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Urbanization, agricultural water use, and regional and national crop production in China

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ABSTRACT

The overall goal of this paper is to analyze the impacts of the urbanization on regional and national agricultural production through its impact on water use in agriculture in China. Given the historical trend of water use in agriculture and its correlation with urbanization, the change in agricultural water use due to urbanization is estimated. Then the impacts of this change on regional crop production are simulated based on the China Water Simulation Model (CWSM). Within CWSM, a positive mathematical programming (PMP) optimizes water allocation among crops and between irrigated and rainfed areas within a crop in each of ten river basins in China. The results show that water use in China has an obvious increasing trend, particularly in the industrial and domestic sectors, while the share of water use in agricultural sector has been dropping. A 1-percentage-point increase in urbanization can result in a 0.47 percentage-point decline in share of water use. Based on the model simulation, this will lead to the further decrease of irrigated areas and the increase of rainfed areas at both the national and river basin levels, particularly for water intensive crops (such as rice and wheat). Accordingly, average yields and total production will also decrease. A river basin with large production of either rice or wheat (or both) decreases more in irrigated area as urban area expands. Adaptation measures are recommended for both authorities and farmers to ensure food security, such as providing incentive for farmers to adopt water saving technology, implementing appropriate institutional and policy innovations (e.g., water use association, water pricing and water use rights).

1. Introduction

Urbanization in China is one of the most important driving forces that will shape China and global development during the twenty-first century (Fang, 2009). Urbanization is an inevitable trend in development for China, which is the most populous country in the world. Until 2011, China's urban population was 682 million, accounting for almost one-fifth of the world's urban population and exceeding China's rural population for the first time in history (NBS of China, 2012). It took six decades for China's urbanization to expand from 10% to 50%; this same process took 150 years in Europe and 210 years in Latin America and the Caribbean (UNDP, 2013). This rapid transition will continue, and, according to the United Nations (2012), China's urbanization level will exceed the world average (53.4%) in 2014 and reach nearly 70% in 2030.

Policy makers in China also have considered urbanization as an important driver for promoting socioeconomic development. It has been well documented that urbanization can play a significant role in unleashing enormous consumption and investment demand, and creating numerous job opportunities (Friedmann, 2006; World Bank, 2014). After an average GDP growth rate of about 10% in 1978–2008, the growth rate of China's economy has slowed down recently. To maintain its high economic growth, Chinese government has used urbanization to one of major growth engines. For example, urbanization in China was set as one of the key national development strategies for the first time in the 10th Five-Year Plan (2001–2005) (Liu, 2004). The roles of urbanization on China's development have particularly been emphasized in the 12th Five-Year Plan (2011–2015). The plan of the government's top leaders is to increase the rate of urbanization over the next 10 years by 10 percentage points.

Therefore, since the roles of urbanization in socio-economic development and ecological environment are significant (Zhang et al., 2009; Ji, 2011), there has been growing concern on the

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Table 1
Increase and growth rate of water use by sector in different periods in China (1949–2011).

	Total increase within each period (%)				Annual growth rate (%)			
	Total	Agriculture	Industry	Domestic	Total	Agriculture	Industry	Domestic
1949–1965	166	154	654	200	6.31	6.01	13.46	7.11
1965–1980	62	45	152	1456	3.26	2.53	6.37	20.08
1980–1993	17	3	98	70	1.23	0.24	5.41	4.15
1993–2000	6	−1	26	21	0.80	−0.13	3.33	2.77
2000–2011	9	−1	28	37	0.79	−0.10	2.29	2.93
1949–2011	481	274	5991	13065	2.88	2.15	6.85	8.19

Source: Authors' calculation based on data from the following sources: (1) water in the Past 50 Years, 1999, published by China Water Power Published Press. (2) China Water Resources Bulletin (1997–2011), Ministry of Water Resources.

impacts of rapid urbanization on shifting resources from agriculture to non-agriculture and potential impact on China's food security (Satterthwaite et al., 2010). Based on literature review, most of recent studies have focused on the impacts of urbanization on food security through its impacts on cultivated land. For example, Chen (2007) found that in the past 30 years, 21% of the total loss of cultivated land was converted to urban use. However, Deng et al. (2012) pointed out that urbanization might slow down the rate at which cultivated land is lost in China. In addition to land, rapid urbanization also places a strain on water allocation between rural and urban areas. Some studies have suggested that urbanization can result in large decrease of water use in agriculture (Meinzen-Dick and Appasamy, 2001; Kendy et al., 2007; Wu and Tan, 2012). Interestingly, although water is very scarce and its important role on sustaining agricultural production and ecological system has been significantly addressed by many scholars (such as Boelee, 2011; Wang et al., 2013), little study has examined the impacts of urbanization on regional and national agricultural production through its impacts on water uses.

Faced with rapid urbanization and its pressure on food security, several questions can be raised: What are impacts of urbanization on agricultural water use or how much water used in agricultural sector will be reallocated to other sectors due to urbanization in China? What are the potential impacts of falling water use in agriculture due to urbanization on regional and national crop production and production structure? Specifically, given the change in agricultural water supply in each region, how will water allocation to different crops and the irrigated and rainfed areas of each crop change in each region? What are likely impacts on crop yield and production at regional and national levels? What are implications to China's food security?

The overall goal of this paper is to provide some answers to the above questions through analyzing the impacts of urbanization on agricultural water use and resulted impacts on crop areas, yield and production at the regional and national level in China. In order to realize the goal, we have conducted the following studies. First, based on historical data, we examine the relationship between urbanization and agricultural water use in China. Then the change in total agricultural water use due to urbanization is estimated by using econometric method. Second, the impacts of the change in agricultural water use due to urbanization on regional crop production are simulated based on the China Water Simulation Model (CWSM). CWSW divides China into ten river basins (Liaohe, Songhuajiang, Haihe, Huaihe, Yellow, Yangtze, Pearl, Southeast, Southwest and Northwest river basins). Within CWSM, a positive mathematical programming (PMP) can optimize water allocation among crops and between irrigated and rainfed areas within a crop in each of ten river basins in China. Finally, based on CWSM simulation, the impacts of urbanization through water on crop yield and production are further explored at each river basin and China as a whole.

The rest of this paper is organized as follows. Section 2 analyzes China's historical trend of water use and the correlation between urbanization and agricultural water use. The parameter measuring the impacts of urbanization on agricultural water use obtained in this section is used in a shock to a simulation model, the China Water Simulation Model (CWSM), which is briefly introduced in Section 3. Section 4 presents the simulation results on the impacts of urbanization on irrigated and rainfed crops areas, crop yield and production at both the river basin and national levels. Section 5 concludes with policy implications.

2. The relationship between trends of water use by sector and urbanization

2.1. Trends of China's water use

Over the past 65 years, water use in China has displayed an obvious increasing trend, particularly before 1993. From 1949 to 2011, the total water use in China rose by 481% and the annual growth rate reached 2.88% (Table 1). Due to low levels of water use and socioeconomic development, the rate of increase of total water use was highest in 1949–1965. For example, during this period, total water use increased by 166% with an average annual growth rate of 6.31%. The second highest growth rate occurred in 1965–1980. In this period, the total increase of water use was 62% and the average annual growth rate was 3.26%. From 1980 to 1993, total water use in China continued to rise with socioeconomic development. Although the growth rate of water use has been falling, its total use still increased by 17% with an average annual growth rate of 1.23% in 1980–1993. After 1993, despite further demand for water use from various sectors, the growth rate of water use decreased substantially, because of the rising pressures of water scarcity and increasing water use efficiency in various sectors (Huang et al., 2009; Hubacek et al., 2009; Wang et al., 2009a,b). In 1993–2011, the total water use increased by about 15% and the average annual growth rate fell to less than 1%. Consistent with the change trend of total water use, water use in three sectors (the agricultural, industrial, and domestic sectors) had high rates of increase until 1993, at which point the growth began to decrease significantly.

Despite presenting similar trends, both the industrial and domestic sectors had much higher growth rates than the agricultural sector did. For example, since 1949, industrial water use increased by nearly 60 times and domestic water use increased by 130 times, while the total use by the agricultural sector only increased by 274%. Similar results can be found for various periods. After 1980, agricultural water use has had a much lower rate of increase (an annual increase of 0.24% from 1980 to 1993), and since 1993, the rate has been in decline, since 1993, both industrial and domestic water use have displayed increasing trends.

With the rapid expansion of industrial and domestic water use and the constraints on its limited water supply, China's agricultural sector has faced serious competition pressure for water. For