Ocean & Coastal Management xxx (2017) 1–9

Contents lists available at ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Land-sea integration of environmental regulation of land use/land cover change-a case study of Bohai Bay, China

Gaoru Zhu [a, b, 1], Zhenglei Xie [c, *, 1], Huanqing Xie [d], Tuoyu Li [e], Xianli Gu [c], Xuegong Xu [b, **]

[a] Transport Planning and Research Institute, Ministry of Transport of the People's Republic of China, Beijing 100028, China
[b] College of Urban and Environmental Sciences, Key Laboratory for Earth Surface Processes (Ministry of Education), Peking University, Beijing 100871, China
[c] School of Geography & Environment, Jiangxi Normal University, Nanchang 330022, China
[d] School of Hydraulic and Ecological Engineering, Nanchang Institute of Technology, Nanchang 330099, China
[e] Editorial Department of Journal of Capital Normal University, Beijing, China

ARTICLE INFO

Article history:
Received 16 May 2017
Received in revised form
4 October 2017
Accepted 7 October 2017
Available online xxx

1. Introduction

The coastal zone is the transitional region between the terrestrial and marine environments, and it is one of the most productive ecosystems in the world (Olaniyi et al., 2012). Approximately 60% of the world's population is concentrated in the coastal zone (Chuai et al., 2016; Dennison, 2008). Coastal zones provide significant economic benefit in the form of ecosystem services and play a vital role in maintaining ecological balance and ensuring human welfare (Jiang et al., 2015; Portman et al., 2012; Zhu et al., 2016; Hadley, 2009). Coastal zones are often subject to significant impacts, from factors such as intense urbanization, industrial expansion, saltwater intrusion (Xie et al., 2012), and sea level rise (Cui et al., 2015; Niang et al., 2010). All these aspects can significantly increase coastal zone spatial and temporal heterogeneity (Gaglio et al., 2017; Yu et al., 2016; Xu et al., 2016a, b, c; He et al., 2014). In some regions, coastal land use has experienced rapid change over recent decades, and these land use/land cover changes (LULCC) can often cause ecosystem degradation and landscape fragmentation (Cai et al., 2016; Islam et al., 2016; Kesgin and Nurlu, 2009; Noori et al., 2016; Xie et al., 2010). Timely and accurate change detection of Earth's surface features provides the foundation to better understand relationships and interactions between human and natural phenomena, and thus, to better manage and use natural resources (Santhiya et al., 2010; Lu et al., 2004). Spatially explicit land use change detection is necessary to develop effective land management and planning strategies in many coastal areas (Kesgin and Nurlu, 2009). Li et al. (2013) studied the effects of time on the evolution of land use intensity and soil nutrient distribution in a reclamation zone of the Yangtze Estuary. They used the 'space for time substitution' method to test the impact of time on changes in land use intensity after reclamation.

There exists plenty of the material energy exchange between the ocean and land, makes the coastal zone form an integrated component including ocean-land change and lithosphere circulation, and the material and energy flow during the period of geological history. With respect to both biological communities and inorganic elements, there exists a transitional gradient between the terrestrial and ocean environments, often with no obvious boundaries from fresh to saltwater. Further, the terrestrial socio-economic system extends to the marine socio-economic system, including consideration of population, policy, industry, technology, and capital (Fig. 1). Better environmental regulation is necessary, both to increase positive environmental effects of land use change and to limit negative influences; this is the only way to realize sustainable coastal zone development.

The coastal zone in China covers 2.9% of the nation's territory, hosts 15% of the nation's population, and contributes 60.8% to the national GDP. In the 'Twelfth Five-Year' period, the heavy chemical industry expanded its coastal footprint and population migration toward the ocean accelerated; both factors placed increasing strain on coastal land resources (Zhu et al., 2016). China is now reclaiming land from the sea faster than any other country, with an average reclamation rate of 300 km^2/yr (Li et al., 2013). Bohai Bay has experienced land expropriation, land reclamation, reduced cultivated land, and unutilized land since the 1970s. These activities, especially ecological depletion and degradation, have had a significant negative impact on both terrestrial and ocean ecosystems, as well as the reclamation areas. Two industrial developments have

* Corresponding author.
** Corresponding author.
E-mail addresses: xzl2121@163.com (Z. Xie), xxg@urban.pku.edu.cn (X. Xu).
[1] Co-first author.

https://doi.org/10.1016/j.ocecoaman.2017.10.015

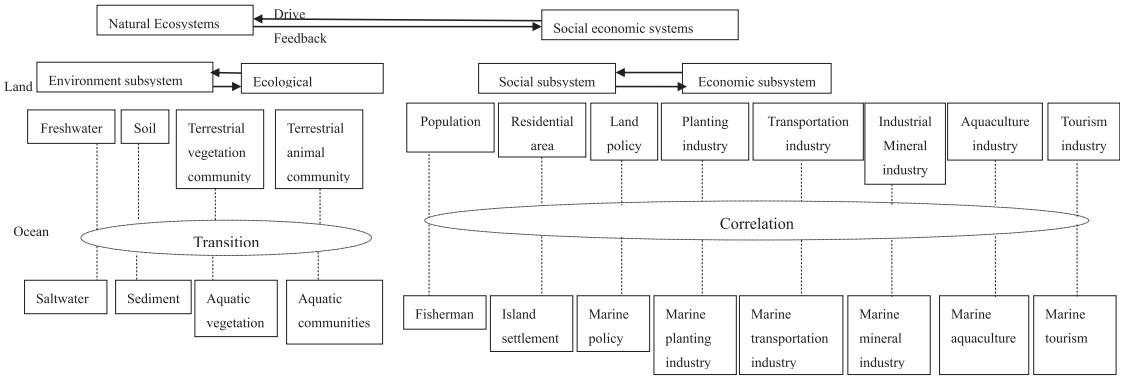

Fig. 1. The relationship and integration between terrestrial land and ocean.

been under construction on the western and northern coasts of Bohai Bay since 1994: Tianjin Binhai New Area, western Bohai Bay, and Caofeidian New Area, in the city of Tangshan, Hebei Province. Since 1970, there have been port construction projects and large-scale reclamation projects along the coastline of Bohai Bay, along with rapid population and economic growth. However, current coastal zone management focuses only on either the ocean or the terrestrial land, and research on land–ocean integration remains scarce. In fact, as previous coastal zone management policies lack an integrated perspective across various zones and land use types, their application would likely lead to the unreasonable spatial resource configuration.

Numerous studies have provided a foundation for understanding LULCC in coastal zones (Li et al., 2013). However, there remain gaps in our understanding of how to quantify zoning in land–ocean integration under the background of reclamation activities and intense coastal landscape changes, and how to quantitatively regulate the cumulative effects of these activities as they continue to expand. Although land reclamation has been practiced worldwide, spatial zonation in the reclaimed and terrestrial land with respect to land–ocean integration has not been sufficiently investigated. To ensure sustainable coastal land use, it is important to study spatial zoning through the perspective of land–ocean integration in coastal zones. In summary, the impact of land–ocean integration control measures are often more focused on a single aspect, and rarely on functional zoning for more integrated environmental control. To address some gaps identified in previous research, in this study we analyzed land use change in Bohai Bay, which has experienced rapid land reclamation and has uncoordinated management between ocean and land. The objective of this study is to provide useful information for better management of coastal ecosystems by: (1) analyzing the mechanism and necessity of integration of land and sea; (2) based on land use data and marine functional zoning data, to obtain the degree of land use integration and its change; and (3) using spatial clustering to partition the degree of land use, which reflects the land use function. Land and sea integrated environmental control measures for each functional area and sub-area are also proposed.

2. Study area

Bohai Bay is located along the north coast of China and has a total area of 22,133 km^2. The seabed terrain of Bohai Bay is inclined from the south to the north, and the sediments are derived from river sand (Fig. 2). The sediments were hydrodynamically sorted and distributed in irregular bands and plaques. The average temperature in January is −4 °C. The climate is characterized by the continental monsoon, and the climate exhibits four distinct seasons. Annual precipitation variation is high, and the bay is semi-enclosed. The main habitats are tidal mudflats, saltpans, and shrimp ponds, and a sea wall separates the saltpans and shrimp ponds from the mudflats. The silty beach water storage conditions are conducive to the development of salt industry. The area is characterized by numerous rivers and shallow tidal flats, which constitute a unique wetland landscape. The coastal area of Bohai Bay, north-western Yellow Sea, is internationally important for water birds migrating along the East Asia-Australasian Flyway, and the intertidal areas of the estuary system are protected. There are salt works, wharfs, oil fields, and industrial areas along the coast. Between 1994 and 2010, a total of 450 km^2 of offshore area, including 218 km^2 of intertidal flats, has been reclaimed along the bay for two industrial projects. The harbour area has the largest proportion, highlighting the role of the harbour and shipping centre in North China as well as the adjacent harbour industry agglomeration area (Zhu et al., 2016).

3. Material and method

Cloud-free Landsat 5 TM and Landsat 7 ETM+ at 30 m spatial resolution of the coastal zone from 1979, 1989, 1999, and 2008 in summer and autumn were collected to evaluate changes in coastal land use of Bohai Bay (Table 1). A visual interpretation method was applied to identify the land use/land cover change process. The primary processing of remote sensing data included image georeferencing, band combination, clipping and mosaic creation. Details on the data processing can be found in Zhu et al. (2016). The reference maps included the topographic map of 1981, the land use database compiled by the Institute of Geographic Science and Natural Resources, Chinese Academy of Sciences, and the land use plan status map. The interpreted images were verified by field investigation in July 2010 and June 2011 based on the identified points of land use with portal GPS. The accuracy of the visual interpretation of land use types is greater than 90%.

Based on the land use data of 1979 and 2008 and the marine functional zoning data, the land use intensity and its change of land-sea integration was obtained. The land use map (1979 and 2008, secondary land classes) was applied to derive land use information within the coastline. The marine functional zoning data of the coastal provinces of Bohai Bay were used to categorize the zones in the functional area beyond the coastline of the beach and the mudflat. The sources of these data include the 'Marine Functional Zoning of Hebei Province (2005–2010)', 'Tianjin Marine Functional Zoning (2008–2012)' (2008), and 'Shandong Marine Function Zoning'.

Please cite this article in press as: Zhu, G., et al., Land-sea integration of environmental regulation of land use/land cover change-a case study of Bohai Bay, China, Ocean & Coastal Management (2017), https://doi.org/10.1016/j.ocecoaman.2017.10.015