Evaluation of Climatic-Change Impacts on Multiobjective Reservoir Operation with Multiobjective Genetic Programming

Parisa-Sadat Ashofteh, Ph.D.[1]; Omid Bozorg Haddad[2]; and Hugo A. Loáiciga[3]

Abstract: Multiobjective genetic programming is used to calculate optimal reservoir-operating rules under baseline and climatic-change conditions. The rules are calculated based on river inflows to the Aidoghmoush Reservoir (located in East Azerbaijan, Iran), storage volume, and downstream irrigation demands. The objective functions are the maximization of the reliability of meeting irrigation demand and the minimization of the vulnerability to irrigation deficits in a baseline period (1987–2000) and a future period (2026–2039), the latter influenced by climatic change. The optimization results show that reservoir-operating rules that take into account changing climate would lead to improvements in reservoir performance on the order of 29–32% relative to operating rules based on baseline climatic conditions. **DOI: 10.1061/(ASCE)WR.1943-5452.0000540.**

Author keywords: Climatic change; Pareto curve; Multiobjective optimization; Reservoir operation; Irrigation.

Introduction

Most water-resources projects, such as reservoirs built to provide water for irrigation, were planned using reservoir-operation rules that correspond to historical conditions. Changing climatic conditions pose challenges to the performance of many water-resources systems that are currently operating under conditions that differ from those that existed when they were conceived decades ago. Climate change affects the planning, design, and operation of water projects, and therefore, a rational approach to future water management calls for the incorporation of climatic-change impacts in all aspects of water-resources management.

Recent publications dealing with optimization methods have covered several domains of water-resources systems, such as reservoir operation (Bozorg Haddad et al. 2011a, 2014; Fallah-Mehdipour et al. 2011b, 2012a, 2013a), levee layouts and design (Bozorg Haddad et al. 2015), hydrology (Orouji et al. 2013), project management (Bozorg Haddad et al. 2010a; Fallah-Mehdipour et al. 2012b), cultivation rules (Bozorg Haddad et al. 2009; Noory et al. 2012; Fallah-Mehdipour et al. 2013b), pumping scheduling (Bozorg Haddad et al. 2011b), hydraulic structures (Bozorg Haddad et al. 2010a), water-distribution networks (Bozorg Haddad et al. 2008; Fallah-Mehdipour et al. 2011a; Seifollahi-Aghmiuni et al. 2011, 2013), operation of aquifer systems (Bozorg Haddad and Mariæo 2011), site selection of infrastructures (Karimi-Hosseini et al. 2011), and algorithmic developments (Shokri et al. 2013).

Genetic programming (GP) and genetic algorithm (GA) are evolutionary algorithms that have been used by various researchers. Sivapragasam et al. (2008) investigated flood routing in natural channels using GP. Sivapragasam et al. (2009) modeled evaporation from two reservoirs in India using GP. Wang et al. (2009) compared the performance of several artificial intelligence methods for forecasting monthly discharge time series for two rivers. Khan and Tingsanchali (2009) developed a new model called reservoir optimization–simulation with sediment evacuation (ROSSE). The model applied GA-based optimization capabilities and embeds the sediment-transport module into the simulation module. In a study by Fallah-Mehdipour et al. (2012a), the GP was used to develop reservoir-operating policies simultaneously with inflow prediction. Khan et al. (2012) applied the ROSSE model with the aim of minimizing irrigation shortages in the Tarbela Reservoir, Pakistan. They calculated the suitable values of various GA parameters required to run the model through a sensitivity analysis. Fallah-Mehdipour et al. (2013c) investigated prediction and simulation of monthly groundwater levels with the GP. Other researchers have used the GP for issues related to water management. However, previous studies indicate that the GP has not been applied to solve multiobjective (MO) problems in the field of water-resources management.

Guo et al. (2007) introduced a hybrid cellular automaton and GA approach, called CAMOGA for MO design of urban water networks. Yang et al. (2007) used MO-GA to generate the various combinations of reservoir capacity and estimate the noninferior solution set. Consequently, the constrained differential dynamic programming (CDDP) was adopted to distribute optimal releases among reservoirs to satisfy water demand. Next, the effectiveness of the proposed methodology was verified by solving a MO planning problem of surface water in southern Taiwan. Redy and Kumar (2008) proposed the MO differential evolution approach for the determination of optimal cropping pattern. Yang et al. (2009) integrated the MO-GA, the CDDP, and the groundwater simulation model ISOQUAD to optimize reservoir releases and

[1]Dept. of Irrigation and Reclamation, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, Univ. of Tehran, Karaj, 31587-77871 Tehran, Iran. E-mail: PAshofteh@ut.ac.ir

[2]Associate Professor, Dept. of Irrigation and Reclamation, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, Univ. of Tehran, Karaj, 31587-77871 Tehran, Iran (corresponding author). E-mail: OBHaddad@ut.ac.ir

[3]Professor, Dept. of Geography, Univ. of California, Santa Barbara, CA. E-mail: Hugo.Loaiciga@ucsb.edu

Note. This manuscript was submitted on July 27, 2014; approved on February 23, 2015; published online on June 8, 2015. Discussion period open until November 8, 2015; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Water Resources Planning and Management***, © ASCE, ISSN 0733-9496/04015030(9)/$25.00.