Risk Analysis of Water Demand for Agricultural Crops under Climate Change

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Abstract: This paper assesses the risk of increase in water demand for a wide range of irrigated crops in an irrigation network located downstream of the Aidoghmoush Dam in East Azerbaijan by considering climate change conditions for the period 2026–2039. Atmosphere-ocean global circulation models (AOGCMs) are used to simulate climatic variables such as temperature and precipitation. The Bayesian approach is used to consider uncertainties of AOGCMs. Climate change scenarios of climatic variables are first weighted by using the mean observed temperature-precipitation (MOTP) method, and related probability distribution functions are produced. Outputs of AOGCMs are used as input to water requirement models. Then, produced by using the Monte Carlo method, 200 samples (discrete values) from the probability distribution functions of monthly downscaled temperature and precipitation in the study area are extracted by using a software for sensitivity and uncertainty analysis. Time series of climatic variables in future periods are then generated (temperature variable to calculate potential evapotranspiration and rainfall variable to calculate effective rainfall). To estimate crop water requirements, crop evapotranspiration (from the product of potential evapotranspiration in the previous step and coefficient of crop computed) and effective precipitation (from time series of the previous step) are calculated. The Food and Agricultural Organization of the United Nations (FAO) methods, FAO-24 and Penman-Monteith, were used to compute crop and potential evapotranspiration, respectively. Because of lack of required data, potential evapotranspiration in future periods is computed through the relationship of temperature and potential evapotranspiration in the baseline period; the same procedure is conducted for temperature. Net water requirement (NWR) and the risk of changes in water demand volume of crops (e.g., wheat, barley, alfalfa, soybean, feed corn, forage, potato, and walnut orchards) are computed by entering 200 monthly time series of downscaled temperature and precipitation in future periods. The results indicate that risk of changes in crop water requirements increases by approximately 3% for a 25% risk, approximately 17% for a 50% risk, and approximately 33% for a 75% risk. Also, based on the current cultivated area, on average, the volume of water demand only for the aforementioned crops will be approximately $2.5(10^6\ \mathrm{m}^3/\mathrm{year})$ with a risk of 25%, approximately $16(10^6\ \mathrm{m}^3/\mathrm{year})$ with a risk of 50%, and approximately $31(10^6\ \mathrm{m}^3/\mathrm{year})$ with a risk of 75%. Wheat and barley are more resistant and less sensitive to climate change than other crops considered. **DOI: 10.1061/(ASCE)HE.1943-5584.0001053.**

Author keywords: Climate change; Net water requirement; Risk; Uncertainty; Monte Carlo.

Introduction

Climate change may have serious effects on agriculture. Changes in average values of climatic parameters, particularly temperature and precipitation, may seriously affect the future availability of water to meet the demand [Intergovernmental Panel on Climate Change (IPCC) 2007]. The impact on agriculture of a probable increase in climatic variables could have negative effects on food security for human consumption.

Recently, many studies have been conducted in all aspects of water resources systems, such as reservoir operation (Afshar et al. 2010; Bozorg Haddad et al. 2008b, c, 2009, 2011a; Fallah-Mehdipour et al. 2011b, 2012), cultivation rules (Moradi-Jalal et al. 2007; Noory et al. 2012), pumping scheduling (Bozorg Haddad and Mariño 2007; Bozorg Haddad et al. 2011b; Rasoulzadeh-Gharibdousti et al. 2011), water distribution networks (Bozorg Haddad et al. 2008a; Soltanjalili et al. 2011; Fallah-Mehdipour et al. 2011a; Seifollahi-Aghmiuni et al. 2011; Ghajarnia et al. 2011; Sabbaghpour et al. 2012), operation of aquifer systems (Bozorg Haddad and Mariño 2011), and site selection of infrastructures (Karimi-Hosseini et al. 2011). Only a few of these works have dealt with the risk analysis of agricultural crops water demand especially under climate change conditions.

Rosenweig et al. (2004) examined changes in crop water demand and water availability to determine reliability of irrigation. The results showed that for most of the relatively water-rich areas studied, there was sufficient water for agriculture for the climate change scenarios. However, some areas suffered from the greatest lack of water availability for agriculture both in the present and in the climate change projections. In contrast, in relatively water-rich areas, changes in water demand caused by climate change effects on agriculture and increased demand from urban growth would require timely improvements in crop cultivars, irrigation and drainage technology, and water management as climate adaptation measures. In their study, despite using global

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