Study on Characteristics of Coastal Evolution Based on Remote Sensing Geomorphic Feature Line——A Case Study of Central Jiangsu Province, China

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Abstract. Coastal evolution is of great significance for the protection and utilization of coastal spatial resources. Taking the coast of central Jiangsu Province as the research area, three typical coastal geomorphic lines such as seawall, vegetation line and low tide waterside line were extracted with remote sensing technology, and their temporal and spatial evolution characteristics were analyzed. The results show that due to the influence of human activities, the coast of central Jiangsu is markedly propelled to the sea. In two periods, the total newly added reclamation could reach 888.7km^2, and the seawall line is averagely propelled 8079.4m to the sea. The differences in spatial distribution are significant, and the high-value area can reach 14000.0m, distributed in the bank between the Doulonggang estuary and the Chuandonggang estuary. The low-value area is only 2000m, distributed in the Red-crowned Crane Nature Reserve. The estuary is relatively low due to the external migration of the tidal gate in the early stage. The vegetation line is averagely propelled 4433.9m to the sea, and the differences in spatial distribution are relatively small, showing the high value in the center and a gradual decrease of north and south sides. The overall shape of the waterside waterline is stable, showing a backward trend of the shore; the low tide waterline is large. The retreat of low tide waterside waterline and the propel of seawall line to the sea has dramatically increased the shrinkage of the intertidal tidal flat. From 1973 to 2017, the intertidal tidal flat area decreased by 1056.7 km^2.

1.Introduction

The geomorphological elements and their spatial distribution patterns profoundly reflect the evolution process of regional spatial geomorphology. As the boundary line between land and sea, the position of the coastline reflects the comprehensive effects of changes in the erosion environment of the coastal zone and the transformation of human activities [1-3]. By analyzing the temporal and spatial changes of different types of coastal geomorphic lines, the evolution process of regional coastal geomorphology and its dynamic characteristics of resources and environment can be fully revealed [4, 5]. This study takes the coast of central Jiangsu Province as an example, and proposes three typical geomorphic lines of seawall, vegetation line and waterside line based on remote sensing [6-13], and then analyzes the temporal and spatial variation of typical geomorphic lines. The characteristics of the development and evolution of coastal landforms such as reclamation, tidal flats and intertidal flats are comprehensively analyzed.

2.Research area

The study area is located in the central part of Jiangsu Province, from the Sheyang estuary in the north to the Liangduo estuary in the south, which belongs to the typical coastal plain coast, and the coastal type is silt and muddy. Affected by Abandoned-Yellow River estuary and the source of the Yangtze River sediments, the coast of the study area is generally silted and developed a large-scale coastal tidal flat. As the development of large-scale tidal flats by human, the seawall line continues to be propelled to the sea. The area is located in the north subtropical zone, with a monsoon climate and abundant rainfall, where the shoal of salt marsh vegetation is developed, and the main vegetations include *Pragmites communis*, *Saueda spp.* and *Spartina spp.*. From the north to the south, there are many rivers emptying into the sea such as Sheyang River, Xinyanggang River, Doulonggang River, Simaoyou River, Wanggang River, Zhugang River and Chuandonggang River.

3.Material and method

3.1 Data source and processing

In this study, three periods of Landsat remote sensing images were used for shoreline information extraction, namely MSS image of 1973, TM image of 1995 and OLI image of 2017. The spatial resolution of the MSS image is 78m×78m, while the spatial resolution of the TM image and the OLI image is 30m×30m. The collected image data is of good quality, which is conducive to the identification and extraction of seawall, vegetation and water-land boundary in the study area. Remote sensing image preprocessing used ENVI5.1 software, including image projection conversion, geometric precision correction, and study area cropping. The other images were fine-corrected based on the image of 2017, and the root mean square error was less than 0.5. The study area was cut using the sea area management shoreline and waterside line, and the remote sensing map of the study area was obtained.

3.2 Typical Landform Indicator Types and Extraction

According to the characteristics of coastal geomorphology, three typical geomorphic features of seawall line, vegetation line and waterside line are selected to comprehensively analyze the coastal evolution characteristics of the study area. The seawall line refers to the most peripheral levee on the seaside formed by the coastal development of fish farming, salt production and reclamation, and is affected by coastal evolution and human development activities. Vegetation line refers to the outer boundary line of the coastal survey of coastal halophytes, and its spatial location comprehensively reflects the characteristics of coastal resources and environment, which is an important indicator of the evolution of coastal zones. The waterside line refers to the boundary line between sea and land that can be regarded as a coastal contour line. The low tide waterside line is a comprehensive reaction of the spatial extent and shape of the coastal intertidal zone. Due to the obvious features of the seawall in the study area, the characteristic band is selected for false color image synthesis, combined with field observation, and the seawall is extracted by visual interpretation; the remote sensing image is enhanced, comparing the field survey with remote sensing image, and a combination of supervised classification and visual interpretation extracts vegetation lines and waterside lines.

3.3 Analysis of coastline evolution

Based on the typical remote sensing geomorphic feature lines, the baseline and statistical analysis methods are used to comprehensively analyze the temporal and spatial evolution characteristics of the coastline [14]. According to the overall shape of the coast, a baseline is set on the sea side, and a measurement section is set at a distance of 1000m from north to south along the baseline, and cumulatively 115 sections are set. The spatial and temporal evolution characteristics of coastal landforms were analyzed using DSAS module in the ArcGIS platform.

4.Results and analysis

4.1 Characteristics of seawall change

The seawall is a typical artificial geomorphological landmark in the coastal area, and it is a basic engineering facility for human to protect or develop the characteristics of coastal evolution. The seawall of central Jiangsu Province in China continued to be propelled to the sea in high intensity during the study period, which is an active feature of the tidal flat reclamation project in this area. Based on the statistical analysis of the measured section, the average seaward propulsion distance from the central coast of Jiangsu Province has reached 8079.4m since 1973, with an average propulsion distance of 2721.0m from 1973 to 1995 and an average propulsion distance of 5358.4m from 1995 to 2017. Overall, the coastline of central Jiangsu Province has been rapidly propelled to the sea, but there are also significant spatial and temporal differences in different shore sections. The Doulonggang estuary to the Chuandonggang estuary is the most significant, and the propulsion distance is between 8000-14000m, while the relatively low value of the propulsion distance in this section is only distributed in the estuary of the river emptying into the sea. The propulsion distance of the Sheyang estuary to the Xinyanggang estuary in the north and the Chuandonggang estuary in the south is at the second level of the study area, which is between 4000-8000m. The Xinyanggang estuary to the Doulonggang estuary section in the northern part of the study area is a low-value area that the seawall line is propelled to the sea. The area is the location of the Red-crowned Crane Nature Reserve, which receives less interference from human activities, and the propulsion distances are below 4000m, and that of the local shore is only 300-400m. The process of propelling the seawall to the sea is also a process of reclamation along the coast in the coastal areas. Statistics show that since 1973, the cumulative reclamation area of the study area has been 888.7km^2, of which 299.3km^2 has been reclaimed from 1973 to 1995, and 589.4km^2 has been reclaimed from1995 to 2017.

4.2 Characteristics of vegetation line change

Salt marsh vegetation is an important ecological landform mark in coastal areas. The sea-side outer edge line of the salt marsh vegetation reflects the control boundary of the ecosystem with plant marks in the coastal wetland, which is the approximate boundary of the high tide line in the coastal area. The area between the salt marsh vegetation and the seawall line is generally regarded as the range with high tide beaches of the intertidal zone. The salt marsh vegetation outside the artificial seawall reflects the influence of the tidal flat landform by seawater immersion, and its distribution range is mainly affected by the erosion and deposition of the bank under the control of regional coastal dynamic geomorphology. At the same time, with the continuous propulsion of the artificial seawall line to the sea, the regional coastal scouring environment achieves a new dynamic balance, and the salt marsh vegetation can carry out new habitat development succession on the tidal flat outside the seawall. Based on the analysis of the measured section, the salt marsh vegetation is widely distributed in the shore area of the whole study area. Since 1973, the vegetation line has continued to evolve toward the sea, and the average propulsion to the sea has reached an average of 4433.9m, of which the average propulsion distance is 1953.3m from 1973 to 1995, and is 2480.6m from 1995 to 2017. The seaward propulsion of the spatial position of the vegetation line is controlled by the continuous high-intensity sea thrust of the artificial seawall. In order to further describe the changes of the salt marsh vegetation habitat, the spatial variation of the tidal flat between the vegetation line and the seawall line was analyzed. Studies have shown that the average depth of the tidal flats in 1973 was 5177.7m, which decreased to 4384.8m in 1995 and further reduced to 1513.9m in 2017. From 1973 to 2017, the tidal flats showed a sharp shrinkage, and only the tidal flat of the northern red-crowned crane reserve expanded.

4.3 Characteristics of waterside line change

Due to the slow slope of the general bank on the tidal flat coast, it is difficult to carry out the conventional topographic survey work because of the frequent changes in the bank. The waterside

line is the dividing line between sea and land, and its position changes with the tides, and at the low tide level, the waterside line, the boundary between sea and land, at the lower moment, when the tidal flat is exposed in a large area. The spatial position and shape of the waterside line can reflect the overall situation of the tidal flat in the study area, and we can use the low tide waterside line in different periods to effectively analyze the evolution of the tidal and silt environment in the intertidal zone. Based on the statistical analysis of the measured section, the low tide waterline along the coast of the study area has been retracted since 1973, and the cumulative average retraction distance can reach 1526.5m, of which the average retreat distance is 881.9m from 1973 to 1995, and is 644.6m from 1995 to 2017. It can be seen from the spatial position change of the low tide waterside line that the waterside line along the coast of the study area is fully retracted. Only the local shore section near the Sheyang estuary in the north is deposited into the sea under the influence of artificial dam construction. In general, the retreat intensity of the waterside line from Xinyanggang estuary to Simaoyou estuary is relatively low, and the retreating distance is around 1000m; the waterside line on the north side of the Xinyanggang estuary and the south bank of the Simaoyou River has greater retraction strength. The distance is about 2000m, and the retreat distance of the local bank on the south side of the Chuandonggang estuary is even 3000m. The large distance retreat of the low tide waterside line reflects the continuous reduction of the sea level in the intertidal zone of the study area. At the same time, the continental side of the seawall line in the inland area is propelled to the sea in large scale, and the land side and the sea side both intensify the shrinkage of the intertidal tidal flat range. The spatial analysis shows that the tidal flat area of the study area has been reduced by 1973, and the cumulative reduction area has reached 1056.7km^2. The tidal flat area decreased by 396.3km^2 from 1973 to 1995 and by 660.3km^2 from 1995 to 2017.

4.4 Analysis of the overall evolution characteristics of the coast

From 1973 to 1995, the sea reclamation time between the seawall lines was long, and it belonged to the coastal area with a long history of development. The history and development time of reclamation between seawall lines from 1995 to 2017 was short; In 2017, between the sea seawall line and the vegetation line, it is the intertidal salt marsh that develops in the silt environment of the bank. It belongs to the mid-high tide beach area of the intertidal zone; the intertidal light beach with natural development is between the vegetation line and the low tide waterside line. The typical coastal geomorphic line of seawall, vegetation line and waterside line is closely related to reclamation, high tide beach and intertidal light beach. The development of time, space and scope reflect the feature of regional coastal evolution. Overall, since 1973, the seawall of the study area has continued to be propelled to the sea, with a cumulative reclamation area of 888.7km^2. The tidal flats are intensively atrophic, and the average shrinkage width can reach 3663.8m. Only the tidal flat of the northern red-crowned crane reserve area expands. The tidal flat scouring environment is significantly affected by the artificial building geomorphology. The low tide waterside line in the sea side continues to shrink, and the land side levee line is propelled to the sea on a large scale, which intensifies the shrinkage of the intertidal tidal flat range of the intertidal zone. The cumulative reduction area of tidal flats can reach 1056.7km^2, and the average shrinkage distance of tidal flats can reach 9606.0m.

5.Conclusion and discussion

The coastal tidal flat reclamation in the study area has been active, and since 1973, the cumulative reclamation area has been 888.7km^2, which has a significant impact on the dynamic geomorphological environment of the coastal waters. The seawall line is rapidly propelled to the sea, and the propulsion distances between the Doulonggang estuary and Chuandonggang estuary are between 8000m to 14000m, the Sheyang estuary to the Xinyanggang estuary Section, and the south bank of the Chuandonggang estuary are between 4000-8000m. The Xinyanggang estuary to the Doulonggang estuary section is the location of the Red-crowned Crane Nature Reserve with the propulsion distance of below 4000m.

The salt marsh vegetation is widely distributed in the bank of the whole research area and is controlled by the continuous high-intensity propulsion towards sea of the artificial seawall. Since 1973, the vegetation line has continued to be propelled to the sea, and the average propulsion distance to the sea has reached 4433.9m. However, the scale of the high tide beach is generally shrinking, except the expansion of the northern red-crowned crane conservation area. In 1973, the average depth of the high tide beach was 5177.7m, which decreased to 4384.8m in 1995 and further reduced to 1513.9m in 2017.

The coastal low tide waterside line is in a state of strong retreat. Only the local shore section near the north side of Sheyang estuary is dredged into the sea under the influence of artificial dam construction. The tidal flat scouring environment is significantly affected by the artificial building geomorphology and since 1973, the cumulative average retreating distance of the low tide waterside line can reach 1526.5m, of which the average retreating distance from 1973 to 1995 is 881.9m, while the average retreating distance from 1995 to 2017 is 644.6m. The land-side levee line is propelled to the sea on a large scale, which intensifies the shrinkage of the intertidal tidal flat. The cumulative reduction of tidal flats in the intertidal zone can reach 1056.7km^2, and the average shrinkage distance of tidal flats can reach 9606.0m.

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