



Ecological zoning for regional sustainable development using an integrated modeling approach in the Bohai Rim, China



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ABSTRACT

China is in its quick social and economic development which has caused various environmental problems to some extent. Ecological zoning and distinguishing the highly-important ecological areas (also termed as the ecological red-line zone in this study) and protecting them from anthropogenic interference is an effective measure for regional environment protection and sustainable development. In this study, we applied an integrated modeling approach to implement the ecological zoning in the Bohai Rim for regional sustainability, and selected 12 single factors to calculate three integrated indicators: ecosystem sensitivity, ecosystem services and ecological risks. Based on three integrated indicators, we obtained the ecological zoning map with three zones for the study area, which are the highly-important ecological areas, the moderately-important ecological areas and the lowly-important ecological areas. The zoning result showed that the highly- and moderately-important ecological zones cover 23.2% and 37.9% of the Bohai Rim respectively, which should be protected. The remained lowly-important ecological zone covers 38.9% of the Bohai Rim, which can be used for economic and industry development. This study shows that the zoning approach is reasonable and instructive to guide and arrange the land use for regional sustainable development. Such an ecological zoning can greatly solve the conflicts between environmental protection and regional economic and industry development and further forms a safe ecological pattern. Two contributions of our work are that (1) our modeling approach is scientific, reasonable and meaningful for other planning works and can be used for reference to the regions and countries with similar situation, and (2) the zoning pattern mapped in our study is helpful to guide Bohai regional development and the safe arrangement of economic and industry development.

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1. Introduction

With the rapid development of human society in China, the environment was influenced significantly, particularly under heavy resource exploitation (Lu et al., 2004; Liu and Xie, 2005). In some areas, the resource utilization and development activities have been the threats to ecological security and human society, such as (1) eutrophication and further algae bloom in Taihu Lake, Jiangsu Province (Song et al., 2011) and Dianchi Lake, Yunnan Province (Liu, 2001); (2) red tide in the mouth region of the Zhujiang River, Guangdong Province (Huang et al., 2010); and (3) *Enteromorpha prolifera* outbreak in the Bohai Rim (Li et al., 2009). The situation is still accelerating (Luo and Liu, 2007), for instance, the serious haze often occurs recently in a large area in China (Zhang et al., 2013).

The Bohai Rim is a region surrounding a relatively closed ocean with only an eastern part connected with the Chinese Yellow Sea. Due to this, its sea-water is hardly to be renewed. Currently, the Chinese central government has defined it as an important economical developing region. Therefore, the development and protection on the terrestrial land plays a key role on controlling the quality of the sea-water as well as the coastal ecosystem. The coastal zone can easily attract a variety of competing use, which sometimes cause adverse impacts on each other (user-user conflicts) (Cicin-Sain and Knecht, 1998) or mostly create worse impacts on the coastal marine environment (user-environment conflicts) (Douver et al., 2007). So, many countries have made attempts to manage the conflicts (Tuda et al., 2014).

The Bohai Rim is important not only in China but also in the world. On one hand, it is the last ecological barrier for the Bohai Sea. On the other hand, this region is a major transit area and breeding ground for diverse migratory birds in East Asia – Australia (Yang et al., 1998; Jia et al., 2002). Due to these, the Bohai Rim

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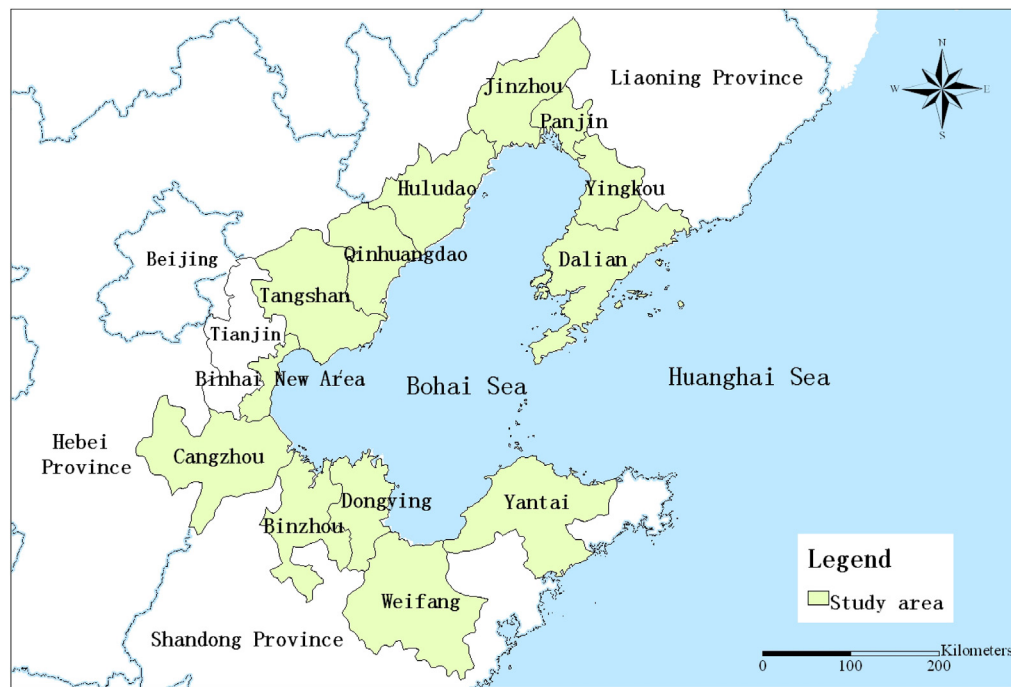


Fig. 1. Geographical location of the Bohai Rim and its cities, China.

has been identified as an important area for the conservation of wetland ecosystem in China and biodiversity in the world (MEP and CAS, 2008). However, the Bohai Rim is also the center of economic circle of the northeast Asia, which is vital to the economic development among North Korea, South Korea, Japan and China. This area gathered many industry enterprises, such as iron and steel, petrochemicals, equipment manufacturing industry, electric power plants, ship factories, construction materials and port cargo. According to Lu (1998) and Zhu et al. (2001a,b), plenty of industrial development activities in the Bohai Rim have brought this region a heavy burden on environment, which has led to discharging of waste water, waste gas, and waste residue. Moreover, intensification of human interference and population flowing and gathering had also created the significant negative effects on environment (Huang et al., 2008; Lin, 2009), particularly on the existing ecological problems, such as seawater intrusion, soil salinization and erosion, biodiversity losing and red tide. Therefore, guiding rational distribution of economic development, preventing further deterioration of environment and protecting the existing high quality ecological areas will have definitely a great significance for regional sustainable development.

The reasonable and effective spatial arrangement of conservation and development, i.e., ecological zoning, is urgent for the current rapid-changing society in China. The “ecological red-line zone” has been greatly emphasized by Chinese central government (SEPA, 2014; Liu et al., 2015) and termed as the areas with a good quality environment and need to be strictly protected and managed for maintaining the regional ecological security under a strong developing situation. Since the damage to ecological red-line zones will lead the nature and society loss much more, their identifying and protecting is a significant task to guide human activities in creation of equivalent economic value with lower environmental cost.

There has been some trying in China to identify the ecological areas for being protected from regional social-economic development. Due to that the protected areas and purpose are different, the distinguishing methods and evaluating factors used for zoning are various. In 2005, Shenzhen City designated many areas

with high ecological values as “basic ecological line zones of control”, including water source protection areas, scenic spots, nature reserves, basic farmland protection areas, forest and country parks, the mountain with a slope steeper than 25° , woodland, upland, trunk rivers, reservoirs and wetlands, ecological corridor and green spaces, islands and coastal land (SZG, 2005). In 2008, Kunming City delineated the areas which are relatively sensitive or with the most critical ecological functions as the ecological red-line zones in its new revision of land-use master plan (Fan et al., 2008). Moreover, Yunnan Province designated red-line zones for land use planning based on the ecological fragility and ecosystem services (Fu, 2008). In recent two years (2012–2013), the term of “ecological red-line” has become popular at both the governmental and public levels.

In fact, some world famous disaster cases have shown clearly that unreasonable spatial planning as well as management would result in serious damages to both human and nature. For instance, the Minamata disease, occurred in Minamata, Japan during 1950s, 1960s and even later time, was caused by the mercury-contained wastewater discharged (between 1932 and 1968) by the Shin Nippon Chisso Fertilizer Company (Chisso) directly into Minamata Bay, a small embayment on the Yatsushiro Sea (Balogh et al., 2015). This mercury pollution in Minamata Bay has caused not only the human health problem but also many other nature species died, such as fish, shellfish, cats and birds. The Rhine river pollution disaster happened in the mid of 20 century, which was caused by industries' wastewater discharging into the Rhine river. The wastewater contained thousands of pollutants. Its consequence were the death of so many aquatic species (Schwabach, 1989). Therefore, more countries paid attention to watershed and river-lake management, especially the developed countries, like the Rhine-related countries (Kiss, 1985; Milich and Varady, 1999). Spatial planning is a way to manage the location of industries and the development planning can help controlling the emission and discharging of wastes from industries. These management measures are also very necessary to the developing countries, such as China, India, Brazil, etc., which are facing the conflicts between social-economic development and environmental protection.

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