# Recent Extraction and Spatial Analysis of Yangtze River Estuary Coastline Using Multi-Source Remote Sensing Data

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Keywords: Coastline Change, Yangtze River Estuary, Remote Sensing Analysis.

Abstract: Remote sensing technology and multi-source remote sensing data resources provide technical support for monitoring coastline changes. This paper focuses on the dynamic evolution of the coastline in the Yangtze River Estuary, which has a profound impact on the local marine-terrestrial ecological environment and economic development.Based on multi-source remote sensing data from 1985 to 2020, this paper conducts a detailed extraction and spatial analysis of the coastline characteristics in the Yangtze River Estuary, aiming to reveal the long-term trends of coastline changes and their underlying influencing factors.After thorough analysis, the coastline of the Yangtze River Estuary has shown a significant expansion trend over the past 35 years, which is related to factors such as river sediment transport, oceanic dynamic conditions, and human activities. Comparative analysis further identifies the main regions and critical time nodes of coastline changes.The research results provide a reference basis for the management and protection of the Yangtze River Estuary coastline, and also offer methodologies and insights for similar studies in other regions, which are significant for promoting the implementation of sustainable development strategies in coastal areas.

## 1 INTRODUCTION

The Yangtze River Estuary, located on the eastern coast of China, serves as a crucial connection between the interior and the ocean. The dynamic changes of its coastline significantly affect the regional ecological environment and economic development. In recent years, the evolution of the Yangtze River Estuary coastline has received increasing attention due to multiple factors such as global climate change and human activities. To scientifically and accurately grasp the characteristics of coastline changes in this critical region, this study conducts feature extraction and spatial analysis of the Yangtze River Estuary coastline based on multi-source remote sensing data from recent years. By comprehensively applying advanced remote sensing technology, this paper aims to deeply reveal the evolution patterns of the coastline, providing a scientific basis for ecological protection, urban planning, and marine resource management. It will also enhance understanding of the dynamic changes of the Yangtze River Estuary coastline and provide strong support for related decision-making (Sümeyra Kurt et al., 2010). In recent years, the evolution of the Yangtze River Estuary coastline has attracted increasing attention due to multiple factors such as global climate change and human activities. Global climate change, characterized by sea-level rise and frequent extreme weather events, poses new challenges to coastline stability and the ecological environment. Meanwhile, rapid urbanization further changes the natural form and ecosystem of the coastline. These changes not only affect the lives and production of coastal residents but also pose new requirements for regional ecological environment, marine resource utilization, and disaster prevention and mitigation.

To scientifically and accurately grasp the characteristics of coastline changes in this critical region, this study conducts feature extraction and spatial analysis of the Yangtze River Estuary coastline based on multi-source remote sensing data from recent years. Remote sensing data, with its advantages of wide coverage, strong timeliness, and multi-scale and multi-spectral capabilities, provides reliable data support for dynamic monitoring and analysis of coastline changes. By integrating satellite imagery, aerial imagery, and other high-resolution

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remote sensing data, this paper adopts advanced remote sensing technology and Geographic Information System (GIS) methods to accurately extract the location and morphological characteristics of the coastline (Kuifeng, 2019).

# 2 MATERIALS AND METHODS

## 2.1 Study Area

The Yangtze River, China's largest river, has a large runoff and abundant sediment, forming a pattern of three-level bifurcation and four outlets into the East China Sea. The Yangtze River Estuary, the largest estuary in China, has a complex estuary evolution mechanism. For the study area, the coastline from Lianxing Port in Jiangsu Province in the east to Xuliujing in Jiangsu Province in the west is selected. This area is a tidal estuary with high suspended sediment concentration and complex bottom sediment distribution. A large amount of sediment from the upstream watershed is transported to this area in various forms, making it a critical zone for sediment deposition and the most active area for land-sea interaction (Zhang & Song, 2023).

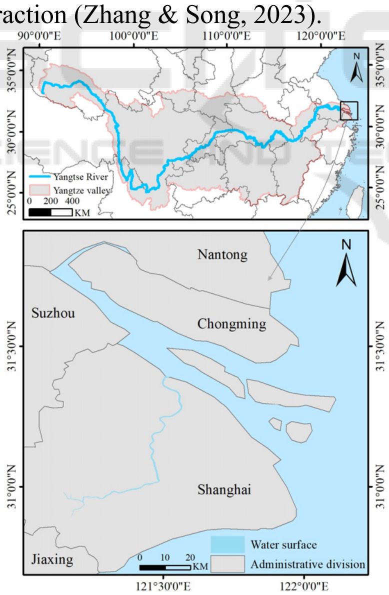


Figure 1. Map of the Study Area (Picture credit: Original)

## 2.2 Data Sources

The primary data sources for this study were obtained from the Geo spatial Data Cloud (http://www.gscloud.cn/). Specifically, Landsat series remote sensing images were collected from eight periods spanning from 1985 to 2020: 1985, 1990, 1995, 2000, 2005, 2010, 2015, and 2020.Among these, the images from 1985, 1990, and 1995 were captured by Landsat 4 -5 TM sensors, while 2000 was recorded by Landsat ETM. Images from 2005 and 2010 were captured by Landsat 7, and 2015 and 2020 by Landsat 8. These images were of high quality, with cloud cover below 10%. In cases where clouds were present, they were not located along the coastline, thus having minimal impact on coastline extraction. The preprocessing of these images involved radiometric correction, atmospheric correction, image registration, band composition, image fusion, and projection conversion (Zhang & Song, 2023).

## 2.3 Analytical Methods

In this study, the Modified Normalized Difference Water Body Index (MNDWI) was utilized for the initial extraction of the Yangtze River Estuary coastline.MNDWI, an improvement upon the Normalized Difference Water Body Index (NDWI) (Guariglia et al., 2009), enhances the ability to distinguish water bodies from soils and man-made structures, thereby ensuring more accurate water body extraction (Wei et al., 2023). The MNDWI is calculated using the following formula:

$$MNDWI=GREEN-MIR/GREEN+MIR \quad (1)$$

Where GREEN -- green band, and MIR -- middle infrared band. In Landsat ETM and Landsat 8 images, these correspond to bands 2 and 5, and bands 3 and 6, respectively.

Despite the efficiency of MNDWI, manual visual interpretation remains a high-precision method in remote sensing interpretation. Therefore, the initially extracted coastlines were refined through manual visual interpretation, and the corrected coastline data were overlaid with the processed remote sensing images in ArcMap (White & Asmar, 1999). For regions with unclear images or doubts, high-resolution remote sensing images from Google Earth at similar time periods were referred to ensure the accuracy and completeness of the coastline interpretation. Following data processing, Geographic Information System (GIS) techniques were employed to conduct spatial analysis on the extracted coastlines, calculating parameters such as area, perimeter, and shape indices to quantitatively describe sediment deposition characteristics in the Yangtze River Estuary.

Coastline Extraction Process:Coastlines featuring rocky substrates in the intertidal zone typically exhibit a distinct rocky structure and topographic relief (Taveira-Pinto & Veloso-Gomes, 2009), making their demarcation evident in remote sensing images. In interpretation, the boundary between land and sea water was considered as the coastline (Alesheikh et al., 2007).

# 3 RESULTS

## 3.1 Shoreline Morphology and Feature Extraction Results

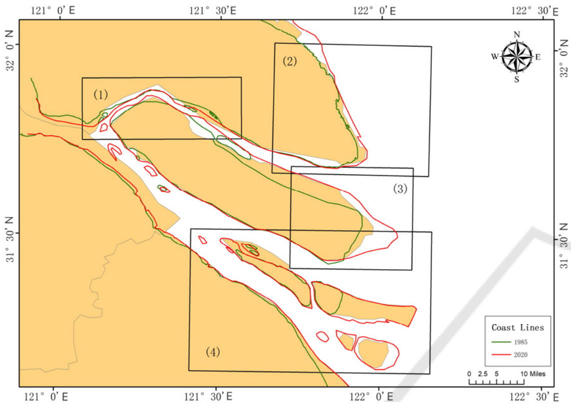


Figure 2. Analysis of the Study Area Divided into Four Regions (Picture credit: Original).

The Yangtze River Estuary coastline demonstrates a pronounced expansion trend, particularly notable in the eastern segments of Chongming Island, Pudong New Area, and Nantong City . This phenomenon can be attributed to various factors, including natural processes (e.g., sedimentation, sea-level rise) and human activities (e.g., land reclamation, port construction).

Area-1: Southern Section of Haimen City

From 1985 to 2010, the shoreline length slightly decreased (from 46.78 km to 46.59 km), indicating a flattening trend. However, the area increased by 37.34 km² due to the construction of artificial embankments. The curvature remained relatively unchanged, and the shoreline direction was stable with no significant turns.

Area-2: Eastern Section of Chongming Island

The shoreline length significantly increased (from 4 4.08 km to 59.57 km), averaging an advance of 2.83 km towards the sea, demonstrating a strong eastward expansion. This was primarily driven by the artificial construction of silt promotion dikes, which led to coastal accretion. Although local curvatures might exist due to the increase in shoreline length, the overall direction remained eastward. The significant seaward advancement of the coastline in this area could be associated with large-scale land reclamation projects aimed at expanding land area for urban development and industrial expansion.

Area-3: Eastern Section of Pud ong New Area

The shoreline length slightly decreased (from 64.89 km to 64.34 km), while the area increased by 112.5 km², indicating a straightening effect through land reclamation. Minimal changes in curvature and a stable shoreline direction suggest significant human intervention in this region. The notable coastline expansion in Pudong New Area can be linked to rapid urbanization, port development, and infrastructure construction.

Area-4: Eastern Section of Nantong City

Anticipated changes in shoreline length and area are likely due to urbanization and population growth, potentially leading to a flattening of the shoreline with a relatively stable direction. The significant coastline changes in this area are associated with economic development and population growth, increasing the demand for land resources and, subsequently, promoting artificial modification of the coastline.

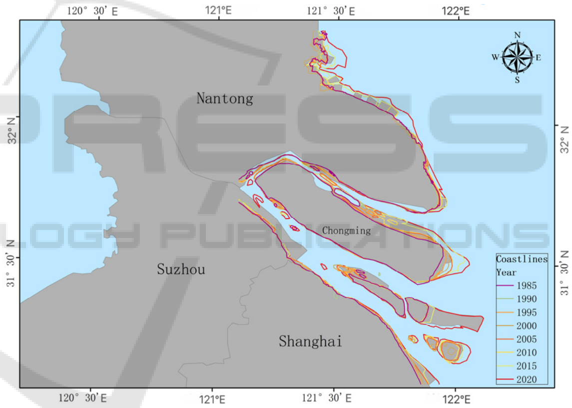


Figure 3. depicts the coastline changes from 1985 to 2020 (Picture credit: Original).

## 3.2 Analysis of Coastal Dynamics and Evolution

Between 1985 and 2020, Area-1 (southern section of Haimen City) experienced a coastal area growth of approximately 11.7%, reaching 76.75 km ², and a shoreline length increase of about 6.0%, or 5.81 km. This growth is attributed to artificial embankments and silt promotion projects, which stabilized the coastline and increased land area. Meanwhile, Area-2 (eastern section of Chongming Island) showed a remarkable coastal area growth of about 62.5%, reaching 196.1 km², and a shoreline length increase of approximately 31.8%, or 17.56 km. This expansion is attributed to large-scale land reclamation and natural sedimentation processes.

In contrast, Area-3 (eastern section of Pudong New Area) exhibited a coastal area growth of about 12.6%, adding 81.07 km², but a decrease in shoreline length of approximately 14.7%, or 11.67 km. This change is associated with coastline straightening and land reclamation activities, resulting in a shorter total length. Area-4 (eastern section of Nantong City) also saw a coastal area growth of about 35.3%, reaching 389.62 km², and a shoreline length increase of approximately 11.3%, or 10.55 km. This growth is linked to economic development and urbanization, particularly in infrastructure and port development.
Both the eastern shoreline of Chongming Island and the eastern shoreline of Pudong New Area display significant siltation phenomena, primarily attributed to the net movement of sediments at the Yangtze River Estuary and the implementation of artificial siltation promotion projects. The average annual siltation of the Chongming Island shoreline is 6.11 km², while the eastern segment of Pudong New Area experiences an average annual siltation of 4.69 km², indicating that these regions serve as primary sites for sediment accumulation .

Both the eastern coast of Chongming Island and the eastern coast of Nantong city experienced significant expansion of their shorelines, mainly due to land use changes caused by artificial reclamation and urbanization. Although the length of the southern coast of Haimen varies little, the increase in its area also indicates a degree of expansion.

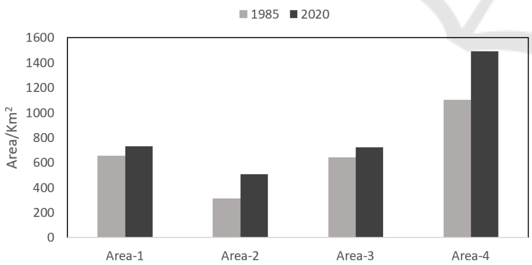


Figure 4. Statistics of Coastal Area by Zone (Picture credit: Original).

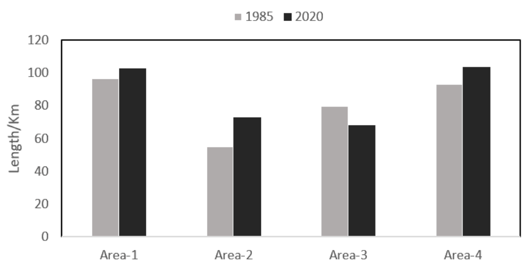


Figure 5. Statistics of Shoreline Length by Zone (Picture credit: Original).

Table 1. Statistics of Shoreline Length (1985-2020).

| Year | Total area/Km$^2$ | Total Length/Km |
|---|---|---|
| 1985 | 11749.83 | 800.86 |
| 1990 | 11739.50 | 771.22 |
| 1995 | 11921.56 | 821.68 |
| 2000 | 12683.43 | 837.33 |
| 2005 | 11533.47 | 845.68 |
| 2010 | 12532.14 | 859.23 |
| 2015 | 12787.96 | 872.70 |
| 2020 | 13423.08 | 932.34 |

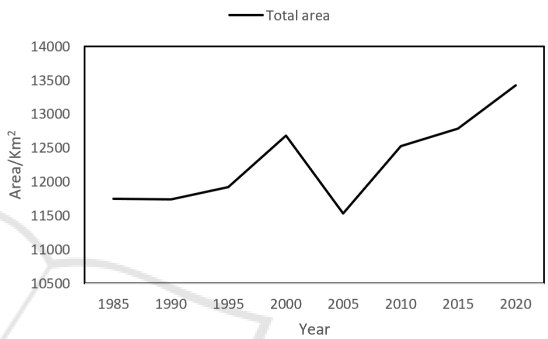


Figure 6. Coastal Area Change (1985- 2020). (Picture credit: Original).

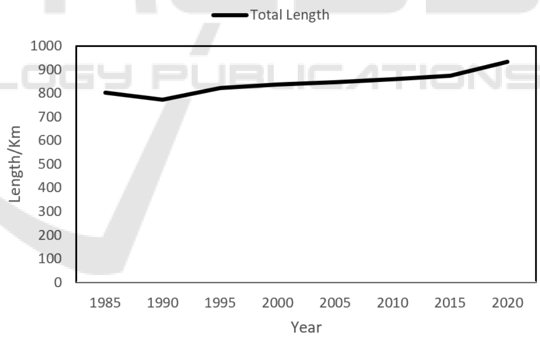


Figure 7. Shoreline Length Change (1985-2020). (Picture credit: Original).

## 3.3 Analysis of factors affecting shoreline change

The changes in the Yangtze River Estuary's coastline are primarily influenced by human activities, especially construction projects and land use changes.

Land Reclamation: The southern shoreline of Haimen City, the eastern shoreline of Chongming Island, and the eastern shoreline of Pudong New Area have all undergone land reclamation activities, which have directly led to changes in shoreline length and increases in regional area. Land reclamation has flattened the original natural shoreline, altering its morphology. These land reclamation projects in the region are primarily for industrial and commercial development, aimed at expanding land area to meet economic development needs. These projects have not only altered the shoreline morphology but also significantly impacted the local ecological environment, such as destroying original wetlands and habitats. The land reclamation projects in the eastern part of Chongming Island are intended for agricultural and urban construction, increasing farmland and residential land through land reclamation. These projects have altered sediment deposition patterns , resulting in significant shoreline changes.

Port Construction: Although the document does not directly mention the impact of port construction on the coastline, typically, port construction involves large-scale shoreline modifications and dredging projects, which significantly affect shoreline morphology and ecological environments. The construction and expansion of Shanghai Port involve substantial land reclamation and shoreline modifications. The development of port facilities requires vast areas of land, replacing the original natural shoreline with port terminals and breakwaters. Dredging projects alter the natural sediment deposition process, potentially intensifying erosion in certain areas.

Artificial Siltation Promotion: The artificial siltation promotion projects in the eastern shoreline of Chongming Island and Pudong New Area have accelerated sediment accumulation and shoreline expansion, playing a crucial role in shaping the coastline's evolution.

Urbanization: The changes in the eastern shoreline of Pudong New Area and the assumed similar trends in the eastern shoreline of Nantong City are also influenced by urbanization. With population growth and economic development, the demand for land increases, driving land reclamation and shoreline modification activities.

The changes in the Yangtze River Estuary's coastline are the result of both natural and anthropogenic factors, with human activities playing a dominant role. Through the analysis of multi-source remote sensing data, a clearer understanding of the characteristics and evolution patterns of coastline changes can be gained, providing a scientific basis for coastal zone management and ecological protection.

# 4 CONCLUSIONS

This study delineates the intricate dynamics of shoreline changes in the Yangtze River Estuary, particularly focusing on the southern section of Haimen City, the eastern sections of Chongming Island and Pudong New Area, and the eastern section of Nantong City. The period from 1985 to 2020 witnessed notable alterations in coastal areas and shoreline lengths, predominantly influenced by human interventions such as land reclamation, port construction, and artificial siltation promotion, alongside natural sedimentation processes.

The southern section of Haimen City and the eastern shoreline of Chongming Island experienced substantial growth in both coastal area and shoreline length, driven by artificial interventions aimed at stabilizing the coastline and increasing land area. Conversely, the eastern shoreline of Pudong New Area, despite a similar increase in coastal area, exhibited a reduction in shoreline length, indicative of the impact of coastline straightening and land reclamation activities.

Significant siltation phenomena were observed along the eastern shorelines of Chongming Island and Pudong New Area, primarily due to the net movement of sediments at the Yangtze River Estuary and artificial siltation promotion projects. The eastern coast of Nantong City also demonstrated considerable shoreline expansion, largely due to economic development and urbanization, particularly in infrastructure and port development.

The study underscores the dominant role of human activities in shaping the coastline of the Yangtze River Estuary, with land reclamation projects flattening natural shorelines and altering sediment deposition patterns. Port construction and artificial siltation promotion have accelerated sediment accumulation and shoreline expansion, significantly impacting shoreline morphology and ecological environments.

The analysis of multi-source remote sensing data has provided a clearer understanding of the characteristics and evolution patterns of coastline changes, offering a scientific basis for coastal zone management and ecological protection. This study captures the cumulative effect of underlying dynamic processes, utilizing remote sensing and GIS techniques to model shoreline changes and reduce uncertainty associated with hydrodynamic parameters.

The findings contribute to a comprehensive understanding of the evolution of the entire delta, highlighting the potential of remote sensing and GIS techniques for facilitating detailed and in-depth assessments of shoreline changes. The methodology employed in this study is considered valuable for evolution studies of other large global delta systems, providing a template for future research and policy-making in coastal management and ecological conservation.

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