Agricultural Water Management 212 (2019) 349–357

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Farmers' adoption of water-saving irrigation technology alleviates water scarcity in metropolis suburbs: A case study of Beijing, China

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ARTICLE INFO

Keywords:
Water-saving irrigation technology
Farmers
Adoption
Water scarcity
Metropolis suburbs
China

ABSTRACT

Water scarcity has threatened the food security and been a critical concern in China. Promoting modern agricultural irrigation technologies has been identified as an important measure against water scarcity. The overall goal of this study was to analyze the adoption of water-saving irrigation technology by farmers and to identify the major influencing factors of this decision for metropolis suburbs. Based on a field survey of Beijing of China, the results showed that 53.1% of farmers adopted water-saving irrigation technologies to cope with water scarcity, most of which adopted engineering water-saving technologies. The number of adopted water-saving irrigation technologies followed a strong negative correlation with the share of adopters. Econometric analysis revealed that education, farm size, on-farm demonstration, cooperative, training, groundwater, access to information, water use associations, drought-prone area, neighboring farmers, and policy subsidies significantly improved the adaption to water scarcity. Age, production specialization, and cost posed a negative effect on famers' adoption of water-saving irrigation technologies. These results and implications provide an understanding of farmers' sustainable irrigation practices and offer an insight to influencing factors to frame improved strategies and policies that enable to cope with water scarcity of metropolis suburbs.

1. Introduction

Water scarcity and drought have been of critical concern, and pose severe threats to both food security and economy throughout many parts of the world (Alam, 2015; Chen et al., 2014). About 40% of the global population lives in regions where water resources are over-allocated due to scarcity and competition (Wheeler et al., 2015). Water shortage in China is very severe, particularly in the north and northwest of the country (Zhang et al., 2013). With water scarcity becoming an increasing constraint for food production in northern China, the pressure to procure sufficient agricultural water is growing, and has been the most important factor to threaten China's food security (Chen et al., 2014; Yang et al., 2003).

In light of increasingly severe water scarcity conditions, appropriate measures were taken to mitigate its impacts for China. Despite an improvement of water use efficiency in the agricultural sector from about 40% in 2006 to nearly 50% in 2013, it is very low compared to the 70% to 90% reached by most developed countries (Deng et al., 2006; Zhu et al., 2013). In addition, future climate change will further require irrigators to improve irrigation water-use efficiency, thus enabling a decreased reliance on water as input (Wallace, 2000; Wheeler et al., 2015). More widespread use of water-saving irrigation is one central way to promote water conservation in irrigated areas (Nikouei et al., 2012; Peck et al., 2004).

In the water-saving irrigation extension system, how to apply water-saving technologies is key for the production practice to achieve better economic, social, and environmental benefits. This has aroused concern on how to promote the adoption of water-saving irrigation by producers. For instance, Bjornlund et al. (2009) indicated that the major drivers for the adoption of improved irrigation technologies and management practices were to ensure the security of the water supply during droughts, to increase quantity and quality of crops, and to decrease the costs involved. Alam (2015) reported that farmers with more experience of farming, better schooling, more secure tenure rights, better access to electricity and institutional facilities, and an awareness of climatic effects are more likely to embrace adaptation strategies to avoid water scarcity. Cremades et al. (2015) emphasized that governmental subsidies and extension service policies have played an important role in promoting the adoption of modern irrigation technology.

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https://doi.org/10.1016/j.agwat.2018.09.021
Received 11 January 2018; Accepted 10 September 2018
0378-3774/

However, the majority of adoption studies to date focused on rural areas and major grain producing areas, while studies specifically focusing on agriculture in metropolis suburbs are rare (Abdulai et al., 2011; Alam, 2015; Cai and Rosegrant, 2004; Mostafa and Fujimoto, 2014; Wang et al., 2014, 2015; Zhang et al., 2013). Agriculture is an essential component of the sustainable development of metropolis. It plays an important role to ensure steady farmers' income and thus promote rural economic development. The important function of agriculture is to serve the metropolis, generating as stable supply of safe agricultural products, improving the ecological environment, as well as enhancing leisure tourism and cultural education for citizens. With the enormous population and limited area of metropolis, increasing demand for water from urban and industrial sectors exert increased pressure on agricultural water (Nikouei et al., 2012; Zhang et al., 2013). However, farmers in metropolis suburbs are different from those of other areas, benefiting from multi channels of revenue sources, multi functions of agricultural production, higher production requirements, and increased pressure on environmental resources. This leads to differences in farmers' attitudes and adoption behaviors of water-saving irrigation technology (WSIT) in metropolis suburbs and rural areas. Studies are required that investigate metropolis suburbs in light of water scarcity to increase our understanding of farmers' adoption behaviors and influencing factors to ultimately promote a sustainable development of agriculture.

Beijing, located on the northern North China plain of China, is a metropolis with more than 21.7 million people (in 2015), making it one of the world's most water-scarce cities (NBSC, 2016). In this area, water resources per capita (124.0 m^3) are far below the national average (of 2039.2 m^3), which is only 1/4 of the world's average (Cheng et al., 2015; NBSC, 2016). Therefore, the objective of this study was to provide an understanding of farmers' sustainable irrigation practices used to cope with water-stress in water scarcity environments of Beijing, China. Furthermore, identifying major factors that influence farmers' adoption of WSIT in the study area is a further important research aim. The results obtained in the present study provide insights that could help goverments to understand barriers and drivers of farmers' adoption of WSIT.

The remainder of this paper is arranged as follows: the next section provides a brief overview and classification of WSIT. Section 3 considers theoretical arguments, while also discussing the conceptual framework and hypothesis. Section 4 presents the empirical model and data. Section 5 discusses empirical results. The final section provides conclusions and policy implications.

2. Water-saving irrigation technology

For crop irrigation, ideal water efficiency refers to reducing losses caused by evaporation, runoff, or subsurface drainage while increasing production (Yang, 2012). Water-saving irrigation is required to reduce agricultural water waste while timely and fully meeting the requirements of crop water. Using WSIT not only saves water and increases production, it also improves the nutrition of agricultural products ensuring food safety by improving the environment (Abdulai et al., 2011; Cremades et al., 2015; Jalota et al., 2009; Wang et al., 2002).

Water-saving includes the entire irrigation process. All measures, techniques, and methods for reducing water loss and improving water use efficiency are part of water-saving irrigation. Fig. 1 shows that agricultural irrigation water, from water sources to final crop use, has undergone roughly three stages. During the first state, the water was drawn from the water source and moved to the field through canals. During this process, there will be leakage, seepage, and further means of water loss. During the second state, the water is drawn from the field to the crop root system to facilitate water absorption by the crops. This is also the traditional irrigation concept, including traditional irrigation (e.g., flood irrigation and furrow irrigation) and modern irrigation (e.g., drip irrigation and micro sprinkler irrigation). The final state, accompanies the whole process of crop growth, where water from the roots of the crop is transported throughout the entire plant, which is also the ultimate use of water resources for crop growth. The core of water-saving irrigation lies in minimizing water loss during these three processes while improving the efficiency of water resources utilization.

Various definitions for the adaption options against water scarcity have been classified. To make these easy to understand for farmers, Chen et al. (2014) classified the adaptation options against drought as types of either engineering (e.g., investment or maintenance options) or non-engineering (e.g., technological, regulatory, or market options). Alam (2015) defined adaptation as the increased use of surface water, increased use of ground water, crop diversification, and calendar adjustment, all of which are changed land use strategies to cope with drought. Pereira et al. (2002) summarized adaptation methods to drought, including supplemental irrigation, deficit irrigation, improved irrigation methods and performance, distribution uniformity, and various soil and water conservation practices. Since we collected information on whether farmers have actually adopted WSIT, our analysis investigated adaptation practices of adopting WSIT rather than of potential adaptation options and other adaptation measures.

Based on theoretical analysis and personal experience during a field survey, we classified the WSIT as types of engineering water-saving technology (EWST), agricultural water-saving technology (AWST), biological and chemical water-saving technology (BCWST), and managerial water-saving technology (MWST) (Fig. 2). EWST is mainly accomplished through the construction of a variety of water-saving irrigation projects that reduce water consumption, including the delivery of water, the distribution of water, the irrigation of water, and other processes of water leakage and evaporation to improve the utilization of irrigation water (Chen et al., 2014; Wang et al., 2002). AWST is mainly accomplished through specific measures that control the field of water and optimize the production structure while improving water-use efficiency (Jiménez and Chávez, 2003; Zou et al., 2013). BCWST is a real-time and reasonable irrigation system that promotes crop growth with biological and chemical technology. It also involves the use of biotechnology for breeding and cultivating of crop varieties that are drought-resistant and water saving (Wang et al., 2007). MWST can achieve a reasonable allocation of irrigation water resources and an optimal scheduling of irrigation measures to reach a specific target, which is deriving the maximum benefit from limited water resources (Gebrehiwot and van der Veen, 2013; Naranjo-Gil, 2017; Reilly et al., 2003).

3. Conceptual framework and hypothesis

According to the theory of innovation diffusion (Rogers, 2003), the

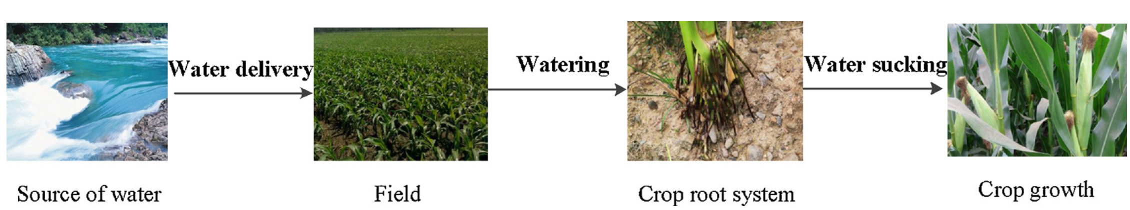

Fig. 1. The process of crop irrigation.