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Original Research Article

The impact of mining changes on surrounding lands and ecosystem service value in the Southern Slope of Qilian Mountains

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ABSTRACT

Surface mining can destroy the ecosystems and result in the loss of the service values of the surrounding ecosystems through direct occupation and indirect impact on the neighboring ecosystems. In the Qinghai-Tibet Plateau (QTP), where the ecological system is fragile and sensitive, the mining development has led to a series of ecological and environmental issues and social controversies and aroused much attention in the recent years. This paper selected six typical open-pit coal mines in the Southern Slope of Qilian Mountain (SSQM) in the northern QTP to monitor the changes of mining extent and the surrounding land cover from 1975 to 2016 and estimate the surrounding ecosystem service value (ESV) changes by considering spatial adjacency effects. A trade-off analysis is finally employed to compare the mining benefit and ESV loss associated with the development of mining areas. Results showed that the mining areas increased in six regions, especially after year 2000, which resulted in the decline of wetland, meadow and grassland areas. The regional ecosystem service values decreased with the expansion of mining areas, and the spatial adjacency effect has accelerated with the loss of ecosystem service value, especially the service value of wetlands and hydrological regulation function. The larger the mining extent and unit area value of the surrounding ecosystem services, the greater the ESV loss due to mining activities, and the dispersive and disorderly exploitation of mining areas will also result in a rapid increase in ESV loss, while mining development in areas with lower ESV is more beneficial. The results of this paper are instructive to the development and planning of mineral resources in Qinghai-Tibet Plateau and other ecologically fragile areas.

1. Introduction

Surface mining is a process that removes the soil and rock attached to the surface of a deposit (Erener 2011; Townsend et al., 2009). Compared to the underground mining method which minerals are transported through shafts or tunnels, surface mining can destroy the vegetation and affect the hydrological cycle, and even wholly destroying the ecosystem (Demirel et al., 2011; Erener 2011). In addition, it also has the potential to cause a number of ecological and environmental problems such as surface subsidence, vegetation degradation, soil degradation, surface and groundwater pollution and loss of biodiversity (Erener 2011; Huang et al., 2014; Miao and Marrs 2000; Townsend et al., 2009). Coal mining has expanded rapidly on the southern slopes of the Qilian Mountains (SSQM) in the northern Qinghai-Tibet Plateau (QTP) of China in recent years and the largest open pit coal mine in the Qinghai Province is in this region. It has aroused considerable attention because of the ecological and environmental damage to a nature reserve and the headwaters of several major rivers (Ottery 2014), but there have been few studies on how changes in mining in the SSQM area have changed the environmental conditions. The environmental degradation caused by mining development can be evaluated if there are long-term data available for changes in the total area mined.

Ecosystem service (ES) is defined as “the contributions of the ecosystem to human well-being” and the link between biophysical reality (ecological system) and human well-being (socio-economic system) (Haines-Young and Potschin 2010), it is provided by ecosystem functions derived from ecosystem properties, and considered beneficial to humans. Ecosystem service value (ESV) is the willingness to pay for ecosystem goods and benefits that people create or derive from ecosystem services and quantified in a economic perspective. Costanza et al. (1997) estimated the global ecosystem service value by

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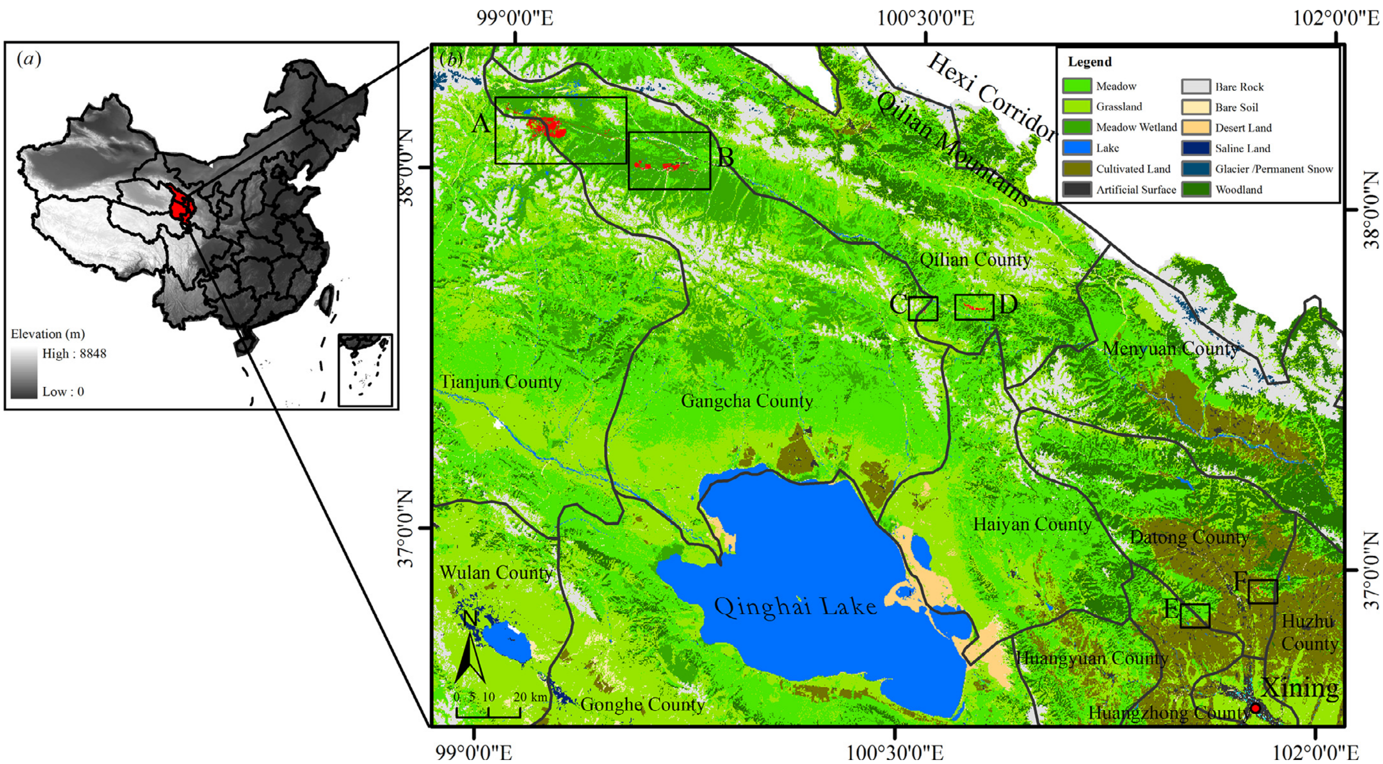

Fig. 1. Location map of surface mining areas of southern slope of Qilian Mountains.

constructing unit area values of different ecosystem services in diverse ecosystems. Xie et al. (2008) suggested that the values should be modified to adjust to the actual situation in China. In their method, the equivalence factors table of different ecosystems and ecosystem services was composed by a standard equivalent factor (unit area of cropland was assigned to 1) and other equivalent factors that evaluated by expert knowledge based on their relative importance to the standard equivalent factor, then the unit area ecosystem service values (also called value coefficients) table was calculated by the actual price of the grain and the other corresponding equivalence factors. Then, the final ESVs of China were obtained by multiplying the unit area ecosystem service values and their actual area.

Mining development not only results in the loss of ecosystem service value through direct destruction of ecosystems but also has an indirect impact on the surrounding ecosystem. For example, the accumulated waste residue could have a negative effect on the water quality and the vegetation health. In addition, pollution (such as noise and dust) generated during the excavation process will also affect surrounding plants and animals (Chukwuma 2011; Lin et al., 2005). These adverse effects not only affect the single element or function of the ecosystem adjacent to the mining area but also impair the regional ESV. Therefore, the influence of the mining area on the value of adjoining ecosystem service cannot be ignored. In the study of ecosystem service flow and ecosystem health, the spatial neighboring interaction or effect was recognised as vital part of the relationship between landscape pattern and ecosystem services (Bagstad et al., 2013; Peng et al., 2017). For example, for the supply of ecosystem services, the benefits that adjacent natural vegetation or wetland are more significant than those of desert, bare land and artificial types, this is because natural vegetation types (or wetland) are often functional areas or source regions in the ecosystem service flows (Bagstad et al., 2013; Marulli and Mallarach 2005), or because of the functional diversity of their properties (Palacios-Agundez et al., 2015; Santika et al., 2015).

However, empirical studies of this effect are rare at present, and its quantification is usually based on expert scoring. Marullia and Mallarach (2005) defined an affinity matrix ranged from 0–1 to represent the potential of connections in energy, information and matter between different ecosystems. Peng et al. (2017) introduced the coefficient of spatial neighboring effect to characterize the adjacency effect on ecosystem services according to the land use types. In their study, the coefficients of ecosystem services for different land use types were assigned in 0–1, and the spatial neighboring effects were represented by the coefficients of spatial neighboring ranged from −5% to 5%, which indicates the promotion or inhibition of the service value of the target ecosystem type by the adjacent ecosystems. However, the impact of mining areas on the value of adjacent ecosystem services still needs further study.

Mining activities in QTP have always been full of controversy due to its fragile and sensitive ecosystems; the opponents consider that the damage of mining activities to the environment is far higher than the economic benefits, while supporters believe that the development of the mining area will contribute to the economic development of the region. However, there are few studies focus on the relationship between loss of ESVs and economic benefits during the development of mining area, and the results could guide the planning and development of the mining area. Therefore, a trade-off analysis of the mining income and ESV loss in SSQM is needed to provide a reference for the rational development of coal mines and other resources in the region.

Based on the theory of remote sensing technology and ecosystem service value and trade-off analysis, the specific objectives of this study are to: (1)monitor surface mining and the surrounding land cover changes from 1975 to 2015; (2)evaluate the changes of ecosystem service value under the influence of spatial adjacency effect of mining areas; (3) analyze the trade-off between economic benefit and ESV loss due to mining development; and (4) provide implications for sustainable development of the mining area.

2. Data and methodology

2.1. Study area

The SSQM is in the north-eastern part of the Qinghai-Tibet Plateau,