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Remote sensing investigation of anthropogenic land cover expansion in the low-elevation coastal zone of Liaoning Province, China

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ABSTRACT

Anthropogenic land cover (ALC) expansion is one of the major drivers of regional environmental change in coastal zones. With increasing scientific and political interest in regional aspects of global environmental changes, there is a strong impetus to better understand the patterns, causes and environmental consequences of ALC expansion in the low elevation coastal zone (LECZ) of Liaoning province, China, one of the areas in the nation with fast economic growth and high population density. Satellite remote sensing images (Landsat TM, ETM+ and OLI) obtained from 1990 to 2014 were employed to detect anthropogenic land cover changes. Based on the multi-period land cover data, we analyzed the process of ALC expansion and investigated the main drivers and regional implications of these changes. Our analyses documented 1317 km^2 growth of anthropogenic land cover, with industrial land having the largest expansion of 609 km^2. Dramatic aquaculture pond expansion (+565 km^2), residential land sprawl (+323 km^2) and arable land decline (−270 km^2) also characterized the changes in anthropogenic land covers. There are remarkably differences in ALC changes in the periods of 1990–2000 and 2000–2014: industrial land, aquaculture pond and residential land expanded slowly during the first period, but grew rapidly in the second period. Arable land experienced a small decline (−46 km^2) during 1990–2000 and a considerable reduction (−224 km^2) during 2000–2014. Socioeconomic factors such as increasing population, booming economy and changing policies were the most significant factors driving ALC expansion. Substantial expansion of ALC has caused extensive environmental issues in the study region.

1. Introduction

The coastal zone refers to a broad geographic area in which terrestrial and marine factors are mixed to produce unique landforms and ecological systems (Liquete et al., 2013). Coastal zones are biologically highly productive regions, and they play a vital role in regulating climate and the global ecosystem (Nemani and Running, 1996). Favourable biophysical and climatic conditions, as well as the ease of communication and navigation frequently offered by coastal sites, have attracted human settlement in coastal areas since prehistoric times (Kesgin and Nurlu, 2009). The coastal zone represents approximately 10% of the earth's surface, but its coastal low lands are inhabited by approximately 60% of the world population (Thia-Eng, 1993). Coastal zones are exposed to rapid urban growth, increasing population pressure, expansion of major industries, and extensive exploitation of marine resources (Ranu et al., 2014). Rapid urbanization and economic development spawn a host of complex resource use conflicts and environmental degradation in coastal zones (Lakshmi and Rajagopalan, 2000). Due to the vulnerabilities of the ecosystem and environment, as well as human intervention, the environmental and ecological processes of coastal zones are highly dynamic, complex and diverse (Prabaharan et al., 2010).

Coastal zones are being rapidly degraded globally by the anthropogenic impact (Myers and Worm, 2003; Lotze and Jackson, 2006) that occurs in developed countries such as Australia (Prahalad, 2014), the USA (Kennish, 2001), the Netherlands (Hoeksema, 2007), South Korea (Hong et al., 2010) and Japan (Suzuki, 2003), as well as developing countries such as China (Duan et al., 2016), Egypt (Shalaby and Tateishi, 2007) and India (Lakshmi

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and Rajagopalan, 2000). Coastal zones have been extensively exploited all over the world for industrial and aquaculture development along the coast, as well as for residential land expansion (Wang et al., 2014). While anthropogenic land cover expansion can provide new land for commercial, industrial or residential use, it has often resulted in immediate and severe damage to coastal ecosystems and the deterioration of marine environments (Primavera, 2006). Coastal wetland shrinkage and degradation, landscape fragmentation, habitat destruction, biodiversity loss, marine pollution and frequent harmful algal blooms are all coastal environmental issues caused by over-exploitation that have drawn considerable public attention and concern (Turra et al., 2013; Duan et al., 2016). Determining the pace, degree and magnitude of anthropogenic land cover expansion (ALC) and exploring its consequences will be of significance for nature conservation and the environmental management of coastal zones.

The coastal zone of China, located in the east of Asia and the west of the Pacific Ocean, is a highly developed economic region with a fragile ecological zone characterized by complicated natural environments (Cao and Wong, 2007). In China, 1.3 billion people are rapidly shifting from a largely agrarian society in the interior of the country to an industrial economy concentrated in coastal regions (He et al., 2013). China's 32,000 km of coastlines and 348,090 km^2 of seas sustain 28,000 species (plant and animal), support nearly half of its human population and 45 of its 60 major cities, and provide more than 60% of the gross domestic product (NBSC, 2014; Liu, 2013). A swelling population and an unbroken trend of urbanization and industrialization increasingly challenges the conservation of China's vast coastal zone (Lau, 2003). The coastal zone of Liaoning Province is an important part of the Bohai Economic Rim, which is one of three main economic rims of China and borders on the Democratic People's Republic of Korea. The unprecedented combination of economic and population growth has led to dramatic anthropogenic land cover expansion across the coastal zone of Liaoning, especially after China initiated the socialist market economic system in the early 1990s. Rapid and periodic assessment of the human imprint on and interaction with the land surface of the coastal zone of Liaoning Province is important for sustainable coastal management.

In this paper, we undertake a comprehensive investigation of anthropogenic land cover expansion in the low-elevation coastal zone (LECZ) of Liaoning Province using multi-temporal Landsat remote sensing datasets. The objectives of this study are to (1) adopt an effective method for extracting ALC of the low elevation coastal zone of Liaoning Province, China, in 1990, 2000 and 2014; (2) determine land cover dynamics associated with human activity and possible causes of ALC expansion; and (3) assess the environmental consequences of ALC expansion. Results from this study may further our understanding of anthropogenic land cover expansion as well as its ecological implications, and contribute to policy making toward reasonable development of the coastal zone and effective regional ecosystem management and services.

2. Materials and methods

2.1. Study area

In this study, the low-elevation coastal zone is defined as the

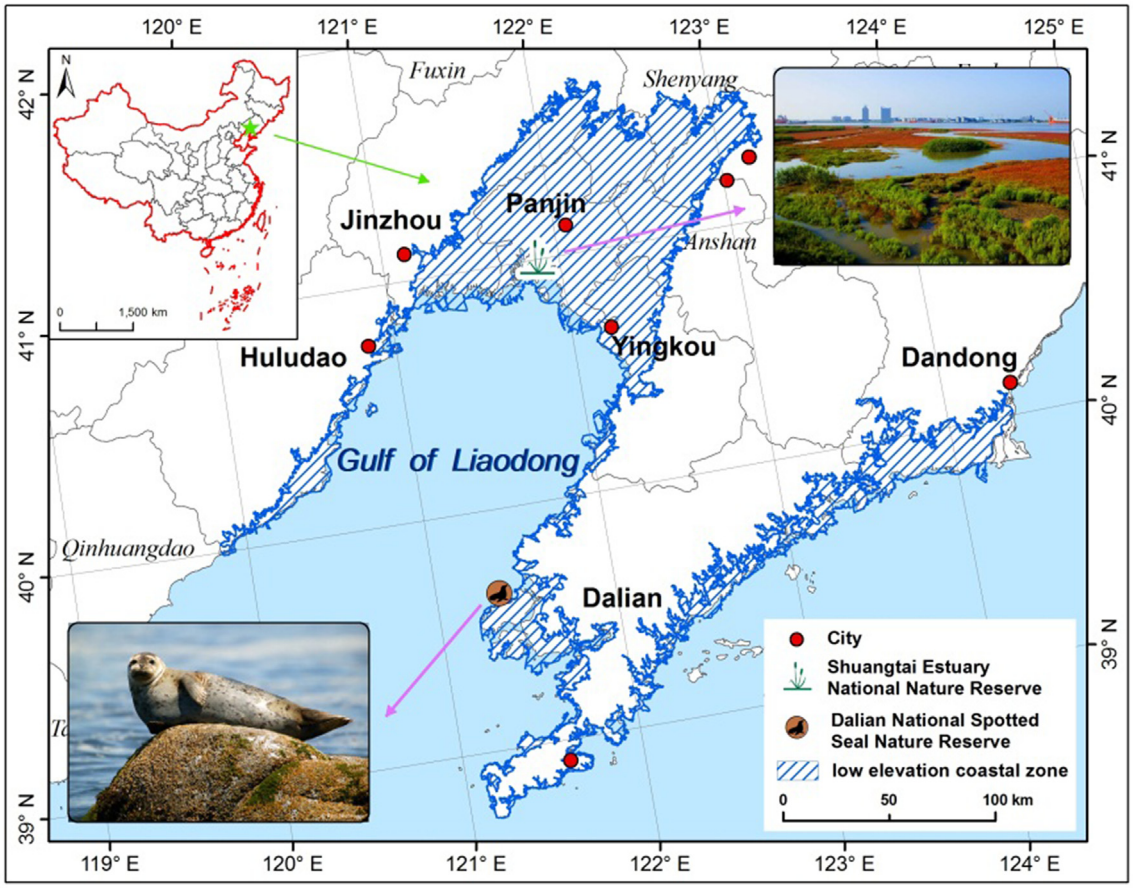

Fig. 1. Location of the study area.