Ocean and Coastal Management 152 (2018) 62–69

Contents lists available at ScienceDirect

Ocean and Coastal Management

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

Accelerated expansion of built-up area after bridge connection with mainland: A case study of Zhujiajian Island

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ARTICLE INFO

Keywords:
Land use change
CLUE-S model
Sea-cross bridges
Zhujiajian Island

ABSTRACT

Around the world, numerous sea-cross bridges have been constructed for economic reasons. Land use of islands is often influenced deeply after the construction of bridges, especially with the increase of built-up area. Estimating the impact of sea-cross bridges on island land use becomes more and more urgent. In this study, the observed land use and the simulated land use without fixed link to mainland were compared to derive the impacts of sea-cross bridges. The main results are: 1) The land use of island is greatly affected by sea-cross bridges, with growth rate of built-up land 1.59 times higher than that before the bridge construction. Compared with the scenario of without fixed link to mainland, the centroid of built-up area moved about 500 m to the southeast, while the centroid of farmland moved nearly 300 m to the northwest; 2) After being connected with mainland, the island faced serious pressures, such as rapid land use change, explosive growth of tourists and continued stress on the ecosystem; and 3) Future construction of sea-cross bridges forming fixed link between island and mainland should take the economic development needs of the island, the carrying capacity of the island resources and the ecosystem responses into consideration, in addition to the feasibility analysis.

1. Introduction

More than half of the world's population is concentrated in the coastal zone (Barragán and de Andrés, 2015). As an important part of the coastal zone, island ecosystems play a key role in biodiversity conservation, vegetation cover, fishery production, nutrients and carbon cycling, fresh water supply and tourism (Cao et al., 2017; Spalding et al., 2014). But traffic conditions often restrict the economic growth of islands, making them a relatively lagging area in the coastal zone (Pan et al., 2016; Tzanopoulos and Vogiatzakis, 2011). By construction of the sea-cross bridges, the accessibility of the islands can be largely improved, and the transportation costs between islands and the mainland can be reduced. It is one of the most effective measures to develop the island economy. Many sea-cross bridges become fixed link between islands and the mainland, such as the Canadian Federal Bridge (McElroy, 2007), the Bahrain-Saudi Arabian Bridge (Madany et al., 1990) and some other sea-cross bridges in Japan and China. Although the impact of sea-cross bridges on island ecosystems is not yet clear, many new sea-cross bridges have been planned already. There are also concerns about the environmental impact, such as the Messina Strait Bridge, whose construction has been repeatedly delayed (Porta and Piazza, 2007). Due to the small size of area, limited resources and other characteristics, islands are more vulnerable to the impact of sea-cross bridges than the mainland. There have been some studies about the potential influence of sea-cross bridges on the islands (Cao et al., 2017; Tzanopoulos and Vogiatzakis, 2011).

Improvement in traffic conditions can improve the accessibility and play a key role in regional economic development (Munroe et al., 2014; Wu et al., 2012). For example the cross-bay or cross-river bridge had a significant “time-space compression” effect (Wu et al., 2012), changing the regional spatial relationship significantly. Bridges can enhance the mobility of people, material, information and services between isolated areas (Patarasuk and Binford, 2012). As a driving factor, the construction of roads and bridges can change the land use along the route and related areas (Liang et al., 2014). Due to the similarity of natural environment conditions, the presence of city hinterland can be a buffer zone for the construction of a cross-bay or cross-river bridge (Pan and Liu, 2014; Pan et al., 2016). But island is surrounded by sea water, with limited land area and resources, which means the island does not have enough space as buffer zone for disturbance. Under the influence of sea-cross bridges, the land use of island can be changed dramatically (Cao et al., 2017; Pan et al., 2016). Meanwhile, on account of the relative difficulty of island data collection and the lack of typical cases, few studies were focused on the impact of the sea-cross bridges on the island.

For the islands that have fixed link to mainland by bridges, most of

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https://doi.org/10.1016/j.ocecoaman.2017.11.014
Received 7 September 2017; Received in revised form 20 November 2017; Accepted 21 November 2017

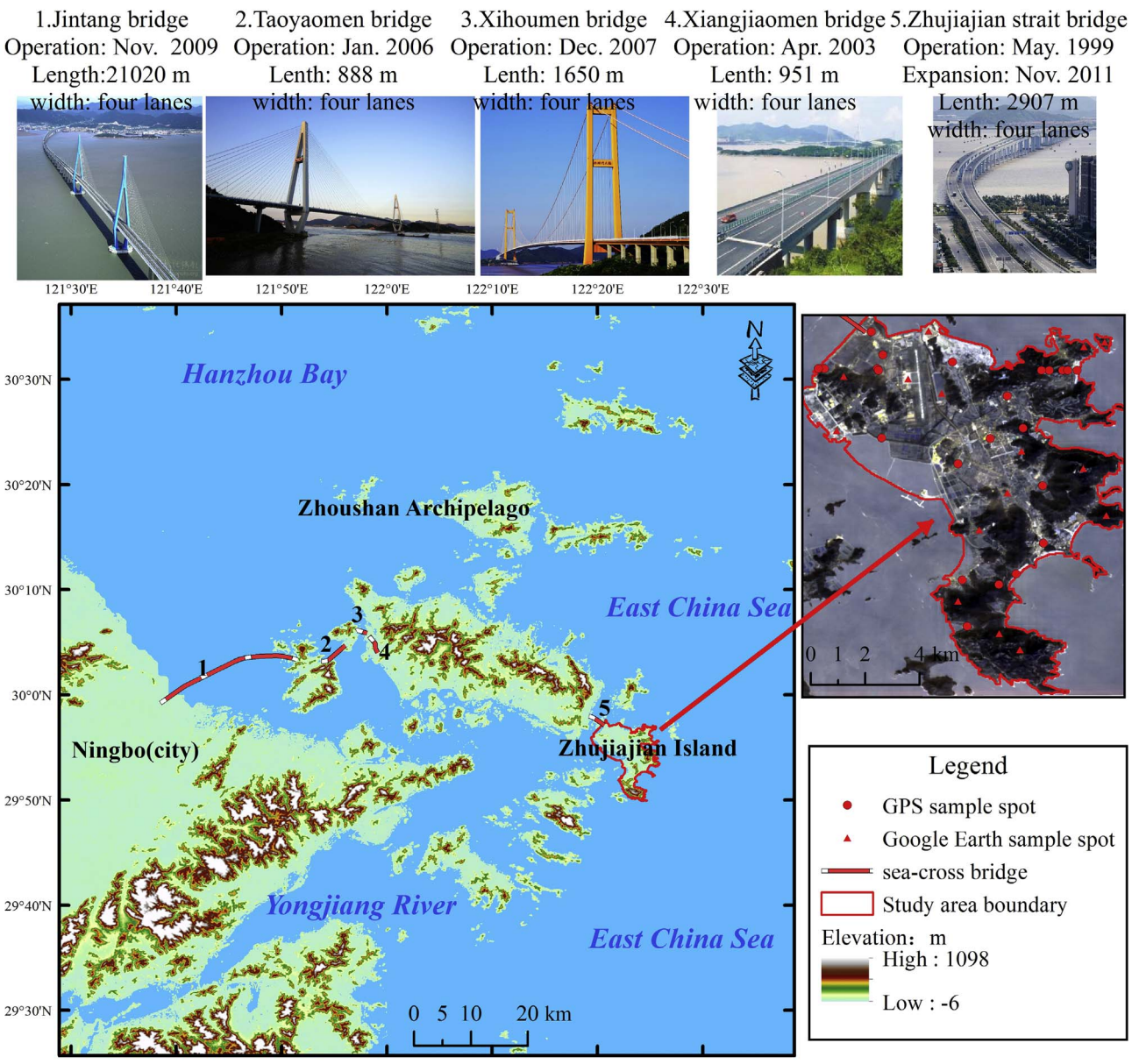

Fig. 1. Geographic location of the Zhujiajian Island.

the research focused on the safety of the design of the sea-cross bridges, the performance of the material, the operational monitoring and the prediction of traffic flow (Aljarad and Black, 1995; Gazder and Hussain, 2013; Li et al., 2004). The bridges will increase the traffic flow and result in the change of vegetation and environment quality (Jassim and Coskuner, 2017; Madany et al., 1990; Salim Akhter and Madany, 1993). Most of the world's islands are experiencing rapid urbanization and high-speed economic development, causing irreversible drastic changes in land use across the island (Saint-Béat et al., 2015). Earlier studies focused on land-use change in those islands having fixed link with main land suggested that the increase in tourism population and the improvement of transport infrastructure caused by sea-cross bridges are important driving factors leading to land use change (Pan et al., 2016). However, most studies only consider sea-cross bridges construction as an improvement in traffic conditions, and lack of quantitative assessment of land use change caused by bridges (Cao et al., 2017; Li et al., 2011; Pan et al., 2016). With the development of remote sensing technology, it has become an effective method to quantify island land cover changes (Racault et al., 2014). Cao et al. (2017) investigated the land use changes of the Zhoushan Islands based on remotely sensed images, and found that the sea-cross bridge was an important driving factor of land use change along with urbanization.

Along the coast of China, many islands have unique natural landscapes and marine cultures, which attract many tourists each year. But the traffic condition becomes a constraint on the tourism development of these islands. In recent years, Ningbo and Zhoushan, Shanghai and Chongming, Shanghai and Yangshan Port, Wenzhou and Dongtou, Fuzhou and Pingtan, Zhanjiang and Donghai Island have all established fixed link to the mainland through sea-cross bridges. The impact assessment of land use change caused by the construction of the bridges becomes imperative. The objective of this study is to evaluate the effect of sea-cross bridges on the land use of island after being connected with the mainland. To exempt the influence from the bridges between islands, we chose Zhujiajian Island at the end side of Zhoushan Island Mainland Link Project. Based on remote sensing and geographic information technology, combined with Conversion of Land use and its Effects at Small extent (CLUE-S) model (Verburg et al., 2002), the land use of 2015 was simulated. Then the simulated map was compared with the observed map to quantify the influences of sea-cross bridges on the island land use change.