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Authors
Ashofteh, Parisa-Sadat
Bozorg-Haddad, Omid
Loáiciga, Hugo A

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Forum

Role of Adaptive Water Resources Management Policies and Strategies in Relieving Conflicts between Water Resources and Agricultural Sector Water Use Caused by Climate Change

Parisa-Sadat Ashofteh

Assistant Professor, Dept. of Civil Engineering, Univ. of Qom, 31587-77871, Qom, Iran. E-mail: PAshofteh@ut.ac.ir

Omid Bozorg-Haddad

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

Hugo A. Loáiciga, F.ASCE

Professor, Dept. of Geography, Univ. of California, Santa Barbara, California 93016-4060. E-mail: Hugo.Loaiciga@ucsb.edu

Abstract: *Forum papers are thought-provoking opinion pieces or essays founded in fact, sometimes containing speculation, on a civil engineering topic of general interest and relevance to the readership of the journal. The views expressed in this Forum article do not necessarily reflect the views of ASCE or the Editorial Board of the journal.*

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Previous water-resources studies indicate that to achieve a balance between water resources and water uses in most regions it would be necessary to reduce agricultural water use by up to 50% of current use and to increase the efficiency of water supply. A review of past research (Ahmadi et al. 2015, 2014; Akbari-Alashti et al. 2014; Ashofteh et al. 2013a, 2015c; Beygi et al. 2014; Bolouri-Yazdeli et al. 2014; Bozorg-Haddad et al. 2013, 2014, 2015a, b; Farhangi et al. 2012; Fallah-Mehdipour 2013a, b, c, 2014; Jahandideh-Tehrani et al. 2015; Orouji et al. 2013, 2014a, b; Shokri et al. 2013, 2014; Soltanjalili et al. 2013) shows that a few studies have been conducted to evaluate the effects of climate change and adaptive strategies qualitatively, yet less attention has been given to the quantitative analysis of climate change and adaptation in the water-resources sector. The effects of climate change on agriculture have been investigated either at the global scale (FAO 2003) or at the local scale (Morid and Massah 2008). It is essential to evaluate water-management strategies in the agricultural sector with criteria such as crop yield, farm profitability, and water-use efficiency (WUE). Crop simulation models are useful tools for evaluating adaptive water-management strategies and adopting management policies for water and land uses (Ashofteh et al. 2013b). This report quantifies the effect of adaptive water-resources strategies in the agricultural sector under climate change. An irrigation district in Iran is used as a case study to illustrate the possibility of adapting agricultural practices to adapt to climate-change phenomena.

Adaptive Strategies and Their Evaluation

Among the most important strategies to adapt to climate change in the water-supply sector is the improvement of water-resources management. Other adaptive strategies include the search for new water sources provided that such sources can be found, but this raises new considerations and costs. Other methods of widening the supply side of water resources are the reuse of properly treated urban sewage and seawater desalination, whose success depends on cost and technological considerations. The treatment and reuse of sewage would provide little additional water compared with the overall water shortages. In most regions, interbasin water transfer is infeasible due to endemic water shortages.

Reducing the area under cultivation can be used as an adaptive strategy in the agricultural water sector under climate change. Yet, this strategy is not usually viable with irrigation networks. This is so because farmers have acquired debt to construct irrigation networks in their lands and must maintain crop production to repay those debts. Therefore, the permanent reduction of cultivated land is not viable considering the ensuing social and economic impacts.

The strategy of changing cropping patterns as an adaptation strategy depends on several factors such as crop price, processing industries, agricultural extension and education, as well as policies and tariffs on exports and imports of agricultural products. It is key in this regard that feasibility studies and economic evaluation be conducted observing principles that consider all aspects governing the choice of cropping patterns, the design characteristics of all irrigation network components, and the economic variables to achieve a realistic adaptive strategy to water shortages in a changing climate.

The study area of this work is the largest irrigation network in Iran, namely, the Aidoghmoush network, which is considered as a pilot study for climatic change adaption strategies. Climatic preprocessing for future periods was carried out with the HadCM3 climatic model under the emission scenario A2 (high emission of CO_2). Monthly climatic data for the HadCM3 were obtained from the Intergovernmental Panel on Climate Change (IPCC) site (IPCC 1988) for the baseline period (1987–2000) and the future period (2026–2039). This was followed by climatic simulations.

These authors considered modifying resources management from standard reservoir operation policies (SOP) to hedging rule (HR) as an adaptation strategy to climate change in the water-supply sector. The results of the two approaches to water management (SOP and HR) on the water system flexibility index were compared. The flexibility index is the ability of a system to respond to shortages with the least possible damage (Hashimoto et al. 1982). Reliability is the percentage of time of adequate water supply relative to the total operational period (Ashofteh et al. 2015b). Vulnerability is the percentage of time during which severe water deficiency occurs (Ashofteh et al. 2015a). Resiliency is

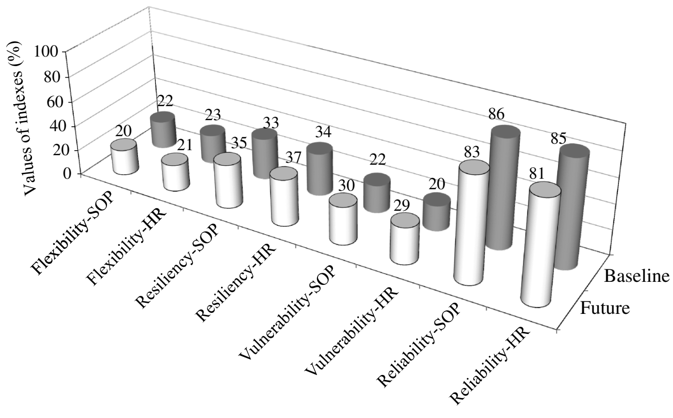

Fig. 1. Comparison of indices in the baseline and future conditions corresponding to the SOP and HR management approaches

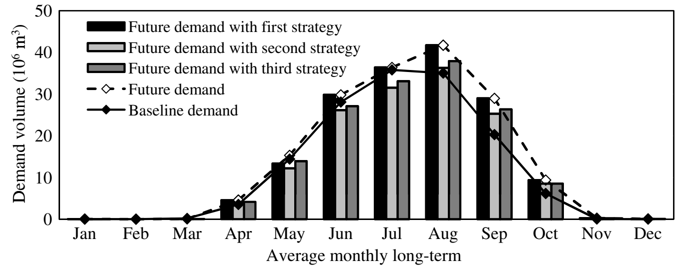

Fig. 2. Comparison of the average monthly long-term water use with and without the strategies

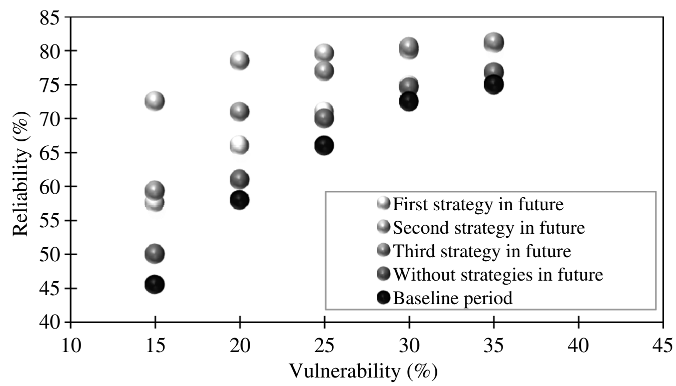

Fig. 3. Comparison of the vulnerability and reliability indices in future period with and without the strategies

the probability that a water system returns from a shortage status to a nonshortage status. The results of modifying the management approach on system flexibility revealed that applying this new management approach (i.e., HR) would not have significant impact on the system flexibility index compared to the current management approach (i.e., SOP), so that the flexibility of the system in the future period associated with SOP and HR management approaches equal 20 and 21%, respectively (Fig. 1).

These findings refocused attention on adaptation strategies in the consumer sector. The main adaptive strategies in the agricultural sector include delaying the planting date (the first strategy), applying water stress to crops (the second strategy), and increasing the irrigation efficiency (the third strategy). The effects of these three strategies on water-use adaptability can be quantified with crop simulation models [such as decision support systems for agro-technology transfer (DSSAT)]. The water use in the agricultural sector is computed with the implementation of the adaptive strategies, and the optimal water allocation is then determined.

The level of irrigation efficiency is important in devising adaptive strategies for agricultural water use. Significant reductions in water use can be achieved by raising the water efficiency in traditional or semimodern irrigation systems with low efficiency. The gains that be achieved in distribution efficiency are low in modern and well-constructed irrigation networks that employ closed conduits for water distribution. Yet, in the latter systems one can expect increases in the irrigation application efficiency through educational and extension programs that discourage wasteful practices and encourage the choice of the most efficient irrigation system for specific conditions. These actions may raise the total water efficiency, thus lowering the water use in the irrigation network.

Fig. 2 compares the long-term monthly average values of water use by resorting to delaying the planting date, applying water stress, and increasing irrigation efficiency. It is inferred from Fig. 2 that the future water use increases compared to the baseline use in most months. The increases are equal to 8, 18, and 57% in the spring, summer, and autumn, respectively. However, the future demands decrease relative to the baseline in winter by about 55%. Also, Fig. 2 shows that the implementation of adaptive strategies in the future would decrease water demand in most months compared to the action of not applying the strategies in the corresponding period. Specifically, the first strategy (delay in the planting date) reduces water demand about 4% in the spring, whereas the reduction is negligible in the other seasons. The second strategy (applying water stress to crops) leads to a reduction of 15, 15, 13, and 9% of the water demand in the winter, spring, summer, and autumn, respectively. Reduction of water demand in all seasons equals 9% by implementing the third strategy (improving the irrigation efficiency). These results indicated that among the possible adaptive strategies that of applying water stress to crops leads to the most significant reduction in water demand compared to other strategies.

The effect of applying adaptive strategies in the consumer sector on the vulnerability and reliability indices was herein analyzed. The results show that by applying the latter strategies the vulnerability and reliability indices improve relative to the action of not applying the strategies (Fig. 3). Our results demonstrate that, among the three adaptive strategies, applying water stress to crops would have a significant influence on the improvement of the vulnerability and reliability indexes compared to the other strategies when considering the effects of climate change. Thus, by accepting a 20% vulnerability of the water system the reliability index would be 65, 78.5, and 71% by delaying the planting date, applying water stress, and increasing irrigation efficiency, respectively.

Conclusions

It is noteworthy that applying water stress to crops is associated with decreasing yield. At the same time, the cost of crop production is reduced by diminished water use. Moreover, the effect of the adaptive strategies on the reliability rises by accepting less vulnerability of the system. This study has shown the possibilities offered by nonconventional methods of reducing agricultural water use to adapt to raising water scarcity associated with climate change while maintaining food security.

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