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Effects of urbanization on ecosystem service values in a mineral resource-based city

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ABSTRACT

A dramatic urbanization process might severely impact the ecosystem service functions in resource-based regions, affecting the quality of life for the residents. Taking Huaibei, a mineral resource-based city in China during the period of 1990–2011 as a case study, this paper evaluates its level of urbanization and analyzes the relationship between the level of urbanization and ecosystem service values, using Xie's ecosystem unit service value table. The results show that Huaibei's level of urbanization has progressed gradually during the study period while ecosystem service values increased at the earlier time period but dropped in later time. Moreover, the relationship between the level of urbanization and ecosystem service values over time exhibits an irregular inverse "U" shape. From 1990 to 2002, Huaibei's ecosystem service value rose with the growing urbanization level, while it declined from 2003 to 2011. This indicates the possible effect that urbanization weakens the study area's ecosystem service function by altering ecosystem structure, ecological habitat and ecosystem circulation process. This paper provides the evidence why a coordinated development of urbanization and ecosystem service function is needed towards the sustainable management of mineral resources area.

Introduction

As a fast-paced urbanization process often leads to economic growth, it may also cause serious ecological problems in resource-based regions (Shen & Zhou, 2014). This is especially apparent in that urbanization often severely impacts the ecosystem service functions in a region. It is estimated that urban areas take up 1%–6% of the earth surface and occupy a large share of the world's resource input and landfill areas. The world's population living in urban areas in 2010 represents 52% of the total population (World Bank, 2012). The ecosystem provides service functions for human beings and other living creatures. As a contrasting force, the process of urbanization affects the functioning of local or even the global ecosystems (McDonald, 2009). At a very local scale, the pattern of urban development determines how native biodiversity may be impacted and where invasive species become established. Alberti (2005, 2008) conceives that urban ecosystem is a complex system that is coupled with human-natural systems. In most urbanized areas people are the dominant force that modifies ecosystems. These modifications often produce hybrid social-ecological landscape patterns and processes.

Urban ecosystems affect the quality of life for the majority of the planet's residents. They are characterized by their complexity, heterogeneity, and hybridity. As these attributes involve many knowledge domains, an interdisciplinary solution to reducing negative impacts on ecosystem by urbanization is desired. Urbanization modifies land cover and natural land use, exerting an important influence on regional ecological structure (Kreuter, Harris, Matlock, & Lacey, 2001). Faulkner (2004) investigates the effects of urbanization on structure and function of forest wetland, and states that the development of urbanization would alter the regional hydrogeological conditions, impact nutrient cycling of ecosystem, destroy the ecological environment, decrease species of plants, large invertebrates, amphibians and birds, and reduce ecosystem service functions of habitat, flood storage and water quality maintenance. Buyantuyev and Wu (2009) find that changes in urbanization of land use improve net primary productivity of ecosystem in dry areas during drought years, increasing the spatial heterogeneity of net primary productivity. Eigenbrod et al. (2011) study the relationship between urbanization and three kinds of ecosystem services (flood control, agricultural products provision and carbon storage). They discuss different magnitudes of influence

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that urban densification and urban sprawl impact on the above three kinds of ecosystem services. They conclude that urbanization affects not only the supply and use of ecosystem service function, but also the number, behavior and distribution of users.

There is strong evidence that modern metropolis has climatic and hydrologic consequences that increase with city size and urban densities (Berry, 2008). This means even if environmental impacts from the developed countries could be significantly reduced, rapid development of urbanization in the Third World would still cause serious threats to the global environment (Alberti, 2008; Ding, 2003). Therefore, influences of China's urbanization on ecosystem service value have been attracting considerable attention (Zhong, Mitchell, & Huang, 2014). For ways to measure these influences, Zhang, Li, and Xie (2010) suggests approaches to transferring the evaluation results of ecosystem services into the traditional cost-benefits analyses of land use strategy, and to establishing a comprehensive accounting system for ecosystem services and natural capital.

Although there is a growing list of studies in this area, most of the existing literature focuses on the effects of urbanization on ecosystem service functions through regional spatial heterogeneity, primary productivity, and change in values (Wu, Ye, Qi, & Zhang, 2013). Moreover, most of the existing literature focuses on studying watershed, forest, and wetland from the perspective of theoretical and quantitative research (Sridhar & Wan, 2014). However, there are only several studies that choose mineral resources areas to evaluate ecosystem service value and examine the relationship between urbanization and ecosystem service (Bian & Lu, 2013). To fill this gap, we consider in this paper a mineral resources area as the research object to explore the general rule of urbanization in mining areas and how that impacts ecosystem service values. This paper provides insights into the policy-making process that ensures a coordinated development of urbanization and ecosystem service function for the purpose for achieving conservation and management of ecosystem service function in mineral resources area.

Conceptual framework

Ecosystem service function is natural resources and assets for the survival of humans. In general, it is referred to as the direct or indirect benefits derived from ecological system to human beings and environments. It includes importing useful material and energy to the economic social system, receiving and transforming waste from economic social system, and providing services directly to members of human society, such as clean air, water and other comfortable resources that people enjoy (Daily, 1997). Notably, there are three factors that provide and maintain ecosystem service function. They are: ecological system structure, ecological habitat and ecosystem circulation process. The complete ecosystem structure is the premise to maintaining ecosystem service function. That is, any damage or loss of ecological structure would affect the realization of ecosystem service function. Ecological habitat is the regional environment for biological individuals, population, and community to survive. It is the foundation for realizing ecosystem service function value. In the process of ecosystem circulation, many functions and values are generated via ecosystem structure, such as water cycle, biogeochemical cycle, gas regulation, climate regulation, and raw materials production (OuYang & Zheng, 2009).

The urbanization process often alters the composition, structure and function of ecosystem, thus affecting ecosystem service function. Urbanization involves various elements, including population, economic system, landscape, and lifestyle, through influencing three main factors of regional ecosystem structure, ecological habitat and circulation process to impact ecosystem service function (Vitousck, Mooney, Lubcheneo, & Melillo, 1997). The flow chart that shows how urbanization affects ecosystem service function is shown in Fig. 1.

In the process of *population urbanization*, increases in urban population size and density create additional demands for food and products, and consumption of energy and water resources. On the one hand, consumption of food and products and energy leads to a shortage of food and water resources and a reduction in coal, oil, natural gas and other mineral resources (Alberti, 2005). As a result, more efforts are made to exploit water resources and mineral resources, such as exploiting groundwater, building dam, and expanding mining area and strength. To some extents, these often impair the hydrological cycle and alter soil structure in an ecosystem (Berry, 2008). They affect ecosystem functions of hydrology regulation and soil conservation. On the other hand, excessive use of energy produces large amounts of waste water, waste gas and solid waste. Direct emissions of all these untreated pollutants would destroy the regional ecological environment. Specifically, the burning of coal, oil, natural gas and other mineral resources results in emission of large amounts of surplus heat (Bian & Lu, 2013). The burning of these materials also produces carbon dioxide, sulfur dioxide and nitrogen oxides gas that cause the greenhouse effect and despair the air quality. In addition, the discharge of waste water pollutes the rivers and lakes, reduces the water quality, and destroys the hydrological cycle. The accumulation of solid waste accelerates air pollution, water pollution and solid pollution in the accumulated area, which in turn affects the regional ecosystem function of gas regulation, climate regulation, hydrology regulation, waste regulation, and soil conservation (Buyantuyev & Wu, 2009).

In the process of *economic urbanization*, industrial development often proceeds rapidly and is often accompanied with an increasing demand for energy and resources and an expanding exploitation of mineral resources in resource-based regions (McDonald, 2009). Therefore, this process often results in an increase in high pollution industries such as mining and chemical industry (Bian & Lu, 2013). In the production process, the direct emissions of industrial waste gas, waste water, and solid waste reduce regional air quality and water quality, destroy the structure of soil and vegetation, cause a series of ecological environment problems, and damage the circulation process of ecosystem health. Extensive mining of mineral resources may lead to occurrences of large areas of land subsidence, vegetation reduction, changes in biological genetic variation, loss of biodiversity, water cycle disorders, pollution emissions, and land desertification. This destroys ecological structure, ecological environment and ecosystem material circulation in the mining area, and influences ecosystem function of climate regulation, hydrology regulation, waste regulation, soil conservation and biodiversity maintenance (Xiao, Xie, & An, 2003).

In the process of *landscape environment urbanization*, continuous outward expansion of a city and human activities brings changes in landscape patterns and regional land use classifications (Wu et al., 2013). With a growing population, part of the cultivated land, woodland and unused land would be transformed into construction land because of the increasing demands for residential land and transportation land, and construction land. Meanwhile, due to more demands for all kinds of agricultural products, part of the woodland and agricultural land would be turned into gardens, flower bases to grow fruits, vegetables and flowers that urban population needs. In addition, extensive mining and other human activities may cause land subsidence, where many subsided areas may even be gradually shifted into the wetland and water areas. Consequently, land use classifications in the study area are changed