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A System Dynamics Approach for Evaluating the Impacts of Water Demand Management Policies in Kheirabad River Basin

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ABSTRACT

Kheirabad river basin is part of Zohre-Jarahi basin which is rich in surface water resources. But unprincipled usage of water and soil resources and also increasing water harvesting under climate change reduced the ability of the basin to respond to water demand. Reducing water storage of the Kowsar Dam as a result of reducing surface water inflows, make a concern to meet the future water demand at the basin. Therefore, the management of water resources in this basin is essential. In this study, we used a systemic approach to identify the factor affecting water supply and demand along with feedback and interaction between different elements for studying the behavior of the water resources system over time. The results of the study showed that the available surface water decrease and groundwater balance will be negative. Also, population growth and development of the agricultural sector will lead to an increasing trend in water demand and an increase in the surface and groundwater resources withdraw. Under these circumstances, water scarcity index is increasing and the water system sustainability index is smaller than the unit. The results also revealed that under business as usual (B.a.U) condition, the vulnerability index and maximum deficit of the water system are 0.119 and 0.213, and the reliability and sustainability indices are 0.50 and 0.703, respectively. Therefore, according to the results, the probability of not meeting the increasing demand of water, thus increasing the population and the level of crop cultivation, is predicted by using available water resources during the study period. Therefore, it is necessary to apply demand-side and supply-side management policies in Kheirabad River Basin. Among water demand-side management policies, increasing irrigation efficiency and changing crop pattern, by increasing the sustainability index from 0.703 to 1, are the most efficient policies. Besides, decreasing per capita water consumption plays an important role in increasing the water sustainability index in the basin.

Keyword: System Thinking, System Dynamics, Water Management, Sustainability, *Kheirabad river* basin.

JEL Classification: Q01, Q50, Q21

EXTEND ABSTRACT

Introduction

Generally, due to the complexity of the water system, one of the best tools for understanding the relationship between all components within a complex system is the system dynamic (SD) (Sterman, 2000). Given the growing population and demand for food, as well as the reduction of water supply by precipitation, this paper presents an integrated SD simulation model for exploring the water resource security index in the *Kheirabad river* basin in southwestern Iran. The water stored in *Kowsar* dam (located in *Kheirabad river* basin is in the west of *Gachsaran* County in

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Kogiluyeh and Boyerahmad province) has declined in recent years. Because one of the most important goals of the Kowsar dam construction is the supply of drinking water in the southern provinces of Iran and agricultural development in these areas, meeting the growing water demand in this basin is becoming a concern among policymakers. Therefore, there is a crucial need to make an accurate simulation about the water availability to help policymakers adopting appropriate policies as well as achieving sustainable water management.

System Dynamics Methodology

System dynamics modeling involves the following steps: (1) articulating the problem and defining system boundary; (2) developing a conceptual model or casual loop diagram (CLD) and a stock and flow diagram of system; (3) Testing model; and (4) analyzing policy options (Sterman, 2000). The first step in SD modeling is to be specific about the dynamic problem and problem articulation (Ford, 1999). Model formulation is representing the structure of the problem and formulating a SD simulation model of the causal theory (Sterman, 2000; Zhuang, 2014). There are several diagram tools to capture the structure of the system, including causal loop diagram (CLD) and stock and flow diagram. Model testing begins as the first equation is written and it is a critical step in SD modeling (Sterman, 2000). Tests to rely on SD model can be divided into two groups, structure tests and behavior tests (Forrester, 1997). Structure tests compare the structure of the SD model with the available knowledge about the real system presented in historical data. Behavior test is to run the model and compare the results to the reference mode (Historical or observed data). When the simulation results match the reference mode, you have reached a major milestone in the modeling process (Ford, 1999).

Result and Discussion

The performance of the model is discussed by comparing model outputs for the selected variables to the corresponding historical data. The simulated results follow the same trend as the observed date, indicating that the model is well calibrated. After testing the reliability of the model, the SD model is implemented under different water demand management scenarios. The behavior of the system is simulated over time to assess the availability of water resources and sustainability index. The results showed that during the simulation period, the water availability would be declining. While water demand, which is directly impacted by population growth and agricultural development, is rising. the water sustainability index is 0.703, indicating that the water supply at the basin will likely be unsustainable and total water demand is more than water supply and the maximum deficit index is more than zero in some years. Therefore, demand management policies can play a significant role in the sustainable management of water resources by reducing water use per capita or increasing irrigation efficiency and reducing water consumption per hectare of agricultural production.