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Assessing the Effect of Droughts on Complex Multi-sector Water Systems

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In recent years, climate change has significantly intensified the frequency and severity of drought events. Rising temperatures, altered precipitation patterns, and changing weather dynamics have led to more prolonged and intense droughts altering water availability and exacerbating tradeoffs, especially in complex multi-sector water systems.

An archetypal example of this situation is the Lake Como water system, in the north of Italy. Lake Como is operated to provide water downstream to the agricultural sector, control floods on the lake shores, and contrast low water levels that would negatively impact navigation and aquatic ecosystems. The conflict between the interests of these sectors is expected to exacerbate in the years to come due to the evolving hydroclimatic regimes. Among different adaptation options considered by the regional authority, we investigate the potential expansion of the lake's active storage capacity enabled by the recent construction of flood mobile dykes.

Here, we contribute a framework for evaluating the impact of droughts on multiple water users. Specifically, we adopt a synthetic weather generator to create multiple streamflow ensembles (scenarios) controlling the drought's frequency, duration, and intensity. Drought features are then linked to impacts (e.g., agricultural deficit) using a simulation model of the lake. Failure thresholds are defined for each impact indicator to set the minimum level of performance acceptable to each sector. Finally, a logistic classifier is used to identify the combination of drought features leading to a system failure.

Our results show that system failures can be accurately estimated using a linear combination of drought frequency, duration, and intensity. The combined effect of these three characteristics, rather than the extreme values of one of them, is responsible for system failure. Our analysis also proves that storage expansion is fundamental to reduce the downstream deficit, as well as to prevent most of the flood events.