# Evolution of reclamation sustainable development in Zhuhai city based on triangle model

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**Key word:** Evolution of sustainable development; triangle model; reclamation; Zhuhai city

**Abstract.** With the development of economy and population growing, the need for sustainable land use evaluation reclamation domain in Zhuhai city. This article reflects the economic, ecological, 21 indexes from all sectors of society, construct the economic feasibility to (EI) (NSI), the social acceptability and the ecological rationality (NREI) as evaluation index of reclaimed land sustainable use appraisal triangle model, the domain of Zhuhai city in 2004-2014 reclamation land sustainable status and trends were analyzed and evaluated. The results have showed that: reclamation domain trend of sustainable utilization of land use in Zhuhai relatively strong from unsustainable to sustainable. There are two conclusions .One is that the triangle model in terms of sustainable utilization evaluation reclamation has certain feasibility. Second is that reclamation region land use in Zhuhai city has become increasingly reasonable.

## Introduction

With the development of urban economy, the increase of population and the acceleration of urbanization, the demand for land is increasing. Lack of land always led to the intensification of the contradiction between people and land, so it will affect the development of economy and society[1].This situation is extremely serious around the coastal areas. In order to ease the contradiction between people and land in coastal cities, more and more coastal city government consider that reclamation is a important mean to solve the contradiction between people and land. So whether the reclamation activities bring us economic, social and ecological benefits, this will be the focus of this paper.

The reclamation activities have close contact with other industries. Large scale reclamation activities will bring great economic benefits, but it will also bring the ecological and social impact. Now, more and more researchers at home and abroad study on reclamation. there is no doubt that the reclamation activities are important. The reclamation activities abroad are distributed mainly in Holland, Japan, Singapore and other countries. Reclamation activities of China are also Mainly divided into the stage of 4 large-scale activities. Researches domestic and abroad on reclamation are from the influence of reclamation on ecological environment and resources. Ma Z Y, Chen B study on the influence of reclamation on landscape ecology and ecological effect of reclamation project in Fujian[2]. Song H L study on the effects of reclamation on marsh plants, animals, soil, water greenhouse gas emission to explain reclamation will made great influence to estuary delta. Yu D Y use PSR model to explain that development of reclamation have important influence in ocean resources and evaluate reclamation project in Fujian[3].Zhang J X found reclamation had positive

and negative effects, so use three indicators with social, economic, ecological and environmental benefits to build up comprehensive benefit evaluation model[4]. So he analyzed comprehensive benefit evaluation set of Dalian World Trade Center second project for an example. More foreign literature study on reclamation from the impact of environmental, land because of reclamation and study on coastline. In many research on coastline we find the coastline changes will have an impact to the marine climate[5].From the view point of sustainable development, coastline changes lead to coastal ecosystem more vulnerable. Studying on reclamation, we find much serious metal pollution caused by reclamation, thus reclamation has much more serious impact on land and soil, even lead to red tide[6,7].Study on reclamation about economy, ecology, society is less, that is why our article focus more on it.

**data sources and data processing**

**data sources.** According to the purpose of the study, data availability, reality principle, choose the level of two scene L1t Landsat7 etm remote sensing image data (feb 14, 2004, 02 Nov. 2009) and the level of one scene L1t Landsat8 OLI remote sensing image data (feb 07, 2016), the satellite orbit ranks number is 122/45. The three remote sensing images have less cloud cover, and the features are clear and can be distinguished to meet the requirement of extracting the coastline. In order to clip and interpreter, this article also selected the Zhuhai city administrative division map, Zhuhai city function zoning map. The research data are mainly derived from the Statistical Yearbook of Zhuhai from 2005 to 2015.

**data processing.** In this paper, three remote sensing data are pretreated. Landsat8 OLI image preprocessing includes geometric registration, radiation correction, atmospheric correction, full color band and multi-spectral fusion processing, radiation enhancement. . Because the Landsat8 oli L1T image data is the data product is the radiation correction data using the ground control point and the digital elevation model data for the accurate correction of the data product, the horizontal resolution is 30m, the relative precision is 10m, under normal circumstances can be used directly Do not need to do geometric correction. Landsat7 etm + image processing also includes geometric registration, with tm-despire plug-in to remove the band, synthesis and editing the header file.

Remote sensing image tailoring and coastline extraction: Based on the administrative divisions of Zhuhai City, Zhuhai City on the basis of marine functional zoning maps, digitized the boundaries of Zhuhai City with other municipal land, and then interpreted along the coastline. The extraction of the coastline uses the method of visual interpretation to extract the instantaneous land and sea boundary line of the satellite transit as the coastline of Zhuhai. Visual interpretation mainly relies on the characteristics of the water spectrum to select the false color synthesis band or the near-infrared band to identify the coastline. Visual interpretation of Zhuhai coastal landline coast after its supervision classification. The land use types of the reclamation area are classified by the maximum likelihood supervision classification method. The results are shown in Fig. 1, including construction land, cultivated land, forest land, water area and bare land. The kappa coefficients were 0.9105, 0.8640 and 0.9463 in the 2004, 2009 and 2016 years. The overall classification accuracy was 94.3662%, 90.7979% and 95.4372%, which were basically in line with the demand. Shown in Fig. 1.

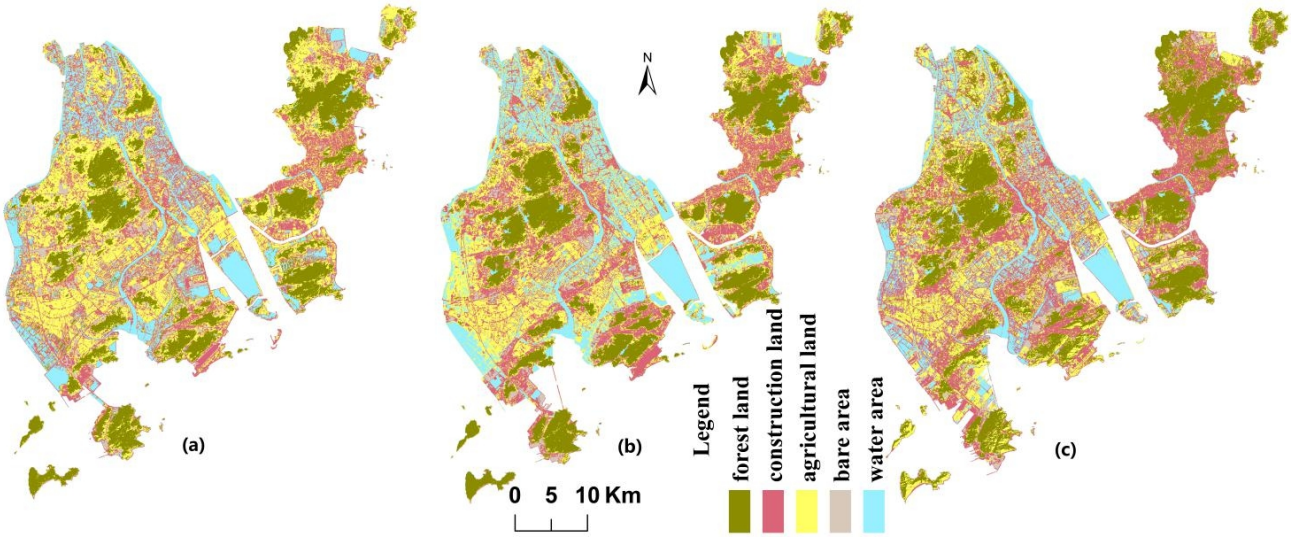


Fig.1 Classification of reclamation land reclamation in 2004, 2009 and 2016

notes:(1)Yellow represents agricultural land;(2)Pink represents construction land;(3)Green represents forest land;(4)Grey represents bare land;(5)Blue represents water land.

## Research method

**The triangle method.** This paper is based on the triangular model from the reclamation activities on the economic, social and ecological impact of three aspects, to obtain comprehensive benefits, to determine the sustainable development situation, and the establishment of index system. Data collection and processing, including the establishment of the original data matrix. Data were standardized to determine the weight of the evaluation index. And then, establish triangular model Figure. In this paper, we try to use the triangular model to refer to the comprehensive benefit evaluation of the reclamation area in Zhuhai, and use the economic impact index, ecological impact index and social impact index to measure the comprehensive benefit of Zhuhai reclamation area, sustainable development capacity and sustainable development trends[8].

**Create the triangle method.** This paper evaluates the comprehensive benefits and sustainable development of the reclamation area, reveals the development law of the reclamation with time. In addition, it explores the ecological and social impacts of the reclamation area. So the study of the sustainability of the reclamation area must take into account the three interrelated systems of ecology, economy and society. This article choose economic feasibility index (EI) index (NSI), the social acceptability and the ecological rationality (NREI) of three groups of interrelated index, reclamation using triangular model of comprehensive benefit quantitative evaluation[9]. As shown in table 1 and 2:

Table 1 Relative status evaluations of reclamation sustainable use

| Region | Index range | | | The relative index value | | | Sustainable development state |
|---|---|---|---|---|---|---|---|
| | EI | NSI | NREI | EI | NSI | NREI | |
| A | 0.8~1.0 | 0~0.2 | 0~0.2 | highest | lowest | lowest | strongest |
| B | 0.6~0.8 | 0~0.4 | 0~0.4 | high | Lowest to low | Lowest to low | strong |
| C | 0.4~0.6 | 0~0.6 | 0~0.6 | median | Lowest to median | Lowest to median | ordinary |
| D | 0.2~0.4 | 0~0.8 | 0~0.8 | low | Highest to high | Highest to high | weak |
| E | 0~0.2 | 0~1.0 | 0~1.0 | lowest | Lowest to highest | Lowest to highest | weakest |

Table 2 Relative trends evaluations of reclamation sustainable use

| Trend | Variation range | Index movement | | | Sustainable trend |
|---|---|---|---|---|---|
| | | EI | NSI | NREI | |
| T1 | 0°~60° | increase | reduce | increase | ordinary |
| T2 | 60°~120° | increase | reduce | reduce | strong |
| T3 | 120°~180° | increase | reduce | reduce | ordinary |
| T4 | 180°~240° | reduce | increase | reduce | weak |
| T5 | 240°~300° | reduce | increase | increase | unsustainable |
| T6 | 300°~360° | reduce | increase | increase | weak |
| T7 | unchanged | unchanged | unchanged | unchanged | Initial conditions |

**Build the index system.** There is no uniform standard for the index system of land use health evaluation at present. Most of the researches on land evaluation have adopted the "pressure-state-response" evaluation system. However, this paper aims to evaluate the development of reclamation from the three aspects of economy, ecology and society[10]. Therefore, this paper takes the ecological impact, economic impact and social influence as the evaluation criterion, with 21 specific factors as the evaluation index, Comprehensive assessment of the situation of reclamation. The higher the positive index value, the better the comprehensive benefit of the reclamation area, the higher the reverse index value is, the stronger the comprehensive benefit of the reclamation area[11].

**Data standardization.** As the standard indicators exist in different dimensions, and some indicators of different polarities. In order to eliminate the influence of dimension on the results of sustainable evaluation, the standard standardized method is used to standardize the data of each index [12,13]. Under normal circumstances, with the extreme value method for data on the dimensionless processing, where the formula is that when the evaluation index is a forward indicator.

**Index weigh determination.** According to the characteristics of entropy, we can determine the randomness and disorder degree of an event by calculating the entropy value. We can also use the entropy to judge the degree of discretization of an index. The greater the degree of discretization of the index, The greater the impact.

**Calculate composite exponents.** Using the weighted average method to calculate 2004-2014 in each of the economic feasibility index (EI) and social acceptability index (SI) and the rationality ecological index(REI). According to the nature of the triangle model, non - social acceptability (NSI), non - ecological rationality (NREI) and economic feasibility (EI) were selected as the evaluation index to construct the triangular graph. Among them $NREI_i = 1 - REI_i$, $NEI_i = 1 - EI_i$. The higher the EI value, the smaller the NREI and NEI values, and the higher the level of sustainable land use [14].

## Evaluation of sustainable land use in reclamation area of Zhuhai

**Evaluation on Sustainable Utilization of reclamation area in Zhuhai.** Based formula compute sustainable evaluation index of Zhuhai reclamation in 2004-2014. EI show a rising trend in general, and the growth rate is faster, increased from 0.0041 in 2004 to a maximum of 0.9807 in 2014, indicates that the impact of all aspects of the index to the good direction, this is closely related to the improvement of people's living standard, the rapid economic development and the intensive use of land reclamation in Zhuhai. NREI in 11 years showed a trend of ups and downs, increased from 0.7884 in 2004 to 0.8944 in 2007,And then dropped to the minimum value of 0.0495 in 2010, Increase to 0.4992 in 2014. Due to the development of regional Gaolan Port Economic Zone, Zhuhai City, coupled with the rapid industrial development, industrial construction scale is expanding constantly, so the index reached the highest value in 2007.2007-2010 is Zhuhai farming reclamation boom period, which is characterized by the reclamation of transgression beach and Pearl River Estuary accounted for. By the way of water dike, products in the beach aquaculture activities, the breeding area of aquatic products increased rapidly[15].Rose from 0.0495 in 2010 to 0.4492 in 2014, leading to an increase in non ecological rationality due to economic development. NSI from the highest value of 0.9514 in 2004 continued to decline slightly to the lowest value of 0.1480 in 2014. Shown in Fig. 2:

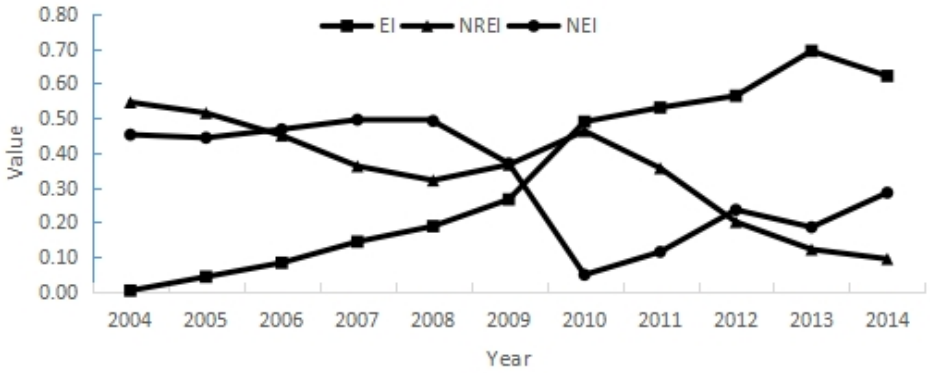


Fig.2 Changes of three indexes from 2004-2014 in reclamation sustainable use of Zhuhai

**Analysis evaluation on Sustainable Utilization of reclamation area in Zhuhai.** In 2009 this is located in the D region, the transition from a non sustainable state to a weak sustainable state, its economic index has been developed, the ecological state of lag. During this period, the Zhuhai municipal government issued a series of policies on reclamation with the state policy. In 2010-2012, these three points fall in the C region of the center of the triangle, which is in a state of general sustainability and is on the rise. During this period the government introduced measures to speed up economic development and measures to greatly mobilize the enthusiasm of all sectors of the community to invest in entrepreneurship. Combined with the density of economy and reclamation

area, it is found that the rapid development of the reclamation area economy in Zhuhai makes the non ecological rationality index reach the lowest value in 2010, which indicates that the ecological environment pressure in Zhuhai increases. In 2013 and 2014, two points in the triangle B region, which is in a strong state of sustainability. EI reached the highest value of nearly 0.7, and NEI reached the lowest value of close to 0.1. At the same time to ensure the rapid and stable economic development of industrial restructuring, expanding employment channels, so that social security work has been strengthened, focusing on the quality of life of the people. Shown in Fig. 3:

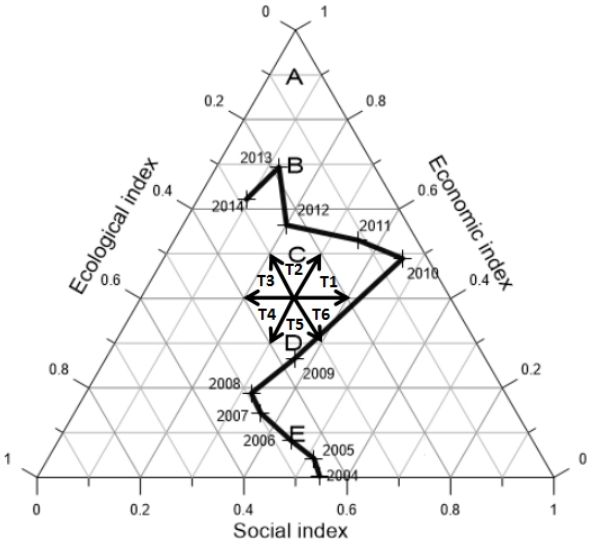


Fig.3 2004-2014 evaluation and trend on Sustainable Utilization of reclamation area in Zhuhai

## Conclusion and discussion

In Order to evaluate status and trend of sustainable land use in Zhuhai reclamation area, our article use economic feasibility(EI)Non social acceptability index(NSI)and Non ecological rationality index(NREI). According to the relationship between the three, the triangle model is established. The selection of index is based on the property of triangle model, and three index can reflect the land use status of the reclamation area. Analysis structure of triangle model we can find the triangle model is feasible in the evaluation of sustainable utilization of reclamation. Through the description of the triangle of three composite index, it can reflect the state of sustainable development and the trend of development, and it match with reality certainly.

Analysis the triangle model, we find that the sustainable utilization of land reclamation in Zhuhai reclamation area has experienced unsustainable and weak sustainable development since 2004.In 2013 and 2014 has reached general sustainable utilization. The number of EI NEI NREI are0.6215,0.0938,0.2847.the number of NSI is much bigger. The relative trend of sustainable utilization of land use in the reclamation area of Zhuhai is from not sustainable to Strong sustainability, and the EI, NREI and NSI three indexes change in a favorable direction, and it will reach strong sustainable in near future. In order to solve the contradiction between man and land in coastal areas, reclamation was put into effect by government. It bring economic and social benefits, but every coins have two sides, it bring about a series of serious environmental problems inevitably. Therefore, it is necessary to regulate and adjust the reclamation movement.

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**References**

[1] Ma Z Y, Chen B, Yu W W, et al., 2009. Impact of reclamation on wetland landscape ecology in Xinghua Bay. *Journal of Applide Oceanography*. 28(2): 169-176. (in Chinese)

[2] Song H L, Liu X T, 2013. Effect of Reclamation Effect of Reclamation Activities on Wetlands in Estuarine Delta in China. *Wetland science*. 11(2): 297-304. (in Chinese)

[3] Yu D Y, Wang C H, Liu H C, et al., 2011. Study On RecIamation Impact on Marine Resources Based On PSR ModeI. *Periodical of Ocean University of China.* 41(z2): 170-175. (in Chinese)

[4] Zhang J X, Chu C, 2011. Comprehensive Benefits Evaluation Model of Land Reclamation from Sea and its Application. *Journal of Engineering Management*. 25(5): 526-529. (in Chinese)

[5] Ohnson J M, Moore L J, Kenneth E, et al., 2014. Recent shifts in coastline change and shoreline stabilization linked to storm climate change. *Earth Surface Processes & Landforms*. 40(5): 569-585.

[6] Misra A, Balaji R, 2015. A Study on the Shoreline Changes and LAND-use/ Land-cover along the South Gujarat Coastline . *Procedia Engineering.* 116(1): 381-389.

[7] Wang L, Coles N A, Wu C, et al., 2014. Spatial variability of heavy metals in the coastal soils under long-term reclamation. *Estuarine Coastal & Shelf Science.* 151: 310-317. (in Chinese)

[8] Zhang X H, Zhang H B, Zhao S X, et al., 2013. Trend and Spatial-temporal Differentiation of Cultivated Intensive Utilization of Farmland in Henan Based on Triangle Model. *Chinese Journal of Soil Science.* (2): 277-283. (in Chinese)

[9] Zhu P Q, Zhao Z Q, Chen Y, 2016. Dynamic assessment of land ecologic safety based on triangle model -A case study of Xi`an city. *Research of Soil and Water Conservation*. 23(1): 244-248. (in Chinese)

[10] Yuan Y J, Qi C J, 2013. Dynamic assessment of regional agricultural sustainability of Hunan province based on entropy method. *Resources and environment in the Yangtze Basin,* 22(2): 152-157. (in Chinese)

[11] Yang H J, et al., 2013, Evaluation of Land Sustainable Utilization Based on the Triangle Model in Zaoyang City. *Guizhou Agricultural Sciences*, (2): 277-283. (in Chinese)

[12] Jian Z H, Yang M Z, 2015. Study on the dynamic changes and driving forces based on remote sensing images and GIS of land reclamation in Zhuhai. *Guangdong Land Science*, (3): 33-38. (in Chinese)

[13] Dafang Wu, Yanyan Liu, Yuxiang Dong, et al. 2010, An Analysis of Cultivated Land

Landscape Pattern Change Based on GIS in Zhuhai [C]. 2010 International Conference on Combating Land Degradation in Agricultural Areas, Springer, 612-616.

[14] Shi X X, Feng Z X, Liu Y L, 2012. Evaluation of land use efficiency in zhengding county of hebei province based on triangle model. ***Bulletin of Soil and Water Conservation***, 32(2): 206-210. (in Chinese)

[15] Yang Y, Lin D R, 2014. Research on the innovation development of regional integration of Guangdong, Hongkong and Macau-differential division and cooperation of innovation platform between qianhai, hengqin and nansha. *Forward Position or Economics.* (4): 89-95. (in Chinese)