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Development of payment standards for ecosystem services in the largest interbasin water transfer projects in the world

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ABSTRACT

Interbasin water transfer (IBWT) projects effectively overcome water shortages resulting from the uneven distribution of water resources and water demand. However, these projects may also create water conflicts between the water source and receiving areas. As a method to solve water conflicts, the payments for an ecosystem services (PES) approach determines a payment standard based on different calculation methods. However, an overall survey revealed that few PES studies had applied to evaluate IBWT projects by these different calculation methods, and no comparison has been made among these payment standards. This study applied the conservation cost method (CCM), the market value method (MVM), and the payment ability method (PAM) to determine payment standards for the Middle Route Project of the South-to-North Water Diversion project in China, the largest IBWT project in the world. It seems that the CCM-based payment standard (72.30 billion CNY) would contribute to environmental conservation and economic loss compensation in the water source area. The MVM-based payment standard (82.44 billion CNY) would stimulate economic development in the water source area besides environmental conservation and economic loss compensation. The PAM-based payment standard (109.74 billion CNY) would greatly accelerate economic development in the water source area; however, it should solely be used as a reference value in order to allow for economic development in the water receiving area.

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1. Introduction

Worldwide, the uneven distribution of water resources and demand frequently leads to water shortages, and regional water demand often exceeds water supply even in countries with an abundance of water (Matete and Hassan, 2006). Interbasin water transfer (IBWT) projects across national and regional boundaries have been well developed to overcome water deficits and to increase the resilience of the global water system (Singh and Jain, 2007), e.g., China (Zheng et al., 2016), United States (Emanuel et al., 2015), Australia (Grant et al., 2013), Spain (Rey et al., 2016), Brazil (Berbel-Filho et al., 2016), and etc. Among such projects, the South-to-North Water Diversion (SNWD) project in China [a three-route (i.e., East, Middle and West) IBWT project begun in 2002] is the world's largest one with the ability to transfer 44.5 billion m^3 of water annually from the Yangtze River to North China, affecting almost one-third of China's landmass (Zhang et al., 2009). However, IBWT projects may break the long-established balance of water quality and quantity in the water source area and lead to conflicts between the water source and receiving areas (Yang and Zehnder, 2005).

Payments for ecosystem services (PES), also known as payments for environmental services (or benefit) or ecological compensation, are a transparent system for the provision of environmental services through conditional payments to voluntary providers. Recently, PES has been increasingly recognized as an important tool in resource and environmental management (e.g., forest protection (Yang et al., 2013), land conservation (Lyle et al., 2015) etc.) and has been applied to address water conflicts in upstream and downstream regions of watersheds (Kolinjivadi et al., 2014; Xu et al., 2015). PES aims to reduce economic loss and promotes environmental conservation upstream, while guaranteeing quality water resources downstream (Kosoy et al., 2007; Zhang et al., 2007). Payment standards can be determined in terms of cost [e.g., opportunity cost method (Adams et al., 2010) and conservation cost method (CCM)], benefit [e.g., ecosystem services value method

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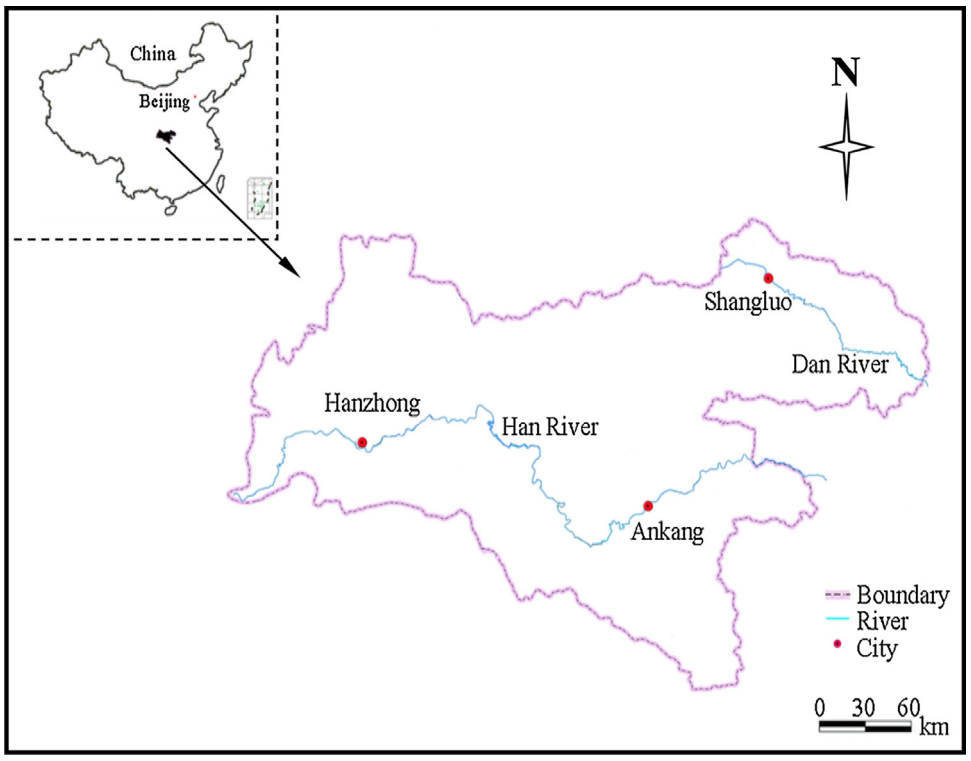

Fig. 1. Location of the Shaanxi water source area in China.

(EVM) (Fei et al., 2016) and market value method (MVM) (Kroeger and Casey, 2007)], or payment ability [e.g., contingent valuation method (CVM) (Chee, 2004) and payment ability method (PAM)]. In previous investigations, In previous researches, Dong and Wang (2011) and Dong et al. (2011) individually determined the payment standards for IBWT project solely by the CCM, while Li et al. (2010) determined the payment standard for IBWT project solely by the EVM. However, an overall survey revealed that no other PES studies have been performed for IBWT projects. Furthermore, no comparison has been made among different payment standards which were determined by different calculation methods, which hampers the wide application of PES strategy to overcome water conflicts between the water source and receiving areas worldwide.

As one of three sub-projects of the SNWD project, the Middle Route Project (MRP) covers a total area of approximately 155,000 km^2 (Zhang et al., 2009). In this study, we determined and compared three representative payment standards for the Shaanxi water source area (SWSA) of the MRP using CCM, MVM, and PAM, which will provide important information for other IBWT projects.

2. Data and methods

2.1. Study area

The water conveyance system of the MRP originates at the Danjiangkou Reservoir, goes across the Tangbaihe plain, and passes through the pediment plain and the south foot of Funiu Mountain. It then crosses the Yellow River, extends north along the pediment plain at the east foot of Taihang Mountain, and finally reaches Beijing and Tianjin municipalities. The study area (the SWSA) is located in the upper basin of the Han River and the Dan River, including three cities (Hanzhong, Ankang, and Shangluo) in southern Shaanxi province (Fig. 1). It has a population of 9.54 million and a total area of about 62700 km^2, approximately 66% of the Danjiangkou Reservoir control area. The Han River in the study area is about 652 km long with a watershed area of 55213 km^2, and the Dan River is about 250 km long with a watershed area of 7510 km^2. The Han and Dan watersheds in the study area account for 41% and 56% of the individual main streams, and 37% and 45% of the individual basins, respectively. As the principal water source of the MRP, the average annual reservoir inflow of the SWSA is 28.5 billion m^3 (approximately 70% of the average annual inflow of the Danjiangkou Reservoir) (Wei et al., 2010). It seems that the study area investigated in this study is more important than that (i.e., Shiyan City in Hubei province) investigated in two previous PES studies for the MRP (Dong and Wang, 2011; Dong et al., 2011).

The water receiving area in the first phase of the MRP includes Beijing and Tianjing municipalities, as well as Henan and Hebei provinces. These areas are located in the northeastern part of China and belong to the semi-humid climate region dominated by the Pacific monsoon. The current available water resources in this area are only 247 m^3 per capita annually (Wei et al., 2010), and the water receiving areas experience extreme water deficits (defined as <500 m^3 per capita annually).

2.2. Data sources

This study focused on the first phase of the MRP (2006–2015). All value calculations were standardized to 2006 price levels to allow for direct comparison among different results when the inflation rate of −0.7%–5.9% were considered for the period covered in this research. The data were collected from (1) monitoring stations and control sections along the Han River and Dan River, (2) official reports and planning documents, including the Water Pollution Prevention and Water and Soil Conservation Plan of Danjiangkou Reservoir Area and Upstream ("the Plan") (DGP, 2005), as well as statistical data from the Soil and Water Conservation Bureau in Shaanxi Province, and (3) Chinese statistic yearbooks (2007–2011) for relevant areas at different administration levels (NBSC, 2007–2011; SXBS and NBSSOSX, 2007–2011). From

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