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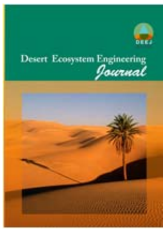

Dynamic Simulation of Drought Tolerance in Demand-Driven Management Basins

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Extended Abstract

Introduction: Surface water scarcity and overexploitation of water have brought about a serious crisis in the contemporary age. Therefore, if the factors contributing to such a crisis remain unexplored and proper management is not implemented, water resource systems will face more severe problems. On the other hand, as complex systems possess their own specific elements, their analysis requires a kind of simulation that interconnects all components and phenomena within and outside the system using a specific boundary, helping to obtain more realistic results. Moreover, unlike linear thinking, the variables of a system are governed by causal relationships in dynamic thinking, indicating that changing one componential element of the system affects other components. However, the review of the related literature reveals that the majority of studies already conducted on drought have applied a linear perspective, and only a few studies have followed a dynamic approach. Moreover, it could be argued that no study has investigated the influence of long-term hydrological droughts on water resource systems with hydraulic structures on a daily scale. Therefore, when dams are constructed on water currents, it is necessary to investigate and simulate hydrological drought and the consequent changes made in downstream. This study used a dynamic perspective to simulate hydrological drought from 1991 to 2022 in the Qhorveh Dehgolan watershed in Kurdistan, Iran, on a daily basis, using the Vensim software.

Materials and Methods: The study area included the Qhorveh Dehgolan sub-basins in Kurdistan province. The study simulated the daily dam outflow and the hydrological drought using the data regarding the river flow statistics, crop types, cultivated area, cropping patterns, irrigation requirements, precipitation, and hydrograph network from 1991 to 2022. As one of the most commonly used methods for analyzing hydrological droughts, the sequence theory, which was also applied in the current study, determines the drought index threshold, according to which the daily flow rates below the specified threshold indicate the occurrence of drought. However, there are instances where, for a short period, the flow rate exceeds the threshold level, leading to the classification of the drought period into smaller, dependent droughts. The problem mostly occurs in studies carried out on a daily basis, where small droughts with shorter durations are also counted as severe droughts. The problem can be solved by aggregating such small droughts.As the Internal Criterion method exhibits greater accuracy than other similar approaches used for aggregating small droughts, the current study used both sequence theory and the Internal Criterion method. The primary advantage of the current research model lies in its multidimensionality, obviating the need to separately obtain the feedback and variables for all stations. This characteristic allows for the introduction of equations, feedback, and all variables for a single station without necessitating the expansion of equations and other factors to accommodate multiple stations. Another advantage of the model is that it uses feedback mechanisms to determine the drought tolerance level at each station,

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indicating that the model initially calculates sequences and volumes at various drought levels using the data collected from stream gauging stations. Then, through feedback loops to flow-dependent variables at each station, the model adjusts the relevant figures within permissible limits to ensure that flow rates approach the minimum flow over the statistical period without reaching zero. Accordingly, based on a long-term time series of flow rates for each station and the related dependent variables, the drought tolerance level for each station was determined, considering the fact that drought conditions at any given station do not necessarily conform to a specific level.

Results: While the precipitation trend was not decreasing throughout the study period, drought has significantly increased in terms of frequency and intensity during certain years. The precipitation trend in the region indicated an increase in the 1999–2001 period, concurrently accompanied by severe drought conditions, substantiating that an external factor has brought about such drought. The construction of dams and the declining outflow volumes in proportion to the entire period have affected both the slope of the flow duration curve and the drought conditions. Therefore, on a daily scale, the flow rate and its variations determine the intensity and severity of drought events. Accordingly, when flow rates are similar, droughts occur over longer durations in less severe intensity, whereas sudden changes in flow rates result in droughts with shorter durations but greater severity. For instance, at Sang Siah station, the minimum drought intensity (0.0006 MCM) with a long duration (172 days) was recorded in 2013. Similarly, at Gol Bolagh station, a drought lasting 216 days with an intensity of 0.122 MCM was recorded in 2013. However, at Shadi Abad station, which did not exhibit significantly distinct or varying flow rates, the maximum drought duration (215 days) coincided with the maximum drought intensity (0.73 MCM) in 2014. The same was true for Delbaran station, where the maximum number of dry days was recorded in 2014 (305 days), with a corresponding maximum intensity being 0.46 MCM.

Discussion and Conclusion: This study carried out simulations in a dynamic environment, finding that according to the dam outflow rates when river flows exhibited minimal fluctuations, droughts were characterized by higher frequencies and less severe intensity. On the other hand, when flows were higher with significant variations in peak values, drought showed greater intensity and lasted for shorter periods. It can be concluded that analyzing the trend of changes made in the flow rate as a result of constructs built in the region and investigating the precipitation variations are required for investigating hydrological droughts that may occur over the dams' inflow rates and simulating the discharge rates. This is consistent with the results found in some other studies (Hamedi and Paimozd, 2023; Alishahi Chegeni et al., 2023). The similarity of the behavior of the stations near the newly constructed dams was also notable. The Sural, Sang Siah, and Gol Bolag dams were constructed and filled in the region in 2011 and 2013, respectively, coinciding with the recorded drought events, which also resulted in rivalry over water harvesting and the development of farmlands. Hassan Khan and Dehgolan stations recorded completely different flow duration curves throughout the period. Therefore, severe and very severe drought levels in these stations will have a lower threshold compared to other stations. In this study, a simulation was designed to calculate the tolerable drought level of the station, which was achieved by employing feedback loops and flow duration curves to assess the severity of drought conditions, particularly when flow rates were low and severe drought events occurred at levels beyond those officially declared. Hassan Khan and Dehgolan stations, which were under the influence of their upstream dams, showed severe droughts in lower values than the declared average drought tolerance threshold of 25%.

Keywords: Demand, Drought, Drought Tolerance Threshold, Simulation.