Application of Wind Energy to Withdraw Groundwater for Irrigation Management

Hilda Keshtkar[1]; Omid Bozorg-Haddad[2]; Mohammad-Reza Jalali[3]; and Hugo A. Loáiciga[4]

Abstract: Increases in greenhouse gases emissions have encouraged the replacement of fossil fuels with renewable energy sources. This paper investigates the potential of wind energy as a renewable resource for producing agricultural water in Eghlid city, Iran. The purpose of the optimization model herein considered is to maximize the net benefit from crop production by selecting an optimal cropping pattern. This paper's results demonstrate that wind energy can be efficiently applied to provide irrigation water and optimize cropping patterns. Specifically, the application of wind energy to withdraw irrigation water increases agricultural production benefits in the amount of 1,254 million Rials (US$45,000). **DOI: 10.1061/(ASCE)WR.1943-5452.0000706.** © *2016 American Society of Civil Engineers.*

Author keywords: Windmill; Optimization; Crop pattern; Wind energy; Groundwater.

Introduction

Many techniques have been developed and applied in water resources systems, such as reservoir operation (Bozorg-Haddad et al. 2008b, c, 2009, 2011a; Afshar et al. 2010; Fallah-Mehdipour et al. 2011b, 2012), cultivation rules (Moradi-Jalal et al. 2007; Noory et al. 2012), pumping scheduling (Bozorg-Haddad and Mariño 2007; Rasoulzadeh-Gharibdousti et al. 2011; Bozorg-Haddad et al. 2011b), 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). None of these works dealt with the application of wind energy to withdraw groundwater for irrigation management.

Wind energy has been used since ancient times. This energy was commonly used to provide mechanical power for pumping water and grinding grain until the early twentieth century. The emergence of fossil fuels was synchronous with the decline of wind as a power source for the remainder of the twentieth century. Increasing concerns with the adverse impacts of fossil fuels on the environment has encouraged the development of clean, renewable energy sources, wind among them, over the last decade. Although wind energy was used for elementary applications in the past, it is currently a clean resource for electricity production or energy supply in agriculture and other activities in rural areas and has not been given due consideration in previous water resources investigations (Ashofteh et al. 2013, 2015a, b, c; Beygi et al. 2014; Bozorg-Haddad et al. 2013, 2014, 2015a, b; Bolouri-Yazdeli et al. 2014; Fallah-Mehdipour et al. 2013; Orouji et al. 2013, 2014; Shokri et al. 2013, 2014; Soltanjalili et al. 2013).

Research on applications of wind energy to hydraulics and water resources has thrived over the last decade. That research can be classified into two general categories: (1) feasibility of wind projects and (2) development of wind energy tools and turbines. Several pertinent studies are briefly reviewed next.

Regarding the feasibility of wind projects, Parikh and Bhattacharya (1984) discussed the possibility of using windmills for lifting irrigation water. For the wind velocity pattern considered in their study, it was found that 1.214 ha of wheat and mustard could be irrigated during winter if the daytime pumped volume of water is used for irrigation. If nighttime discharge is also utilized the minimum cropping area could be 1.94 ha. Panda et al. (1998) determined the investment per unit amount of water supplied and the levels of daily irrigation demand satisfied by the most economic windmill irrigation system at various levels of risk. Mohsen and Akash (1998) determined locations with high, medium, and low potential for water pumping with wind power in Jordan. According to the results of Al Suleimani and Rao (2000), the wind resources in remote areas of Oman are sufficient for extracting groundwater using a wind-powered, electric, water-pumping system. Lu et al. (2002) simulated the annual generated power from wind turbines in the Hong Kong islands. Bakos (2002) investigated inexpensive electricity generation using a wind–hydropower system and confirmed the feasibility of this method. Buenoa and Carta (2006) proposed a wind-powered pumped hydro-storage system installation in the Canary Islands. Kumar and Kandpal (2007) estimated and compared the utilization potential of different renewable energy–based pumps for irrigation water pumping in India. Results showed that solar photovoltaic (SPV) pumps have the maximum utilization potential in India, followed by windmill pumps. Renewable energy technologies (RETs) for irrigation water pumping were evaluated financially by Purohit (2007). Keyhani et al. (2010) studied the wind energy potential in Tehran, Iran, and explained that although

[1]Graduate Student, 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: Keshtkar_h@ut.ac.ir

[2]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]Assistant Professor, Dept. of Civil Engineering, Iran Univ. of Science and Technology, 31587-77871 Tehran, Iran. E-mail: MrJalali@iust.ac.ir

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

Note. This manuscript was submitted on January 27, 2016; approved on June 7, 2016; published online on July 21, 2016. Discussion period open until December 21, 2016; 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.