Estimation of morphological change using waterline method in the Ganghwado tidal flats

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ABSTRACT... Waterline extraction is the one of widely used methods for studying changes in tidal flat environment and coastlines using multi-temporal optical images such as Landsat TM and Landsat ETM+. High dynamics of tidal currents and land reclamation which accelerate sedimentation and/or erosion cause waterline change in tidal flats. The amount of sediment deposited or eroded can be evaluated by precisely estimating waterline changes in tidal flats. The objective of this study is to detect the change of waterlines during 17 years and analyze the trends of erosion and sedimentation in the study areas. The Ganghwado tidal flat on the west coast of the Korean Peninsula was selected. The study area is famous for high dynamics of tidal currents and vast tidal flats. Land reclamation which has been carried out on a large scale is also considered as one of elements that have accelerated the environmental changes in this tidal flat. In this study, we acquired 26 waterlines from Landsat TM and Landsat ETM+ images. We extracted the waterline from each satellite image to generate a digital elevation map (DEM) which was used for reference and to compare with the other waterline which was extracted from DEM having a same tide. The result of comparison well depicted the areas of dominant sedimentation and erosion, and general trends of sedimentation and erosion according to sub-regions are also revealed during the investigation time. Results showed that erosion during a decade was dominant at the west of the Southern Ganghwado tidal flat, while sedimentation was dominant at the wide channel between the Southern Ganghwado tidal flat and the Yeongjongdo tidal flat. This area has been commonly affected by high currents and sedimentation energy. Although we were not able to verify the accuracy of the waterline changes, this result clearly showed the waterline change and therefore, the waterline extraction method used in this study has proven as an effective tool for long term tidal change estimation.

KEY WORDS: morphologic change, waterline method, tidal flat, Ganghwado, DEM

1. INTRODUCTION

Interaction between the estuary and the seaward environment defines the amount and moving pattern of sediment fluxes and influences morphologic change of tidal flat(Thomas *et al.*, 2002). In a sediment supply limited situation an estuary may exist in a theoretical equilibrium state where ebb and flood sediment fluxes are both very small. But the change of hydrodynamic flow conditions, the artificial structure like dike and land reclamation have significant implications for sediment transport pathways and influence morphological change. Biological environment and surface sediment distribution change according to the morphologic change.

Remote sensing has been widely used for monitoring change of the tidal flats within a short or long time on the large area. Field survey combined with remote sensing technique has been accepted as complementary tools in geomorphology (Kevin *et al.*, 1999). The objectives of this study are: (i) to generate intertidal DEMs by the waterline method using Landsat TM/ETM+ images, and (ii) to detect a change of waterlines during a decade and analyze the trends of erosion or sedimentation in the study areas.

2. TEST SITE & DATA

Ganghwado tidal flat locating in the mid-western part of Korean Peninsula is an open type and one of the biggest flats on the west coast of Korea (105km^2) (Fig. 1). Substantial amount of sediments input from the Han River.

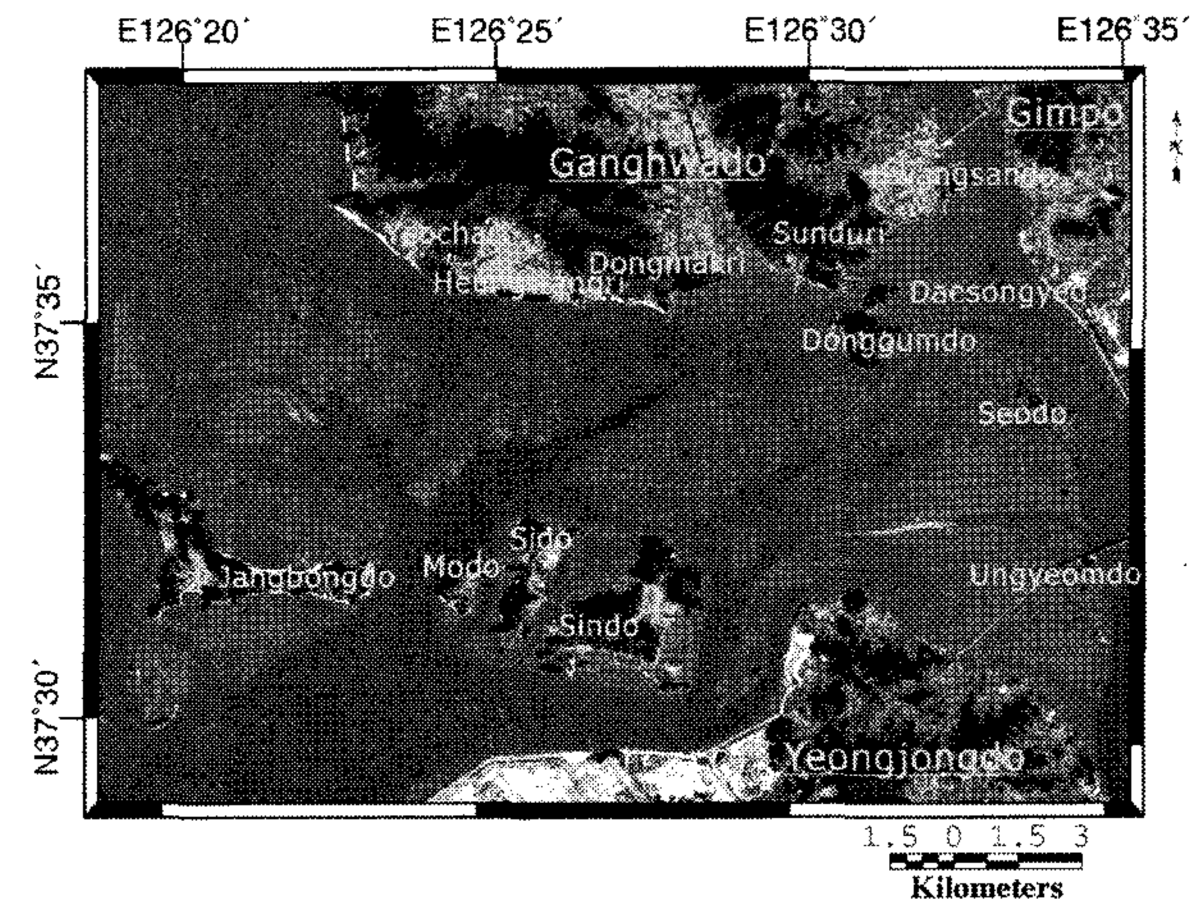


Figure 1. Landsat ETM+ image of the southern tidal flat of Ganghwado acquired on Feb. 14. 2002.

The study area is famous for high dynamics of tidal currents and vast tidal flats. There are two prominent tidal channels (Yeomha channel located in eastern Ganghwado: 300-1500 m wide, Sukmo channel located in western Ganghwado: 1200-3800 m wide).

The tides are semi-diurnal, with a mean tidal rage of 6.5m (spring tide = 8 m, neap tide = 4 m). Mud flats are located in the eastern part of the Ganghwado tidal flat, sand flats near the western part, and the mixed flats in the broad transition zone between them (Woo & Je, 2002: Choi and Dalrymple, 2004). Several land reclamation projects has been occurred on a large scale such as Incheon New Airport project and Choji Bridge.

We acquired a total of 23 sets of satellite images. The images are listed in Table1. Among the 23 sets we used 6 images to generate early 2000's DEM. Horizental accuracy of less than 0.3 pixel was achieved after geometric rectification. Tide conditions were recorded by a tide gauge during image acquisition.

3. METHOD

Waterline method is a one of popularly used methods for DEM construction of tidal flat using satellite image such as Landsat TM and Landsat ETM+. The waterline method is based on three assumptions; (i) that the waterline represents an equal elevation at the moment of image acquisition; (ii) that topographic change is negligible during the period of time-series data acquisition; and (iii) that the absolute elevation of each

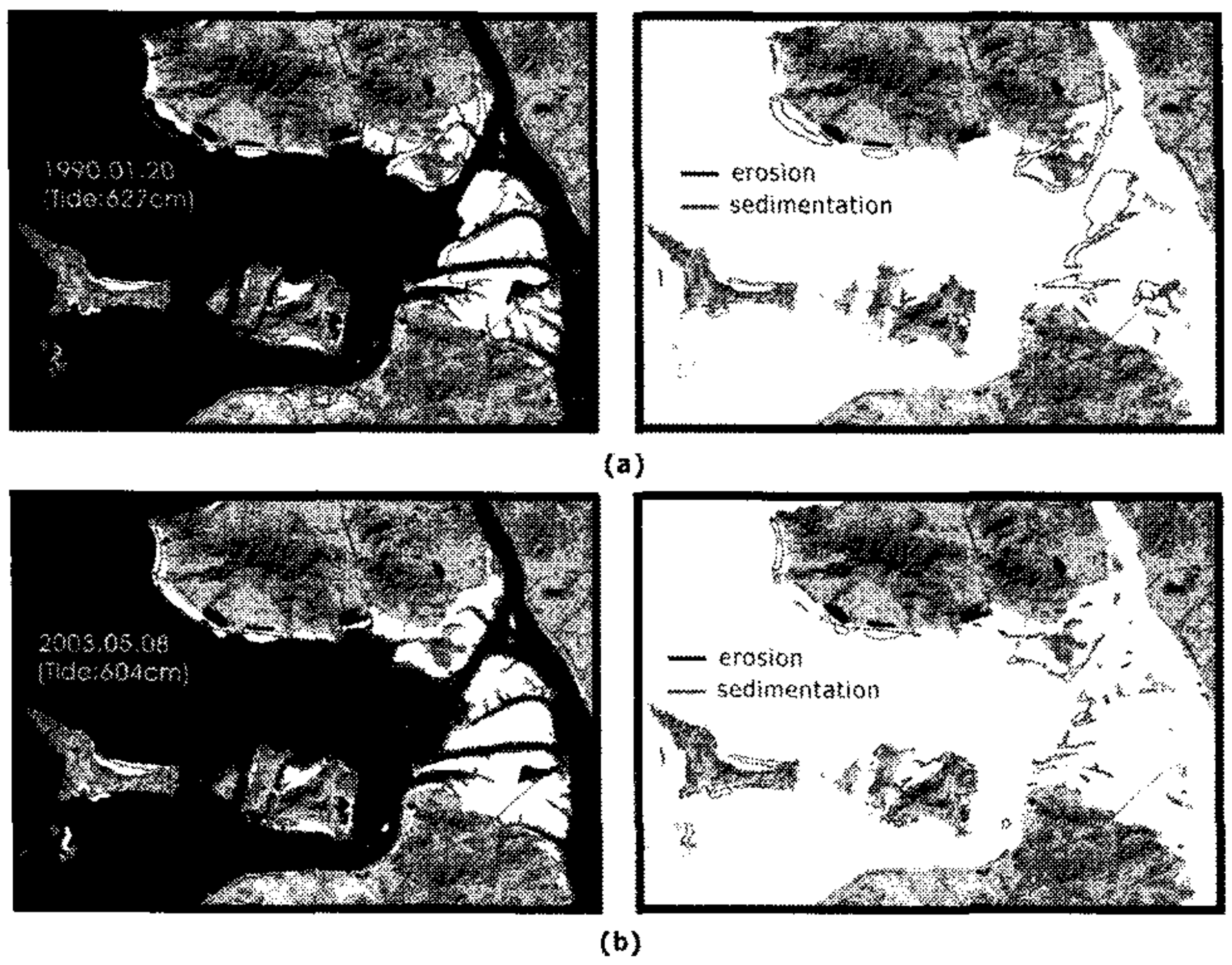


Figure 2. (a) Red line represents waterline on Jan. 20, 1990 which was acquired at the moment of image acquisition, white area means waterline which was extracted from the early 2000's DEM having a same waterline with compared image. In the right image, blue line represents eroded area and red line represent deposited area compared early 2000's DEM to Jan. 20, 1990. (b) Red line represents waterline on May, 08, 2003. In the right image, blue line represents eroded area and red line represent deposited area compared early 2000's DEM to May, 08, 2003.

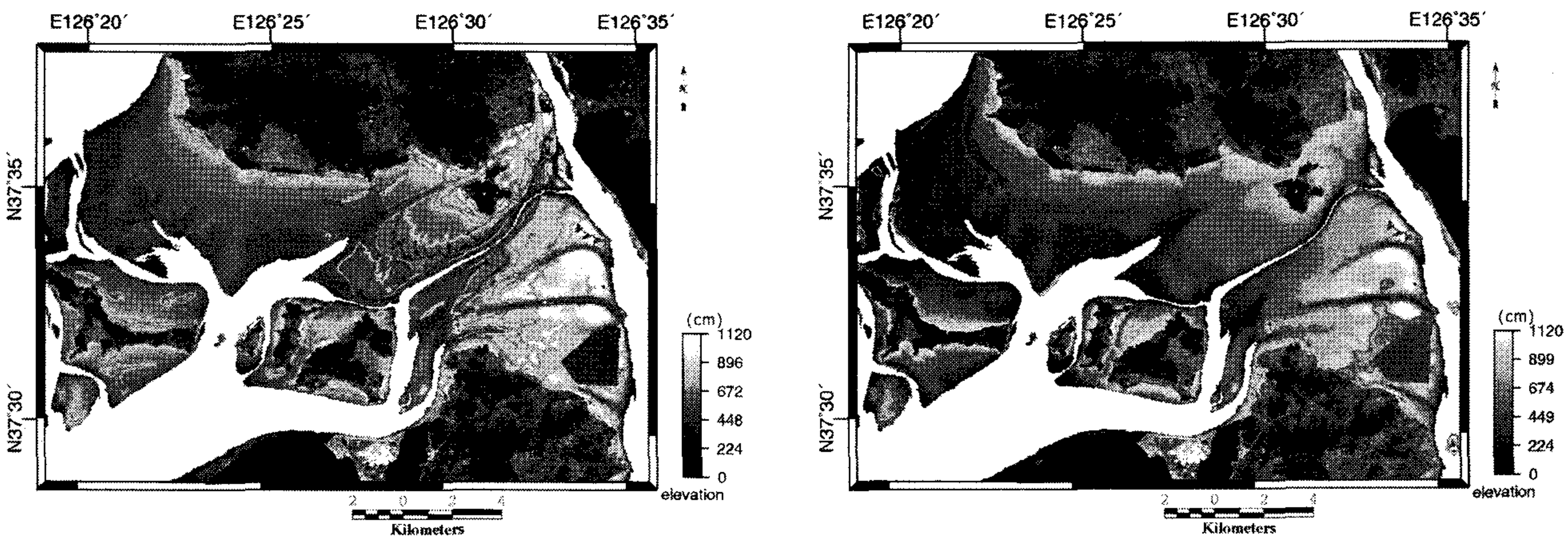
waterline is known. The extraction of waterlines from multi-temporal satellite data and the absolute elevation assigned to the waterline produce information on the topographic relief of tidal flats.

We extracted waterlines by applying the procedures proposed by Ryu *et al.* (2002). Tide conditions observed from the nearest station were used for the study area. Measuring station was change from Wolmido to Inchon on May 1999. Observed tide conditions were rectified to minimize the difference between the nearest measuring station and study area. Tide difference between two stations was 15.2cm.

Extracted waterline from satellite image were compared with waterlines from DEM having same tide condition. Comparison should be based on two assumptions; (i) that topographic change during a year is very small while sediment facies alter due to the effect of seasonal wind; (ii) that influence of sediment supply by floods and typhoon during a certain short time is negligible whereas land reclamation affects to change of sediment supply. Fig. 2 shows how to compare different waterlines. Comparison order is different based on the May 1995 when the measuring station changed. If we subtract waterline which was acquired before May 1995 at the moment of image acquisition from waterline

Table 1. Summary of satellite images used in this study. Images written in italic were used to generate DEMs.

No.	Sensor	Date	Tide(cm)
1	Landsat TM	87.05.20	724
2	Landsat TM	89.05.17	314
3	Landsat TM	89.09.30	127
4	Landsat TM	90.01.04	715
5	Landsat TM	90.01.20	609
6	Landsat TM	90.04.10	170
7	Landsat TM	90.05.31	440
8	Landsat TM	91.10.22	70
9	Landsat TM	91.12.01	478
10	Landsat TM	91.12.09	269
11	Landsat TM	96.02.22	434
12	Landsat TM	96.04.10	721
13	Landsat TM	97.10.06	386
14	Landsat TM	97.10.22	577
15	Landsat TM	97.12.25	452
16	Landsat TM	99.03.02	50
17	*Landsat TM*	*99.05.21*	*803*
18	*Landsat TM*	*01.11.18*	*222*
19	*Landsat TM*	*01.12.20*	*483*
20	*Landsat TM*	*02.01.05*	*633*
21	*Landsat ETM+*	*02.01.29*	*6.3*
22	*Landsat ETM+*	*02.09.10*	*361*
23	Landsat ETM+	03.05.08	604
24	Landsat ETM+	04.01.03	446
25	Landsat ETM+	04.07.29	322
26	Landsat ETM+	06.05.16	361
27	Landsat ETM+	06.06.17	696



(a) (b)

Figure 3. (a) Reddish lines represent tendency of accretion from 1989 to 2000. (b) Bluish lines represent tendency of erosion from 1989 to 2000. Gray image under the lines shows the elevation of the early 2000's DEM. The areas where construction had finished are masked in blue and red masked means the area now on construction.

which was extracted from the early 2000's DEM having a same tide condition, we could know eroded area. If we subtract waterline was acquired after May 1995 at the moment of image acquisition from waterline which was extracted from the early 2000's DEM having a same tide condition, we could know accumulated area.

4. RESULT AND DISCUSSION

The Ganghwado intertidal DEM for early 2000 was constructed for standard to compare with other waterlines. Absolute elevation was assigned to each waterline using tide gauge data. The minimum curvature interpolation was used for two-dimensional completion. Waterline acquired from the data acquisition was compared with standard waterline extracted from the early 2000's DEM show in Fig. 2. From the comparison between two waterlines, we could figure out which area has been eroded or accumulated. All of waterlines' change piled up to see the tendency of sedimentation/erosion in Fig. 3 in which sedimentation is presented in red and erosion in blue. The change in the Yeonjongdo tidal flat and some part of Kimpo area which are masked in blue in Fig. 3 were disregarded because it was an artificial change for construction of Inchon Internatinal Airport. Red masked area in Fig. 3 represents the area on construction, but flow of seawater is blocked.

Sedimentation had been dominant the wide channel between the southern Ganghwado tidal flat and the Yeongjongdo tidal flat during the decade around. Especially, the width of this channel has been narrowed and curvature of channel has also been changed. Sedimentation area has about 483cm height in DEM2000. It shows gentle gradient from the south-west of Hwangsando where the DEM shows the shape of tongue to the outer tidal flat. But it shows steep gradient at the northern edge of Yeongjondo. We could notice dominant sedimentation between Sido and Sindo and some part of northern and southern Jangbongdo.

On the contrary, erosion had been dominant during the decade specifically in the west of southern Ganghwado tidal flat. Erosion area has below 300cm height in DEM2000. This area needs a care due to the high soil moisture while density slicing method is applied. Because of the relatively very gentle slope, small change of tidal condition could affect to the large area.

Changes in tidal flat morphology are closely related with potential changes in flow regime. The Han River is a main source of sediment at the tidal inlet. Volumetric change of long-term averaged sediment flux might have affected sedimentation and erosion process in this area. Construction of the Inchon International Airport also have greatly influenced on tide dynamics in this area, which consequently contributed to changes in sedimentation and erosion rates.

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