Chapter 6

# Predictive Modeling and Generative AI for Anticipating Water Shortages


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## ABSTRACT

*Faced with the intensification of water shortages caused by climate change and human pressures, this chapter presents a hybrid architecture combining predictive modelling and extreme scenario generation to strengthen territorial resilience. The approach is based on the integration of time series transformers and deep generative models to anticipate the evolution of hydrological variables and simulate critical events. In the absence of sufficiently rich real data, a set of realistic synthetic data was constructed from hydrological distributions, seasonal cycles and stochastic processes, then qualitatively validated. This game allows a rigorous evaluation of predictive and generative performance. Results demonstrate the complementarity of*



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*the two dimensions to improve risk visualization and activation of early responses. The chapter also discusses technical limitations, ethical issues, and proposes concrete perspectives for integration into digital twins, warning systems or decision support tools for climate adaptation.*

## INTRODUCTION

In the face of intensifying climate change, rapid urbanization and sustained population growth, freshwater resources are under unprecedented pressure worldwide. According to projections by international institutions, almost two thirds of the world's population could be living in water stressed areas by 2030, due to a combination of prolonged droughts, excessive groundwater exploitation, pollution of water sources and increasing variability of precipitation.

Recent studies intensively highlight the rise of extreme phenomena such as 'flash droughts', which increase the risks of short-term water scarcity, particularly in semi-arid areas (Chouhan et al., 2023)This reinforces the urgency to develop robust and resilient predictive approaches, capable of operating in a context of increasing hydrological variability and increased uncertainty. This critical situation is not confined to arid or desert regions; it also affects temperate zones, where the regularity of hydrological regimes is increasingly disrupted by extreme events such as droughts, heat waves or intense precipitation concentrated over short periods. Climate change is exacerbating these imbalances by altering water cycles, which complicates the planning and sustainable management of available resources(Z. Liu et al., 2024) . In addition, demographic pressure and accelerated urbanization in many parts of the world are intensifying competition between agricultural, domestic, industrial and environmental uses of water(Mekonnen & Hoekstra, 2016). This is compounded by challenges related to equitable access and governance of water systems, particularly in developing countries where infrastructure is inadequate or obsolete. In this context, the issue of water security becomes a central issue of socio-economic and geopolitical stability, calling for a thorough rethinking of integrated water management strategies (Dai et al., 2025a). This emerging crisis, multidimensional and largely amplified by the enthronization of environments, requires advanced tools for analysis, forecasting and decision making to anticipate and mitigate future shortages(Mekonnen & Hoekstra, 2016).

Anticipating water shortages is now a strategic lever to ensure the resilience of urban, agricultural and industrial systems in the face of increasing scarcity of water resources. In urban areas, the availability of sufficient quality water is essential for the proper functioning of infrastructure, public health and the continuity of essential services. The slightest disruption to supply can have ripple effects, affecting