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Determining eco-compensation standards based on the ecosystem services value of the mountain ecological forests in Beijing, China

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ABSTRACT

Ecological forests play a key role in the maintenance of urban ecological security in Beijing, and 91% of these ecosystems are located in mountain areas. To better address the issues that are related to ecological conservation and the environmental, eco-compensation programs that target mountain ecological forests have been implemented by the local government since 2004. However, these eco-compensation programs that are currently conducted in Beijing now are still confronted with issues regarding payment standards. In this study, three eco-compensation standards for the mountain ecological forests in Beijing are presented based on the ecosystem services value and location diversity indicators that include major function oriented zoning, population density, and ecological importance and ecological fragility. The average payment in Beijing varies from 1607 RMB/ha/a to 2051 RMB/ha/a and is approximately from 0.7 to 1.2 times higher than the current standard. The increase from the current payment standard to the recommended ones is consistent with recent social and economic development in Beijing. The recommended eco-compensation standards also reflect the relative importance of forest ecosystem services that consider geographical location. These recommended standards also have the potential for use in the establishment of differentiated compensation standards based on the different protection results of mountain ecological forests. This study will help policy and decision makers to design eco-compensation initiatives with a high success rate and contribute to the conservation and sustainability of the forest resources in Beijing.

1. Introduction

Ecosystems provide services to maintain human livelihood, and people obtain benefits from ecosystems and their structures and processes. Ecosystem services represent the value and benefits of nature to people (MA, 2005), and the ecosystem services approach is a useful way to analyze the anthropocentric valuation and utilization of ecosystem functions to meet human demands (Matthies et al., 2015). To address the misalignments between socially and privately optimal levels of ecosystem services provisioning, payments for ecosystem services (PES, expressed as eco-compensation in China) are distributed by policymakers to manage natural resources (Matthies et al., 2015; van Noordwijk et al., 2012; Zhen and Zhang, 2011). PES schemes internalize the benefits that are associated with enhancing or maintaining ecosystem services to ensure that land managers and other providers of ecosystem services have incentives that agree with the interests of the users of these ecosystem services (Richards et al., 2015; Zhen et al., 2014a, 2010). However, to achieve a desired resources management goal, the payment standard of the PES must to be determined reasonably and scientifically.

A reasonable and scientific payment standard must be based on the service types of the ecosystem and the value that they provided. According to the Millennium Ecosystem Assessment, there are four types of ecosystem services including support services, regulation services, provision services and culture services (MA, 2005). The selection of ecosystem services for valuation should be based on integrated knowledge from the ecosystem service beneficiaries (Malinga et al., 2013; Willaarts et al., 2012). After the selection of specific ecosystem services for valuation, location indicators should also be considered in the establishment of the payment standard, because the actual provision of ecosystem services is determined not only by ecological systems but also by coupled social-ecological systems (Sarkki and Karjalainen, 2015). The payment standard should be based upon greater consideration of the social and economic development dimensions, because the relative value of the ecosystem services and the stakeholder's demand may change under different scenarios (Engel et al., 2015). Accordingly, an eco-compensation standard cannot be separated from the social context in which the ecosystem services are

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embedded, and an eco-compensation standard may define and frame the ecosystem services value for strategic reasons at different location parameter scenarios (Hauck et al., 2013).

Because of rapid economic development and local population growth, Beijing's socio-economic development has been increasingly obstructed by bottlenecks caused by ecological and environmental problems, including water resource pressure (Gao et al., 2016; Liu and Yang, 2013; Zhang et al., 2011), soil and water loss (Tian et al., 2009) and insufficient ecological and environmental carrying capacity (Wang et al., 2014). As the most important ecosystem in Beijing, forest ecosystems covers 35% of the administrative area and play a key role in the maintenance of urban ecological security by providing an abundance of ecosystem services to local and surrounding communities (Xie et al., 2010).

Currently, the general public and policymakers are paying more attention to the importance of forest ecosystem services in Beijing (Xie et al., 2010; Zhang et al., 2010), and eco-compensation has gained recognition as a potentially valuable tool that can address ecological conservation and environmental issues. Thus far, two eco-compensation programs that target forest ecosystems have been implemented in Beijing and involve the districts of Haidian, Fengtai, Mentougou, Fangshan, Changping, Shunyi, Huairou, Miyun, Pinggu, and Yanqing. One program is the eco-compensation Mechanism for Ecological Forests in Beijing's Mountain Areas, which was implemented in 2004. The payment standard for this eco-compensation program was adjusted in 2009, and the current payment standard is 5280 RMB per ranger per year. This eco-compensation program is not intended to ensure the sustainable development, management and protection of forest resources but rather to solve the problem of surplus labor in rural areas and increase the incomes of farmers. The other policy is the Ecological Benefits of Mountain Ecological Forest Development Promoting Mechanism, which was implemented in 2010. Its current payment standard is 600 RMB per hectare per year. Funding for the two eco-compensation programs is from both the Beijing government and the government of the specific districts. Three quarters of the founding for Eco-compensation Mechanism for Ecological Forest in Beijing Mountain Areas and a half of the founding for the Ecological Benefits of Mountain Ecological Forest Development Promoting Mechanism are from the Beijing government.

These eco-compensation programs for forest construction in Beijing have contributed to the equal distribution of ecological and economic benefits between protectors and beneficiaries. However, these two eco-compensation programs confront issues in payment standards for several reasons. First, the current standards are based on the fiscal capability of the government rather than the magnitudes of the forest ecosystem services value in Beijing; thus a payment standard that is based on scientific research is unavailable. Second, the existing payment standard is determined by top level government agencies, and a one-size-fits-all standard is used for eco-compensation programs, which cannot reflect the contributions of different ecosystem services; Third, location diversity indicators are not taken into account in the current payment standard, and the standard is separated from natural and social contexts in which the ecosystem services are embedded. Thus, a reasonable and scientific determination of payment standards is the shortcoming of the current eco-compensation programs in Beijing, although this determination is critical to maintain a sustainable supply of forest ecosystem services.

In order to solve the problems above, this paper scientifically evaluates the ecosystem services that are provided by the mountain ecological forests in Beijing. It also calculates payment standards that are based on the ecosystem services value and adjusting indicators that include major function-oriented zoning, population density, and ecological importance and ecological fragility. This research provides location-diverse payment standards for forest eco-compensation programs in Beijing, and gives scientific support for decision makers to distribute more reasonable eco-compensation programs to balance the interests between forest protection and economic development. The results of this paper may contribute to the conservation and sustainability of forest resources in Beijing.

2. Method

2.1. Study area

Beijing is the capital of China and lies on the northern edge of the North China Plain. The region has a warm and semi-humid continental monsoon climate with cold, dry winters and rainy, hot summers. The annual precipitation averages nearly 700 mm, and the average annual temperature is 11.7 °C. Beijing administers 1.7×10^7 ha, and 62% is mountainous.

Beijing's forested land area is approximately 1.1×10^6 ha, and 71% are ecological forests. Ecological forests in the mountain areas are 6.8×10^5 ha, which accounts for 91% of Beijing's total ecological forests (Wang et al., 2012). These ecological forests play a significant role in the protection of ecological security and the promotion of sustainable development in Beijing's economy and society. However, these ecosystems are primarily located in the upper reaches of rivers and reservoirs, as well as in areas that are characterized by soil erosion, ecological fragility, relatively inconvenient transportation and underdeveloped economies.

Beijing's major forest resources are forest land and shrub land, which account for 58.7% and 30.5%, respectively, of total forest resources. The other five types of forest resources, which include open forest land, newly established open forest land, nurseries, unstocked forest land and suitable forest land, account for 10.8% of total forest resources. The dominant tree species of Beijing's forests are *Quercus dentasa, Platycladus rientalis, Pinus tabulaeformis, Populus* spp., *Robinia pseudoacacia, Populus davidiana, Betula platyphylla*, and *Larix principis-rupprechtii* (Chen and Li, 2011).

2.2. Data sources

The 2009 forest sublot database was provided by the Beijing Forestry Survey and Design Institute (Seventh Forest Resource Inventory of Beijing). There are a total of more than 1.6×10^5 forest sublots in the database. The spatial distribution has a scale of 1:10,000, and the database includes a series of attributes, such as forest type, area, tree species, coverage, tree height, soil type and depth, litter depth, etc. The social-economic data were obtained from both the national and Beijing's statistical year books from 2009 to 2014. Other statistical data were collected from the website of the Beijing Municipal Bureau of Landscape and Forestry. We also incorporated data from the literature on the estimated value of forest ecosystem services.

2.3. Economic value calculation

Ecosystem services are delineated into support services, regulation services, provision services and cultural services base on the Millennium Ecosystem Assessment (MA, 2005). On this basis, Beijing's forest ecosystem services are classified into 13 sub-types following Xie et al. (2010), which include primary products, water supply, gas regulation, hydrological regulation, environmental purification, soil formation, soil conservation, cropland protection, wind erosion protection and sand fixation, biodiversity conservation, increasing employment, recreation and science and education. Water shortages have become the main obstacle to the economic and social development of Beijing, because the water resource per capita in Beijing is only 1/8 of that in China and 1/30 of the water resource per capita in the world (Qian et al., 2014). Moreover, because of the asymmetry in the temporal and spatial distribution of precipitation in Beijing, flood disasters often occur in the mountain areas in the summer (Qian et al., 2014), whereas a dry climate in the winter and