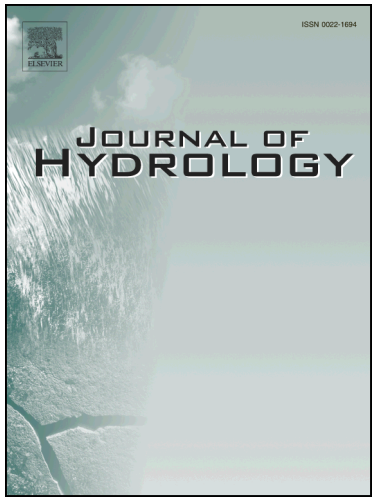

Research papers

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Abbas Sedghamiz, Mohammad Reza Nikoo, Manouchehr Heidarpour, Mojtaba Sadegh

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Developing a Non-Cooperative Optimization Model for Water and Crop Area Allocation Based on Leader-follower Game

Abbas Sedghamiz[a], Mohammad Reza Nikoo[b,*], Manouchehr Heidarpour[c], Mojtaba Sadegh[d]

[a] Darab School of Agriculture, Department of Soil and Water Science, Shiraz University, Shiraz, Iran, E-mail adress: sedghamiz@shirazu.ac.ir

[b] School of Engineering, Department of Civil and Environmental Engineering, Shiraz University, Shiraz, Iran, Tel: +98 713 647 3497; Fax: +98 713 647 3161, Email address: nikoo@shirazu.ac.ir

[c] School of Agriculture, Department of Water Engineering, Isfahan University of Technology, Isfahan, Iran, Email address: heidar@cc.iut.ac.ir

[d] Assistant Professor, Department of Civil Engineering, Boise State University, Boise, U.S. Email address: mojtabasadegh@boisestate.edu

[*] **Corresponding author:**
Mohammad Reza Nikoo
Email: nikoo@shirazu.ac.ir
Tel: +98 713 647 3497
Fax: +98 713 647 3161

Abstract

In this paper, a mathematical model for conflict resolution among a diverse set of agricultural water users in Golestan province, Iran, is developed. Given the bi-level nature of the distribution of power in the current problem, a combination of Leader–Follower game and Nash–Harsanyi bargaining solution method is employed to find optimal water and crop area allocations. The Golestan Regional Water Authority is the leader in this setting, controlling the total water allocations; and the agricultural sectors are the followers, competing over the allocated water. Two objectives for the leader are (i) maximizing profits, and (ii) maximizing share of green water in total agricultural production through selecting more efficient crop patterns. The followers' objective is merely maximizing obtained benefits for the selected crop patterns. Virtual water concept is also factored into the related objective functions, and the water allocation problem is solved considering spatio-temporal crop pattern along with a dynamic water pricing system. This involves using a hybrid optimization structure as a new approach to solving two level optimization problems. The results show that the leader's income is independent of total water allocation and is only affected by crop pattern and crop area, two factors which drive water price too. The followers' benefit also depends on crop pattern and crop area, as they influence the crop yield, cost and water price. Finally, green water plays a key role in selecting the optimal crop pattern and crop area.

Keywords: Green water; Leader-followers Game; Agricultural water allocation; Agricultural benefit; Nash bargaining model; NSGA-II multi-objective optimization model

1. Introduction

Water shortage is a global problem, which is more pronounced in arid and semi-arid areas (Sadegh et al. 2010). While prolonged droughts, change in ratio of snow to rain, global warming, and increased number of dry days all played some role in this issue, population growth and economic development and subsequent rise in water demand aggravate the problem (AghaKouchak, 2015). Agricultural sector as the largest consumer of water around the globe endures highest socio-economical loss from water scarcity, manifested in the reduction of crop yield (Khanjari Sadati et al., 2014). Su et al. (2014) introduced "Virtual Water Trade" as an effective strategy to improve sustainable use of water resources, which can also be employed as a strong tool to effectively allocate water