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National-scale monitoring of irrigated agricultural water use using remote sensing evapotranspiration and a hydrological framework

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Abstract: Accurately quantifying irrigated agricultural water use is essential for sustainable water resource management, informed policy-making, and national ecosystem accounting. Since the Australian Bureau of Statistics (ABS) ceased its farm water use survey after the 2020–21 survey year—ending a continuous dataset of on-farm-applied water collected since 2002-03—a substantial gap has emerged in the national agricultural water use record. Addressing this absence of national on-farm-applied water data, this research highlights how advanced remote sensing, when integrated with hydrological modelling, can replace traditional survey-based methods, delivering a scalable and spatially explicit framework for ecosystem accounting and sustainable water governance for all of Australia at unrivalled spatial resolution. We developed and evaluated 2 modelling approaches for estimating irrigated agricultural water use. The first approach applies a simplified one-dimensional annual water balance model, which estimates irrigated agricultural water use without accounting for changes in soil moisture storage throughout the water-year. The second approach employs an enhanced one-dimensional water balance model, incorporating monthly and seasonal variability while explicitly modelling soil moisture dynamics. Validation against historical on-farm water use estimates from the ABS survey data from 2005–06 to 2020–21 demonstrated substantial accuracy improvements of the enhanced method.

Across all evaluation metrics at the state scale, the enhanced model outperformed the simplified approach: (i) the coefficient of determination (R^2) increased from 0.75 to 0.85; (ii) model bias improved from +12.1% to –10.7%; and (iii) both the Nash–Sutcliffe Efficiency (NSE) and Kling–Gupta Efficiency (KGE) increased markedly (NSE: 0.48 to 0.83; KGE: 0.58 to 0.87). Similar performance gains were consistently observed at finer spatial resolutions, including Statistical Areas Level 4 (SA4, $R^2 = 0.83$, NSE = 0.81, KGE = 0.87) and Level 2 (SA2, $R^2 = 0.69$, NSE = 0.68, KGE = 0.65).

These findings demonstrate that advanced remote sensing integrated with hydrological modelling can provide robust, scalable, and spatially explicit estimates of irrigated agricultural water use, effectively replacing the discontinued survey-based data.

Keywords: *Keywords: Irrigation water use, Remote sensing, Evapotranspiration, Hydrological model*