MEASUREMENT OF COASTAL EROSION ON THE EAST SEA USING CORONA SATELLITE IMAGERY

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ABSTRACT : In this paper, a small portion of coastline on the EAST SEA was studied using CORONA panoramic satellite photo and 1:5000 Korean National Topographic Map. The project site near Kangneung city was 3 Km shoreline on the Kangmoon Beach and the SongJeong Beach, which have suffered from severe erosion. The first and the most important step was to rectify a CORONA image over the project site. A rigid mathematical model and a heuristic polynomial transformation were used for the purpose. The rectified image was overlaid with 1:5000 Korean National Topographic Map produced by aerial mapping. Among numerous methods for shoreline erosion measurement, area-based approach was chosen and used for the computation for annual shoreline recession. The final result of the analysis was that the average recession in the period of 1963-1998 was 33.6m and the annual rate was 0.96m.

KEY WORDS: CORONA satellite, satellite imagery, topographic map, change detection, coastal erosion

1. INTRODUCTION

1.1 General Instructions

From 1960s, with settlement of the Economic Development for Five Year Plan by the Korean Government, many infrastructures were built and seashore structures such as harbors and breakwaters were also built. Howevr, the advent of new seashore structures which neglected environmental effect changed waves and flow of a marine current. It led changes in motion of particles in water and consequently changed aspects of accumulation and erosion.

These changes are very important because the scale of damage is huge, and massive expenditures and time are needed to restore them. Consider that millions of people visit beaches in every summer, the economic damage due to the beach erosion is very fatal. The beach erosion is a loss of a territory and if the degree of erosion is serious, it may threat people's stable residence. Accordingly, farsighted policies which deal with management of territory and future development of seashore structures, precise understanding analysis, and prediction are very necessary.

Because the change of coastal line is occur on a large scale, about a hundred meters to several kilometres, observations on the ground are not proper. Analysis using air-captured images such as aerial photographs or satellite images is needed. In this paper, Kangmoon Beach and SongJeong Beach in Chodang-dong, Kangneung city are selected for the research areas, and measured the change of seashore area for about 40 years using CORONA satellite image which taken in 1960's and topographic map which taken in 1988. Geo-rectification of CORONA satellite image was performed to combine two images, and divided the area change into uniform parts to understand the aspect of coastal changes.

1.2 Literature Review

There are many previous studies on coastal change and CORONA satellite images. Ming and Chiew(2000) had grasp how a breakwater which has specific width and length affects change of coastal line and established standard which classifies a sandbar and just a projecting part. Further, they also verified the mutual relationship between the scale of a sandbar and that of a breakwater. Seymour et al.(2005) observed the change of coastal line of South California, US, using the LIDAR image, improved LIDAR image which passes through water, and digital photogrammetry. They developed a system which supports policy-maker's logical and environmentally sound decision. Chung (2005) analyzed Namhang-jin coast (which located in Kangneung, Korea)'s long-term coastal line change for 25 years from 1972 to 1996 using numerical ortho-rectified images and applied affine transform analysis. He also considered tidal height and effect of waves for accurate analysis and revised the concluding coastal line.

Previous studies using CORONA satellite image are following; M.Schmidt et al.(2001) proposed two methods which utilize extended image by scanning and high quality-scanned image as it is to develop a high-resolution digital elevation model of south area of Morocco. Kim et al.(2006) proposed mathematical model which adopted modified collinearity equations for geometric modelling and produced mosaic image of Seoul, Korea. And they also extracted urban boundaries from CORONA(1972) and SPOT(1995) imagery and detected urban changes quantitatively.

2. OBJECTIVES AND METHODOLOGIES

2.1 Research Area

Kangmoon Beach, the research objective of this study, is located in Kangneung, Korea. Originally it had length of 400m and area of 16,000 m^2, but severe coastal erosion which occurred in 2000 removed about 200m of sand beach and nearby parking lot, eventually the beach didn't open in that season. In the end of 2000, 90m-length groin was constructed and it contributed to temporal beach recovery, but after one year, the erosion occurred again and it threatened not only sand beach but also a residential area. Hence, if related data is easy to collect, this area has a potential to observe 1960's and 1990's coastal line change through a rapid development, and dynamic appearance of change with temporal effect of groins which was constructed to prevent erosion and re-erosion. Fig. 1. shows the location of research area, Kangmoon beach(an area with red dotted) and present image in 2006, after erosion.

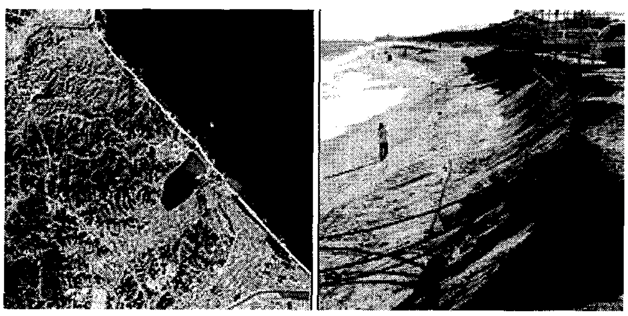

Figure 1. Kangmoon Beach's location and present image

But the CORONA satellite image has very low resolution than other recent satellites' image, Kangmoon beach was very small in the image. And it was hard to classify Kangmoon beach and nearby another beach, Songjeong beach. So, because of the limitation of collected data's resolution and the advantage that more broad tendency of change is observable, we modified the research area from Kangmoon beach to Songjeong beach and its length was 2,990.46m.

2.2 Research Methodologies ; Change Detection

Dynamic segmentation approach : Every specific rate of coastal line, a point is marked on two images which has different time. After, link the point which has same rate and the average value of linked length's decrease is proposed to the rate of coastal area's decrease. The result is visualized with poly-line.

Area-based approach : This is very similar to the dynamic segmentation approach, but this approach divide the change amount of area by average value of two segments. The result is visualized with polygon.

Base line approach : From a line which is parallel to the coastal line, draw a perpendicular line. In this line, the crossing points with coastal line are collected. This approach calculates the subtraction of these lengths for the rate of decrease.

2.3 Collected Data

Scanned image of CORONA satellite image which was produced in 1960's and the Korean National Topographic map in scale of 1:5000 which was produced in 1998 are used in this study. For the limitation of data access, one image of CORONA and two topographic maps which was provided by National Geographic Information Institute of Korea. The numbers of topographic map is 37804087 and 37804088.

CORONA is a spy satellite which was operated by US during the Cold War from 1960 to 1972. It opened to the public in 1995. Since the Korean Peninsula was the matter of primary concern to US, many images were acquired. The satellite operated four cameras and the KH4B, which was the last one, had a maximum resolution of 1.8m.

Since the CORONA image is collected by panoramic cameras with fast-moving satellite, its geometric model is different from a general frame camera's model(Slama, 1980). And this panoramic photographing method induce diverse form of distortion(Kim et al., 2006). These distortions are removable using mathematical modelling and the collected CORONA image for this study was already processed the distortion-revision process.

Fig. 2. shows the original image of CORONA image which used in this study. It has identification number which is 215-105-2, and Kyunggi-do and Kangwon-do are visible in the image. Small dot in red circle is the Kyungpo lake. From the lake, the research area, Kangmoon beach and Songjeong beach are located downward.

The research area is sliced from the original CORONA satellite image, processed by ERDAS IMAGINE. The white line from left-upward part to right-downward is beach of Kangmoon and Songjeong. There are little residential area in a plain field, but no buildings, and roads. This is convincing consider that this image was captured in 1960's.

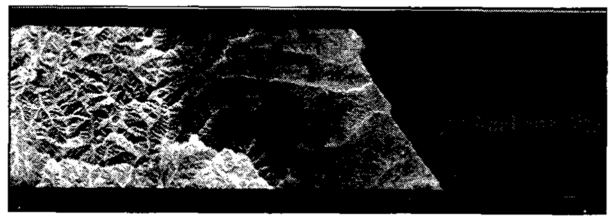

Figure 2. Panoramic CORONA Image

Two topographic map which is provided by National Geographic Information Institute of Korea has scale of 1:5000 and the identification numbers are 37804087 and 30874088 which are part of Kangneung. Each map has annotations, important points, poly-line and polygon and adopted the Transverse Mercator drawing and Bessel ellipse model. The origin (200,000 , 500,000)is shows the degree of longitude of 129 and latitude of 38. Comparing to CORONA image, many residential area and roads are formed near Kyungpo lake and agriculture lands are also visible.

3. DATA ANALYSIS

The data analysis could classify two parts, one is rectification of the CORONA image's coordinate system with topographic map's, and another is measuring area change.

3.1 Geometric Rectification

Fig. 3. shows the process of geometric rectification of CORONA satellite image. First, choose 14 Ground Control Points(GCPs) using ERDAS IMAGINE, then corresponding coordinates of topographic map are inputted. The ERDAS IMAGINE requests at least 6 GCPs, and the correctness of geometric rectification is increases as the number of GCPs are increase.

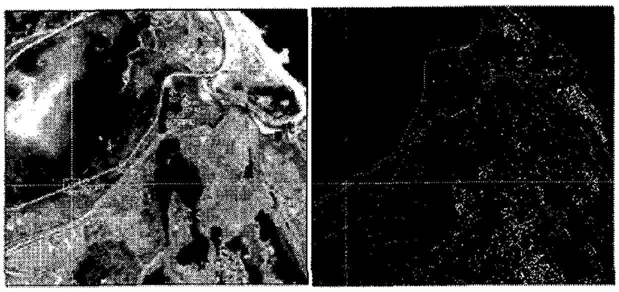

Figure 3. Geometric Rectification of CORONA image.

Because the CORONA image was produced in 1960's, there are 40 years temporal gap between two images. Hence, there are no building and roads in CORONA satellite image which are exist in the topographic map, so 14 GCPs are selected near Kyungpo lake. This may induce some distortion in no-GCP part, in future research, this should be improved.

All selected GCPs are set as 'control points', so 14 GCPs are applied to rectifying coordination. Another available setting for GCPs is 'reference point' which is a standard to measure error amount of geometric rectification. After rectification, the RMS error were distributed from 0.000 to 2.600 and the average value was 1.231, though proper range of RMS error is from 0.000 to 1.000. This may harm the accuracy of change detection, but in this study, it is hard to find more proper GCPs, this result of rectification was applied for change detection the last of several trial. Fig. 4. shows the result of the geometric rectification with CORONA image and topology map.

3.2 Change Detection

The beach including Kangmoon and Songjeong has a slope length of 2,990.46m and a vertical length of 2,132m. We divided this long area into 11 parts in the direction of slope line to analyze more accurate and grasp the tendency. ArcMap is applied as a tool to draw polygons. First, shape file of CORONA image and topology map are copied in ArcCatalog. Then 11 polygons which means the eroded amount during 40 years are drawn at regular vertical interval of 200m. Finally, the area of each polygon are measured.

Figure 4. The Result of Geometric Rectification

Table 1. shows the calculated value of each polygon. First column is number of each polygon. Second column is the measured area and third column is eroding rate which is divided area by slop length of coastal line. The last column is recession rate per year which is divided the third column by time interval, 40 years. Fig. 5. visualizes the result, the red column and green line represent average eroded length along coastal line and recession rate per year, respectively.

Table 1. Measured Erosion Value

Pol.	Area (m^2)	Per 1m (m)	Per Year (m/year)
1	3,084.75	15.42	0.45292
2	6,098.38	30.49	0.522247
3	9,211.62	46.06	0.872676
4	13,339.09	66.70	1.240984
5	11,497.08	57.49	1.006115
6	7,348.70	36.74	0.643223
7	13,591.66	67.96	1.156029
8	7,335.10	36.68	0.693954
9	10,345.59	51.73	0.845836
10	6,828.12	34.14	0.632632
11	9,079.32	68.78	1.091685

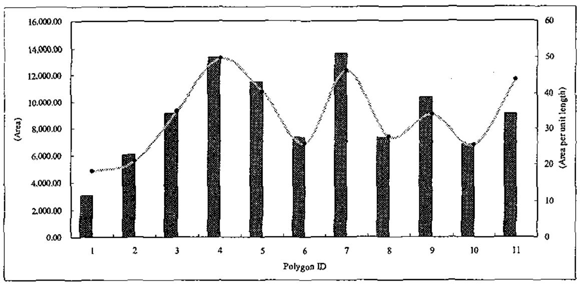

Figure 5. Visualized Erosion Value

The curved line in Fig. 5. could apply to understand and identify the tendency of geo-morphology. Because only two moments' image, 1960's and 1998 are applied, there may be some exaggeration to say that this study could support to understand geo-morphology. If sufficient data collection is available, detailed analysis of geo-morphology will be possible.

4. CONCLUSION

During the last half of century, Korea has undergone a great change with a rapid economic development and it brought out constructing many infrastructures and seashore structures had no exception. But these structures near seashore affected nature and it caused coastal erosion. In this study, comparing a satellite image of CORONA which was a spy satellite of US in 1960's with a topographic map which was produced by National Geographic Information Institute of Korea in 1998, change area of Kangmoon beach and Songjeong beach that are in Kangneung due to erosion are measured. Geometric rectification to revise CORONA satellite image's coordinates to be coincide with that of topographic map is performed, and divided the change area into 11 elements to measure the area and understand the tendency of coastal erosion in this area. The result provided not only the total area of erosion, but also erosion tendency along coastline, and yearly recession rate, this presents change detection using satellite image has potential to understand geo-morphology.

But there were many limitations and matters for to be improved. Time interval between CORONA satellite image and topographic map and low resolution of them made it hard to process correct geo-rectification, eventually it induced high RMS error of 1.231. Because only two times are considered, it may be misleading to say that the result of this study could help understanding geo-morphology. Hence, future study should secure many images with more short time interval. Lastly, change detection methodologies which are mentioned in this paper are applied together, it may possible to find the most correct change detection method.

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