A Study on the Long-term Shoreline Changes in East Coast of Korea using Satellite Images

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INTRODUCTION

The coast refers to the narrow and long zone where the land meets the sea, influencing each other when they come together. The coast is a dynamic region where natural forces such as marine environments and terrestrial areas meet, affected by both natural activities like erosion and deposition and artificial actions like coastal development. Among these, the shoreline delineates the indefinite zone of land that extends into the terrestrial area, separating natural water bodies.

Recently, accelerated coastal erosion has been observed due to rising sea levels and increased occurrence of storm surges, causing rapid changes that threaten artificial structures and the living environments of coastal residents. Establishing strategies to address exacerbated erosion due to rising sea levels and mitigating coastal residential area damages requires securing fundamental data for policy development. Continuous monitoring of coastal environments and shoreline changes is essential to formulate improvement strategies for spatial policies and systems.

In our research, we have extracted long-term coastlines from satellite images spanning over 10 years. We established criteria and analysis guidelines for coastline changes and width assessment, reviewed long-term coastal changes on the East Coast of Korea, and researched methods for establishing digital monitoring techniques.

METHOD

We had collected a variety of satellite data that can be utilized from various cases. Fig. 1(Turner et al., 2021). was a list of currently available satellite data.

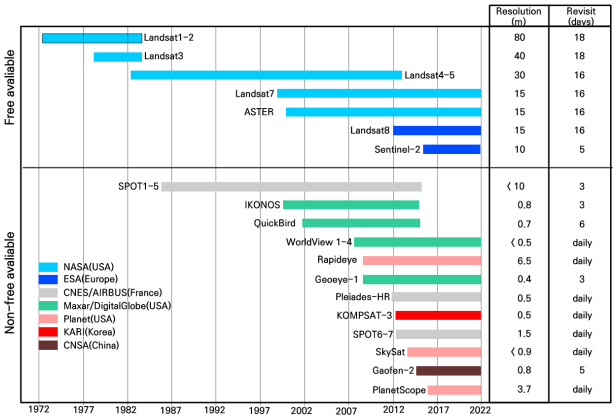

Figure 1 - Collection and analysis of various satellite data to review applicability to this study.

The selection criteria for satellite data include the ability for 1) long-term change analysis, 2) high resolution of 20 meters or less, and 3) high-frequency data collection. Landsat and Sentinel-2 generally meet these conditions and have been adopted as the primary data sources for this study. Landsat image data varies depending on the type, visited from around 1 month to 15 days. Before 2000, satellite image could be collected about once a month. Satellite image for Sentinel-2, released in the latter half of 2010, provides free-available data with a high frequency(10m resolution) of data, visited of every 5 days. Specifically targeting major erosion areas on the East Coast where social issues arise, I selected these as Regions of Interest (ROI) and utilized Landsat and Sentinel-2 satellite data accumulated on the Google platform for research purposes.

The collected satellite data for coastline analysis is composed of R, G, B, NIR, and SWIR1 bands. Referring to the study by VOS et al., 2019, we utilized a technique that combines the MNDWI (Xu, 2006) method and Machine Learning (ML) to recognize the coastline, allowing us to extract the coastline from satellite images, see Fig. 2.

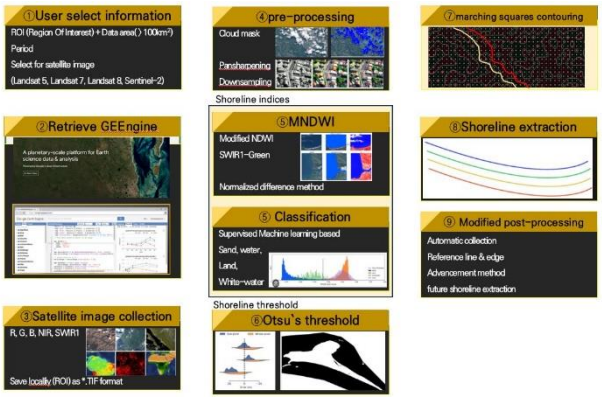

Figure 2 - Flowchart for long-term free satellite image automatic collection and coastline extraction and analysis process.

The MNDWI technique was based on the function of the SWIR1 and G bands to extract the coastline. It was modified technique from the commonly used NDWI, enabling clear extraction of coastlines, particularly in the shadow zones near structures. The ML technique used the scikit-learn classification adopted to distinguish terrestrial areas, coastlines, and break zones from satellite data. The model used pre-trained data for learning before its public release.

CONCLUSION

Fig. 3 showed the Won-pyeong Beach on the East Coast of South Korea, which is our significant area of analysis.

Since 2000, numerous structures have been installed in the area, leading to rapid and substantial changes, preventing the coastline from maintaining a parallel state. Notable structures include the installed of a breakwater in 2013, the installed of the third submerged breakwater in 2017, and the breakwater and groins in 2022.

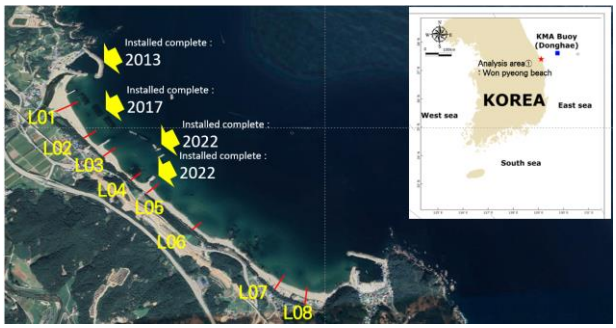

Figure 3 - Location of major erosion areas, history of structure installation in the target area, and 8 baselines used for analysis.

Results obtained from collected and analyzed satellite data spanning approximately 40 years (1985-2023) were depicted in Fig. 4. The study utilized Landsat 5 data from 1984 to 2011, Landsat 7 data from 2011 to 2015, and Sentinel-2 data from 2015 to 2023. These datasets provide crucial information for examining long-term coastal changes, including patterns of coastal alterations, prolonged equilibrium states, and sudden shifts, allowing us to understand the history of coastal transformations. In analysis, the linear trendline represents the shoreline, with year 0 marking the coastline in 1985, serving as the reference point to assess trends in advancement or retreat. The overall analysis indicates a prevalent trend of coastal retreat, although some areas display tendencies of advancement. The analyzed area encompasses multiple installed structures and was region where long-term beach nourishment was conducted, involving both natural and human-induced changes. To conduct a more detailed analysis of these shoreline changes, Fig. 5. demonstrates an assessment based on the completion of structure installations.

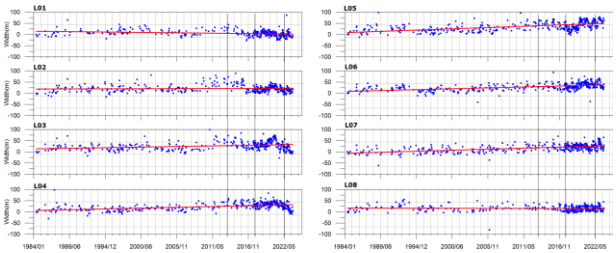

Figure 4 - Long-term coastline analysis for about 40 years from eight baselines at Won-pyeong Beach on the east coast of Korea.

The left side of the Fig. 5. displays the instantaneous satellite shoreline data of coastal changes during the period of structure installation completion, including the trendline, while the right side illustrates the yearly amplitude and slope of changes for each period to analyze the trendlines uniformly. Before the completion of structures in 2013, it was generally observed that the shorelines along 8 selected sections of Won-pyeong Beach were in a state of equilibrium. However, the analysis period includes instances such as typhoons. Although short-term erosion during specific typhoon periods is noticeable in satellite imagery, it is generally observed that the coastline restores its original state over the long term. After the installed of the breakwater in 2013, the shoreline changes along each analyzed section mostly exhibited a distinct trend of erosion. Though some sections showed advancement, the extent of this advancement was relatively minor. This analysis suggests that the coastline was retreating due to the installation of structures and was unable to maintain its previous beach width. Such analyses of change trends could significantly enhance understanding of the erosion process on the coast and the points of change in the erosion environment, potentially aiding in the formulation of strategies for responding to erosion phenomena and minimizing damages to coastal residential areas. With the installation of revetments and groins in 2022, the trend in coastal changes appears somewhat mitigated. However, as this period includes changes due to artificial factors such as nourishment, comprehensive examination involving short-term, seasonal and among others, will be conducted to closely analyzed the shoreline change trends.

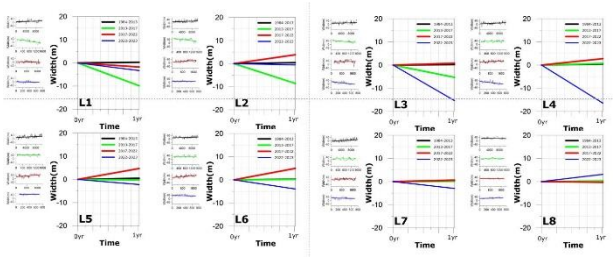

Figure 5 - Comparative analysis of annual coastline change range and change slope in a period classified by the completion of structure installation

ACKNOWLEDGMENT
This research was supported by the Korea Institute of Marine Science & Technology Promotion (KIMST) funded by the Ministry of Oceans and Fisheries (No. RS-2023-00256687).

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