

Climate change-induced drought impacts on Zambian energy, water and economic systems

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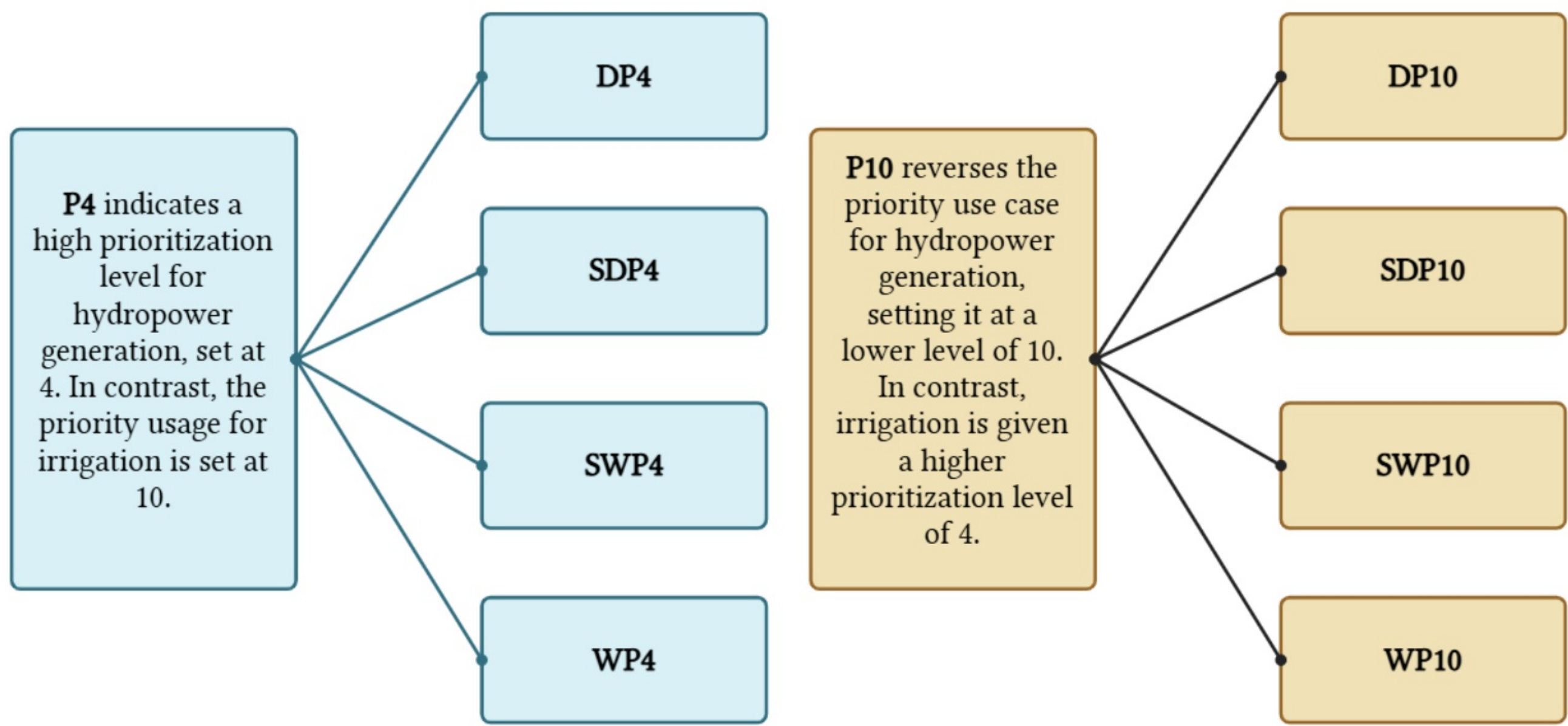


WHY THIS MATTERS: The water–energy nexus is crucial to climate resilience particularly in Zambia given its high reliance on hydropower (averaging 94% of national generation between 2015 – 2021) and agrarian output. This study examines how competing hydropower and irrigation demands interact under declining water availability, and their subsequent ripple effects on the Zambian economy. As drought intensifies, we quantify the electricity (and irrigation) shortfalls, and its respective macroeconomic shocks.

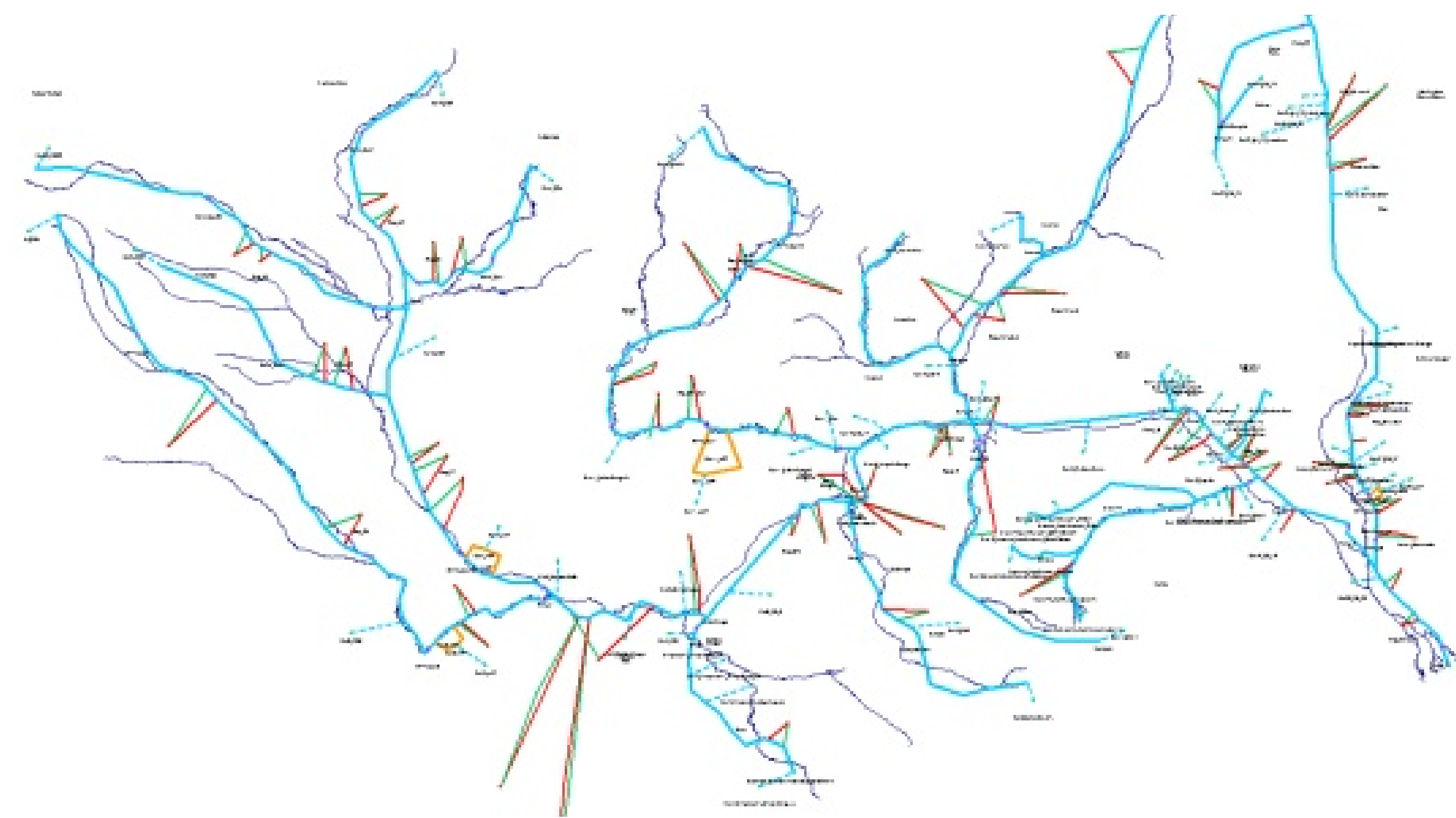
RESEARCH GAP: The water–energy nexus remains underexamined in the Zambezi River Basin. Existing studies omit climate variability or examine hydropower and irrigation in isolation, leaving limited understanding of how competing water uses interact as water availability declines. This study models hydropower, firm power and unmet irrigation demand across alternative climate and water-allocation scenarios.

POLICYMAKING SIGNIFICANCE: Understanding these interactions is critical for water management and energy security in the Zambezi River Basin. As water availability becomes more constrained, allocation between hydropower and irrigation becomes increasingly consequential. Quantifying these trade-offs can help policymakers assess climate risks and develop resource-allocation strategies that account for both energy reliability and competing water demands.

METHODS

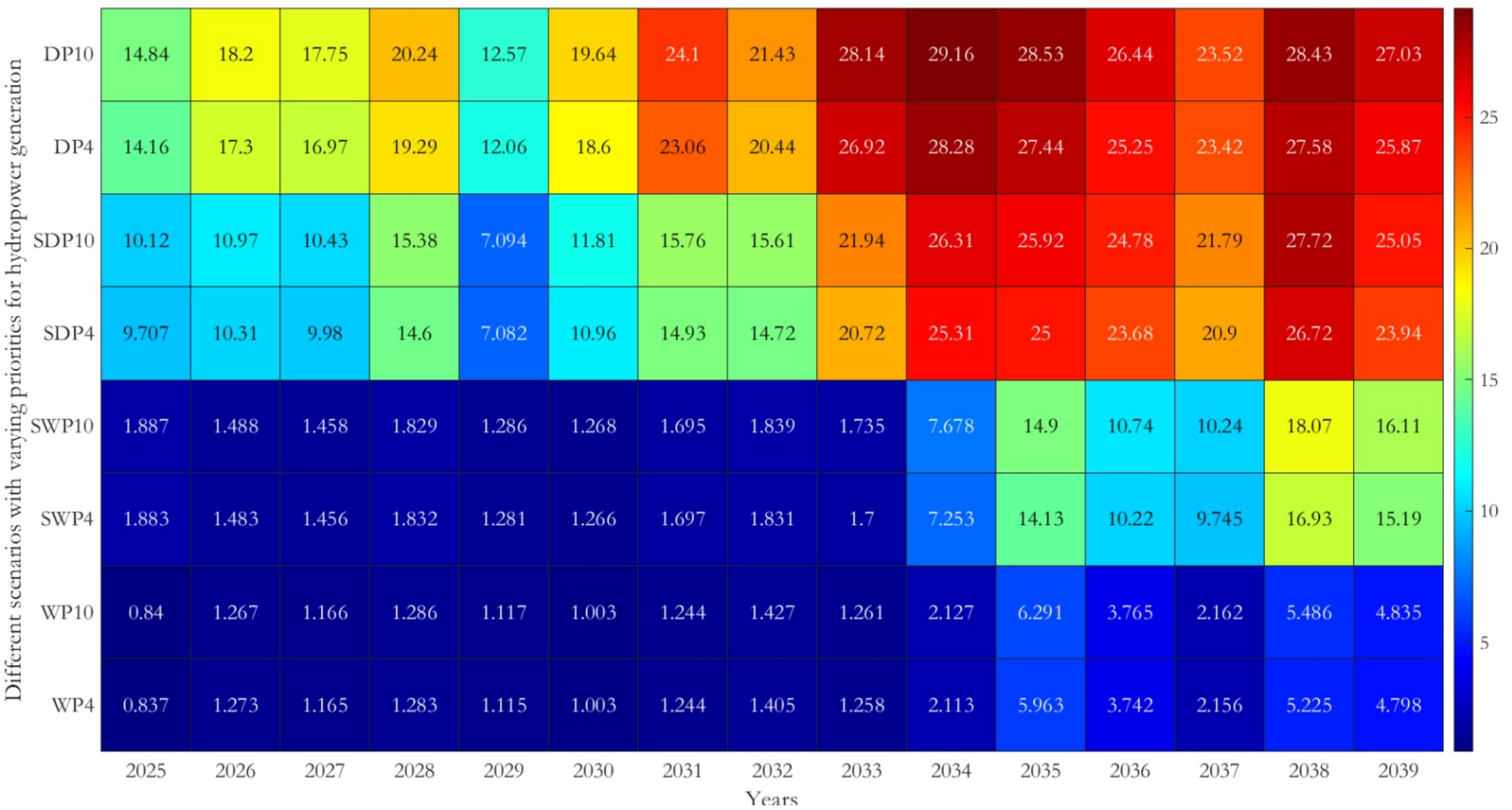


SCENARIO GENERATION: 8 scenarios combine four climate profiles (wet, semi-wet, semi-dry and dry) with two competing water-allocation priorities over 2025–2039. **P4** subset of scenarios prioritises hydropower. **P10** prioritises irrigation.

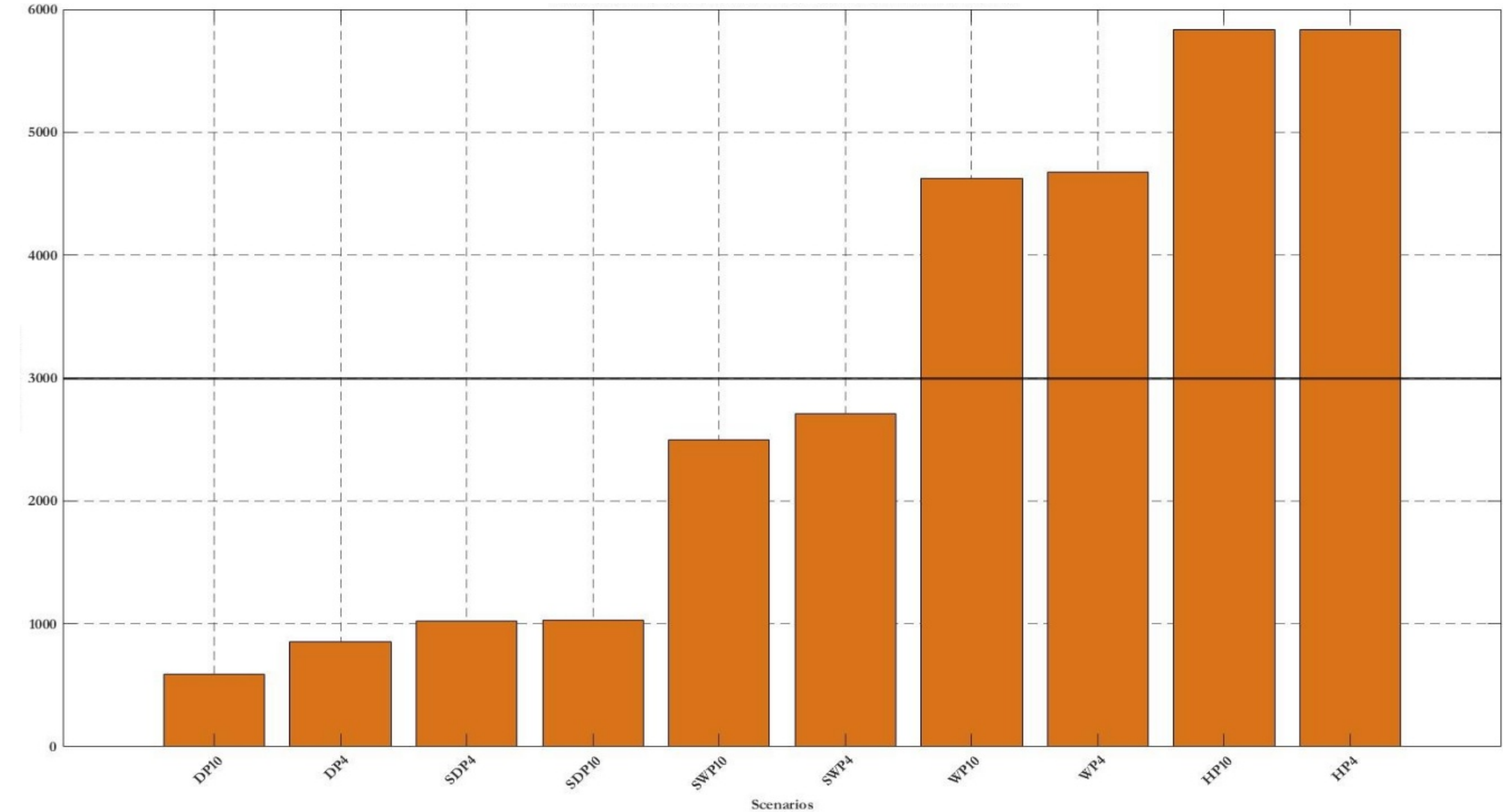


MODELS USED: Our primary model was **Water Evaluation and Planning (WEAP)**. It was used to simulate water availability and unmet demand for hydropower and irrigation across the Zambezi River Basin, alongside changes in hydropower generation and firm power. Secondary modelling entailed using an unconstrained **Leontief input–output model** based on Zambia’s 2019 Social Accounting Matrix (SAM) was used to translate hydropower and irrigation shortfalls into sectoral production shocks, capturing their direct and indirect repercussions across the Zambian economy.

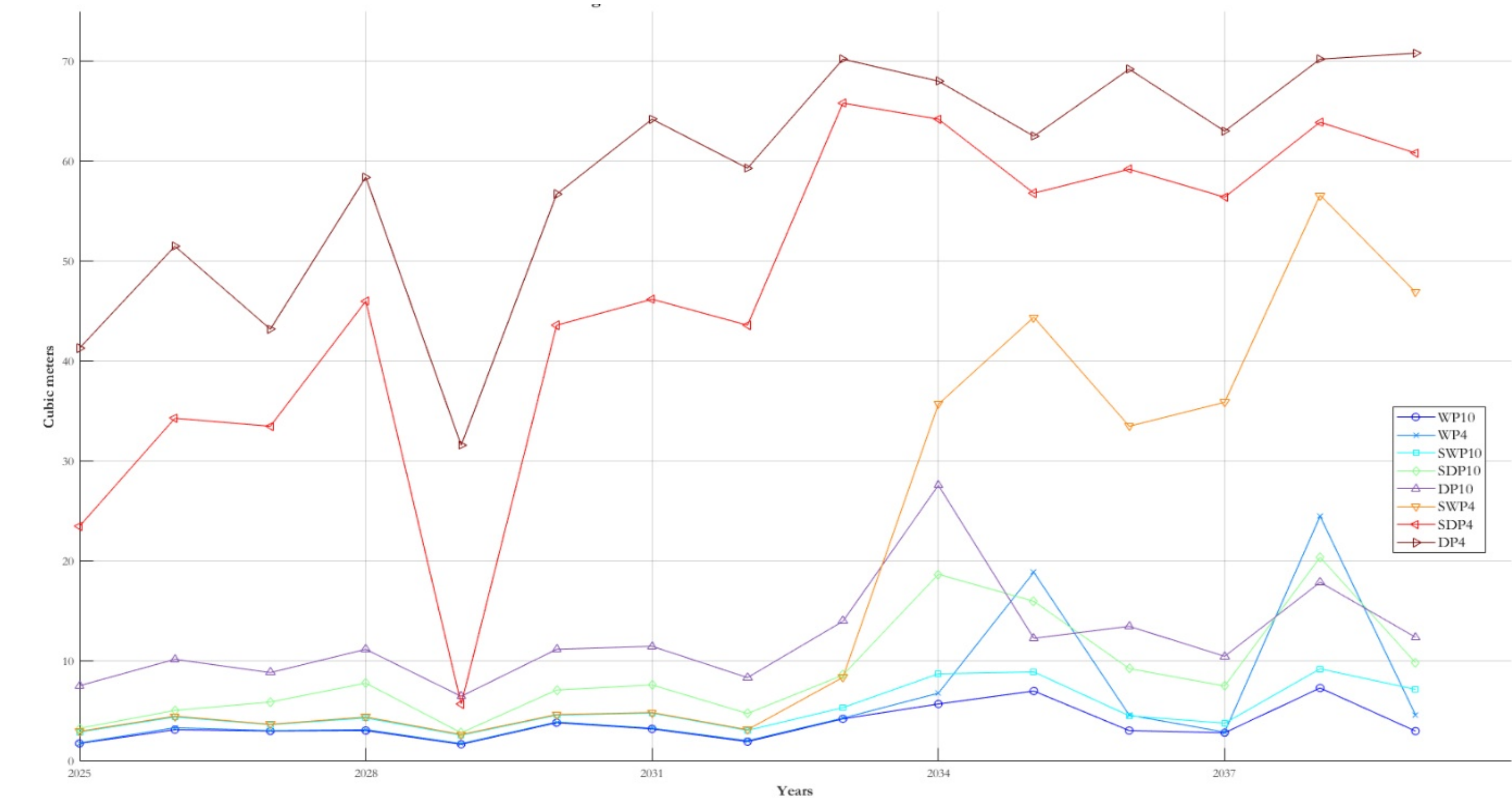
RESULTS



Lower hydropower output becomes a substantial supply deficit. Mean unmet hydropower demand rises from 2,305 GWh (5.0%) in WP4 to 22,668 GWh (49.3%) in DP10. Shortfalls intensify particularly after 2033, leaving almost half of modelled hydropower demand unmet under the driest, irrigation-prioritised future.



Reliability loss is considerably greater than the decline in average generation. Firm power is generation equalled or exceeded 95% of the time. This falls from 4,674 MWh in WP4 to 590 MWh in DP10, an 87.4% decline. Over the same scenario range, mean hydropower generation falls by 57.0%.



Irrigation becomes increasingly vulnerable under drier conditions. **SECONDARY MODELLING RESULTS:** Increased coal production compensates for lost electricity output, while solar does not scale sufficiently to offset lost generation. Economic losses concentrate in energy-intensive manufacturing and mining, while irrigation shocks were relatively limited as agrarian output is primarily rainfed.