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Linking ecosystem services supply, social demand and human well-being in a typical mountain–oasis–desert area, Xinjiang, China

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ABSTRACT

Identifying the links among ecosystem services (ES) supply, social demand and human well-being is important to realize sustainability, especially in mountain–oasis–desert (MOD) areas, which are facing an intense conflict between socioeconomic development and ecological conservation. Using a biophysical model, we mapped six ES in the Manas River Basin, which is a typical MOD area. A questionnaire survey was employed to evaluate social demand for ES and human well-being in four different regional units (i.e., high mountain, low hills, oasis and desert) in our site. Spider diagrams were applied to identify the links among ES supply, social demand and human well-being. The results showed that a high supply of provisioning services occurred in the oasis, while a high supply of regulating services existed in the high mountain region. The ES social demand was not completely accordant with the biophysical supply in spatial distribution, and the factors from the supply side and demand side could both cause ES supply–demand mismatches. The total well-being level of all indicators was higher in the oasis and desert than in the upstream areas (i.e., the high mountain region and low hills region), but some indicators (e.g., water consumption) were the inverse. The supply–demand mismatches in provisioning services had a strong impact on human well-being, while the supply–demand mismatches in regulating services had a low impact on human well-being. This can be explained by the ES social demand questionnaire results, which showed that the level of social importance was higher for provisioning services than for regulating services at our site. In accordance with our results, we recommended several policies to promote ecological conservation and improve human well-being in the Manas River Basin, and these policies could also be applied in other MOD areas.

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1. Introduction

Ecosystem services (ES) refer to the direct and indirect contributions to human well-being that originate from ecosystems (de Groot et al., 2010); therefore, a strong connection exists between ES and human well-being. Understanding the relationships between ES and human well-being is important not only for the purpose of scientific research but also to inform policy and practice (Alkemade et al., 2014; Bennett et al., 2015; Daily et al., 2009; Geijzendorffer et al., 2017). Since the Millennium Ecosystem Assessment (MA) proposed a conceptual framework about the relationships between ES and human well-being on a global scale (Millennium Ecosystem Assessment, 2005), the number of studies integrating ES and human well-being has gradually increased (Bennett et al., 2015; Costanza et al., 2007; Haines-Young and Potschin, 2010; Horcea-Milcu et al., 2016; Hossain et al., 2017; Santos-Martin et al., 2013; Yang et al., 2010). Haines-Young and Potschin (2010) proposed the cascade framework from biodiversity to human well-being. Santos-Martin et al. (2013) used the DPSIR (Driver-Pressure-State-Impact-Response) framework to unravel the relationships between ES and human well-being. Horcea-Milcu et al. (2016) constructed the conceptual model of mediating factors to disaggregate the contributions of ES to human well-being. In a case study, Yang et al. (2010) quantified the change in ES and farmers' well-being in the city of Guyuan in the Loess Plateau and analyzed the relationships between them. Abunge et al.

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(2013) applied a participatory well-being assessment in Kenya to connect marine ES and fishermen's well-being. Wang et al. (2014) used cluster analysis to investigate different patterns of relationships between ES and human well-being in the upstream watershed of the Miyun Reservoir. Ciftcioglu (2017) applied a socio-cultural preference method to evaluate the relative values between ES and human well-being based on local people's perceptions in the Lefke Region in North Cyprus. However, most case studies have applied the single supply-side or demand-side to assess ES and have then analyzed the relationships between ES and human well-being. The relationships between ES supply–demand match states and human well-being are neglected and still unclear. Wei et al. (2017) noted that ES supply–demand mismatches may impact human well-being by causing unsatisfied demand. Studying the relationships between ES supply and social demand is important to understand the interactions between ES and human well-being, especially on a small spatial scale.

In recent years, several studies have attempted to integrate the supply and social demand in ES assessment. Kroll et al. (2012) quantified the supply–demand ratios of food, energy and water from 1999 to 2007 in the Leipzig–Halle region of Germany to reveal the relationships between land use change and ES. Burkhard et al. (2012) proposed a matrix approach based on land cover types to map imbalances between ES supply and demand. Schulp et al. (2014) mapped the supply and demand of agricultural pollination services in Europe and determined that the demand area was larger than the supply area. Castro et al. (2014) applied different value-dimensions to evaluate ES and established that high mountains and coastal platforms exhibited the greatest differences between ES biophysical supply and social preference in the province of Almería, Spain. Baró et al. (2015) identified mismatches between regulating services supply and demand based on environmental quality standards in five European cities. However, these case studies almost always conclude at the supply–demand relationship stage and lack further analysis about the impact of the mismatches on human well-being. We need to fully understand the ES supply-side and demand-side to successfully link ES and human well-being and to formulate scientific decisions (Geijzendorffer et al., 2017; Mensah et al., 2017; Wang et al., 2017a). To resolve the problem, employing interdisciplinary approaches (e.g., biophysical and sociological approaches) to assess ES supply, social demand and human well-being is greatly needed but severely limited.

Linking ES and human well-being has attracted much attention, but case studies in a mountain–oasis–desert (MOD) area are limited (Fu et al., 2017; Xu et al., 2016). The combination of a mountain, oasis and desert has been defined as an MOD system (Zhang, 2001). The MOD system is a coupled socio-ecological system that faces conflict between socioeconomic development and ecological conservation. The Manas River Basin (MRB) is a typical representative of MODs in the arid region. Extending from upstream to downstream in the MRB, natural and socioeconomic conditions have considerable differences, and the relationships between ES and human well-being remain to be elucidated. In this study, we aim to: (i) clarify the spatial patterns of ES supply, (ii) quantify ES social demand and human well-being in four different regional units (i.e., high mountain, low hills, oasis and desert) and (iii) identify the links among ES supply, social demand and human well-being for policy decisions (i.e., the mismatches between ES supply and social demand and the relationships between ES and human well-being).

2. Study area

Located in northern Xinjiang, China (43°27′-45°21′N and 85°01′-86°32′E) (Fig. 1), the MRB is adjacent to Tianshan Mountain and the Gurbantunggut Desert (Yuan et al., 1995). The basin is in an arid area, and the landscape is dominated by mountains, plains and sand dunes. Following the construction of a key water-control project and reservoir in the plain, the Manasi River and adjacent rivers have been linked by crisscrossing channels, so the scope of the MRB often includes the Manasi River (the longest river) and three adjacent rivers, the Bayingou River, Jingou River and Taxi River (Cheng et al., 2006) (Fig. 1). The annual average runoff volume of all the rivers is 2.3×10^9 m^3 (Cheng et al., 2006). The MRB covers an area of approximately 2.29×10^4 km^2. The longest distance from east to west is 198.7 km, and the longest distance from north to south is 260.8 km. In the MRB, grasslands, croplands and sand are the major land use types and account for 2.85%, 23.11% and 22.06% of the area, respectively. The administrative districts in the MRB include the Shihezi reclamation area, Shawan County and Manasi County (Yuan et al., 1995). The population of our site was 5.91×10^4 in 1949 and increased to approximately one million in 2015. During the past sixty years, along with the desert turning into an oasis, the MRB has been a rapid economic development area. Our site is also the grain, oil and cotton production base for the Xinjiang Uygur Autonomous Region (Zhang et al., 2012).

Mountains, oases and deserts are the primary geographic landforms in inland arid regions in China (Xu et al., 2016). From upstream to downstream in the MRB, geographic landforms successively occur as mountain, oasis and desert. According to the differences in natural ecological and socioeconomic conditions, the MRB is divided into four regional units, including the high mountain, low hills, oasis and desert (Fig. 1 and Table 1). Human well-being and ES social demand are involved in our study, and there must be a certain population in the regional units, so the transitional zone between the oasis and desert is included in the scope of the desert area. The dominant physical geography and socioeconomic characteristics in different regional units are listed in Table 1. In the high mountain region and low hills region in the upstream watershed, the population is sparse and composed primarily of minorities, and socioeconomic development is relatively backward. Moreover, soil fertility is low, which is not conducive to crop farming. The oasis region in the middle of the watershed supports approximately 76.65% of the total population and has the highest urbanization rate with the largest city, Shihezi. Additionally, agriculture and industry are both relatively developed, and economic output accounts for approximately 85.11% of the total gross domestic product. The desert region in the downstream watershed contains approximately 17.74% of the total population, and the agricultural population accounts for 60.00% of the total population. Agriculture has reached a relatively high level, but the desert region has low rainfall, which is a restriction on agricultural development. Land use change (e.g., desert turning into oasis) has promoted the socioeconomic development in recent decades in the MRB, but it has also caused ecological problems (e.g., grass degradation and soil loss). Aiming to address the ecological problems caused by socioeconomic development, a series of ecological conservation policies have been implemented, such as closing hillsides to ban grazing and returning grazing land to pasture (Li et al., 2015; Liu and Zheng, 2014). However, determining how to realize a win-win between promoting ecological protection and improving human well-being is still a difficult problem.

3. Methods

3.1. Research framework

Considering both the supply-side and demand-side ES, our study aimed to identify the links among ES supply, social demand

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