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Identifying ecologically valuable and sensitive areas: a case study analysis from China

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ABSTRACT

The expansion of artificial constructs with the rapid economic development in China has led to ecological and environmental emergencies. The extent of the decline in natural resources and environmental conditions has recently been recognized. Identifying "ecological protection redlines", i.e. ecological limits, to guarantee ecological baselines for natural resources and ecosystem service functions would therefore help to coordinate economic development and to protect ecological resources in the coming years. We used remotely sensed and climatic data to delimit the ecological protection redlines for Zibo, a typical and important city in Shandong province, as an example to illustrate the principles and methodology of ecological protection redlines. The area of the ecological protection redlines for Zibo encompassed 1132.26 km^2, accounting for 18.98% of the total area of Zibo, were mainly distributed in the southern regions of the municipality, and consisted of extremely important areas of ecosystem service functions, including water conservation, both soil and water conservation, windbreaks and sand fixation, and the conservation of biodiversity. This area is extremely sensitive, and development is forbidden. Strict measures of management and control should be implemented to protect the long-term effectiveness of ecological protection redlines.

1. Introduction

Environmental and resource problems have become serious challenges in developing countries (Barbier & Hochard, 2016; López-Angarita, Roberts, Tilley, Hawkins, & Cooke, 2016; Matschullat, 2014). China has been under growing pressure in recent years to protect the environment and its resources as the economy grows and urban construction rapidly expands. National-level policies have thus been adopted by the Chinese government to ensure the sustainable provision of ecosystem services, including programs such as the Natural Forest Protection Program, Sloping Land Conversion Program, Desertification Combating Program around Beijing and Tianjin, Shelterbelt Network Development Program, Wildlife Conservation and Nature Reserve Protection Program, and Industrial Timberland Plantation Program, that aim to protect forests and grasslands to reduce the risk of natural disasters and to restore China's degraded ecosystems (Wang, Wang, Zhang, Lu, & Ren, 2015; Yin, 2009; Xi et al., 2014).

These policies have improved ecosystem services in recent years (FAO, 2010; MEP, 2007; SFA, 2009), but the challenges of environmental problems and dwindling natural resources remain (Fu, Zhuang, Jiang, Shi, & Lü, 2007; Xi, Bi, & He, 2012). The first China Ecosystem Assessment, which included all of mainland China from 2000 to 2010, reported that most of the ecosystem services evaluated increased during this period, suggesting that China's national conservation policies contributed substantially to the increase in ecosystem services such as carbon sequestration, soil retention, sand fixation, and water retention (Ouyang et al., 2016). The assessment, however, also found that the ecosystem service of habitat provision decreased by 3.1% in the decade (Ouyang et al., 2016) and that services decreased in some regions affected by few or no policies. Major environmental problems still plague China, e.g. air pollution (especially fog and hazy weather), water shortages and contamination, soil pollution, and lack of conservation of biodiversity (Guo, Guo, Fang, & Zhu, 2015; Sherwood, 2013; Yao, 2016; Yu, 2010), which the Chinese government has considered as key elements of environmental protection (The State Council of China, 2013, 2015, 2016).

The programs for the protection of the environment and its resources, however, focus on increased investment in afforestation on local scopes rather than the country as a whole. These measures have improved the degraded resources and environment to some extent but have not satisfied the pressing global demands of resource and environmental protection with the crises of ecosystem degeneration and

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decreasing biodiversity. Nationwide programs have been implemented to "draw a line" for delimiting areas where economic development needed to be coordinated with ecological and resource protection. These "redlines" were first established to protect cropland and forest, but new redlines are needed to safeguard China's vast biodiversity, environmental resources, and ecosystem services (Sang & Axmacher, 2016). To guarantee the baselines of regional and national security, regional boundary control lines were demarcated in some areas of key ecological function and in sensitive and fragile eco-environments, called "ecological protection redlines" (EPRs).

EPRs refer to areas that have special important functions of ecological spaces and are strictly protected. They are the baselines and lifelines for protecting and maintaining national ecological security, usually including areas with important ecological functions of soil and/or water conservation, maintenance of biodiversity, wind protection, sand fixation, coastal ecological stabilization, ecological protection of areas vulnerable to soil erosion or land desertification, prevention of rocky desertification, and soil desalinization (CGP, 2017a, 2017b). They can be defined as the ecological baseline areas needed to provide ecosystem services for guaranteeing and maintaining ecological, environmental, and biological safety (Bai et al., 2016). EPRs can be used as key areas for coordinated and improved ecological and environmental conservation by the Ministry of Environmental Protection and local governments (Lü, Ma, Zhang, Fu, & Gao, 2013).

An EPR is a systemic innovation of ecological environmental protection in China and is also a system of integrated management. It can be a spatial, areal, or managerial redline, encompassing the entire process of management from pattern to structure and then to the functional protection of ecosystems. An EPR is a baseline of ecological security and a risk line for managing ecosystems. The delineation of ecological protection redlines is therefore both a scientific and a management issue. The demarcation of EPRs for ecological and environmental management will facilitate institutional innovation for establishing an integrative system of ecosystem and environmental management in China (He, Yang, Guo, & Zhao, 2014; Rao, Zhang, & Mou, 2012).

The Chinese government defined the EPRs in 2011 and integrated them into the Environmental Protection Law (SCNPC, 2014). Some new EPRs are currently being established (Ma, Ma, Cai, & Nian, 2015; Si, Li, Zhang, Liang, & Sun, 2013; Wang, Sun et al., 2015; Wang, Wang et al., 2015). EPRs in the Beijing-Tianjin-Hebei region and the provinces (municipalities) along the Yangtze Economic Zone should be established by the end of 2017, EPRs in other provinces, autonomous regions, and municipalities should be established by the end of 2018, and the identification, demarcation, and calibration of the EPRs should be complete by the end of 2020 (Xinhua, 2017). EPRs will be established on a national scale, which is important for the protection of Chinese resources and environments during subsequent actions.

This study identified the EPRs for the city of Zibo in Shandong province, China, using ArcGIS 10.0 (ESRI) (http://www.esrichina.com.cn/softwareproduct/EI//), a platform for analyzing geographic information. Our objectives were to: (1) present the principles and methodology for delimiting EPRs, (2) delimit the EPRs in Zibo, and (3) discuss the challenges of EPR delimitation.

2. Materials and methods

2.1. Study area

The study area (35°55′20″–37°17′14″N, 117°32′15″–118°31′00″E) is in Shandong province, eastern China, in the lower reaches of the Yellow River, and includes five districts and three counties (Fig. 1). The total area is 5965 km^2, accounting for approximately 3.80% of the area of Shandong. The semi-humid and semi-arid continental climate of this temperate area has four distinct seasons. The mean annual temperature is 12.5–14.2 °C, and mean annual rainfall is 629.5 mm. Mountains, hills, and plains account for approximately 42.0, 29.9, and 28.1% of the area of Zibo, respectively. Zibo, an important industrial city in Shandong province and China, is rich in mineral resources. The annual regional gross domestic product was 400 000 million Yuan in 2014, 7.4% higher than the previous year. The gap between the supply and demand of resources, however, is growing due to extensive industrial production.

2.2. EPR classification and data collection

EPRs delimit the following important classified areas of national and regional ecological security (MEP, 2015).

(1) Areas with important ecological functions: areas where ecosystems are degraded but are very important to national or regional ecological security. These areas are needed to maintain and improve the ability to supply ecological products by limiting large-scale and intensive development of industry and urbanization. They contain areas for water conservation, soil conservation, windbreaks and sand fixation, and biodiversity conservation.
(2) Ecologically sensitive areas: areas that are especially susceptible to interference and environmental change or to the effects of potential natural disasters, which can have negative ecological effects due to improper developmental activities.
(3) Areas where development is forbidden: areas where natural and human resources are protected at various levels where other ecological functions need protection, and where development of industry and urbanization is prohibited.

We used land-use data, a digital elevation model, climatic data, and the normalized difference vegetation index (NDVI) (http://ladsweb.nascom.nasa.gov/data/search.html) to evaluate the ecological importance and sensitivity of the study area using a geographic information system (ArcGIS 10.0) (ESRI) and the matrix laboratory, MATLAB (MathWorks). The data for areas where development is forbidden, land-use data, and remotely sensed data were provided by the local authorities, including the forestry, agriculture, territorial resources, environmental protection, building, and water conservancy departments in Zibo. These data were entered into the ArcGIS environment for visualizing images.

2.3. General principles for EPR identification

The delimitation of EPRs should obey the principles of natural, ecological, economic, and social development. Key areas associated with ecosystem compositions and functions are scientifically estimated and discriminated. The area and implementation of EPRs should be assured and combined with the feasibility of the local situation of development and management. As an overall requirement for economic and social development and ecological environmental protection, EPRs must be in accordance with existing plans, such as planning principal functional districts, ecological-function areas, and land uses, which would reserve appropriate space for both development and environmental capacity. EPRs are mandated by the laws of environmental protection, prescribing that EPRs should be delimited and under rigid protection in the areas of key ecological function for national and regional ecological security, ecologically and environmentally sensitive areas, and other important ecological areas (SCNPC, 2014). The delimitation of EPRs is a dynamic process. As productivity and the capacity for ecological protection increase, EPRs can be optimized and adjusted to incrementally increase their scope (MEP, 2015).

2.4. Method of EPR identification

2.4.1. Identification of key ecological-function zones

EPRs emphasize relative importance, so the areas of key ecological

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