Land Use Policy 79 (2018) 94–101

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Net value of grassland ecosystem services in mainland China

Xinyi Zheng[a,b], Junze Zhang[c], Shixiong Cao[a,*]

[a] School of Economics, Minzu University of China, No. 27 Zhongguancun South Street, Haidian District, Beijing 100081, PR China
[b] School of Public Policy & Management, Tsinghua University, No. 30, Shuangqing Road, Haidian District, Beijing, 100084, PR China
[c] Faculty of Geographical Science, Beijing Normal University, No. 19, Xinjiekouwai Street, Haidian District, Beijing, 100875, PR China

ARTICLE INFO

Keywords:
Environmental conservation
Net value of ecosystem services
Grassland degradation
Potential cost
Land management
Policy development

ABSTRACT

To understand the difference between the value and the net value of ecosystem services (*VES* and *NES*, respectively), we used government statistics and data from published papers about the values and costs of grassland services to calculate their VES and NES in China. We found that when the associated costs (investment in ecological conservation and restoration, reduction of the risk of natural disasters, water consumption, and land rent) are subtracted from this total, the NES of China's grassland ecosystem services equaled -0.12×10^3 RMB $ha^{-1} yr^{-1}$. Except for northeastern China and Inner Mongolia, which have abundant natural resources and lower population and livestock pressure, China's other seven regions had a negative grassland *NES*. The pressure on grassland by livestock has increased steeply (by 1066.1%), from 29.2×10^6 sheep units in 1977 to 340.5×10^6 sheep units in 2014. This strongly suggests that China's grasslands are being heavily overexploited. In contrast with China's well-funded afforestation programs, the low investments in grassland restoration and management have combined to produce severe degradation of grasslands. China's government should re-examine the benefits of livestock culture by accounting for the costs of this land use and of various restoration methods, and should take measures to preserve and restore the country's fragile grasslands. Our results provide a warning for managers of other ecosystems around the world where calculations of grassland *VES* may be ignoring significant costs of ecological restoration and preservation, leading to overuse and degradation of the ecosystem.

1. Introduction

Since *Nature* first published a paper on the value of the world's ecosystem services and natural capital (Costanza et al., 1997), calculation of the value of ecosystem services (*VES*) has become a popular and widely applicable method for valuing ecosystems. The goal of this approach is to support how economists and governments think and plan (i.e., based on monetary values) by attempting to quantify the value of an ecosystem beyond its ability to produce commercial products such as food (for agricultural ecosystems) and lumber (for forest ecosystems). By accounting for these additional values (i.e., ecological services such as air purification), *VES* increases the perceived value of an ecosystem and encourages managers and planners to protect the ecosystem for more reasons than just its ability to provide commercial products. In November 2016, when we began researching the present paper, more than 18×10^3 papers in this field were found in the *Web of Science* database (http://www.webofknowledge.com). Because *VES* is such a popular field of research, it now provides a strong foundation for research on ecological compensation payments (Pearce, 1997; Tilman et al., 2002). Unfortunately, there is no such thing as a free lunch (Joppa, 2012): all services provided by ecosystems have associated costs. Natural ecosystems are strongly affected by human activities, and these activities create a range of costs (Tilman et al., 2002; Dai et al., 2016). To preserve the *VES* offered by various types of natural ecosystems, humans must invest heavily to prevent natural disasters, maintain the stability of ecosystems, and promote the recovery of natural ecosystems that have been damaged by human activities (Kinzig et al., 2011; McCarthy et al., 2012; Ouyang et al., 2016). This approach can preserve natural ecosystems and their ability to continue providing services by mitigating the competitive relationship between the needs of nature and the needs of human socioeconomic systems (Corbera and Pascual, 2012; Cao et al., 2016).

Although *VES* represents a good first effort to place a value on ecosystem services, most calculations of *VES* haven't rigorously calculated the costs associated with these services (Cao et al., 2016; Ouyang et al., 2016). Existing research related to ecosystem restoration costs only accounts for part of the cost or concentrates on a small scale, such as a specific region (Zheng et al., 2009; Wegner and Pascual, 2011). As

* Corresponding author.
E-mail address: shixiongcao@126.com (S. Cao).

https://doi.org/10.1016/j.landusepol.2018.07.043
Received 23 May 2018; Received in revised form 15 July 2018; Accepted 28 July 2018

a result, the calculations are likely to overestimate the value of these services, thereby creating errors in calculations of ecological compensation payments and providing flawed guidance for land use planning (Bonnie et al., 2000; Kinzig et al., 2011; Bateman et al., 2013). Furthermore, this inaccurate valuation may conceal the potential risk to the health of ecosystems and the humans that depend on them (Corbera and Pascual, 2012; Joppa, 2012).

Given that billions of dollars are being spent across the globe on ecological conservation projects, and given that an unknown number of these projects may fail to achieve their goals (Goldstein et al., 2008; Cao et al., 2016; Ouyang et al., 2016), it is urgently necessary to improve our ability to identify which projects will result in net benefits for humans and the environment (Chen et al., 2009). To do so, it's necessary to account for the costs of these projects as fully as possible. Only after fully considering the cost of providing these services can we fully understand the true value of these services. This more accurate assessment of the service values can reveal both ecosystems with a high net value for nature and human society and ecosystems that have been overutilized and that are showing reduced provision of ecosystem services. Governments, residents of these ecosystems, and organizations can use the improved values to identify where it will be necessary to increase ecological investments or develop policies to reduce the pressure on a degraded ecosystem (Costanza et al., 2014; Polasky et al., 2015).

Globally, grassland ecosystems cover 3.2×10^9 ha, accounting for 20% of the world's land surface (Peichl et al., 2012). Mainland China (excluding Taiwan, Hong Kong, and Macao) has 394×10^6 ha of grassland, which accounts for 40% of China's land area (Ministry of Agriculture, 1978-2015aMinistry of Agriculture, 1978aMinistry of Agriculture, 1978-2015a). A previous study showed that the world's grassland ecosystems have a total annual value of US$906 $\times 10^9$, which accounted for 2.7% of the overall *VES* for all ecosystems (Costanza et al., 1997). However, as noted earlier, to comprehensively account for the net benefit provided by the world's ecosystems and evaluate their stability and health, it's necessary to find a way to quantify the costs associated with their provision of services. To do so, we chose China's grasslands as a case study, and attempted to quantify these costs and compare them with previous assessments of *VES* (Bonnie et al., 2000; Foley et al., 2005; Kinzig et al., 2011; Cao et al., 2016; Dai et al., 2016). The results of this research will provide a useful reference for grassland management and preservation in China, but the approach will also have implications for other grasslands around the world because their managers also need to obtain a comprehensive assessment of conditions (such as grazing pressure) that undermine the services provided by their grassland. In addition, the method described in this paper provides a reference that can guide comprehensive assessments of other ecosystems, thereby contributing to ecological restoration in these ecosystems. Finally, the method we have proposed provides a starting point for developing further improvements in methods to assess the costs of ecosystem services.

2. Methods

When we estimate the value of ecosystem services (*VES*) in a given situation, the associated costs (*C*) should be not ignored. On this basis, we can define a net ecosystem services value (*NES*) that represents the real benefits after accounting for any costs (Cao et al., 2016):

$$\mathrm{NES} = \mathrm{VES} - \mathrm{C} \tag{1}$$

where *C* includes the direct costs of the investment in ecological conservation and restoration (C_d), the opportunity costs of utilizing the resources (C_o), and the costs entailed by risks (C_r), such as the risk of failing to provide adequate ecological conservation:

$$C = C_d + C_o + C_r \tag{2}$$

Direct costs can be obtained from government statistics and the budget reports prepared by ecological conservation managers (Ministry of Agriculture, 1978-2015aMinistry of Agriculture, 1978aMinistry of Agriculture, 1978-2015a; National Bureau of Statistics, 1978-2015; National Bureau of Statistics, 1978). To simplify the calculations, we defined the opportunity cost of grassland projects (C_o) as the cost that results from not using the land (C_l) and water (C_w) for other purposes:

$$C_o = C_l + C_w \tag{3}$$

However, this is clearly a coarse-grained evaluation. We hope that future researchers will refine this analysis using finer-grained data and the values for different combinations of land uses. We also defined a risk cost (C_r) that must be paid to manage the grasslands to prevent natural disasters, including outbreaks of diseases and insect pests and the occurrence of wildfires. We based C_r on government statistical data on expenditures for the control of insects, diseases, and wildfire (Ministry of Agriculture, 1978–2015bMinistry of Agriculture, 1978bMinistry of Agriculture, 1978–2015b).

We also obtained data from published papers on ecosystem services (Xie et al., 2001, 2003; Jiang et al., 2007; Chi et al., 2015) and statistics on management payments (Ministry of Agriculture, 1978–2015aMinistry of Agriculture, 1978aMinistry of Agriculture, 1978–2015a). We obtained data on the area of grassland in each of China's provinces, including provincial-level cities (e.g., Beijing) and autonomous regions (e.g., Inner Mongolia), from 1977 to 2014 using China's annual agricultural statistical yearbooks and China's animal industry yearbooks (Ministry of Agriculture, 1978–2015aMinistry of Agriculture, 1978aMinistry of Agriculture, 1978–2015a,b).

Because many of the areas where grass has been irrigated to ensure adequate growth are arid to semi-arid, water is a precious resource in these areas. We therefore used the potential evapotranspiration (ET) to represent water consumption by man-made and natural grasslands using seven previously developed evapotranspiration models. All seven models were previously tested by Chen et al. (2014) to confirm their ability to reliably estimate ET under China's conditions. Because it was not possible to determine the optimal ET model for each of China's highly diverse regions and parameterize each model for each region, we used the mean ET estimated by the seven models to represent water consumption by grasslands.

Because the price of natural resources should follow marginal benefit theory (i.e., prices increase with increasing scarcity or increasing demand), we assumed that the cost of water and land should increase with decreasing supply (i.e., with increasing resource scarcity) in a given region. To estimate the different costs, we used the following equation:

$$V_{it} = b - a\, P_{it} \tag{4}$$

where V_{it} is the value of the resource (here, water) and P_{it} is the resource endowment per person in province *i* in year *t*, and *b* and *a* are curve-fitting parameters.

To estimate these coefficients, we assumed that the water price in Beijing, the region of China with the most expensive water, was 1.2 RMB m^{-3} in 2014 based on data from the South-to-North Water Diversion Project (Liu and Yang, 2012), and assumed that the water price in Tibet, which has the highest per capita water availability in China and thus the lowest price, was 0.17 RMB m^{-3} (National Bureau of Statistics, 1978–2015National Bureau of Statistics, 1978National Bureau of Statistics, 1978–2015). In this analysis, we have assumed that urban and domestic uses (the uses for which the two previous prices were obtained) are the primary competing uses for the water, and thus provide a reasonable proxy for the opportunity cost of using that water for grassland irrigation. In this context, the source of the water (e.g., precipitation versus wells) is not important. For any province where reliable water cost data was available, we used that data to represent the water cost. Where data was unavailable, we interpolated linearly between the Beijing and Tibet values using Eq. (4). (Determining