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# Multiple Policy Instruments for Sustainable Water Management in Crop Production - A Modeling Study for the Chinese Aksu-Tarim Region

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ABSTRACT

China's crop production sector faces severe water scarcity issues. Previous research has shown that effective water conservation policies exert strongly negative impacts on agricultural production and farmers' income, which make them politically unfeasible under Chinese conditions. To highlight ways out of this dilemma, the present study tests three alternative water policies complemented by supportive agricultural policies to reduce the trade-offs between water conservation and rural development policy goals. Using the case of the extremely arid Aksu-Tarim Region in northwest China, a regional supply model is developed which serves as the analysis framework. Applied as stand-alone water policies, irrigated area tax, water quota and water pricing differ clearly in effectiveness and efficiency. Combined with agricultural policies (subsidies) into multiple policy instruments, the price-based and quota-based instruments mitigate the negative impacts on rural development goals. Targeting a water conservation rate of 20%, the tested multiple policies perform alike on the level of the entire study region; cotton production decreases by 15%, cereals production remains stable, and regional income decreases by 13%. However, at the sub-regional level, the impacts on water conservation, production and income differ significantly between the alternative policy instruments and sub-regions, constituting a crucial challenge for practical water policy implementation.



## 1. Introduction

### 1.1. Agricultural Water Demand and Related Challenges

The availability of fresh water is considered the most critical development factor for future global food production. Continuous expansion of irrigated agriculture in many regions worldwide led to an increasing pressure on global fresh water resources over the last decades (Siebert et al., 2015). Today, irrigated agriculture is responsible for about 60% of global fresh water withdrawals (Döll et al., 2014). With the global population projected to further increase, the competition for scarce fresh water resources is likely to accelerate in the near future (Mariolakos, 2007). Additionally climate change may aggravate water scarcity. Increasing temperatures result in higher evapotranspiration and subsequent higher crop water demand. Furthermore, the projected increase in variability of natural precipitation will lead to a more uncertain and regionally scarce water supply in the future (Candela et al., 2012).

China, as one of the most important and rapidly growing economies worldwide, is endowed with only one fourth of world's per capita water availability (Falkenmark et al., 1989). The Chinese population's living standards are continuously rising, which increases the demand for water intensive products (e.g., dairy products, meat). Thus, China is confronted with a severe water scarcity issue (Jiang, 2009). Water resources are distributed highly uneven over the country, and many disadvantaged regions experience a continuously worsening water resource situation (Holst et al., 2014; Zhang et al., 2013). In the extremely arid Aksu-Tarim Region (ATR) in northwestern China, all human activities and the natural ecosystems depend on the water supplied by snow- and glacier-melt from the surrounding mountain ranges (Huang et al., 2011; Song et al., 2002). The water is distributed throughout the region by the more than 1000 km long Tarim River, the longest inland river of China, and its main tributary the Aksu River (Fig. 1). Continuous expansion of irrigation agriculture in the oases along the region's rivers led to a massive overuse of water resources, which results in a severe degradation of natural riparian ecosystems and increasing competition among water users (Rumbaur et al., 2015).

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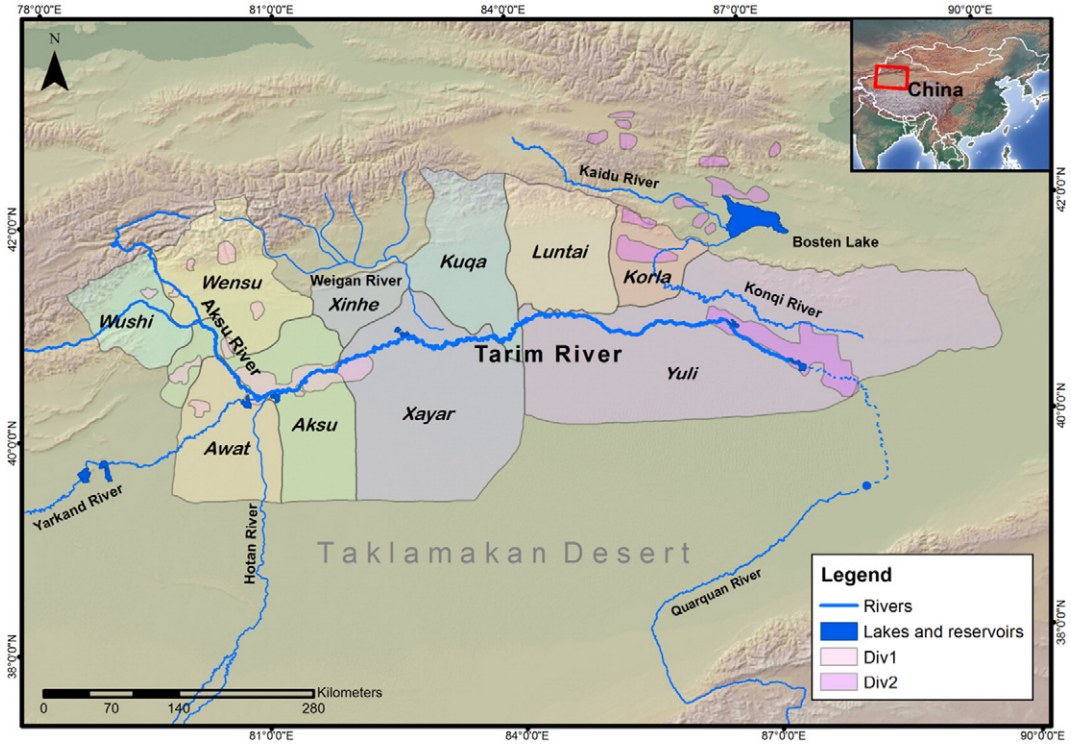


**Fig. 1.** Map of the Aksu-Tarim Region with the location of all sub-regions (counties and divisions) and major water bodies.

Water resource conflicts may be aggravated in the future due to increasing competition among different water users. With agriculture consuming by far the greatest share of fresh water in the ATR (Peng et al., 2014), the reduction of agricultural water usage promises high water conservation potential. The conserved water would be available to satisfy the continuously increasing industrial and domestic water demands, arising from rapid industrialization, urbanization and growing living standards (Jiang et al., 2014). Additionally, conserved water would be available for ecological purposes to restore the degraded natural riparian ecosystems along the Tarim middle and lower reaches and maintain their ecosystem functions (Aishan et al., 2015).

### 1.2. Water Policy Instruments

The ATR and other water-scarce regions in China require appropriate policy instruments focusing on agricultural production as the most water intensive and a highly water dependent sector (Chen et al., 2014). Water policy instruments generally aim at optimizing the allocation and usage of water to realize water conservation and a more efficient use of water resources. The complex relationship between water management and the political and socio-economic conditions of water users constitute a critical challenge for designing and implementing effective and efficient water policies (Shen and Lein, 2010). Therefore a comprehensive evaluation of policy instruments for sustainable agricultural water management is of high scientific interest and great political relevance, especially in arid and semi-arid regions of the world (cf., Bennear and Stavins, 2007; Millington et al., 2006; Molle, 2009; Varela-Ortega et al., 1998).

Three of the most commonly applied and widely discussed agricultural water policy instruments are water quota, water pricing and irrigated area tax. The command and control instrument water quota aims at restricting the available water quantity, and is as such considered as an effective instrument to reach a predefined water conservation target (Bate, 2002). A quota generally entails no extra production costs for producers, and additionally can be implemented at comparatively low cost by the water authorities (Tsur and Dinar, 1995). It is furthermore considered as suitable to be applied under data scarce conditions prevailing in developing countries (Eskeland and Jimenez, 1992).

The market-based instrument water pricing charges per consumed unit of water, and is thus considered an incentive to the farmers to reduce the water-related production costs by using water more efficiently (Dinar and Mody, 2004). Farmers may respond according to their individual production situation by switching to water saving irrigation techniques (e.g., drip technique) or turning towards the production of less water consumptive crops (Chen et al., 2014). However, water demand is relatively price inelastic (Moore et al., 1994; Scheierling et al., 2004). Thus, significant reductions in water demand only occur at rather high price ranges, which give sufficient incentives to producers to limit their production costs (Davidson and Hellegers, 2011).

An irrigated area tax charges a water fee for each unit of irrigated land. Entailing rather low implementation and administration costs, it is a popular and widely applied policy instrument in many regions in the world including China (Mamitimin et al., 2015a). However, its effect on water conservation is considered rather small as there is no direct link between the actually applied amount of water and the charged irrigated area tax (Huang et al., 2007a; Tsur, 2005).

### 1.3. Water Policy Analysis in China

A limited though steadily growing body of literature exists on agricultural water policy analysis in China. Among the available studies, very few analyze the policy instruments water quota and irrigated area tax, while the vast majority focuses on the assessment of water pricing (e.g., Huang et al., 2010; Mamitimin et al., 2015b; Wang et al., 2016b). Accordingly, comparative assessments of the three alternative water policy instruments are not available for China. A single study conducted by Shi et al. (2014) compares water pricing and water quota in the Heihe River Basin. The authors conclude that water quota is more effective than water pricing. The studies focusing on the sole assessment of water pricing largely use modeling approaches, which build on profit maximization under resource constraints (e.g., Huang et al., 2007b; Wei