

## Integrated modelling for water resource management during droughts

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Drought periods make the water supply sometimes critical. Urban areas are particularly sensitive to water scarcity since they must meet the increasing demand for water to satisfy human needs due to the growing urban population all over the world. About 58% of the world population currently lives in cities; the trend is continuing to grow, and the United Nations (2018) expects that by 2050, it will be about 68%. On the other hand, water scarcity periods have been becoming more frequent, and the Intergovernmental Panel on Climate Change (Price et al., 2022) stated that if average global temperatures rise 3°C above pre-industrial levels, 170 million people are expected to experience extreme drought. Water scarcity provides several environmental, economic, socio-cultural, and health impacts since it can compromise a wide range of ecosystem services and may result in significant, long-term economic losses in a range of sectors. A substantial number of water distribution systems worldwide are operated as intermittent water supply systems, delivering water to consumers in irregular and unreliable manners. Intermittent water supply consumers commonly adapt to flexible consumption behaviours characterized by storing the limited water available during shorter supply periods in intermediate storage facilities for subsequent usage during more extended non-supply periods (Abhijith et al., 2023). In this context, it is urgent to define new strategies to improve the resilience of water supply systems. The use of alternative water resources, such as shallow waters, rainwaters, reclaimed waters, etc., can be of support to the traditional distribution networks. For example, rainwater harvesting is an ancient and well-known solution for drought risk mitigation with different levels of advanced technology associated with it (Raimondi et al., 2023). It involves several environmental and social benefits linked to the Sustainable Development Goals of the ONU Agenda 2030. It has been estimated that about 50% of water demand for non-drinking domestic use can be supplied by rainwater, and this is currently encouraged by laws and regulations.

Rainwater harvesting systems must be designed and managed to optimize water resource control under different climate and demand scenarios. In this sense, probabilistic modelling can be suitable for its versatility and multi-objective approach. The method enables the estimation of the probability distribution function of the variable of interest from the probability distribution function of the rainfall input and the roof characteristics. It can relate the storage volume to a return period, also considering the possibility of pre-filling from previous rainfall events and the retention time for water quality features. The integration of a probabilistic approach and a predictive model based on artificial intelligence can increase its potential and applications. Green-Tea is an integrated cloud-streaming platform for time-series exploration and forecasting as a service for environmental data (Puoti et al., 2023). Following the as-a-service approach, it provides useful insights into users demand for water supply, allowing them to leverage the exploration and forecasting/prediction abilities of machine and deep learning algorithms.

For the definition of the best practices and management rules to maximize the benefit, it is fundamental to estimate the vulnerability of the different users as a function of the socio-economic context and, at the same time, the strategically important sources of supply. To this end, it is essential to consider the use of models that integrate results from climate models, resource allocation models, and simplified network hydraulic models, considering losses, user behaviors, and water demand reduction strategies. The proposed

methodology involves the analysis of the impact of water scarcity and self-adaptation strategies on water demand under intermittent flow conditions. This analysis was conducted on consumption data collected from a residential agglomeration in the metropolitan area of Palermo, in which the contribution that the private tanks of four single users (A, B, C, and D) and one condominium type (E) produce over the entire system was evaluated (Criminisi et al., 2009). A monitoring scheme was set up for all users, lasting 6 days, which involved measuring the pressure in the network every 15 minutes using a pressure meter installed upstream of the fiscal meter. The water volumes upstream and downstream of the user's private tank were measured through two class C meters ( $Q_{\min}=15$  [L/h],  $Q_{\max}=5$  [m<sup>3</sup>/h], sensitivity of 7-8 [L/h], pressure drop at  $Q_{\max}$  of 1 bar, operating pressure of 16 bar) equipped with a pulse emitter and connected to a data logger, programmed to record data every minute. Finally, the water level in the tanks was acquired through a pressure cell level meter connected to a data logger which recorded data every 15 minutes (Figure 1).

Models for water distribution and quality evaluation can be useful to define key performance indicators for water resilience in urban areas in order to evaluate the impact of urban strategies with respect to the efficiency of water demand reduction, the implementation rate, the long-term mitigation capacity, the reactivity in the short term, and the overall cost.

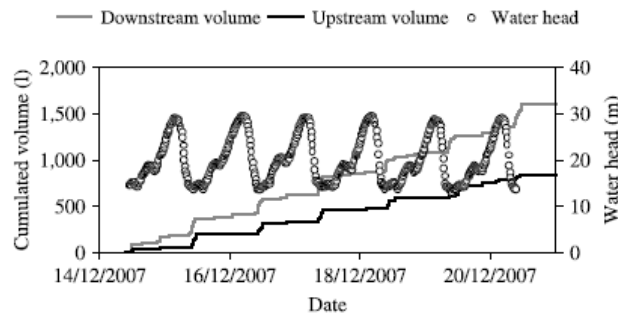


Figure 1 – Temporal trend of measured network water head and volume, downstream and upstream of the tank (household A).

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