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# Eco-compensation standards for agricultural water conservation: A case study of the paddy land-to-dry land program in China

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ABSTRACT

Compensation programs ensure the efficacy of water conservation programs and sustainability of interregional water cooperation. Here, a water conservation compensation standard model based on the cost and contribution to benefits regarding water quality and quantity was constructed and then applied to the Paddy Land-to-Dry Land Program (PLDLP) in the Beijing-Hebei region of China. We found that the PLDLP reduced the pollution load of total nitrogen and total phosphorous to downstream areas by 27.63% and 88.53% respectively; runoff to downstream areas increased by 4.22%. Without considering the labor costs of family members, the net income of farmers decreased 41.65%, and the compensation standard was calculated at 5165.41 CNY per ha. From the perspective of social comprehensive value, income generated from becoming migrant worker was treated as an opportunity cost for farmers and under this model the net income of farmers decreased 10.99% and compensation standard was calculated at 1362.95 CNY per ha.

## 1. Introduction

As a result of water mobility and the integrity of watersheds, different regions within watersheds are interconnected during the development, utilization, pollution management, treatment and conservation of water resources (Engel et al., 2008; Rao et al., 2014). During water shortages, competition and conflict are inevitable between cities upstream, downstream, left bank and right bank (Kosoy et al., 2007; Dasgupta et al., 2008; Robins et al., 2017). When the whole watershed is segmented by administrative divisions, a city alone often finds it difficult to tackle water shortages and environmental problems individually (Wunder et al., 2008; Guan et al., 2016). A more efficient approach to solving competition and conflict is when different administrative regions in watersheds cooperate to promote coordination between ecological environmental protection and economic development (Barrantes and Gamez, 2007; Huang et al., 2009).

One important source of agricultural non-point source pollution is the transport of nutrients such as nitrogen and phosphorus from surface runoff to surface water (Hanifzadeh et al., 2017). Nitrogen and phosphorus runoff from rice paddies are estimated to be a large contributor to algal blooms in downstream lakes, reservoirs and rivers (Ho and Michalak, 2015). The transformation of land use patterns in upper reaches of a watershed because of programs such as the Sloping Land Conversion Program or Paddy Land-to-Dry Land Program represents an opportunity for cooperation, reallocation of resources, and environmental and economic benefits (Vincent, 2010; Hecken and Bastiaensen, 2010). These programs are often accompanied by eco-compensation policies that aim to coordinate interests between shareholders and provide interest drivers and economic incentives for preserving water resources (Zhang et al., 2008; Bennett, 2008).

The payment standards for watershed services are a significant issue when establishing compensation mechanisms and remain an important indicator affecting implementation, acceptability and fairness (McDermott et al., 2013). The determination of standards according to existing literature is mainly by valuing ecosystem services provided by the upper reaches of the watershed, or on inputs for water conservation and ecological protection (Xu et al., 2014; Kauffman, 2014). While some studies have used factors such as water quantity and water quality to better distribute and revise total costs (Xu et al., 2009; Van Hecken et al., 2015), current methods are static and ignore changes in the value of services, costs and benefits downstream before or after implementing water conservation measures (Wu et al., 2012; Zanella et al., 2014).

During the determination of payment standards, considering the effects of water resource conservation measures and contributions to downstream benefits is necessary to guarantee the effects of water resource protection measures. Here, we construct a calculation model of

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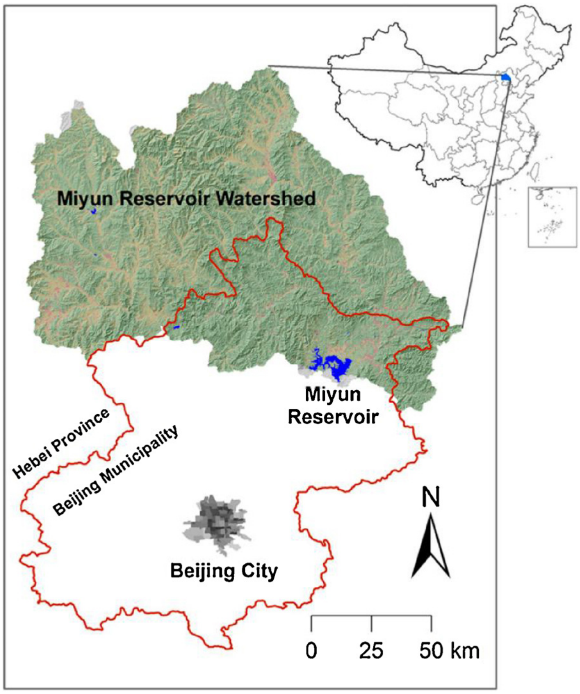


**Fig. 1.** Location of the Miyun Reservoir watershed (Zheng et al., 2013).

payment standards for water conservation services based on upstream contributions. We then apply this novel method to the Paddy Land-to-Dry Land Program (PLDLP) across the Beijing-Hebei area of China.

## 2. Methods

### 2.1. Study site

Beijing is a city of severe water shortages. It has an average annual rainfall of 585 mm and annual average water resources of 3.74 billion $m^3$ (Zuo et al., 2011). Miyun Reservoir (Fig. 1) is the largest artificial lake in Asia and located 100 km north of Beijing. The reservoir is an important surface water source for Beijing (Zheng et al., 2013). It comprises more than 20% of the total water supply to the city and more than 50% of urban water supply. However, since four-fifths of this watershed is located in adjacent Hebei province (Tang et al., 2011), both water quality and quantity are important concerns for the Beijing government. Since 1999, farmers in the upper reaches of the Miyun Reservoir have plant large amounts of rice, consuming large volumes of water and producing surface pollution (Wang et al., 2004; Chen, 2007). In the late 1990s, the area of rice in the upper reaches of the reservoir reached 13400 ha (Du et al., 1999). Annual water consumption is great, a large volume of water resources are trapped by rice systems, and pesticides and fertilizers have caused non-point source pollution problems for the Miyun Reservoir (Gao et al., 2002).

Diminishing water quantity and quality in Miyun Reservoir has intensified competition and sparked interprovincial conflict between Hebei and Beijing (Zheng et al., 2013). On 11 October 2006, the Beijing municipal government and Hebei provincial government formally signed the memorandum of *Understanding Between the Beijing Municipal People's Government and the Hebei Provincial People's Government on Strengthening Economic and Social Development*. The memorandum stated that 6866.67 ha of rice in the upper reaches of the Miyun Reservoir should be converted to dryland and that the Beijing government would compensate farmers for any losses. This program is called the Paddy Land-to-Dry Land Program (PLDLP), and by 2014 farmers in the upper reaches of Miyun Reservoir had converted all 6866.67 ha of rice fields to corn (Fig. 2).

### 2.2. Model of eco-compensation standards for water conservation

According to natural migration and transformation rules of pollutants in water, the environmental impact of water pollutant emission reduction or excessive discharge has a certain scope (Liu and Yang, 2012). Water conservation methods such as conserving water source forests or converting paddy land to dry land may increase water flows in the watershed, but the effects may be affected by other water usage behavior or natural evaporation and leakage (Zheng et al., 2013; Serna-chavez et al., 2014). Based on the theory of internalizing externalities, we quantified the contribution of water resource conservation upstream to downstream from the perspective of water quality and water quantity into a model based on the costs of ecological protection to produce a more acceptable payment standard for stakeholders.

#### 2.2.1. Basic assumptions

For the purpose of simplification, the model is based on the following assumptions:

(1) Payments for the watershed services take place in both areas *a* and *b* within the same watershed, where *a* is located upstream of the watershed and *b* downstream.
(2) The upstream landholders who adopt water resources conservation measures and contribute to water quantity and quality downstream are objects of payments (ecosystem service providers) and those who benefit from water quantity and quality are subjects of payments (ecosystem service beneficiaries).

#### 2.2.2. Cost accounting for water conservation behavior

The costs of implementing water conservation measures in the upper reaches include both direct and indirect costs. Direct costs (*DC*) mainly refer to additional costs for protection or construction in order to preserve water resources, including direct inputs of human, material and financial resources.

Indirect costs (*IC*) are the loss of income and development opportunities during the process of water resource conservation, arising from constraints on development and changes in land use patterns in upstream areas. According to different subject bearing loss, the indirect cost of water conservation is calculated as:

$$IC = EOC + GOC + IOC \tag{1}$$

wherein, *IC* is the indirect cost of preserving water resources in the watershed; *EOC* is the opportunity cost for enterprises; *GOC* is the opportunity cost for government; and *IOC* is the opportunity cost for residents.

#### 2.2.3. Contribution of water conservation practices

According to the inseparable characteristics of water quality and quantity, the impact of preserving water resources in the upper reaches is usually manifested in water quality and water quantity.

(1) Contribution coefficient of water quality

Water conservation practices often improve water quality by reducing the generation and discharge of water pollutants (e.g. reducing the use of chemical fertilizers and pesticides in agricultural production) from the source, by reducing the transport of water or by depositing pollutants so to prevent the transport of pollutants to receiving water (e.g. farmland boundary belt, coastal vegetation buffer), or by strengthening the self-purification capacity of water ecosystems (e.g. wetland restoration and reconstruction). Water resource preservation in the upper reaches of the watershed improves the quality of the aquatic environment across the whole watershed, provides high quality water resources for downstream areas, increases the quality of the local aquatic environment and availability of water resources, and reduces the costs of pollution treatment. The proportion of benefits received by beneficiaries downstream from water conservation practices upstream