



Scenario analysis for integrated water resources planning and management under uncertainty in the Zayandehrud river basin



Hamid R. Safavi^{a,*}, Mohammad H. Golmohammadi^a, Samuel Sandoval-Solis^b

^a Department of Civil Engineering, Isfahan University of Technology (IUT), Isfahan, Iran

^b Department of Land, Air and Water Resource, University of California, Davis, CA, USA

ARTICLE INFO

Article history:

Received 25 February 2016

Received in revised form 30 April 2016

Accepted 31 May 2016

Available online 5 June 2016

This manuscript was handled by Geoff Syme, Editor-in-Chief, with the assistance of Bellie Sivakumar, Associate Editor

Keywords:

Integrated Water Resources Management

Scenario analysis

Uncertainty

Zayandehrud basin

Sustainability index

Fuzzy approach

SUMMARY

The goal of this study is to develop and analyze three scenarios in the Zayandehrud river basin in Iran using a model already built and calibrated by Safavi et al. (2015) that has results for the baseline scenario. Results from the baseline scenario show that water demands will be supplied at the cost of depletion of surface and ground water resources, making this scenario undesirable and unsustainable. Supply Management, Demand Management, and Meta (supply and demand management) scenarios are the selected scenarios in this study. They are to be developed and declared into the Zayandehrud model to assess and evaluate the imminent status of the basin. Certain strategies will be employed for this purpose to improve and rectify the current management policies. The five performance criteria of time-based and volumetric reliability, resilience, vulnerability, and maximum deficit will be employed in the process of scenario analysis and evaluation. The results obtained from the performance criteria will be summed up into a so-called 'Water Resources Sustainability Index' to facilitate comparison among the likely trade-offs. Uncertainties arising from historical data, management policies, rainfall-runoff model, demand priorities, and performance criteria are considered in the proposed conceptual framework and modeled by appropriate approaches. Results show that the Supply Management scenario can be used to improve upon the demand supply but that it has no tangible effects on the improvement of the resources in the study region. In this regard, the Demand Management scenario is found to be more effective than the water supply one although it still remains unacceptable. Results of the Meta scenario indicate that both the supply and demand management scenarios must be applied if the water resources are to be safeguarded against degradation and depletion. In other words, the supply management scenario is necessary but not adequate; rather, it must be coupled to the demand management scenario. Finally, it will be shown that applying the Meta scenario will improve the water resources from sustainably.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Uncertainty and risk are part and parcel to any real-world decision-making process, particularly that of water resource management systems (Gough, 1988). The issue of uncertainty is of primary importance in risk assessment (Arunraj et al., 2013). The three main sources of uncertainty in any problem are (i) about model structure; (ii) about estimation of model parameters whenever (i) is known; and (iii) unexplained random variation in observed variables assuming (i) and (ii) are known (Chatfield, 1995).

Water resource problems widely involve uncertainty so that each problem is specified by a level of uncertainty (Manca et al.,

2004; Alvarez et al., 2005; Pavlovska, 2014). Hydrological exogenous inflows and demand patterns have a high level of uncertainty in water resource planning systems (Pallottino et al., 2005). Many scientists believe that the theory of fuzzy sets originally introduced by Zadeh (1965) is an important turning point in the evolution of the modern concept of uncertainty (Celikyilmaz and Turksen, 2009). Numerous fuzzy system-modeling approaches have been developed to capture uncertainty in a wide variety of fields (Sadeghian and Tahayori, 2015). The decades since 1972 have witnessed many developments in Zadeh's theory and its applications (Tamir et al., 2015). Based on this theory, many soft-computing approaches such as Adaptive Network-based Fuzzy Inference Systems (ANFIS) (Jang, 1993; Jang and Sun, 1995; Nayak et al., 2004; Fullér, 2013); Fuzzy Neural Networks (FNN) (Nie and Linkens, 1994; Chang and Chen, 2001); Fuzzy Wavelet (Ramsey, 1999; Ho et al., 2001; Partal and Kişi, 2007); and Genetic Fuzzy Systems

* Corresponding author. Tel.: +98 31 3391 3826; fax: 98 31 3391 2700.

E-mail address: hasafavi@cc.iut.ac.ir (H.R. Safavi).

(GFS) (Herrera and Verdegay, 1996; Sanchez et al., 1997; Córdón et al., 2004) have been developed to simulate and optimize systems, especially those of water resources planning, with different levels of uncertainty.

Decision-making in water resources management for future development is one of the most important circumstances where uncertainty plays an important role, mainly because every future event is fundamentally uncertain and involves ambiguity. This is the basic reason underlying the tendency and the requirement for adopting different water resource scenarios (Dong et al., 2013), the formulation and analysis of which form the most popular approaches to the identification and assessment of the uncertain future of water resources in pursuit of sustainable development (Huss, 1988; Duinker and Greig, 2007; Van der Heijden, 2011). It has been maintained that scenario analysis serves as an alternative to modeling water management policies in uncertain conditions (Pallottino et al., 2005). As fully defined by Huss (1988), different approaches are available for constructing viable scenarios that include intuitive logics, trend-impact analysis, and cross-impact analysis.

Supplying water demand in terms of quantity and quality by the socio-economic systems is defined as the primary goal of water resource planning and management and application of Integrated Water Resources Management (IWRM) strategies to watersheds and basins is meant to realize this very goal (GWP, 2000; Safaei et al., 2013; Adgolign and Rao, 2014). IWRM is known as a process that promotes the coordinated development and management of water, land, and related resources in an attempt to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (Loucks, 1997; Snellen and Schrevel, 2004; GWP, 2010). Development of various scenarios for water management aimed at sustainable water resources planning and management depends on the Sustainability Index (SI) as one of the most popular approaches used to qualify the scenarios and to select the best among them (Loucks, 1997; ASCE, 1998; Sandoval-Solis et al., 2011). Such performance criteria as time-based and volumetric reliability, resilience, vulnerability, and maximum deficit form the essential components involved in the process of estimating SI (Sandoval-Solis and McKinney, 2014; Lane et al., 2014). Accurate and reliable estimates of the performance criteria are pivotal to the credible quantification of SI and the reliable evaluation of scenarios. Golmohammadi et al. (submitted for publication) developed a new technique for the credible estimation of performance criteria in which a fuzzy approach is employed to deal with uncertainty. The technique could be used in any problem with any level of uncertainty, especially in water resource planning and management.

In this study, a conceptual framework is proposed to model and consider different levels of uncertainty in historical or observed data (using the Incremental Flows approach), rainfall-runoff models (using ANFIS models), management policies for current and future water management (using scenario approach), water demands and water resources priorities or weights (using the Fuzzy Analytic Hierarchy Process), and system evaluation against performance criteria (using fuzzy performance criteria). For the purposes of this study, the scenario analysis technique is employed in which different levels of uncertainty are considered to investigate three scenarios developed for the Zayandehrud basin. The study draws upon Safavi et al. (2015) who developed a Zayandehrud planning model using a Water Evaluation and Planning System (WEAP) platform and investigated the near future (2015–2020) status of the Zayandehrud basin under the current water management policies, referred to as the 'baseline scenario', considering climate change conditions. Their study showed that maintaining the current management policies, as the baseline

scenario, would lead to the depletion of the water resources in the Zayandehrud basin, making it thoroughly unsustainable. They concluded that the present management policies in the basin needed to be revised. Hence, the three scenarios of Supply Management (SM), Demand Management (DM), and Supply–Demand Management (Meta) have been investigated in this study for the near future (from October 2015 to September 2020) status of the basin. The SM scenario surveys the near future situation in the Zayandehrud basin considering inter-basin water transfer policies; DM tries to determine which demands could be reduced by how much; the results are then used to evaluate the status of the basin under effective and possible policies selected; and the Meta scenario is developed to determine how simultaneous application of DM and SM scenarios would affect the Zayandehrud basin in the near future. Meanwhile, the methods and the underlying reasons for the development of these scenarios are presented. The time-based and volumetric, reliability, resilience, vulnerability, and maximum deficit are the five performance criteria used for scenario analysis and evaluation. Also, the Water Resources Sustainability Index (SI) is used to coalesce the performance criteria results into one single measure in order to facilitate comparison among trade-offs of different scenarios. The past period under investigation (PUI) in this study covers a 21-water-year period from October 1991 to September 2011.

2. Case study: the Zayandehrud river basin

The Zayandehrud basin is one of the most important basins in central Iran. Covering an area of 26,972 km², it is shared by both Isfahan and Chaharmahal-and-Bakhtiari provinces with about 24,970 km² (93%) of its area located in Isfahan Province and the remaining in the Chaharmahal-and-Bakhtiari Province; however, its main source of surface water – the Zayandehrud River with a length of 350 km – originates in the Zardkuh Mountain in Chaharmahal-and-Bakhtiari Province and terminates in the Gavkhuni Wetland, east of Isfahan (Fig. 1). The basin is a vital source of water for irrigation, industrial, urban, and environmental demands (Murray-Rust et al., 2000). The Zayandehrud Dam with a capacity of 1470 Million Cubic Meter (MCM) was constructed and primed in 1970 to regulate water and to manage demands in the basin; it has been instrumental in increasing the water supply and storage in the basin (IWRM in Isfahan, 2014a). As shown in Fig. 1, the basin is divided into sixteen sub-basins: namely, Chelgerd-Ghaleshahrokh (CHGH), Boein-Miandasht (BM), Damaneh-Daran (DAD), Chel-Khaneh (CHKH), Chadegan (CHD), and Yan-Cheshmeh (YCH) all located upstream the dam; Karvan (kV), Ben-Saman (BS), Alavijeh-Dehagh (ALD), Meimeh (MEIM), Murcheh-Khort (MUKH), North-Mahyar (NMHA), Najafabad (NJ), Lenjanat (LJ), Esfahan-Borkhar, and Kuhpaye-Sagzi (KS) all located downstream the Zayandehrud Dam (Safavi et al., 2015).

The Zayandehrud basin as a crucial basin in Iran with a complex water system (Madani and Mariño, 2009; Safavi and Bahreini, 2009) is characterized by conjunctive use of surface and ground water to supply municipal, industrial, agricultural, and environmental demands over a large spatial distribution, different physiologic and climate conditions throughout the basin, and water transfers from/to other basins. Being shared by two provinces with different cultures and customs, the basin plays important political and socio-economic roles in the center of Iran.

2.1. Surface water resources

In addition to the Zayandehrud River, there are two other main rivers discharging into the Zayandehrud Dam: namely, the Pelasjan and Samandegan Rivers. From the 997 MCM of runoff upstream the

Download English Version:

<https://daneshyari.com/en/article/6409982>

Download Persian Version:

<https://daneshyari.com/article/6409982>

[Daneshyari.com](https://daneshyari.com)