DECISION-MAKING UNDER DEEP UNCERTAINTY MODELLING FRAMEWORK FOR ROBUST WATER RESOURCE MANAGEMENT IN THE UPPER YAMUNA RIVER BASIN, INDIA

Abstract: Water resource management in the Upper Yamuna River Basin (UYRB), India, faces growing challenges due to climate variability, socio-economic pressures, and governance constraints. Traditional predictive models often fall short under conditions of deep uncertainty. This study applies a Decision-Making Under Deep Uncertainty (DMDU) framework to design robust, adaptive water governance strategies. The approach integrates stakeholder co-production, participatory modelling, physical climate storylines (PCS), and fit-for-purpose water resource modelling to stress-test policies and develop Dynamic Adaptation Policy Pathways (DAPP). Using tools such as Bharat CLIMEX, UYR-SWAT, and UYRB-WEAP, the study engaged over 100 stakeholders between 2019–2024 to identify key priorities including Delhi's water supply reliability, demand management, and environmental flows. PCS-based analysis revealed a 30–100% reduction in non-monsoon precipitation, 10–20% increase in monsoon precipitation, and 2–4°C temperature rise. Five qualitative climate scenarios were developed to explore the impacts of extreme shifts on water availability. A stakeholder-informed WEAP model was developed and validated using observed data, capturing seasonal variability, allocation rules, and operational constraints. The model revealed that Haryana is the largest water consumer, followed by Uttar Pradesh, Delhi, and Rajasthan. Scenario analysis exposed policy tipping points where existing strategies became ineffective, particularly under scenarios of high-impact, low-likelihood winter precipitation and rising demand. Demand-side measures (e.g., leakage reduction, metering, targeted subsidies) improved Delhi's water reliability, while supply-side strategies improved both Delhi's water reliability and environmental flow management. Further, DAPP analysis demonstrated that early adoption of demand management can delay tipping points by 10–20 years, providing a window for phased investments. By integrating the XLRM framework, climate scenarios, and stakeholder-driven modelling, this study offers a decision-centric, flexible DMDU modelling framework for climate-resilient water resource management. It provides actionable pathways for managing water security in data-scarce, climate-vulnerable regions of the Global South.

Key words: DMDU, Co-production, Stakeholder engagement, Physical climate storylines, fit-for-purpose model, stress testing, dynamic adaptation policy pathways, National Capital Territory of Delhi, Upper Yamuna River Basin.