Hydro-economic modelling of climate change impacts on water allocations and markets

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Abstract: Climate change has the potential to significantly impact water supply in regulated rivers via its effects on run-off, inflow and water allocations. In many large, connected river systems, water markets have emerged as a tool to manage spatial and temporal variability in water supply and demand. Water markets are likely to play a key role in supporting adaptation to climate change; however, models of regulated rivers typically do not account for water-market responses. Unfortunately, coupling hydrological and water resources models (that can model river flows and water allocations), and economic models (which can predict water demands, water market conditions and water trade) is not straightforward. Most water resource models that operate at the large river basin scale are detailed and complex with daily timesteps. Whilst this complexity is useful for certain applications, such as detailed water accounting, it is less useful when considering an integrated modelling approach that can accommodate uncertainty in future climate change (Jakeman and Letcher, 2003). In contrast, economic models are often at an annual timestep and aim to capture only broad patterns of trade, with limited consideration of short run on-farm planting decisions in response to climate (Hughes et al., 2023). Models that offer commensurate complexity in their representation of the key system dynamics are more likely to offer accurate insights when undertaking future projections because they focus attention on the important drivers of change (John et al., 2021).

This study combines hydrologic and economic modelling to investigate climate-change effects in the southern Murray–Darling Basin (sMDB). We apply a reduced complexity monthly water-resources model to simulate temporal and spatial changes in allocations and link its outputs to a monthly economic model of irrigated agriculture and water trading. We undertake climate change projections using a 37-member CMIP6 ensemble centred around 2050.

Using the coupled framework, we find that climate change significantly alters the seasonal timing and magnitude of water allocations. In the Goulburn system, mean historic opening allocations to High Reliability Water Shares (HRWS) are ~88% and reach ~97% by season's end; under median climate change, openings reduce to ~70% and end-season allocations to ~95%, with the driest ensemble members reducing opening allocations to <30% while still exceeding 80% by season's end. Low Reliability Water Shares (LRWS) are much more exposed to climate change impacts. In the driest scenarios long-term mean LRWS are near zero through much of the year. The Victorian Murray shows similar early-season sensitivity in HRWS and near-zero LRWS under drier scenarios. In New South Wales, opening High Security allocations in the Murray decrease under the more severe scenarios, whereas Murrumbidgee High Security remains ≥95%. General Security products in both systems shift downward across the season, narrowing differences between opening and end-season reliability.

Market and irrigation outcomes reflect these hydrologic shifts. Our modelling allows for long-run adjustments in the level of irrigation development in response to long-term changes in climate or commodity prices. Across trade zones (Goulburn; Murray above/below the Barmah Choke; Murrumbidgee), mean allocation prices rise markedly, with median scenario increases of nearly 300% relative to historic conditions. Not allowing for structural changes in irrigation development shifts prices to even higher levels. Net trade imports below the Barmah Choke increase in dry scenarios, mostly supplied by increased trade from the Goulburn, Broken, Campaspe and Loddon system. Irrigation diversions decrease basin-wide under dry scenarios. Structural changes to irrigation due to market and climate conditions lead to a reduction in planted perennial crop area of up to ~30,000 ha. Importantly, these changes are non-linear with allocation impacts, where significant climate drying leads to an increase in the rate of change in estimated perennial crop area and value of irrigation production.

These results highlight an emerging early-season vulnerability in regulated systems and the value of hydro-economic modelling at monthly resolution to diagnose intra-annual risks relevant to planting decisions, carryover behaviour and delivery planning. The magnitude and timing of price responses underscore potential

shifts in irrigation development and crop mix, with implications for basin communities and environmental water delivery. For the wider modelling and water-management field, the study demonstrates that coupling commensurate-complexity monthly hydrologic and economic models enables basin-scale assessment of climate-change risks to seasonal allocations and markets. This can provide actionable evidence for adaptation policy, inter-valley trade rules and infrastructure operations under a range of plausible futures.

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