CHARACTERISTICS OF HUMAN ACTIVITY IN CHINA'S COASTAL ZONE BASED ON MULTI-SOURCE SPATIO-TEMPORAL DATA

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ABSTRACT:

China's coastal wetlands have an extensive spatial span and a long coastline, which causes very significant regional differences in the coastal geographical environment. Compared with traditional field surveying, multi-source spatio-temporal data can quickly collect coastal landscape pattern and dynamic evolution information, thus saving a lot of labor, material resource and time cost. In this study, time series high resolution image and luminous thematic data (2015-2019) were adopted for the characteristics of human activity and spatial dynamics assessment in China's coastal zone. The results demonstrated that the proportion of man-made landscape types in the China's coastal zone has exceeded 50%, and indicates a steady growth trend with an average annual growth area of 308.35 km^2. In the past five years, the natural land has been continuously transformed into the artificial land. The different development behaviors have caused the spatial differentiation of landscape pattern in coastal zones. The coastal landscape dynamics of China's coastal zones is bounded by the Hangzhou Bay. The comprehensive dynamic attitude in the north is higher, while the comprehensive dynamic degree in the south is concentrated in Hangzhou Bay, Zhejiang, Fujian, Pearl River Delta and Hainan Island. The spatial characteristics of the radiation brightness demonstrate that the change of human activities in the coastal zone is universal in urban and non-urban areas throughout the past five years. The spatial correlation between noctilucent radiation and landscape change in coastal zone is significant year by year, which concludes that human activity is the main driving force of coastal landscape pattern evolution.

1. INTRODUCTION

Coastal zones are a transitional zone of sea-land interaction, with superior geographical location, rich natural resources, and a high concentration of urban, population, economic and other factors. Notably, it is one of the areas with the most drastic changes in land cover (Newton and Icely 2008). In recent years, with increasing human activity in the development and utilization of coastal areas, the degree of development and utilization of coastal resources and environment of coastal wetlands is also increasing. This has subsequently caused the degradation of the coastal wetland ecosystem and leads to environmental problems such as beach loss, deterioration of water quality, reduction of fishery production and so on (Carter 1976; Hardisky et al. 1986; He et al. 2014). For this reason, the International Geosphere and Biosphere Programme (IGBP) has listed land cover as the core research content of land-sea interaction (LOICZ) (Newton and Icely 2008). Meanwhile, scholars from various countries have gradually expanded their research on coastal wetlands. They have also adopted a variety of technical means to monitor and evaluate the ecological environment of coastal wetlands so as to contribute to the sustainable development of coastal wetlands (Di et al. 2015). Since the 1980s, with the rapid social and e[1]conomic development in China's coastal areas, significant changes have occurred in the coastal resources and environment of coastal wetlands. The study on the landscape pattern and evolution of coastal wetlands has important scientific significance for the ecological protection of coastal wetlands throughout the country. Because of the particularity of the geographical location of coastal wetlands, compared with traditional surface mapping methods, the use of multi-source spatio-temporal data is helpful in quickly obtaining the information of coastal landscape pattern and dynamic evolution, thus saving considerable manpower, material resources and time costs (Ozesmi and Bauer 2002; Richards and Richards 1999; Zhu and Zhang 2017). Since the 1980s, the research on the coastal landscape pattern of coastal wetlands has developed rapidly. For example, IGBP and the Human Dimensions of Global Change Programme (IHDP) collaboratively developed the Scientific Research Programme on land use / cover change (LUCC) in 1993 and launched the Global Land Programme (GLP) (Newton and Icely 2008) in 2005. Subsequently, global scientists and various international organizations have employed a series of global and regional scale land cover mapping research, and created numerous scientific data products (Di et al. 2015). For example, on a global scale, the United States Geological Survey (UMD) jointly compiled the IGBP DISCover data set (Hansen and Reed 2000), and the University of Maryland developed the Global Land cover data set (UMD) (Kang et al. 2007). In 2007, the European Union Joint Research Center compiled the GLC dataset and ESA prepared the GlobCover dataset . Meanwhile, in 2008, the National basic Geographic Information Center of China developed the GlobeLand30 dataset (Chen and Chen 2018), and Tsinghua University of China created the FROM-GLC dataset (Feng et al. 2016). All these studies have achieved the complete coverage of the coastal zone, which has played a significant role in promoting the scientific understanding of the pattern of the coastal wetland coastal landscape.

The coastal area of China is considered an active area of economic development, and factors such as society, economy and population are highly concentrated. This has caused immense pressure on the coastal ecosystem of coastal wetlands (Zhang et al. 2020). In recent years, to better understand the landscape pattern of coastal wetlands in China, most scholars have implemented a series of promising targeted studies. In another instance, based on the multi-source data of coastal wetlands in

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China from 1970 to 2013, Shi et al. (2015) studied the expansion characteristics of urban agglomeration in coastal wetlands in China. Notably, Cai et al. (2017) obtained the land cover data of coastal wetlands in Jiangsu Province in 1977, 1997 and 2015 by using Landsat MSS/TM and HJ1B CCD satellite images. The relationship between their changes and coastal aquaculture was analyzed as well. Based on the 1990, 2000 and 2014 Landsat TM/ETM+/OLI image data, Li et al. (2017) investigated the landscape classification and change characteristics of coastal wetlands in Liaoning Province. Additionally, Zhang et al. (2020) obtained the land use status of coastal wetlands in Hebei Province by using Landsat images from the periods of 1987, 2000, 2005 and 2017. This is not to mention that the land use change and its impact on habitat quality were analyzed here as well. These previous studies are of incredible significant to the study of coastal wetland landscape pattern and coastal wetland protection in China.

Coastal wetlands in China have a large spatial span, extending more than 20 latitudes from north to south, including temperate, subtropical, and tropical climatic zones, with a long continental coastline. Coastal wetlands in China possess significant regional differences in climate, geomorphology, vegetation, soil, hydrology, human activities, and other factors (Fan et al. 2020; Li et al. 2015). At present, the multi-source data applied to the coastal zone research of coastal wetlands in China primarily consist of Landsat TM/ETM/OLI, CBERS, HJ medium resolution images and open land cover data products. Meanwhile, some use high resolution data such as SPOT, ASTER, Worldview are used for landscape research as well. It should be noted that the accuracy of medium and low resolution research is low, so it is difficult to reflect the process of fragmentation of human activities, and there is the problem of coarse particles (McCarthy et al. 2015). For a long time, limited by the availability of high-resolution images and purchase cost, the research on the fine-grained landscape pattern of coastal wetlands in China was mainly implemented on the local scale. Consequently, it was often difficult to reflect the large-scale landscape pattern and evolution of coastal wetlands. Up until now, there is no report on the use of high-resolution data to explore the coastal landscape pattern of coastal wetlands on a national scale. Notably, Zhang et al. (2021) identified the high-precision mangrove landscape pattern data in China for the first time by using 2018 2-meter resolution satellite images. Specifically, it clearly demonstrated that the granularity and geometric accuracy of high-resolution data was better than those of medium-and low-resolution data. With the construction of an ecological civilization, China has continuously carried out basic survey projects such as a land use change survey and geographical condition monitoring in recent years. This has been done using high-resolution remote sensing (resolution ≤2 meters) combined with large-scale field investigation. Through such methods, monitoring results such as objective information, rich content and fine scale land cover have been revealed, which provides a good foundation for further study of coastal wetland landscape pattern and protection.

This study collects high-precision land cover classification data of coastal wetlands and time series data such as luminous remote sensing (2015-2019). Particularly, multi-dimensional method is employed to quantitatively characterize and analyze the temporal and spatial dynamics of the landscape pattern of coastal wetlands. This is done with a specific focus on the landscape pattern and transformation characteristics of the natural ecosystem and artificial surface such as agricultural production, urban construction, industrial development and so on. Furthermore, the landscape pattern change characteristics of coastal wetlands are analyzed at national, provincial, and county scales. Meanwhile, the landscape pattern evolution mechanism of coastal wetlands in China is also explored. The research results will provide theoretical reference to further assess the characteristics of the coastal landscape pattern of coastal wetlands and the protection of coastal wetlands in China.

2. MATERIALS AND METHODS

2.1. Study area

China has a mainland coastline of 18000 km, extending from the mouth of the Yalu River in the east to the mouth of the Beilun River in the west, bordering the Bohai Sea, the Yellow Sea, the East China Sea and the South China Sea. It also spans tropical, subtropical and warm temperate zones, including 10 coastal provinces, two special administrative regions of Hong Kong and Macao, and the two island provinces of Taiwan and Hainan. In addition to the Bohai Sea as China's internal and overseas, the Yellow Sea, the East China Sea and the South China Sea are all marginal seas of the Pacific Ocean. Particularly, different topography, hydrothermal conditions and development processes have created rich coastal wetland resources on the long continental coastline (Li et al. 2015). Due to limitations in data, Hong Kong, Macao and Taiwan are not included in the study. Therefore, eight coastal provinces and two municipalities directly under the Central Government and the coastal areas along the continental coastline of Hainan Island were selected as the study area. Notably, the outer boundary of coastal wetlands is defined by water depth, so it is difficult to determine in a specific manner. In the second National Wetland Resources Survey, the intertidal zone between the coastal zone and the-6m low tide line was identified through a unified survey. Under such circumstances, this study utilizes this space area as the outer boundary of coastal wetlands. With reference to the definition of the coastal zone of the conventional coastal wetland, the coastal wetland coastline 10 km to the land buffer zone is the land boundary of the coastal zone, and finally forms the coastal wetland study area of this study.

2.2. Data and pre-processing

Land cover classification data (Figure. 1) monitored by geographical conditions in the study area (2015-2019) were collected to assist in the analysis of the landscape structure and development and utilization of coastal wetlands. Throughout this study, the types of land cover landscape are divided into natural landscape and artificial landscape, in which natural landscape is divided into woodland, grassland, bare land and the water area. Meanwhile, artificial landscape is divided into cultivated land, garden land, house buildings, structures and excavated land. The data set is based on high-resolution images (resolution ≤2 meters), and the minimum landscape granularity is 400 m2. The landscape type definition is appropriately reclassified based on the research objectives and this can be seen in Table 2-5. Through the third-party quality evaluation, the classification accuracy of random sampling is more than 95% (http://www.gov.cn/xinwen/2017-04/25/content_5188665.htm), and the data accuracy satisfies the relevant requirements of landscape pattern research (Ozesmi and Bauer 2002). To facilitate further analysis, the data is spatially cut according to the study area, and further classified and merged and then reclassified naturally and artificially.

Notably, the version of the Earth's luminous data set from the the Chinese Academy of Sciences (codenamed "Flint", Flint) was collected in the study area. Specifically speaking, the flint data set is the average luminous value of a global surface from the period of 2015 to 2019, on a yearly basis. The official version of the data set has a 500m resolution (86400 x 33600 pixels). In this study, the beta1 version is utilized, with a spatial resolution of

1500 meters, that is, each pixel is 0.0125 degrees (http://satsee.radi.ac.cn/cfimage/nightlight/). Luminous remote sensing data of coastal wetlands in China in 2015 are depicted in Figure 2.

In this study, the land cover classification system in geographical monitoring is applied as the coastal wetland landscape classification system (Resources 2020). Moreover, the classification system is based on the objective reflection of the current situation of the landscape and has the characteristics of scientific classification and fine indicators.

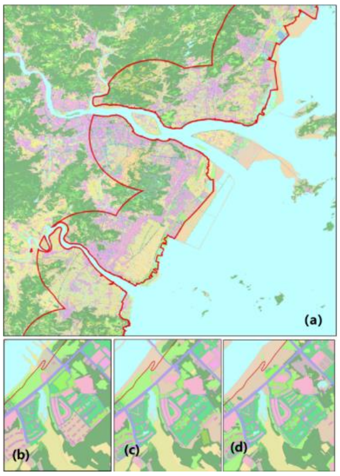

Figure 1. Coastal zone landscape with a 10 km buffer based on high resolution images. The land types are coded as follows: 01, farmland; 03, forest and grassland; 05, buildings; 06, roads; 07, structures; 08 stacked and excavated land; 09, bare land; 10, water areas. (a) (a) Ningde, Fujian in 2019; (b) Danzhou, Hainan in 2015; (c) Danzhou, Hainan in 2016; (d) Danzhou, Hainan in 2017.

To further explore the coastal landscape of coastal wetlands, based on the characteristics of land use / land cover in coastal wetlands and the land use / land cover classification system used in the world, the original land cover classification was partially adjusted. The land cover data used consists of five periods (2015-2019). Notably, the land cover data is based on high-resolution (resolution ≤ 2 meters) aerial or satellite images. Particularly, the data is collected by the combination of computer automatic classification and manual interpretation and interpretation.

Regarding the area that has good image quality and time phase, they are automatically classified through the computer by the object-oriented method. Meanwhile, images with poor image quality and fog are interpreted directly using manual interpretation. Moreover, manual interpretation is the main method used for the type of land cover that is complex and broken. In contrast, for the type of land cover that is considered simple, automatic classification is adopted in the entire area. Before the process of land cover classification data collection, to maintain the accuracy and consistency of the classification, all orthophoto images were analyzed, and the survey samples are collected as reference materials for classification. It should be noted that it is usually difficult for computer automatic classification to extract land cover classification data to achieve the ideal classification accuracy. Therefore, the classification results are edited manually. In this process, the segmentation and classification results are combined with remote sensing orthophoto images. Then, the objects with incorrect classification are edited through image recognition and interpretation, such as merging, splitting, reconstruction and so on.

For the land cover data from the 2015 to 2019 period, the high-resolution satellite images (resolution ≤ 2 meters) were superimposed with the land cover data of the previous year, and the change information extraction method was used to update the data. Notably, there are two ways to identify the change region. The first is to detect the change region automatically or with the combination of man and machine based on the homologous multi-temporal remote sensing image technique. Meanwhile, the other method involves overlaying the existing data on the image of the monitoring period and identifying the change area through manual inspection. The data set for each year is supplemented by various field surveys. The data set for each year is supplemented by many field surveys. Through the third-party strict production quality inspection, the classification accuracy of random sampling is more than 95% (http://www.gov.cn/xinwen/2017-04/25/content_5188665.htm), and the data accuracy satisfies the relevant requirements of landscape pattern research (Ozesmi and Bauer 2002).

The difference of luminous growth degree in the coastal zone (Figure 2) is mainly reflected by two indexes: total luminous amount (Sum of Light, SOL) and luminous growth rate (Light Growth Rate, LGR) (Sun 2020). The calculation formula is detailed as follows:

$$SQL = \sum_{i=1}^{n} r_i \tag{1}$$

$$LGR = \frac{SQL_a - SQL_b}{SQL_b} \times 100\% \tag{2}$$

where r_i = luminous radiance value of the first pixel
n = total number of pixels in the study area

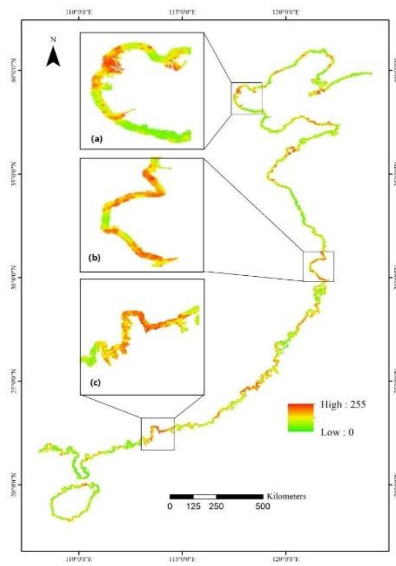

Figure 2. Coastal luminous radiation distribution (2019). (a) Beijing-Tianjin-Hebei region; (b) Yangtze River Delta; (c) Pearl River Delta.

2.3. Landscape pattern analysis

The processed land cover and luminous data was applied to calculate and assess the human activity characteristics of China's coastal zone. This specifically includes the landscape pattern, land type transfer, change degree and type dynamics, etc. The change of the coastal zone landscape is affected by a series of natural and man-made factors. However, in short time scale, human activities disturb and dominate the formation of coastal zone landscape pattern and its process. Consequently, the Index of Coastal Zone Utilization Intensity (ICZUD) was formulated according to landscape types and change characteristics (Wu et al., 2014). Table 1 illustrates the weight assignment methods of coastal zone intensity of various coastal wetlands (Wu et al., 2014).

Land type	01	03	05	06	07	08	09	10
Weight	2	1	4	4	3	2	1	1

Table 1. Weight assignment of landscape utilization intensity. The land type codes are detailed in Figure 1.

Based on this, the Index of the Coastal Zone Utilization Degree (ICZUD) is calculated to reflect the impact of human activities on coastal zone changes in the study area. It is also used determine the response of the coastal zone to various human development and utilization activities. The formula is as follows:

$$ICZUD = \sum_{i=1}^{n} (B_i \times C_i) \times 100$$

where AB_i = development and utilization intensity index
i = coastal zone types
C_i is the length percentage of class i
n is the number of coastal zone types

3. RESULT

3.1. Statistics of landscape pattern change

The total area of China's coastal zone (10km buffer zone) is 92234.26 km^2 (Figure 3). In 2015, the area of human construction site (planting land, house building, roads, structures, and excavation land) in the coastal zone landscape was assessed to be 46,782.89 km^2, accounting for 50.72% of all land. From the 2015 to 2019 period, except for planting land, housing construction, roads, structures, and excavation land all demonstrated an increasing trend on a yearly basis (Figure 4), with an annual growth area of approximately 308.35^{km2}. In 2019, the share of human construction land reached 52.06%. Accordingly, forest and grass land, bare land, water area and other natural areas decreased year by year. Additionally, the intensity of landscape change was basically stable on a large scale from the period of 2015 to 2019.

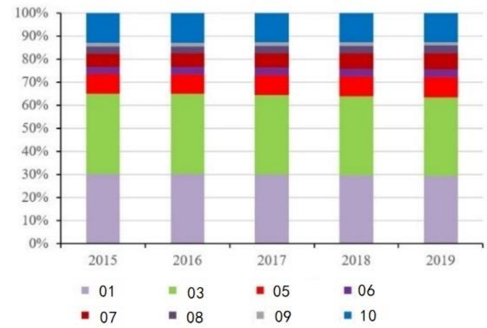

Figure 3. Quantitative composition of the coastal landscape types from 2015 to 2019. The land type codes are detailed in Figure 1.

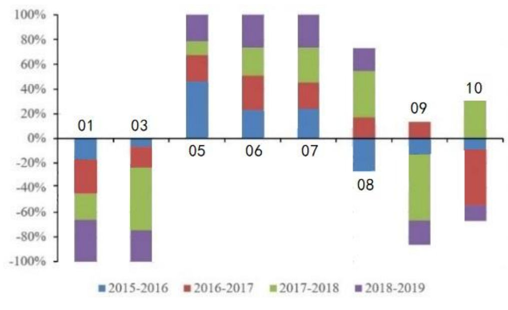

Figure 4. Annual change rate of coastal landscape. The land type codes are detailed in Figure 1.

3.2. Spatial analysis of landscape pattern

According to the statistics of the importance of the change of landscape patch area within the scope of the opposite shore zone by county, the minimum value of the importance of the change of coastal zone area at county level in China is 1.33. Meanwhile, the maximum value is 188.59, the average value is 54.44, and the square deviation is 13.98. Figure 5 reflects the distribution characteristics of landscape significance of county area change in the coastal zone of China.

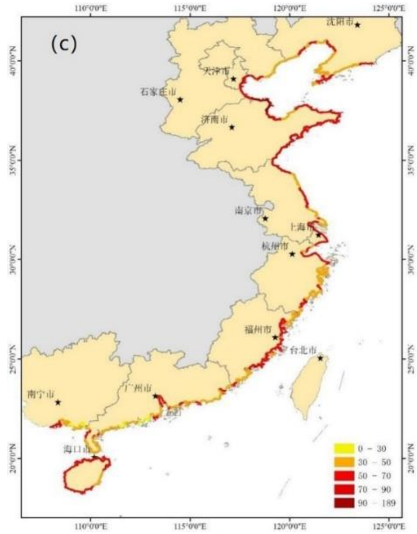

Figure 5. Landscape importance degree variation rate of coastal zone at the county scale from 2015 to 2019.

Land development intensity of coastal wetlands and coastal zone is mapped by county, and the results are demonstrated in Figure 6. The results indicate that from the 2015 to 2019 period, only Shanghai and Fujian experienced a decrease in land development intensity in the 2015 to 2017 and 2017 to 2018 period. Meanwhile, all provinces experienced an increase in land development intensity during the other years. Particularly, Zhejiang province underwent the largest increase in land development intensity from 2017 to 2018, with the annual construction area ratio increasing by more than 1.5%. In other years, the annual construction area ratio of most provinces grew within the 1% range,

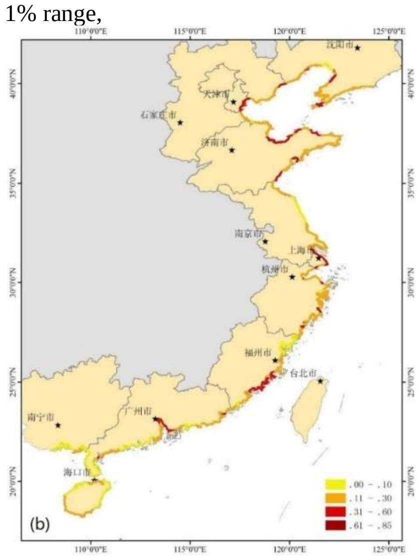

Figure 6. Coastal landscape development intensity in 2019.

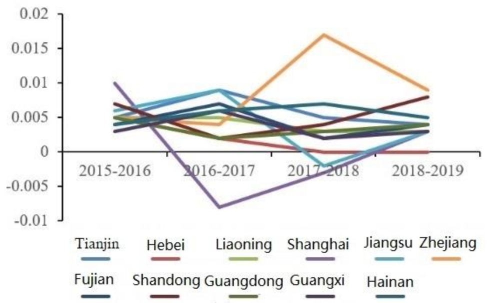

Figure 7. Provincial change trend of land development intensity in coastal zones

Figure 7 illustrates the evaluation results of coastal wetland land development intensity. From the results, the construction area of China's coastal zone reflected an upward trend from 2015 to 2019. Specifically, the construction area increased from 15,902.79 km^2 in 2015 to 17,583.07 km^2 in 2019 and the ratio increased from 0.17 in 2015 to 0.19 in 2019. The intensity of land use and development of coastal wetland zone in China is medium. However, in terms of the increase of construction area, Hainan, Zhejiang and Guangxi provinces have the most significant growth rates, as all three exceeded 10%—a figure far larger than other provinces. Among them, Hainan province has the most significant growth rate, reaching 24.63%, with an average annual growth rate of 6.16%.

3.3. Evolution characteristics of landscape pattern

From the 2015 to 2019 period, the landscape of China's coastal zone primarily shifted from a natural land type to a human site type (Figure 8, Table 2). During this change, housing buildings, roads, structures and excavation sites demonstrated an overall growth trend, and the area growth rate after transformation was 4.49%, 13.91%, 17.96% and 10.61%, respectively. Meanwhile, planting land, forest and grass land, bare land and water area depicted a decreasing trend, and the area reduction rate after transformation was -2.67%, -2.34%, -20.47% and -1.33%, respectively. The conversion reduction rate of bare land reached -20.47%. When comparing the conversion ratio, the 2015-2019 China coastal zone landscape transfer to bare land and waters to gardens, grass land, pile digging, structures (such as clearing use type conversion), and gardens (such as grass, pile digging type) and further to buildings, roads, structures, and other construction land type conversion, formed the hierarchical chain of landscape transformation. Different types of human activities are the most considerable driving factors for landscape transformation in China's coastal zone.

2019 / 2015	01	03	05	06	07	08	09	10
01	25480.84	1022.46	211.06	108.27	645.64	383.79	2.64	177.68
03	1330.28	28539.47	317.22	146.52	499.29	771.56	83.62	409.43
05	66.85	151.33	7166.86	24.7	175.27	208.46	0.55	5.67
06	8.83	56.88	7.55	2536.03	28.55	26.26	1.96	5.56
07	172.59	309.62	152.16	40.28	4407.08	187.43	36.95	125.35
08	77.41	737.92	259.14	152.4	339.21	1172.76	21.45	87.42
09	21.77	170.84	7.11	6.85	55.09	96.09	848.12	388.74
10	124.92	358.08	28.62	28.15	240.04	303.38	272.96	10403.22

Table 2. Conversion matrix of coastal landscape change. The land type codes are detailed in Figure 1.

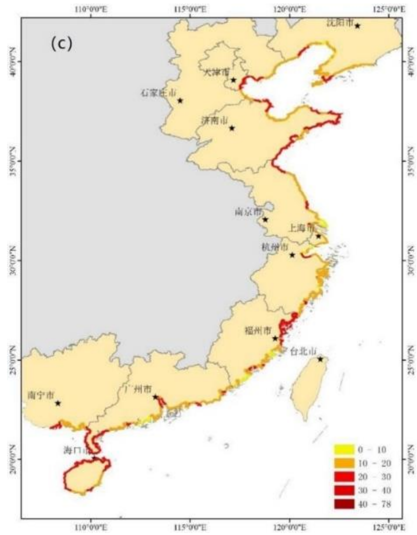

Figure 8. Importance degree of landscape transformation from natural landscape to artificial landscape at the county scale from 2015 to 2019.

Figure 9 indicates the national provincial development and utilization intensity index and the statistics of coastal zone expansion land area. The results of coastal zone development and utilization intensity index show that the intensity of coastal zone development and utilization increased from 170.74 in 2015 to 185.38 in 2020, with an increase of 8.75%. From the provincial level, all 10 provinces showed an increasing trend, indicating that the intensity of coastal zone development and utilization can more fully reflect the situation of human activities. From the 2015 to 2020 period, only the Jiangsu coastal zone development and utilization intensity index decreased by 5.79%. As can be seen from Figure 6-6, the main types of coastal zone expansion in Jiangsu province from 2015 to 2020 were water body and forest and grass land, which may be caused by unfavorable development and construction of large area tidal flat wetland throughout the Jiangsu coast, and artificial reclamation is the main method in these coastal areas.

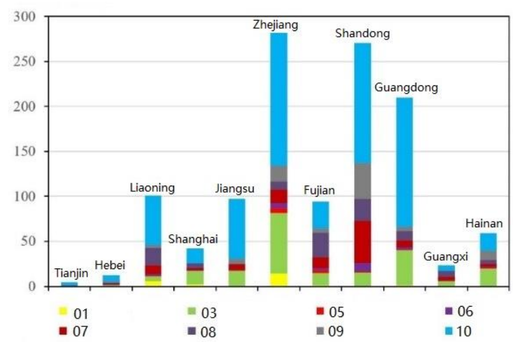

Figure 9. Statistics of coastal landscape expansion (km^2). The land type codes are detailed in Figure 1.

3.4. Collaborative verification of human activity correlation in the coastal zone

Multi-scale distribution of the variation value of radiation brightness of coastal wetlands in China from the 2015 to 2019 period are shown in Figure 10 (grid) and Figure 11 (city). The results demonstrate that the change of human activities in the coastal zone is universal in urban and non-urban areas throughout the past five years. Finally, collaborative quantitative verification was conducted on the driving forces of the coastal zone. The results showed that the provincial linear fitting R^2 of coastal landscape and human activity change in 5 years reached 0.8 (Figure 12), revealing a strong correlation.

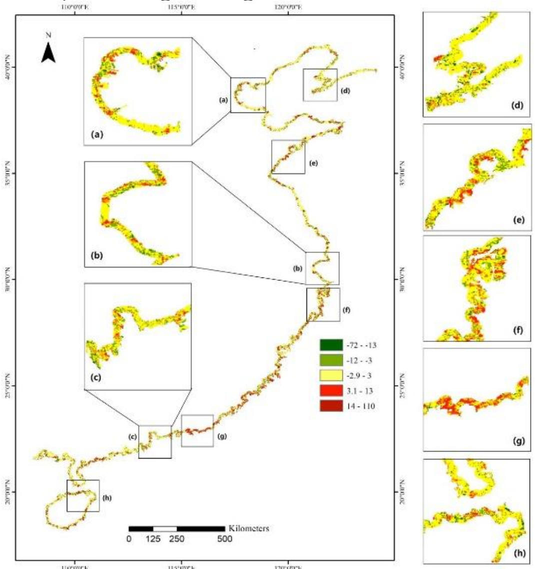

Figure 10. China's coastal luminous radiation change from 2015 to 2019. (a) enlarged map of the Beijing-Tianjin-Hebei region (b) magnified map of the Yangtze River Delta region (c) magnified map of the Pearl River Delta

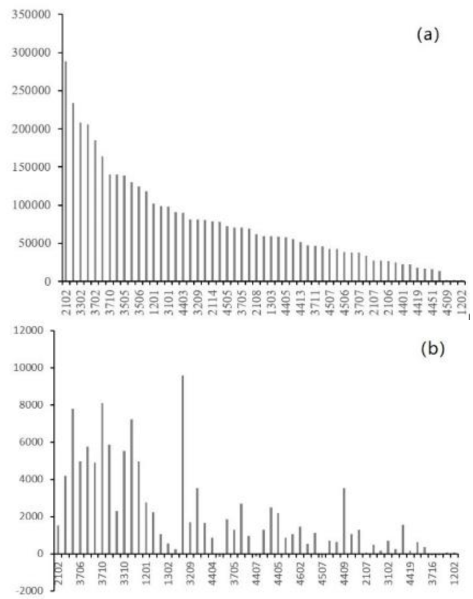

Figure 11. Statistics of coastal luminous areas at a city scale (a) radiation value (b) variation value

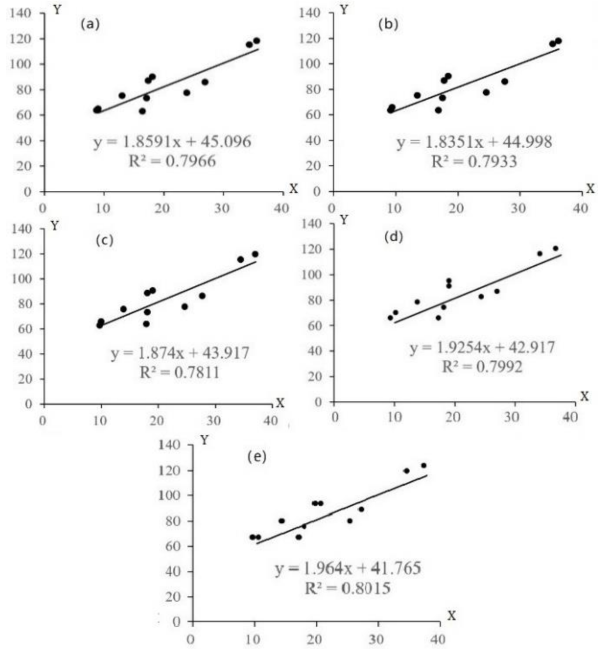

Figure 12. Scatter map of the coastal landscape pattern and luminous radiation, the X axis is the provincial proportion of impervious surface area, and the Y axis is the provincial luminous average value. (a) 2015 (b) 2016 (c) 2017 (d) 2018 (e) 2019

4. DISCUSSION

The coastal zone is the geographical unit of energy exchange and interaction among ocean, land, and atmosphere systems. Notably, it is not only the most active natural area on the earth surface, but also the region with the most favorable resources and environmental conditions, which is most closely related to the survival and development of human beings (Chu et al. 2015). Quantitative evaluation of coastal wetland landscape pattern will assist in correcting the relationship between the coastal wetland ecosystem and coastal landscape pattern. This further helps in clarifying its ecological characteristics, ecological structure, and influence mechanism while also recognizing the value of ecosystem services and functions (Ramsey 2005). It should be noted that numerous studies have applied multi-source remote sensing and landscape pattern methods to help people better understand the unique characteristics of the coastal ecosystem, habitat, and landscape dynamics of coastal wetlands (Di et al. 2015; Duan et al. 2020; Huang et al. 2020; Zhang et al. 2020). In the past, various studies primarily focused on the geographical environment within the coastal provinces, and most data sources utilized medium-resolution remote sensing images. However, there were relatively few studies on large-scale landscape dynamics in coastal wetlands using high-resolution images. Since human activities usually occur more intensely and frequently in densely populated coastal zones (Newton and Icely 2008), this study applies multi-temporal landscape data to evaluate and analyze the landscape pattern of coastal wetlands so as to explore the landscape spatio-temporal dynamics and driving forces in the 10 km buffer zone of coastal wetlands in China.

The function of the ecosystem depends on the size of the patch area, the excellent degree of the environment, the nature of the ecosystem and the human social and economic environment (Lv and Liu 2004). In terms of the study of the fragmented landscape of coastal wetlands, high-resolution data has higher accuracy and accuracy in landscape classification and change detection than medium-resolution data (Lu et al. 2018). This study is based on the national coastal wetland landscape pattern data set extracted from high-resolution (greater than 2 meters) multi-source images from the 2015 to 2019 period. Notably, the landscape classification accuracy of this data is more than 95%. Particularly, it can be used for quantitative evaluation of the coastal wetland landscape pattern. Moreover, traditional medium resolution data (such as Landsat, resolution 30 meters) identifies coarse-grained, while the smaller natural patches in the landscape are more easily affected by human activities, and eventually transformed into various types of man-made landscape. The smallest landscape patch in this study is 400 m^2, and the accuracy of landscape classification and change analysis is high, which can more objectively and accurately grasp the landscape pattern of coastal wetlands in China.

Since the reform and opening of the country in 1978, China has successively established several special economic zones in the areas of Shenzhen, Zhuhai, Shantou, Xiamen and Hainan. Since 1985, the Yangtze River Delta, Pearl River Delta, southern Fujian coast, Shandong Peninsula, Liaodong Peninsula, Hebei and Guangxi have developed into economic open zones. Particularly, after 2000, population migration accelerated and many gathered in coastal areas, resulting in accelerated population urbanization. This subsequently caused the intensity of urban and industrial construction land expansion (Di et al. 2015). Notably, the results demonstrate that the artificial utilization of landscape types of coastal wetlands in China has continued to grow, from 46782.89 km^2 to 48016.29 km^2 from 2015 to 2019, with an average annual growth area of approximately 308.35 km^2, and the growth rate is stable on a yearly basis. From the spatial perspective, the growth rate of artificial utilization types of landscape depicts regional differences. Particularly, there are aggregation characteristics in Liaodong Peninsula, Shandong Peninsula, Yangtze River Delta, Zhejiang coast, northern Fujian, western Guangdong and Hainan Island.

The dynamic results of comprehensive landscape types reflect the considerable differences in landscape distribution of coastal wetlands in China. It should be noted that the main characteristics are bounded by Hangzhou Bay. Here, the comprehensive dynamic attitude of the northern coastal zone is relatively high, and three high dynamic hot spots are formed in Beijing-Tianjin-Hebei, Shandong Peninsula and Yangtze River Delta. The comprehensive dynamic attitude of the southern coastal zone is generally low, forming regional aggregation only in the areas of the Hangzhou Bay, Zhejiang, Fujian, Pearl River Delta and Hainan Island, mainly with hotter climate cities acting as nodes. From the perspective of urban agglomeration, the area conversion rate of the three major coastal urban agglomerations of Beijing, Tianjin, Hebei, Yangtze River Delta and Pearl River Delta from 2015 to 2019 is 13.47%, while that of non-urban agglomeration is 12.47%. The conversion rate of land area is slightly lower than that of the three major urban agglomerations. In terms of the inflow of artificial utilization types, the difference in the new proportion of artificial land in coastal wetlands between the three major urban agglomerations and non-urban agglomerations is only 1.74%. Moreover, the regional difference is not significant, which indicates that land development and utilization in coastal areas during the study period possesses certain universal characteristics.

The coastal landscape of coastal wetlands is affected by multiple factors such as natural and artificial factors. From the dynamic point of view of various landscape types, the dynamic attitude of houses, roads, structures and stacking in artificial land is relatively high, indicating that this type of landscape changes more frequently. Meanwhile, planting land, forest and grassland, bare land and other natural attributes are generally low, and the patch is relatively stable on a yearly basis. Notably, water is a special type of coastal wetland. There are significant dynamic differences among different provinces, in which Tianjin, Liaoning, Shanghai and Hainan have a higher dynamic attitude, constructed wetlands change more frequently, while other provinces have a low dynamic attitude, and natural wetlands tend to be stable. The change rate of stacking and excavation sites varies considerably throughout different periods, demonstrating greater instability, with a decreasing trend of-6.18% from 2015 to 2016, and an increasing trend in the three periods of 2016-2017, 2017-2018 and 2018-2016, with a growth rate of 4% and 9%. Particularly, the stacking and excavation sites are mainly the intermediate state of open-pit mining sites, stacking objects, construction sites and so on. It can be inferred that numerous stacked and excavated sites were built into houses between 2015 to 2016. Throughout this period, the building area increased significantly, mainly in 2016, 2017 and 2018, and the construction speed of houses and buildings slowed down. This change reflects the interannual land development and construction process of coastal wetlands and it has important reference value for the planning and management of coastal wetlands.

5. CONCLUSIONS

Human-land interaction in coastal areas makes coastal wetlands the most sensitive and fragile zone in response to global changes, and it is an area prone to environmental disasters. This study utilizes the buffer zone that is 10 km from the coast to the land as the study area. It also uses the national scale high-precision optical and luminous remote sensing data to explore the human activity characteristics and spatio-temporal evolution in China. The results demonstrate that at present, the proportion of artificial landscape types in China's coastal zone has exceeded 50%, and indicates a steady growth trend; from 46782.89 km^2 in 2015 to 48016.29 km^2 in 2019, with an average annual growth area of 308.35 km^2. The coastal landscape dynamics of China's coastal zone is bounded by Hangzhou Bay, and the comprehensive dynamic attitude in the north is higher. Meanwhile, the comprehensive dynamic attitude in the south is only formed in Hangzhou Bay, Zhejiang, Fujian, Pearl River Delta and Hainan Island. In the artificial landscape types of coastal zone, buildings, roads, structures, and stacked and excavated land have a high attitude towards ground movement. This is not to mention different types of human activities have caused the spatial differentiation of landscape pattern in coastal zone. With the rapid development of coastal urbanization, the landscape pattern in some areas has been considerably altered, and all kinds of ecological problems have emerged. Some examples of this change include the change of wetland landscape, the loss of high-quality cultivated land and the decline of environmental quality. Therefore, scientific understanding of the evolution of coastal zone landscape pattern is imperative in balancing coastal economic development and coastal wetland protection.

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