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

Zuolun Xie, Xiuzhen Li*, Yunqing Zhang, Shenliang Chen

State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai 200062, PR China

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

* Corresponding author.
E-mail address: xzli@sklec.ecnu.edu.cn (X. Li).

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

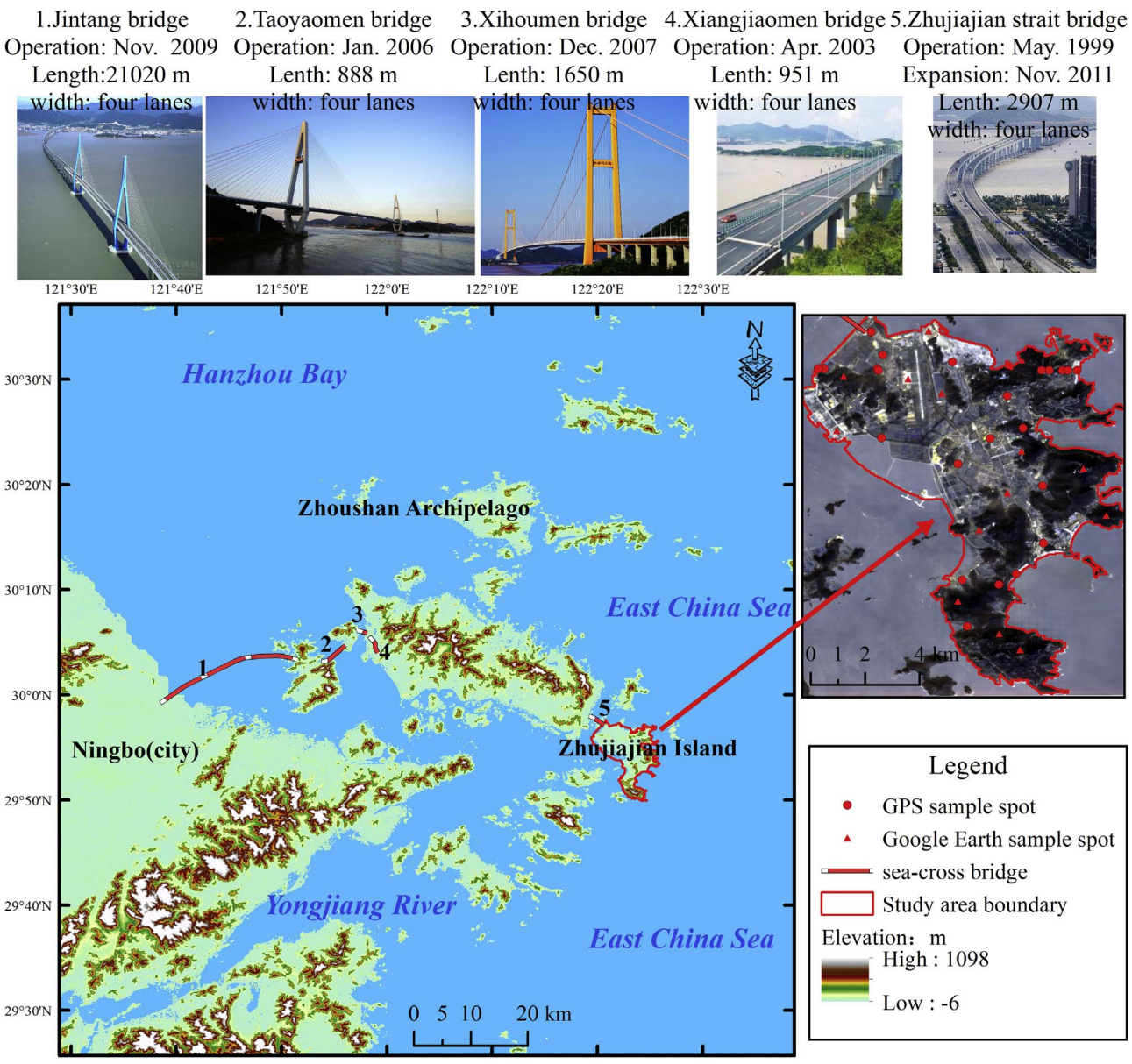

Fig. 1. Geographic location of the Zhujiajian Island.

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.

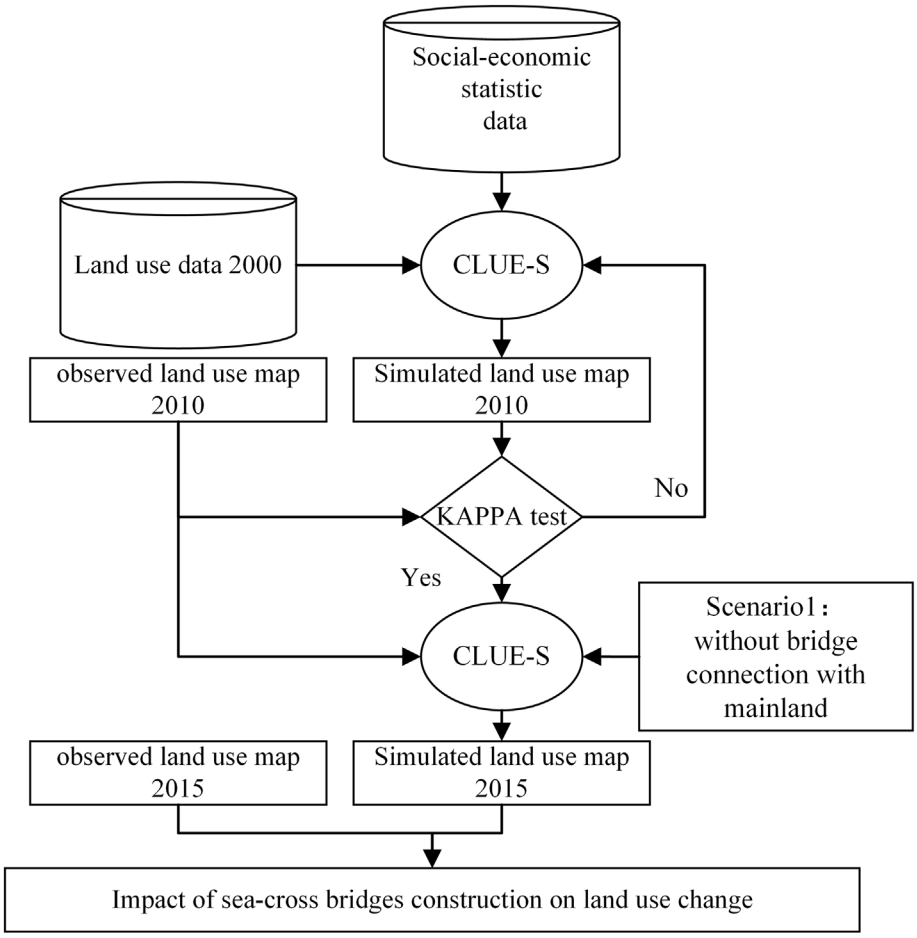

Fig. 2. Flowchart of the methodology adopted in this study.

2. Materials and methods

2.1. Study area

Zhujiajian Island is the fifth largest island in China's largest archipelago Zhoushan with an area of about 70 km^2 at 122°19′–122°25′ E and 29°49′–29°57′ N. This island belongs to the subtropical monsoon climate, and is susceptible to typhoon in summer. The average annual rainfall is 1200–2000 mm. In 2015 the island population was 34, 000. The terrain is high in the south and low in the north, with many attractive sceneries, such as beautiful beaches, lush forests, distinctive fishing villages and vast seaside baths. The beautiful sceneries on Zhujiajian island attract millions of tourists every year, while the International Sand Sculpture Festival contributes one third of the tourist population. The construction of airport, sea-cross bridges and ferry terminals largely improved the traffic conditions. Meanwhile Zhujiajian Island is a transit hub for tourists to the Buddhist holy island - Putuo Mountain. Actually, the east part of Zhujiajian Island has become a part of the Putuo Mountain Scenic Spots Group. Over 5 million tourists visited Zhujiajian Island in 2015.

2.2. Data sources

In this study, Landsat images with cloud cover less than 10% between July and September were selected as remotely sensed data sources. Based on the study purpose and the traffic open time of the sea-cross bridges (Fig. 1), the images of 2000 (Thematic Mapper, TM), 2010 (TM) and 2015 (Operational Land Imager, OLI) were selected. Images were corrected for geometric distortion in ENVI 5.1. The TM data were geometrically rectified by selecting ground control points and projected into Xi'an 1980 coordinates. The root mean square error (RMSE) among the control points selected on the ground was less than one pixel (Lasanta and Vicente-Serrano, 2012). Based on land use properties in the study area and current land use classification in China, the land-use map was classified into 8 land-use categories, including built-up area, farmland, forest land, salt field, ponds and canals, grassland, beach and sea water. Based on the spectral characteristics of different features and field survey data, the interpretation scheme was established, and the remotely sensed data was interpreted interactively. To assist the interpretation, we sampled 25 field survey plots around the island using GPS, and sampled 16 accuracy assessment plots in the study area based on Google Earth in the summer of 2015 and 2016 (Fig. 1). According to the field work and Google Earth data, the interpretation precisions were 91.0% (2005), 93.0% (2010) and 92.2% (2015) respectively from the positional accuracy evaluation. Socio-economic data and historical map were obtained from Statistical yearbook and the local government.

2.3. Methods

According to the study area and objectives, 14 factors were chosen to simulate the land use change. Those factors include slope, aspect, distance from the rural road, distance from the main road, distance from the reservoir, distance from the forest, distance from the beach, distance from the built-up area, distance from the farmland, distance from the coastline, distance from the sea-cross bridges, distance from the administrative center, and the influence of tourists. The tourist influence is the overlay of distance from the scenic spots, the tourist density, and the distance from the Wugongsi ferry terminal, which is the connection point to the holy Buddhist island Putuo Mountain.

Based on the CLUE-S model, the land use in 2010 was simulated

based on the land use in 2000, and the land use in 2015 was simulated based on the land use in 2010. KAPPA test was carried out to compare the simulated results and the actual land use to verify the suitability of selected driving factors and the applicability of the model. Further on, simulated land use map under the assumption of no connection to mainland was compared with the observed land use in 2015 to assess the influence of sea-cross bridges on island land use change (Fig. 2).

The CLUE-S model can be divided into two modules: spatial and non-spatial processing (Verburg et al., 2002). The non-spatial module was mainly used to process land use structure data. At the same time, the spatial module can realize spatial simulation of land use in different scenarios. The study shows that the CLUE-S model can perform a land use simulation at different scales with resolution between 20 m and 1000 m (Overmars and Verburg, 2007; Verburg and Overmars, 2009; Verburg et al., 2002, 2004). For the construction of the land use drive model, the rationality of driving factors is examined with the Relative Operating Characteristics (ROC) test (Verburg et al., 2002). To explore the influence of the bridge on the land use change of the island, a hypothesis scenario of "without sea-cross bridge" is constructed and the land use is simulated in this situation.

3. Results

3.1. Impact of sea-cross bridges construction on built-up area related land use types

Based on the GIS spatial analysis tool, the land use change between 2000 and 2015 was analyzed. The Zhoushan Mainland and Islands Link Project was finished in December 2009. The land use of Zhujiajian Island is shown in Table 1. Compared with the land use before the construction of bridges, the built-up area expanded quickly. During the period from 2000 to 2010, the built-up area increased at 32.7 ha yr^{-1}, while during 2010–2015 the growth rate was 52 ha yr^{-1}. Due to the increased demand for built-up area from tourism, the growth rate of built-up area became much faster than before. Meanwhile the farmland shrank during this period, and the area of ponds and canals increased quickly during 2000–2010, and decreased slowly during 2010–2015.

The transfer matrix was used to explore the transformation between different land use types (Table 2). The main source of built-up area was farmland, and part of farmland was transferred to ponds and canals. Some ponds and canals were used for aquaculture. The transition rate of farmland to built-up area was 17.6 ha yr^{-1} before being connected with mainland, and 24 ha yr^{-1} after the construction of sea-cross bridges. There was a clear expansion of built-up area and the loss of other land use types such as farmland after being connected with mainland. Therefore, the construction of sea-cross bridges will increase the built-up area quickly, accompanied by the transformation of other land use types to built-up land.

3.2. Simulation of land use change based on CLUE-S model

According to the land use situation of Zhujiajian Island, 14 factors were selected for the simulation on island change, the factors were defined in section 2.3, this study. Binary logistic regression analysis was applied in the analysis of the driving factors for land use patterns in 2010 and 2015. The results were verified with ROC, and showed that the simulation precision was greater than 0.8 (Fig. 3), which meant the selected land use drivers can be used to simulate land use changes (Pontius and Schneider, 2001) (see Fig. 4).

Based on the logistic regression model, the CLUE-S spatial analysis module was used to calculate the possibility of every pixel that may be transferred to the next land use type (Luo et al., 2010; Overmars and Verburg, 2007; Verburg et al., 2002). Based on the land use data in 2000, the CLUE-S model was used to simulate the land use map in 2010. Then the model was used to simulate the land use map in 2015 based on the observed land use map in 2010. By comparing with the observed land use map in 2010 and 2015, KAPPA test was used to verify the simulation accuracy. The results showed that the accuracy of the simulation was 74.8% in 2010 and 75.3% in 2015, which indicated that the CLUE-S model can be used to simulate the land use change of Zhujiajian Island.

3.3. Comparison of observed land use and the simulated land use without connection to mainland

Based on the historical analysis of land use change in Zhujiajian Island, and the interview with the local government, the scenario of "without sea-cross bridges" was set up (Table 3) to simulate the land use map of 2015 in CLUE-S model.

The land use map in 2015 was simulated under the assumption of without sea-cross bridges. Compared with the simulated land use in 2015, the actual land use boundaries are straighter due to the land use policy and land use planning under human intervention. Meanwhile, in the simulated map there was a hot spot of built-up area expansion in the northern part of the island because of the proximity to the airport, and the harbor to the tourist hotspot Putuo Mountain Island. But in reality the construction of sea-cross bridges largely increased the number of tourists at the southern part of Zhujiajian Island such as Nansha Beach and Daqingshan forest park, which increased the demand for built-up area in the southeast of the Zhujiajian island (Fig. 5). The centroid analysis of farmland and built-up area (Fig. 6) showed that the construction of sea-cross bridges shifted the built-up area center to the southeast by nearly 500 m, while the farmland moved 300 m to the northwest. Compared with the scenario of without fixed link to mainland, built-up area expanded more quickly by 9.7%.

Table 1
Land use change of Zhujiajian Island from 2000 to 2015.

land use type	2000		2010		2015	
	area (ha)	Percentage (%)	area (ha)	Percentage (%)	area (ha)	Percentage (%)
built-up area	543	8.0%	870	12.8%	1130	16.6%
farmland	1680	24.7%	1355	20.0%	1235	18.2%
salt fields	258	3.8%	246	3.6%	200	2.9%
Ponds and canals	298	4.4%	448	6.6%	414	6.1%
forest land	3077	45.3%	3049	44.9%	3012	44.4%
grassland	185	2.7%	301	4.4%	306	4.5%
beach	63	0.9%	63	0.9%	60	0.9%
sea water	687	10.1%	459	6.8%	434	6.4%
total	6791	100.0%	6791	100.0%	6791	100.0%

Table 2
Transition matrix of different land use types of Zhujiajian Island from 2000 to 2015 (ha).

period	land use type	built-up area	farmland	salt fields	Ponds and canals	forest land	Grass land	Beach	sea water
		area (ha)							
2000–2010	built-up area	543	0	0	0	0	0	0	0
	farmland	176	1355	24	125	0	0	0	0
	salt fields	20	0	222	16	0	0	0	0
	Ponds and canals	12	0	0	286	0	0	0	0
	forest land	28	0	0	0	3049	0	0	0
	grassland	8	0	0	21	0	156	0	0
	beach	0	0	0	0	0	0	63	0
	sea water	83	0	0	0	0	145	0	459
2010–2015	built-up area	870	0	0	0	0	0	0	0
	farmland	120	1225	0	0	0	10	0	0
	salt fields	38	0	200	0	0	8	0	0
	Ponds and canals	34	0	0	414	0	0	0	0
	forest land	27	10	0	0	3012	0	0	0
	grassland	13	0	0	0	0	288	0	0
	beach	3	0	0	0	0	0	60	0
	sea water	25	0	0	0	0	0	0	434

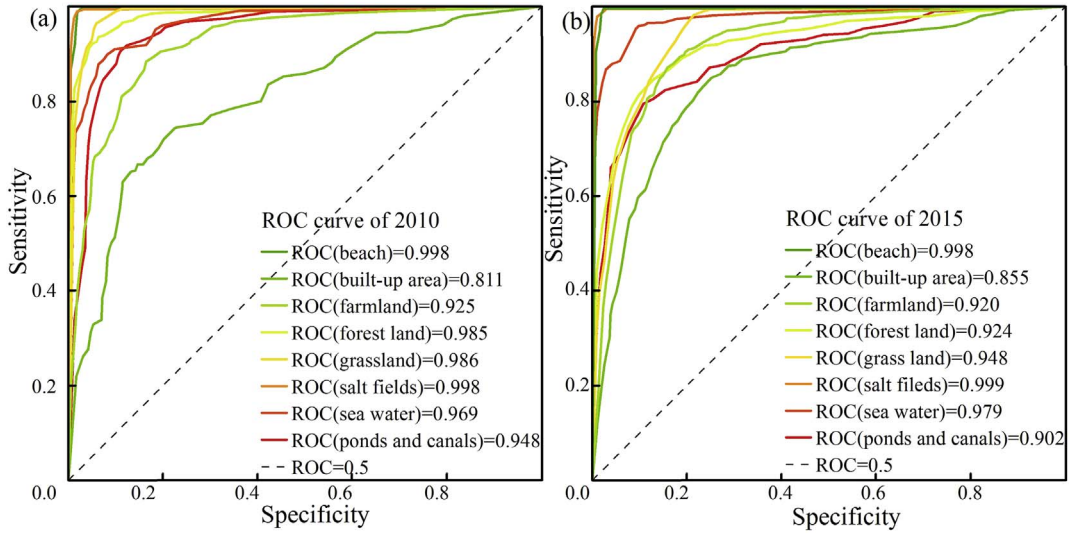

Fig. 3. ROC curves to validate models of land use change on the Zhujiajian island : (a)ROC curve of 2010, (b) ROC curve of 2015.

4. Discussion

4.1. The impact of bridge construction on land use of island

Due to the relative isolation of islands, the material and energy flow between islands and the mainland are relatively slow and inefficient, with traffic conditions the largest limitation factor for island development (Pan et al., 2016; Tzanopoulos and Vogiatzakis, 2011). The construction of sea-cross bridges can improve the accessibility of islands, leading to a rapid economic development on islands. Along with the urbanization process, dramatic land use changes will occur (Cao et al., 2017; Li et al., 2011; Tzanopoulos and Vogiatzakis, 2011).

After the sea-cross bridges were completed, the land use change of Zhoushan archipelago became faster than ever, especially with the increase of built-up area (Cao et al., 2017; Pan et al., 2016). Due to the limitation of data availability, the quantitative analysis of the influence of bridge construction on island land use is relatively rare (Cao et al., 2017). In this study, CLUE-S model was used to simulate the land use map under the hypothesis that Zhujiajian Island was not connected with mainland though sea-cross bridges. Then the simulated map and the observed map were compared to quantify the influence of bridges on island land use. Compared with the period before the bridges were constructed, the expansion rate of the built-up area was nearly 60% higher after being connected with the mainland. Compared to the simulated map in the same period, built-up area expanded larger by 9.7%. On the other hand, the accuracy of land use data interpretation will directly affect the simulation results of CLUE-S model, and further affect the reliability of impact analysis (Benz et al., 2004). In this study, the reliability of the image interpretation is ensured by combining historical image data, field survey, and some regional high resolution Google images to ensure the reliability of the analysis results (Tayyebi et al., 2014).

4.2. The impact of land connection on the development of island tourism

Land use change caused by the construction of sea-cross bridges has two direct and indirect effects. The direct change was the bridges construction and their supporting infrastructure which can be easily detected. The indirect impact was mainly induced by the dramatic increase in the number of tourists along with the rapid economic growth (Cao et al., 2017; Lambin and Meyfroidt, 2011; Lasanta and Vicente-Serrano, 2012; Xiao et al., 2006). Taking Zhujiajian Island as an example, the fixed link between the island and Ningbo city was completed in November 2009. Compared to 2009, the number of tourists in 2010 increased by 135%. In the year of 2015 more than 5.58 million tourists visited the island, which was 196 times of the local population (Fig. 7).

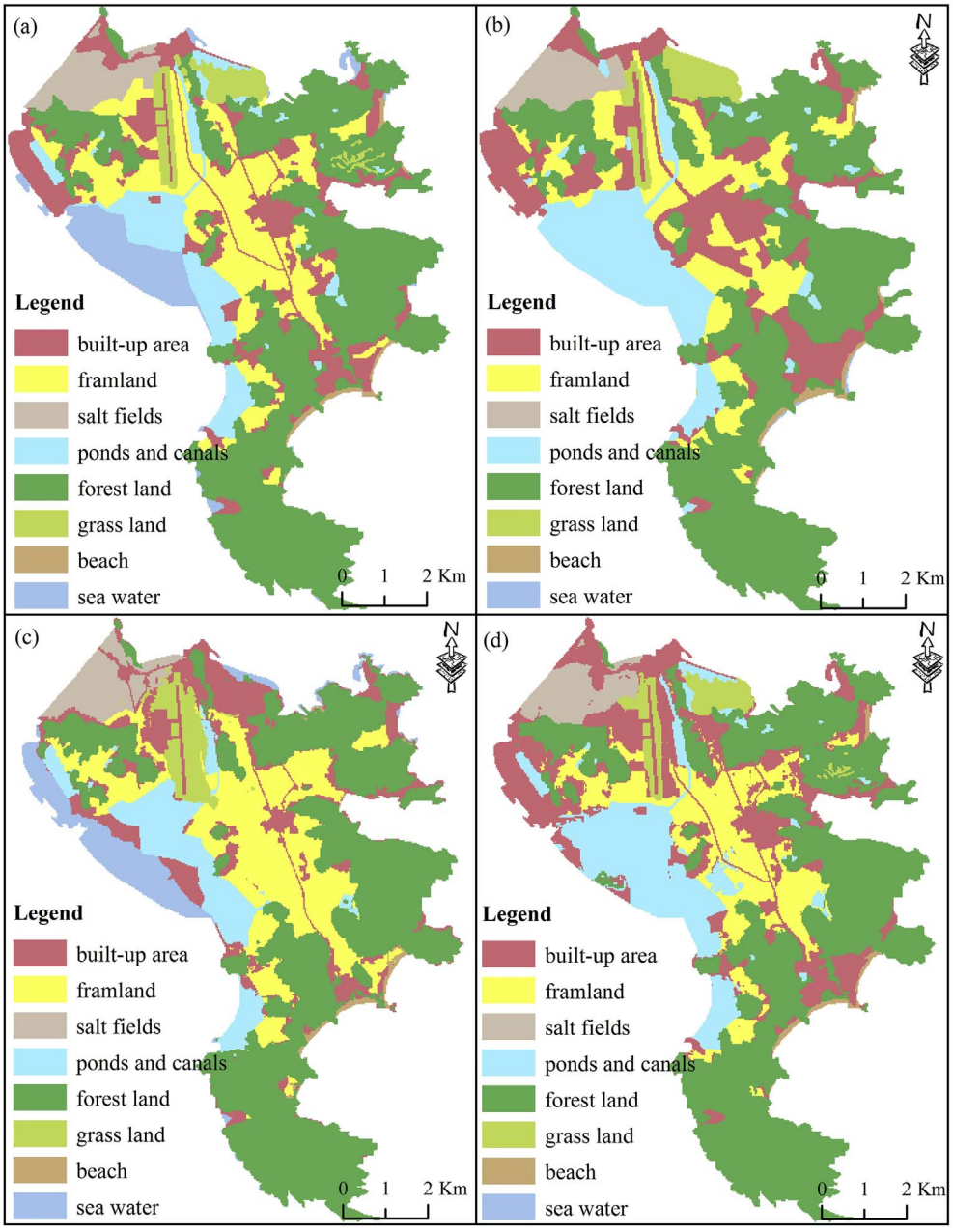

Fig. 4. Observed land use and simulated land use for the corresponding period : (a) 2010 Observed land use map; (b) 2015 Observed land use map; (c) 2010 Simulated land use map; (d) 2015 Simulated land use map.

Table 3
Land requirements under assumption without sea-cross bridge with mainland in 2015.

	Land use of 2010		Land use of 2015 under "no bridge" assumption	
	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)
built-up area	870	12.81	1030	15.17
farmland	1355	19.95	1335	19.66
salt fields	246	3.62	200	2.95
Ponds and canals	448	6.60	414	6.10
forest land	3049	44.90	3012	44.35
grassland	301	4.43	306	4.51
beach	63	0.93	60	0.88
sea water	459	6.76	434	6.39

Obviously, the GDP increased rapidly with the explosive development of tourism.

The rapid increase in the number of tourists, and the rapid economic development along with the urbanization process have led to a rapid increase in the demand for various types of resources, especially the land resource (Cao et al., 2017). Land resources are relatively limited for the island which is surrounded by sea water (Cao et al., 2017; Spalding et al., 2014). The expansion of built-up area on island will change the land use structure and result in marine reclamation land, thus increase the vulnerability of island ecosystems.

4.3. Decision making on island connection with mainland

The fixed link of island to mainland can not only promote the socio-economic development of the island, improve the living standards of the people on the island, but also can develop tourism industry (Munroe et al., 2014; Wu et al., 2012). The decision about whether an island should have a fixed link to the mainland must be based on the

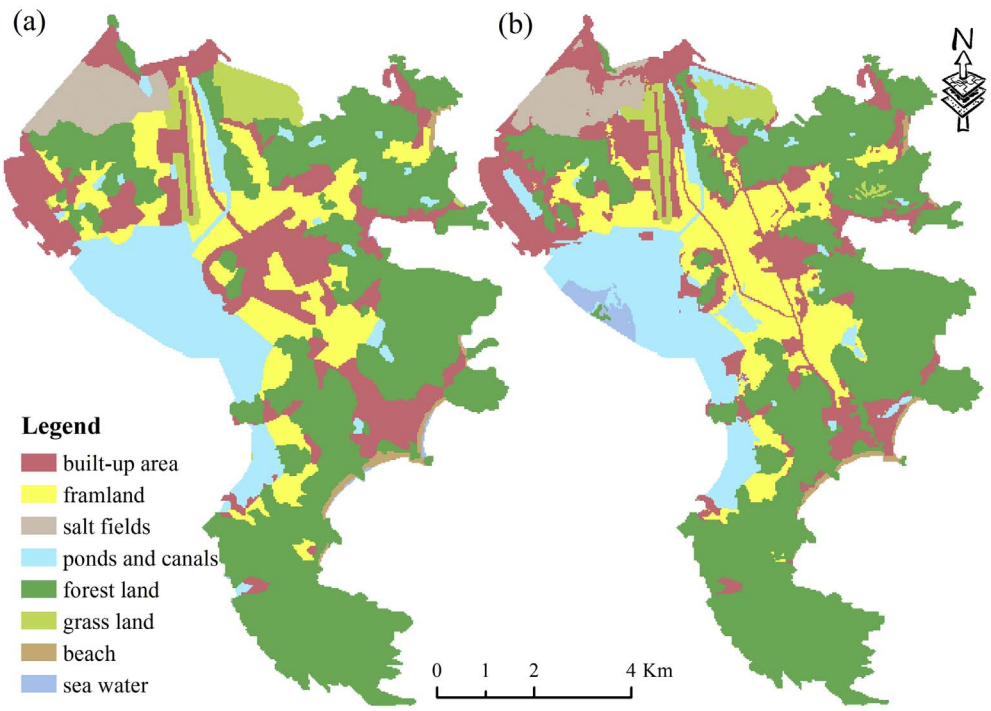

Fig. 5. Observed land use comparison with simulated land use map : (a) Observed land use in 2015; (b) simulated land use map under the assumption of without sea-cross bridge connection in 2015.

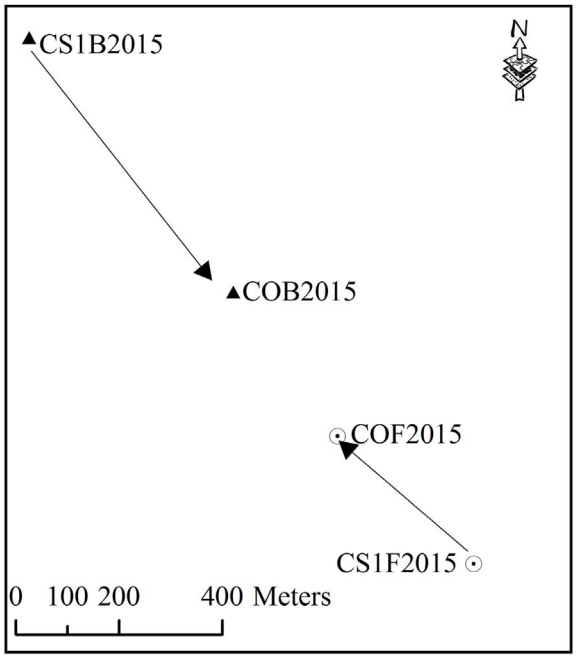

Fig. 6. Centroid of farmland and built-up area in different scenarios: COF2015 means centroid of obseved farm land in 2015, CS1F2015 means centroid of simulated farm land under scenrio 1 without sea-bridge connection with mainland in 2015, COB2015 means centroid of obseved built-up area in 2015, CS1B2015 means centroid of simulated built-up area under the scenrio without sea-bridge connection in 2015.

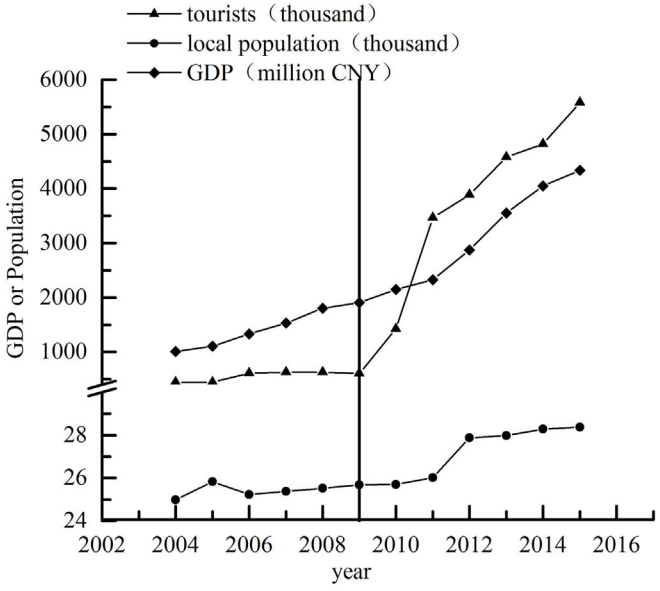

Fig. 7. The main social and economic indicators of Zhujiajian island.

comprehensive evaluation of island carrying capacity (Cao et al., 2017; Spalding et al., 2014). Many aspects should be considered before the construction of sea-cross bridges, for example, whether the island has sufficient land resources to cope with the high-speed expansion of built-up area after being connected with the mainland; whether the island has enough tourism resources to host the throng of tourists; whether the ecosystem can retain steady state under the pressure brought by bridges and tourists; whether the island could supply enough freshwater; whether sewage and waste disposal capacity were enough, and whether the special habitat on the island can sustain. The cost of bridges is also huge. Therefore, the sea-cross bridges must be planned carefully in advance.

5. Conclusion

CLUE-S model was used to simulate the land use map under the hypothesis that Zhujiajian Island was not connected with the mainland via sea-cross bridges. Then the simulated map and observed map was compared to quantify the influence of bridges on island land use. The main conclusion is: After being connected with the mainland, the land use structure of Zhujiajian Island has changed rapidly, and the built-up area expanded quickly. The construction of sea-cross bridges shifted the built-up area center to the southeast, while the centroid of farmland moved to the northwest. Compared with the land use change before the

construction of sea-cross bridges, the annual expansion rate of built-up area increased by more than half. The farmland shrinkage was accelerated. The tourism and economy developed rapidly along with quick urbanization after being connected with the mainland. The decision of island fixed link project should be based on the assessment of economic development needs and ecological capacity. Of course, the impact of sea-cross bridges on the island is very complicated, and needs further investigation on the ecosystem responses and long-term social-economic influence.

Acknowledgement

This study was supported by Public Science and Technology Research Funds Projects of Ocean (No. 201505012).

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ocecoaman.2017.11.014.

References

Aljarad, S.N., Black, W.R., 1995. Modeling Saudi Arabia-Bahrain corridor mode choice. J. Transp. Geogr. 3, 257–268.
Barragán, J.M., de Andrés, M., 2015. Analysis and trends of the world's coastal cities and agglomerations. Ocean Coast. Manag. 114, 11–20.
Benz, U.C., Hofmann, P., Willhauck, G., Lingenfelder, I., Heynen, M., 2004. Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. ISPRS J. Photogramm. remote Sens. 58, 239–258.
Cao, W., Li, R., Chi, X., Chen, N., Chen, J., Zhang, H., Zhang, F., 2017. Island urbanization and its ecological consequences: a case study in the Zhoushan Island, East China. Ecol. Indic. 76, 1–14.
Gazder, U., Hussain, S.A., 2013. In: Traffic Forecasting for King Fahd Causeway Using Artificial Neural Networks, Computer Modelling and Simulation (UKSim), 2013 UKSim 15th International Conference on. IEEE, pp. 1–5.
Jassim, M.S., Coskuner, G., 2017. Assessment of spatial variations of particulate matter (PM10 and PM2. 5) in Bahrain identified by air quality index (AQI). Arab. J. Geosci. 10, 1–14.
Lambin, E.F., Meyfroidt, P., 2011. Global land use change, economic globalization, and the looming land scarcity. Proc. Natl. Acad. Sci. 108, 3465–3472.
Lasanta, T., Vicente-Serrano, S.M., 2012. Complex land cover change processes in semi-arid Mediterranean regions: an approach using Landsat images in northeast Spain. Remote Sens. Environ. 124, 1–14.
Li, D., Maes, M.A., Dilger, W.H., 2004. Thermal design criteria for deep prestressed concrete girders based on data from Confederation Bridge. Can. J. Civ. Eng. 31, 813–825.
Li, X., Lin, T., Zhang, G., Xiao, L., Zhao, Q., Cui, S., 2011. Dynamic analysis of urban spatial expansion and its determinants in Xiamen Island. J. Geogr. Sci. 21, 503–520.
Liang, J., Liu, Y., Ying, L., Li, P., Xu, Y., Shen, Z., 2014. Road impacts on spatial patterns of land use and landscape fragmentation in three parallel rivers region, Yunnan Province, China. Chin. Geogr. Sci. 24, 15.
Madany, I.M., Ali, S.M., Akhter, M.S., 1990. Assessment of lead in roadside vegetation in Bahrain. Environ. Int. 16, 123–126.
McElroy, J.L., 2007. A world of islands: an island studies reader. Geogr. Rev. 97, 304–306.
Munroe, D.K., McSweeney, K., Olson, J.L., Mansfield, B., 2014. Using economic geography to reinvigorate land-change science. Geoforum 52, 12–21.
Overmars, K.P., Verburg, P.H., 2007. Comparison of a deductive and an inductive approach to specify land suitability in a spatially explicit land use model. Land Use policy 24, 584–599.
Pan, J., Liu, W., 2014. Quantitative delimitation of urban influential hinterland in China. J. Urban Plan. Dev. 141, 04014033.
Pan, Y., Zhai, M., Lin, L., Lin, Y., Cai, J., Deng, J.-s., Wang, K., 2016. Characterizing the spatiotemporal evolutions and impact of rapid urbanization on island sustainable development. Habitat Int. 53, 215–227.
Patarasuk, R., Binford, M.W., 2012. Longitudinal analysis of the road network development and land-cover change in Lop Buri province, Thailand, 1989–2006. Appl. Geogr. 32, 228–239.
Pontius, R.G., Schneider, L.C., 2001. Land-cover change model validation by an ROC method for the Ipswich watershed, Massachusetts, USA. Agric. Ecosyst. Environ. 85, 239–248.
Porta, D.D., Piazza, G., 2007. Local contention, global framing: the protest campaigns against the TAV in Val di Susa and the bridge on the Messina Straits. Environ. Polit. 16, 864–882.
Racault, M.-F., Sathyendranath, S., Platt, T., 2014. Impact of missing data on the estimation of ecological indicators from satellite ocean-colour time-series. Remote Sens. Environ. 152, 15–28.
Saint-Béat, B., Baird, D., Asmus, H., Asmus, R., Bacher, C., Pacella, S.R., Johnson, G.A., David, V., Vézina, A.F., Niquil, N., 2015. Trophic networks: how do theories link ecosystem structure and functioning to stability properties? A review. Ecol. Indic. 52, 458–471.
Salim Akhter, M., Madany, I.M., 1993. Heavy metals in street and house dust in Bahrain. Water Air Soil Pollut. 66, 111–119.
Spalding, M.D., Ruffo, S., Lacambra, C., Meliane, I., Hale, L.Z., Shepard, C.C., Beck, M.W., 2014. The role of ecosystems in coastal protection: adapting to climate change and coastal hazards. Ocean Coast. Manag. 90, 50–57.
Tayyebi, A., Perry, P.C., Tayyebi, A.H., 2014. Predicting the expansion of an urban boundary using spatial logistic regression and hybrid raster–vector routines with remote sensing and GIS. Int. J. Geogr. Inf. Sci. 28, 639–659.
Tzanopoulos, J., Vogiatzakis, I.N., 2011. Processes and patterns of landscape change on a small Aegean island: the case of Sifnos, Greece. Landsc. Urban Plan. 99, 58–64.
Verburg, P.H., Overmars, K.P., 2009. Combining top-down and bottom-up dynamics in land use modeling: exploring the future of abandoned farmlands in Europe with the Dyna-CLUE model. Landsc. Ecol. 24, 1167–1181.
Verburg, P.H., Schot, P.P., Dijst, M.J., Veldkamp, A., 2004. Land use change modelling: current practice and research priorities. GeoJournal 61, 309–324.
Verburg, P.H., Soepboer, W., Veldkamp, A., Limpiada, R., Espaldon, V., Mastura, S.S., 2002. Modeling the spatial dynamics of regional land use: the CLUE-S model. Environ. Manag. 30, 391–405.
Wu, Q., Zhang, H., Ye, Y., SU, Y., 2012. The impact of Hong Kong-Zhuhai-Macao bridge on the traffic pattern of Pearl River Delta. Acta Geogr. Sin. 67, 723–732.
Xiao, J., Shen, Y., Ge, J., Tateishi, R., Tang, C., Liang, Y., Huang, Z., 2006. Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing. Landsc. urban Plan. 75, 69–80.