GIS DETECTION AND ANALYSIS TECHNIQUE FOR ENVIRONMENTAL CHANGE

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ABSTRACT: KOMPSAT-3 is expected to provide data with 80-cm spatial resolution, which can be used to detect environmental change and create thematic maps such as land-use and land-cover maps. However, to analyze environmental change, change-detection technologies that use multi-resolution and high-resolution satellite images simultaneously must be developed and linked to each other. This paper describes a GIS-based strategy and methodology for revealing global and local environmental change. In the pre-processing step, we performed geometric correction using satellite, auxiliary, and training data and created a new classification system. We also describe the available technology for connecting global and local change-detection analysis.

KEY WORDS: Change Detection, Environmental Change, GIS Analysis, KOMPSAT-3

1. INTRODUTION

Many countries are investing in long-term measures and research to control environmental pollution In South Korea, government agencies, private organizations, and business entities are also working to help protect the environment.

Recently, the Korea Research Institute for Human Settlements (KRIHS, 2003) and the Ministry of Land, Transport, and Maritime Affairs (MLTM; reorganized from the Ministry of Construction & Transportation in 2008) reported plans for an environmental monitoring system that would use high-resolution satellite images and help decision-makers plan land use more efficiently.

Previous studies have discussed the use of satellite imagery in environmental monitoring. Palmer and van Rooyen (1997) studied vegetation change in the Kalahari Desert region using Landsat TM observations for 1989 and 1994; to detect movement and change in the area of desert, they applied visible, red, and near-infrared band data to a change vector analysis (CVA).

Ahlqvist (2007) studied land cover for the entire U.S. and the Chester area of England in 1992 and 2001 using National Land Cover Data (NLCD); that study suggested that post-classification by a fuzzy -set approach was more adaptable than general post-classification. Choi and Yang (2003) studied how to extract surface-change information from Landsat TM images.

The goal of the present study was to develop a technique that uses remotely sensed data and GIS technology to provide land-surface cover information, which can then serve as basic data necessary for efficient land management and development and reveal -use trends

Jo, Bae, Lee, and Lee (2004) studied land-cover change detection in urban areas using aerial photos and images from the Electro-Optical Camera (EOC) of the Korea Multi-Purpose Satellite (KOMPSAT). The present study discusses the application of aerial photographs and KOMPSAT-1 EOC imagery for detecting change in a rapidly growing urban area.

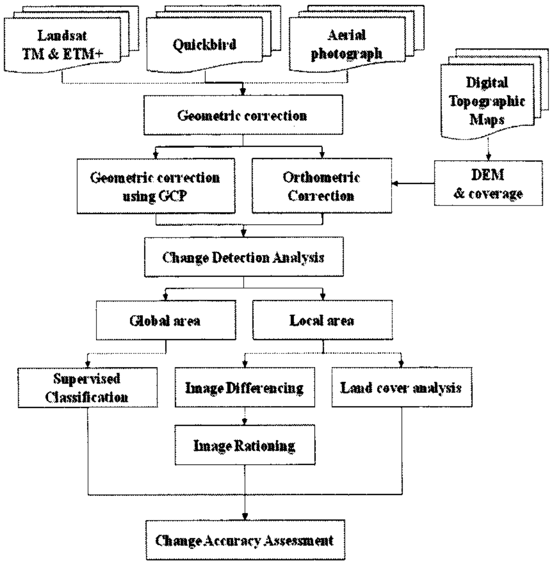

Figure 1. Flowchart of the analysis steps

Local area change detection requires high-resolution satellite images, while global change detection requires multi-resolution satellite images. For this study, we collected satellite images as well as auxiliary data, and training data (ground control points [GCPs]); we then applied a geometric correction procedure. To trace environmental change in a local area, we used the image differencing method. We also developed a classification method and classification systems for both global and local areas; on the basis of the classification analysis, we devised a strategy for change detection (Figure 1).

2. DATA AND STUDY AREA

As shown in Table 1, we used Landsat 5 TM images and Landsat 7 ETM+ images for the global area analysis, and QuickBird 4-m multispectral, and 1-m panchromatic images for the local area analysis. We chose these image products because they have similar resolution to that expected for KOMPSAT-3 images. To detect land-cover change, we also used aerial photographs taken in 1947, 1975, 1985, 1995, and 2005.

Table 1. Summary of the experimental data

Data	Resolution	Date of acquisition
Landsat ETM+	30m x 30m	2002.10.30
Landsat TM	30m x 30m	1999.05.07
Landsat TM	30m x 30m	2001.04.18
QuickBird	1m x 1m	2007.01.29
QuickBird	1m x 1m	2004.02.16
Aerial photograph	1m x 1m	1947.10.25
Aerial photograph	1m x 1m	1975.05.25
Aerial photograph	1m x 1m	1985.05.02
Aerial photograph	1m x 1m	1995.05.24
Aerial photograph	1m x 1m	2005.05.14

Figure 2 shows the study area for the global analysis; the 37 x 37-km area covered the metropolitan city of Busan, South Korea. The first local analysis focused on the Daedong neighborhood (Daedong-dong) of Gangseo ward (Gangseo-gu; 3 x 3.7 km), and the second local analysis covered Haeundae beach in Haeundae-gu (2 x 1.3 km).

Change-detection analysis was applied in three steps. First, each image was geometrically corrected to create a digital elevation model (DEM) incorporating terrain information from a digital terrain map (DTM) produced by the National Geographic Information Institute (NGII). Arcview 3.3 and ArcGIS 9.1 software products were used for this step. Second, to match coordinates, the images were resampled using ERDAS 9.1 software. Third, orthometric correction was applied (Figures 3, 4).

3. METHODOLOGY

3.1 Classification

The classification method used here could easily show trends in the global area. The method involved comparative analysis of pixels from satellite images that were classified independently. We choose the maximum likelihood classification (MLC) approach for image classification.

3.2 Maximum Likelihood

MLC is a common method for classifying satellite images. This approach classifies pixels based on the highest probability of their belonging to a class. Pixel values are compared to predetermined class values, and a classified list of average vectors and variations is created. Final classification is based on the probability of a pixel belonging to the highest classified class, as determined by the probability density function.

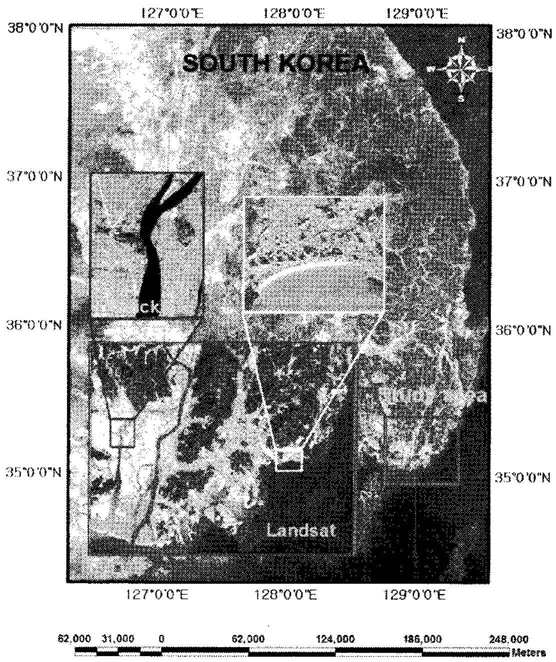

Figure 2. Study areas

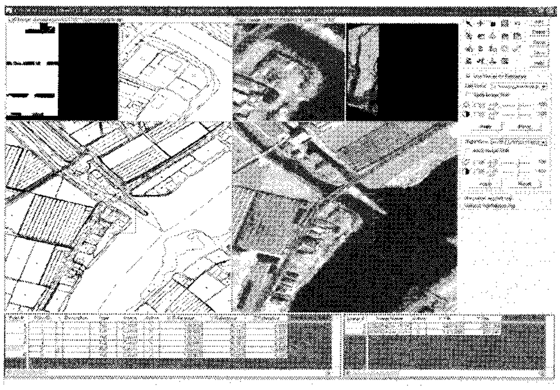

Figure 3. Orthometric correction

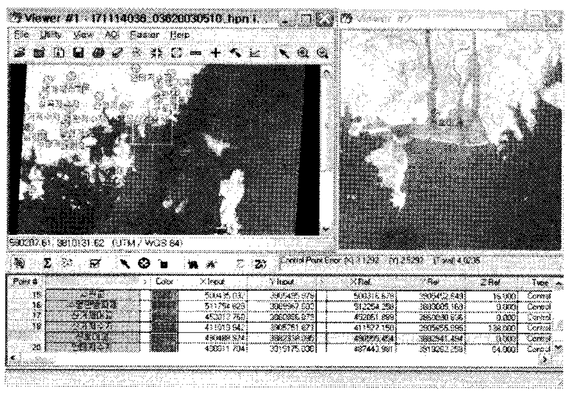

Figure 4. Geometric correction

We classified pixels into eight classes that were widely distributed in the study area: water, forest, grassland, agricultural area, residential area, bare land, wetland, and stream sedimentary topography. We also defined the pixel average for each class and grouped pixels by the highest probability of belonging to a class based on the pixel average.

3.3 Change Detection

Various methods have been used to detect or extract changes in remotely sensed images. Two commonly used methods are image differencing and image rationing, which we chose to detect overall land-cover change.

3.3.1 Image Differencing

In the image differencing method, an image representing change is produced by the subtraction of differently dated images. Pixels with small radiance change are distributed around the mean, while pixels with large radiance changes are distributed at the tails of the distribution (Singh, 1986). Interpreting the difference image can be difficult because different input values can have the same result after subtraction, and the original pixel value information is not retained (Singh, 1989; Cohen and Fiorella, 1998).

In this study, we applied image differencing to QuickBird images and subtracted pixel by pixel using at least two images, as follows:

$$\Delta\chi_{ijk} = BV_{ijk}(1) - BV_{ijk}(2) + C \qquad (1)$$

$\Delta\chi_{ijk}$: Variation of pixel value
$BV_{ijk}(1)$: Pixel value in season 1.
$BV_{ijk}(2)$: Pixel value in season 2.
C: constant (such as 255)
(i, j, k): (Row No., Column No., Band No.)

3.3.2 Image Rationing

Image rationing compares pixel ratios in images taken in different seasons in the same region. This method is effective for variable season image analysis because it reduces environmental effects. Equation (2) below gives the rationing formula (Singh, 1989). A value of 1.0 clearly indicates no change. However, the distance from 1 to 0.5 is not the same as that from 1.0 to 2.0 (Eastman et al., 2005).

$$\Delta r_{ijk} = \frac{BV_{ijk}(1)}{BV_{ijk}(2)} \qquad (2)$$

Δr_{ijk}: Variation of pixel value
$BV_{ijk}(1)$: Pixel value in term 1.
$BV_{ijk}(2)$: Pixel value in term 2.
(i, j, k): (Row No., Column No., Band No.)

3.3.3 Analysis Using a Land-cover Map

Land-cover maps show specific land information. Using on-screen digitizing, we created a land-cover map of trends in land-use change. Because the QuickBird images and aerial photographs have high spatial resolution (1 x 1 m), the sizes and shapes of land cover types are visible (Figure 5).

Table 2. Index of land-cover map

Detailed list	Class code	Detailed list	Class code
Detached house	111	Rice terrace	212
Row house	112	Farmland	221
Apartment building	113	Upland farm	222
Mixing residential and business	132	Broadleaves forest	311
Recreational facility	141	Coniferous forest	321
Stadium	142	Other grassland	433
Railway	153	Inland wetland	511
Road	154	Beach	621
Other traffic and communication facilities	155	Riverside	623
School ground and military installation	163	River	711
Other public facility	164	Seawater	721

We used aerial photographs to create detailed land-cover maps for 1947, 1975, 1985, 1995, and 2005 based on the land-cover classification by the Ministry of Environment (MOE). We input the attributes and digitized the data using ArcGIS 9.1 software.

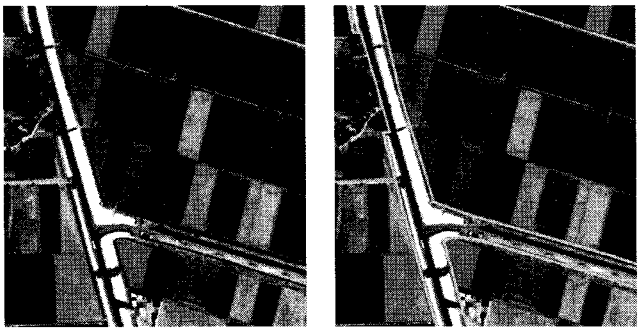

Figure 5. Example of on-screen digitizing

4. RESULTS

4.1 The result of Global area Analysis

Figure 6 shows the land-cover map created using Landsat TM images for 1999, 2001, and 2002. Residential and wetland areas increased from 1999 to 2002. In contrast, forest, water, and stream sedimentary topography decreased after increasing temporarily. Stream sedimentary topography in particular increased from 1999 to 2001 in the Nakdong River, but then decreased when typhoon "Lusa" struck on 31 August 2002. Wetland and bare land decreased over time due to the growth of the residential area.

Figure 7 shows the changes in land-cover classes for 1999, 2001, and 2002.

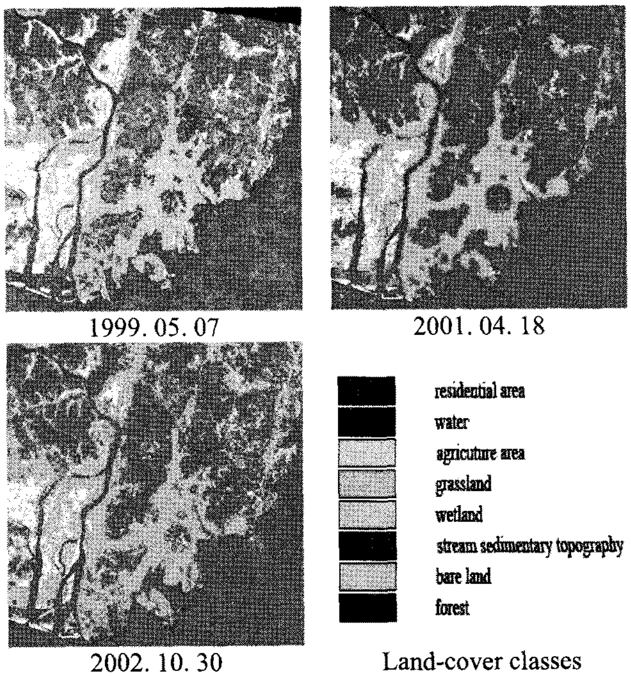

Figure 6. Classification results

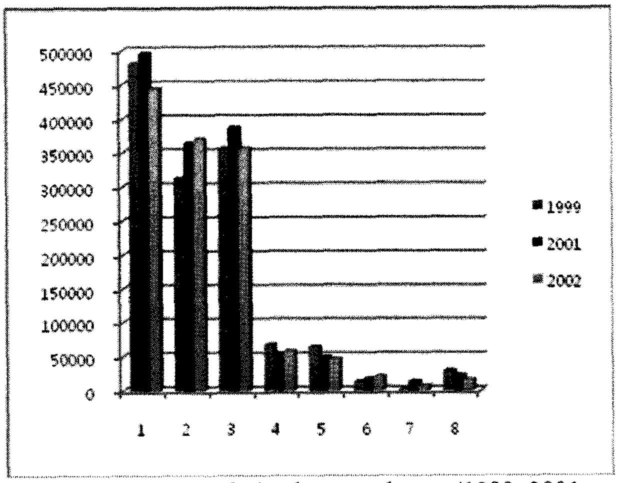

Figure 7. Changes in land-cover classes (1999, 2001, 2002)

(1) Forest; (2) Residential area; (3) Water; (4) Agricultural area; (5) Grassland; (6) Wetland; (7) Stream sedimentary topography; (8) Bare land

4.2 The result of Local area Analysis

There was a remarkable relative gap between the variation shown by the image differencing and image rationing methods (Figure 8, 9, 10).

The image differencing method showed only small abrupt decrement changes; however, the increments indicated by the two methods were similar. In addition, most variation by the image rationing method was the root mean-square error (RMSE) difference in the geometric correction of QuickBird images.

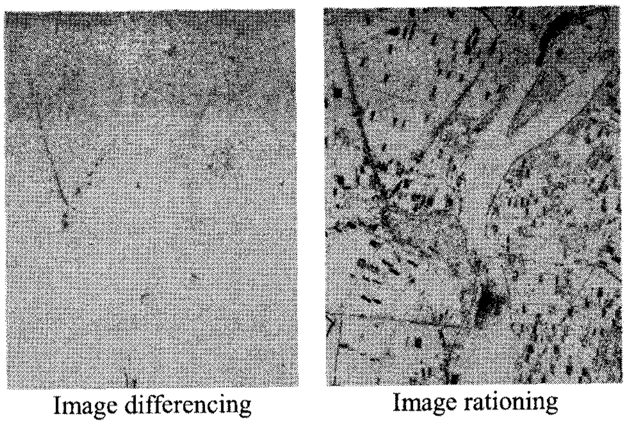

Figure 8. Results of change detection

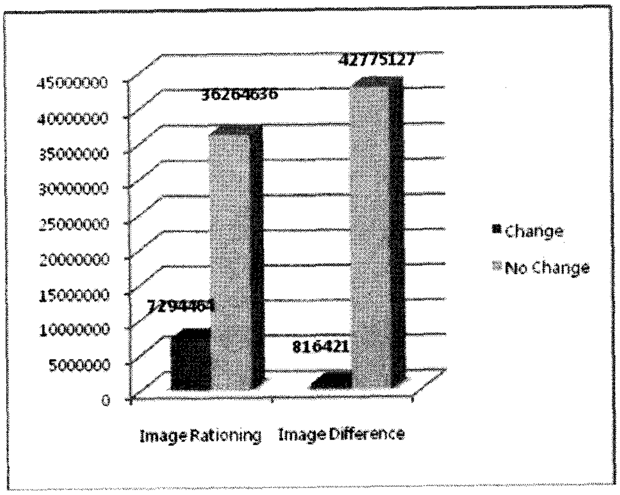

Figure 9. Change in land-cover classes between 2004 and 2007.

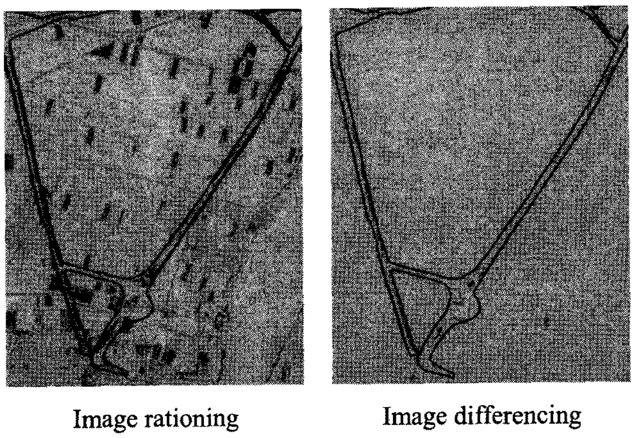

Figure 10. Road detection

4.3 Classification

We quantitatively analyzed land-cover change for each land-cover type by year. We calculated the area of each type and ordered the types by area each year to illustrate change trends (Figure 11).

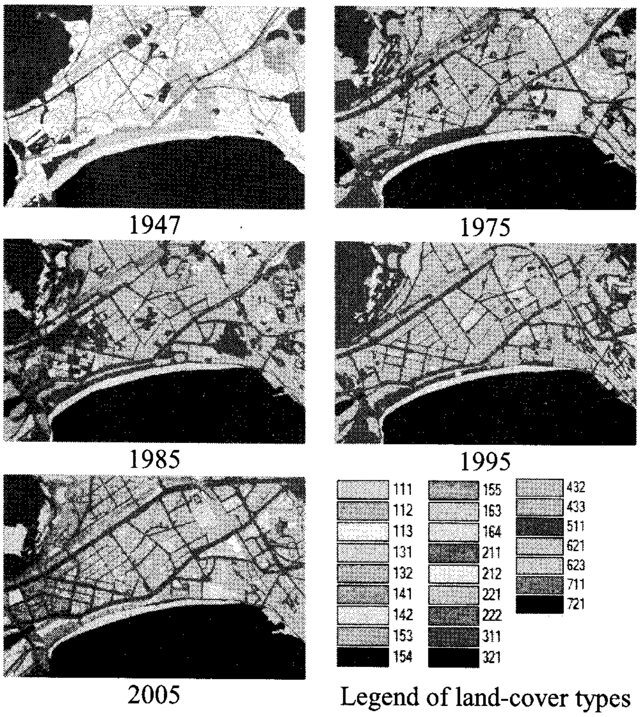

Figure 11. land cover map

Figure 12, 13 presents changes in land cover from 1947 to 2005. The greatest increase occurred in the "mixed" residential and business area. Roads also increased progressively over the time period examined.

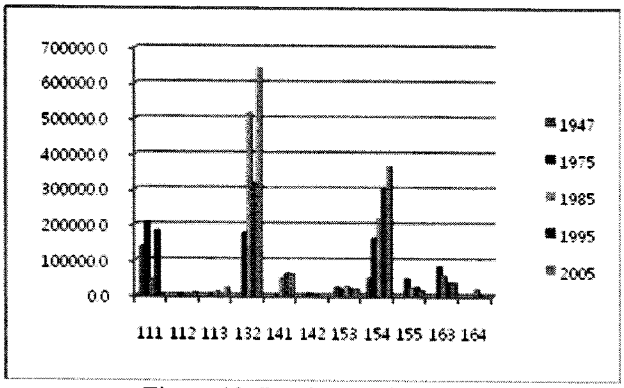

Figure 12. Tendency of classify
(land-cover types are as defined in Table 2.)

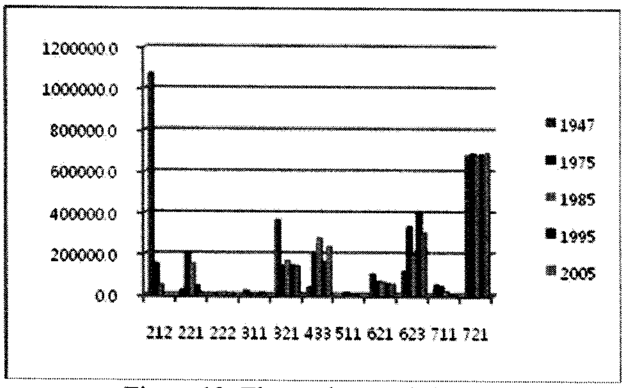

Figure 13. The tendency of classify
(land-cover types are as defined in Table 2.)

Farmland has decreased rapidly since 1975. The river class also decreased following 1975 and disappeared after 1985 when such areas were paved over. Grassland also tended to decrease.

5. CONCLUSIONS

We examined global and local area change detection using various methods. The methods applied to each type of image are as follow:

(1) Landsat TM
- Supervised classification
- Maximum likelihood classification)

(2) QuickBird
- Change detection
- Image differencing
- Image rationing

(3) Aerial photographs
- Land-cover analysis

The global analysis using Landsat TM images allowed for relatively few classes because of the spectral characteristics of the TM. However, change could still be detected for the global area by season, indicating the potential usefulness of this method.

The local analysis provided more detail because the aerial photographs and QuickBird images had higher resolution than the Landsat TM images.

Determining land cover and land-cover changes can be a difficult and time-consuming process. We obtained detailed results showing changes in area and change tendencies by creating various classification classes.

Applying some of the following steps prior to change detection could produce more efficient results:
- Apply a fitted multi-resolution geometric correction image.
- Match coordinates though image resampling
- Adjust brightness
- Create classification classes.

6. ACKNOWLEDGEMENTS

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