustment to the model to account for historical land use changes by using rainfall-recharge relationships derived from detailed field studies; (v) Quantifying uncertainty through 1,000 replicates, ensuring robust spatial recharge estimates.

Point-scale recharge estimates ranged from 0.1 to 442 mm/yr, with a median of 4.1 mm/yr. After incorporating spatially structured residuals, the regression-kriging model explained ~70% of the variance in recharge, with rainfall the dominant covariate. The land use adjustment, applied only where native vegetation has been cleared, resulted in a 0.5 to 2 orders-of-magnitude increase in recharge compared to estimates from the fitted regression equation. After accounting for land-use change, the basin-wide mean recharge was 8.8 mm yr^{-1}, with state means spanning 3.04–16.01 mm yr^{-1} across NSW, QLD, VIC and SA. Mean recharge estimates across basin and across states were consistently higher when land-use change was incorporated. The results demonstrate a refined CMB-based upscaling framework that integrates regression-kriging with an explicit land-use adjustment.

Keywords: *recharge, chloride mass balance, land use, kriging*

