Discussion on the Evolution of Sea Reclamation from 2006 to 2018 in Jimo District, Qingdao, Shandong Province

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Abstract. Sea reclamation is an important way to develop marine resources and expand land space. Based on the extraction technology of remote sensing image, the spatial distribution and evolution of sea reclamation in Jimo District from 2006 to 2018 were discussed. From 2006 to 2018, the reclamation area of Jimo District increased by 32.68 km². The industrial structure adjustment, the implementation of major projects and the increase of population were the main driving forces. The reclamation areas are mainly located in Aoshan Bay, Hengmen Bay and Xiaodao Bay, which occupy the former tidal flat and wetland resources of these bays and cause the change of the hydrodynamic environment. At the same time, the problems of land idle and low intensive utilization still remain. In the face of these problems, some measures, such as establishing and improving a long-term monitoring mechanism, reducing the stock of reclamation in accordance with the principles of economization and strengthening the ecological restoration of coastal zones, should be taken.

1. Introduction
Sea reclamation is an important way to develop coastal resources and expand land space[1]. Many coastal countries in the world, especially with land shortage, such as the Netherlands, Japan, South Korea and Singapore, have carried out a series of reclamation activities. With a long coastline, China is equipped with excellent natural conditions for large-scale sea reclamation and has experienced four large-scale reclamation stages since the 1950s[2]. On the one hand, sea reclamation has greatly promoted the social and economic development of coastal regions and alleviated the contradiction between human and space; on the other hand, it also caused the degradation of coastal wetland, the length reduction of natural coastline and the damage to the stability of marine ecosystem[1,3,4]. Meanwhile, the intensive utilization level of the newly formed reclamation land is not high, leading to a great waste of land space.

With the construction of ecological civilization deepening in the new era, China has issued a series of policy documents to strengthen the management and control of reclamation. In July 2018, the State Council issued Notice on Strengthening Coastal Wetland Protection and Strictly Controlling Sea Reclamation ([2018] No. 24 Document from the State Council), which clearly set out the specific requirements for strictly controlling new reclamation. It can be seen that the government has attached great importance to it. Based on Landsat TM/OLI remote sensing images, this paper extracted the coastline in Jimo District, Qingdao, respectively in 2006 and 2018, and established the remote sensing interpretation signs of development and utilization types of reclamation. Furthermore, the spatial
distribution and evolution characteristic of reclamation in more than ten years were discussed, aiming to provide technical and strategic support for the reclamation controlling and accurate management of the coastline under the new situation.

2. Regional Setting
Jimo District, subordinate to Qingdao, Shandong Province, is located in the southwest of Shandong Peninsula and is adjacent to the Yellow Sea. It has a land area of 1780 km$^2$ and a sea area of about 2500 km$^2$. It has 10 bays such as Dingzi Bay, Kaolao Bay and Aoshan Bay, as well as 24 islands such as Tianheng Island, Daguan Island and Xiaoguan Island[5]. The coastline of Jimo District is tortuous, with a length of nearly 200 km. The shallow water area is broad and the tidal flat is widely distributed in Jimo District, which are suitable for the growth of sea cucumber, abalone and scallop. High-quality coastline resources have laid a good foundation for the development of the marine industry. In 2019, the investment scale of the marine industry exceeded 65.5 billion yuan[6].

3. Data and Methods

3.1. Data
One Landsat 5 TM remote sensing image in 2006 and one Landsat 8 OLI_TIRS remote sensing image in 2018 covering the study area were selected as the data source. Both of them have a spatial resolution of 30 m. The image data were downloaded from the geospatial cloud website of the Computer Network Information Center of the Chinese Academy of Sciences[7]. See Table 1 for the specific image information.

| Data Type    | Data ID               | Path | Row | Date (mm-yyyy) | Cloud Cover (%) | Range                                |
|--------------|-----------------------|------|-----|----------------|----------------|--------------------------------------|
| Landsat 5 TM | LT51200352006300IKR00 | 120  | 35  | 10-2006        | 0              | From Donggang, Rizhao to Haiyang, Yantai       |
| Landsat 8 OLI_TIRS | LC81190352018086LGN00 | 119  | 35  | 03-2018        | 0.75           | From Laoshan, Qingdao to Rushan, Weihai      |

3.2. Methods

3.2.1. Extraction and correction of coastline
The Modified Normalized Difference Water Index (MNDWI) was adopted to process the remote sensing images in 2006 and 2018[8]. Subsequently, the threshold segmentation method was used to normalize the image for identifying the water area and land area on the images[9]. The intersection line of these two areas is the instantaneous water line to be extracted. According to the definition of coastline in the national standard *Oceanographic terminology: marine geology*, i.e., the trace line of multi-year mean high water springs[10], the tidal correction is necessary to ensure that the instantaneous water line conforms to the definition of coastline in *Oceanographic terminology: marine geology*[11,12]. Finally, in accordance with the technical requirements of coastline position in *Specification for Coastline Survey*[13], the coastlines after tidal correction in 2006 and 2018 were adjusted in some areas, especially in mariculture zones.

Establishment of the remote sensing interpretation signs of reclamation development and utilization types
Combined with Digital Elevation Model (DEM) data and previous field survey, overlay analysis of the coastlines in 2006 and 2018 and the high-resolution Shandong Map World were used to distinguish the image features of different types of reclamation development and utilization[14]. According to *Classification Guide of Land, Sea and Island for Spatial Planning in Shandong Province (Trial)*, a
remote sensing interpretation sign database of reclamation development and utilization types in Jimo District was established (Table 2)[15], and the evolution of reclamation was statistically discussed.

Table 2: Remote sensing interpretation signs of reclamation development and utilization types

| Development and utilization type | Definition                                                                                   | Interpretation signs                                      |
|---------------------------------|----------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| Residential land                | Land for residential buildings and corresponding service facilities                          | Continuous layout, large scale                             |
| Transportation land             | Land for ports, wharves and other transportation facilities and their ancillary facilities | Regular block, often with ships                            |
| Continental water region        | Land for rivers, lakes, reservoirs, etc                                                      | Long and narrow coastal morphology, smooth texture         |
| Vacant land                     | Construction land not yet determined for planned use or not to be developed within the planning period or developed under specific conditions | Wasteland, without visible features                        |
| Fishery sea                     | Areas used for fishery infrastructure and Marine aquaculture                                | Most of them are regular strips, and the water is green   |

4. Results and Discussion

4.1. Evolution of reclamation

The reclamation area of Jimo District increased by 32.68 km² from 2006 to 2018, which was mainly distributed in the southern bays, such as Aoshan Bay, Hengmen Bay and Xiaodao Bay (Table 3). Among these bays, the reclamation area in Aoshan Bay increased the most, reaching 25.98 km², accounting for 79.5% of the total. The reclamation area in Hengmen Bay increased by 3.06 km², accounting for 9.4% of the total. The reclamation areas in Chanshan Bay and Nvdao Bay were less than 1 km², only accounting for 2.8% of the total.

Table 3: The Distribution of reclamation area from 2006 to 2018 in Jimo District

| Bay              | Increment of reclamation (km²) | Proportion (%) |
|------------------|--------------------------------|----------------|
| Aoshan Bay       | 25.98                          | 79.5           |
| Hengmen Bay      | 3.06                           | 9.4            |
| Xiaodao Bay      | 2.71                           | 8.3            |
| Chanshan Bay     | 0.62                           | 1.9            |
| Nvdao Bay        | 0.31                           | 0.9            |

The development and utilization types of reclamation from 2006 to 2018 were mainly vacant land and residential land (Table 4) and both of them accounted for 93% of the total reclamation area. The proportion of vacant land is superior, reflecting the low level of intensive utilization. This causes a great waste of space resources to some extent. Residential land is mainly used for urban construction and is intensively distributed in the reclamation areas of Xiaodao Bay and Aoshan Bay. The transportation land is main for the construction of expansion and supporting facilities of Nvdao Port, which is an important measure to develop the shipping industry in Jimo District. Continental water regions, mainly located in the reclamation land of Aoshan Bay, are mainly artificial lakes or rivers excavated to support the commercial residences. It can be seen that the sea reclamation in the past more than ten years had played an important role in promoting the infrastructure construction, shipping exploration and economic development in Jimo District. However, there are still some outstanding issues.

Table 4: Development and utilization types of reclamation from 2006 to 2018 in Jimo district

| Type of reclamation development and utilization | Area (km²) | Proportion (%) |
|-----------------------------------------------|------------|----------------|
| Vacant land                                   | 23.55      | 72.1           |
| Residential land                              | 6.84       | 20.9           |
| Continental water region                      | 1.68       | 5.1            |
4.2. Driving force and impact of reclamation

The sea reclamation is usually characterized by high construction difficulty and long development cycle, and the regional economic development is the root cause. There are several bays in Jimo District, such as Hengmen Bay, Xiaodaoao Bay and Aoshan Bay. In these bays are smooth muddy tidal flats. High-quality natural conditions reduce the difficulty and cost of reclamation project. The contiguous breeding ponds were distributed in the bays in 2006, but became reclamation land in 2018. With the increasing influence of social factors such as population growth and industrial restructuring, the contradiction between human and land is becoming more and more prominent. In 2011, the State Council approved Development Plan of Blue Economic Zone of Shandong Peninsula ([2011] No.1 Document from the State Council) and then the local government issued Development Plan of Oceantec Valley of Qingdao ([2012] No. 6 Document from Qingdao Municipal People’s Government). As an important part of the Blue Economic zone of Shandong Peninsula and the carrier of the Oceantec Valley of Qingdao, Jimo District has a stronger demand for marine development and utilization. A batch of ocean-related research institutes and enterprises, such as Pilot National Laboratory for Marine Science and Technology (Qingdao), National Deep Sea Center (Qingdao), Huawei (Qingdao) Marine Science and Technology Industrial Park, are the evidence for the rapid development of the marine industry in Jimo District. While promoting the rapid economic development, sea reclamation in these bays also brought some ecological and environmental problems. For example, reclamation land is mostly distributed in the tidal flat or estuary of the bay, inevitably encroaching on wetland resources. In addition, the reclamation project has changed the hydrodynamic environment of the bay, causing erosion or siltation in adjacent areas and damaging the stability of marine environment. These problems should be paid enough attention by competent authorities.

5. Conclusions and Countermeasures

The reclamation area in Jimo District increased by 32.68 km² from 2006 to 2018. Which are mainly distributed in Aoshan Bay, Hengmen Bay and Xiaodao Bay. The vacant land and residential land are the main development and utilization types of reclamation land with the problems of idle land and low-level intensive utilization.

Economic and social factors, such as population increase, industrial restructuring and major project conduct, are the main driving factors for the increase of reclamation area.

The reclamation lands are mostly distributed in the tidal flat or estuary of the bay, which occupy the wetland resources and cause the change of the hydrodynamic environment, which should be paid enough attention by competent authorities.

The long-term monitoring mechanism for sea reclamation should be established and improved to enhance the meticulous management in coordinated development of land and marine. The concept of economical and intensive utilization needs to be implemented with the aim of reducing the reclamation land stock. Strengthening the ecological restoration in coastal zones and establishing ecological compensation mechanism for sea reclamation are also necessary to protect marine ecological redline.

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