Land-cover Change Detection of The DMZ and Vicinity in Korea

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Introduction

The Demilitarized Zone in the Korean peninsula -known as the DMZ- is 4 km wide and 250 km long. It is one of the most highly fortified boundaries in the world and also a unique thin green line. Environmentalists want to declare the DMZ as a natural reserve and a biodiversity zone, but nowadays through the strengthening of the inter-Korean economic cooperation, some developers are trying to construct a new-town or an industrial complex inside of the DMZ. This study will investigate the current environmental conditions, especially deforestation, of the DMZ through the construction of GIS maps and to analyze the land-cover changes adopting remote sensing techniques to overcome the difficulties of direct survey of the area.

The main objectives of this study are as follows :

1. To classify land-covers of the DMZ and vicinity of the 1987 and 2002 using Landsat TM and ETM+ imagery respectively.

2. To adopt Spectral Mixture Analysis(SMA) technique to enhance the accuracy of land-cover classification of DMZ, the inaccessible study site. Recently, SMA technique has been used to detect and identify ecological factors like forest, paddy and wetlands.

3. To investigate land-cover changes from 1987 to 2002. DMZ has many changes due to recent inter-Korean cooperation projects and North Korea's food and fuel shortage.

Study Area and Data Used

The DMZ in Korea can be designated according to the cease-fire agreement made in 1953. The DMZ is about 5% of whole Korean peninsula. The Civilian control zone(CCZ) is the area where entrance of civilian is possible but restricted for military operation and military installment. With 5~20km area outside from the Southern limit line, the Civilian control line is set up.

Fig. 1. DMZ and Vicinity in KOREA

The civilian control line generally makes parallel with the truce line. So that, the CCZ is forming belt shape of 5 ~ 20km area on the north latitude between 37° 45′ ~ 38° 40′ following the 248km truce line from the west coast to the east coast. The east is forming a steep slope and west is forming gentle slope.

As mentioned before, DMZ is 248km and it's too long to investigate for a time. So this study focused on western part of DMZ and vicinity. For a specific investigation, ordinarily DMZ can be divided 3 regions of western, middle and eastern part, and western and middle parts are splitted by Sami-chun river which is a brach of Imjin-gang river. The Gaeseong industrial complex which is the most representative inter-Korean project, is located in near western part of DMZ. For this economic cooperation, a new road to connect South and North Korea was constructed and recently, Gyungui-railway, traversing the DMZ and vicinity, was recovered.

In and around the DMZ, 10km buffers from the Military Demarcation Line were included as study areas, which cover half of the CCZ in case of South Korea.

Fig. 2. Wester part of DMZ and vicinity

A TM image for May 20, 1987 and an ETM+ image for June 06, 2002 were radiometrically calibrated to reducing path radiance values(Lillesand and Kiefer 2000). The imagery were geometrically rectified based on GCPs taken from digital topographic maps at 1 : 50,000 scale (UTM/WGS84 Zone52). Nearest-Neighborhood resampling was adopted and the RMS error was smaller than 0.5 pixel.

Land-cover Change Detection using SMA technique

Linear Spectral Mixture Analysis is a new technique that "in theory" would allow you to determine the fraction of each surface type in a pixel in order to unmix a pixel. It assumes that the spectrum measured by a sensor is a linear combination of the spectra of all components within the pixel(Roberts et al., 1998; Ustin et al., 1998). For example, in remote sensing a spectral endmember is the spectral signature of a ground component such as green vegetation(Endmember *a*), soil(Endmember *b*) and water or shade(Endmember *c*) from the scattergram of bands *i* (TM 3) and *j* (TM 4) as shown in Figure 2 (Fig

3). The spectra of mature paddy field and forest located in the Endmember *a* but the radiance values of mature riparian vegetations are generally located in inside the simplex between centroid and endmember *a* of the data cloud due to the background effect of ordinary hydrologic conditions in wetlands.

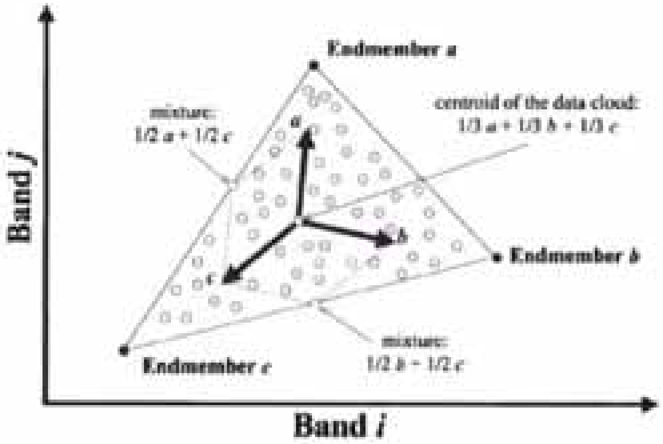

Fig. 3. Scatterplot of two-dimensional spectral data illustrating the physical interpretation of a mixture model based on endmembers. (Source : adapted from Plaza et al., 2002)

SMA involves two main steps. The first step is to define a set of pure spectra for selected land-cover material, often referred to as endmembers. Endmembers can be identified using either (a) libraries of known spectra collected with a spectrometer in the field or in a laboratory, (b) libraries of known spectra from previous SMA studies, or (c) spectrally pure or extreme pixels identified within the images being analyzed. Most applications of SMA will use the third option because libraries of field-collected endmember spectra are rare, and field spectrometers are expensive and not readily available to researchers(Schweik and Green 1999). The empirical portion of this article uses this third option. SMA endmembers are selected by testing whether a given pixel's spectra can be described as a mixture of pixel spectra previously analyzed or whether it is itself another endmember (Adams et al., 1993). Because the Scatterplot of two-dimensional spectral data didn't show a exact triangle, There are several convex models such as PPI, N-FINDER and MESMA to draw an optimum simplex for accurate endmember selections of the data cloud. But ordinarily these models doesn't hold exactly and some observations lie outside of the simplex(CSIRO 2003).

The second step in SMA is to estimate, for each pixel, the abundance of each endmember contained within it by applying a linear mixing equation (Adams et al., 1993). The general form of this equation, in matrix form, is as follows:

$$p_{ij} = \sum_k e_{ik} c_{kj} + \varepsilon \ , \quad (1) \qquad \sum_k c_{kj} = 1 \ . \quad (2)$$

where

P_{ij} is the i-th band of the j-th pixel,

e_{ik} is the i-th band of the k-th endmember,

c_{kj} is the mixing proportions for the j-th pixel from the k-th endmember,

ε is gaussian random error (assumed to be small)

Since the pixel compositions are assumed to be percentages, the mixing proportions are assumed to sum to one.

This SMA equation is used to convert the existing image spectra values for each pixel into endmember fraction matrices. One fraction image is produced for each endmember along with the RMS error matrix. This procedure requires the fraction values produced in matrix X to be positive and sum to unity (Adams et al., 1993; ENVI, 2002).

In this study, 3 endmembers of GV(Green Vegetation), Soil and Water from the 2 images were identified not by the convex geometry models but by the 3 vertices of the tasseled cap scatterplots of band TM (or ETM+) 3, 4 and 5. We subdivide The abundance of selected land cover materials from 3 endmembers were validated through the field survey(May, June, July, 2004) and high resolution SPOT 5 image.

Results and discussion

The fraction images were developed using SMA technique based on two period data respectively. Figure 4 is a fraction set for 1987 TM image and figure 5 for 2002 ETM+ data. In the GV fraction of '87 scene, forest has relatively high values, while agriculture and waterbody have very small fraction values. In the GV fraction of '02 scene, forest has significantly higher fraction value than that of agriculture and water-body. In the Soil fraction of '02 scene, the newly constructed road across the DMZ and vicinity can be detected very easily.

Fig. 4. Fraction images from SMA of 1987 TM image (GV, Soil, Water and RMSE fractions)

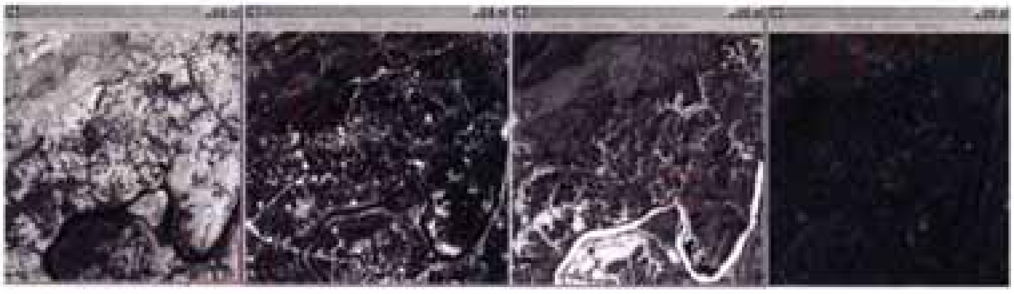

Fig. 5. Fraction images from SMA of 2002 ETM+ image (GV, Soil, Water and RMSE fractions)

For the land-cover change detection analysis, fraction sets of '87 and '02 were classified using a maximum likelihood classifier (MLC) respectively. In supervised classification method, training set data for four land cover classes of forest, agriculture (e.g. paddy and dry field and grass), waterbody, bare land (including urban areas, roads and bare soil) were collected and defined according to the land-cover characteristics of the DMZ and vicinity. Every region of interest (ROIs) for training sets of five land-cover classes was extracted from digital maps of the area and SPOT 5 high spatial resolution image. ROI polygons were created on a geo-referenced true-color display of the image by matching features in the images visually around the study site.

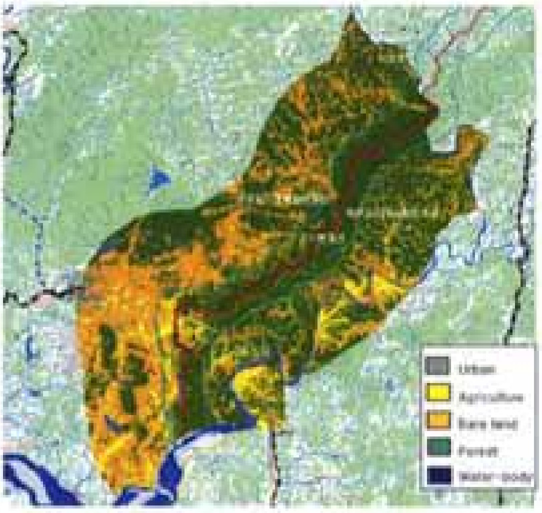

Fig. 6. Land-cover classification result from '87 fraction images

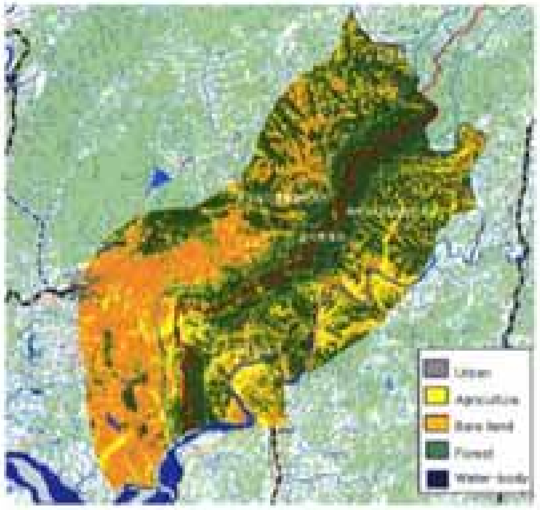

Fig. 7. Land-cover classification result from '87 fraction images

Figure 6 shows the land-cover classification result of 1987. The centered red line is the military demarcation line and two green line is southern and northern limit lines respectively. In case of the southern part of western DMZ, forest in DMZ is comparatively well preserved and agricultural land is distributed through the Imjin-gang river in the CCZ. In the northern part of western DMZ, bare land is distributed widely and forest is seriously fragmented compared with the southern part in and outside of DMZ.

Figure 7 shows the land-cover classification result of 2002 in and outside of DMZ. Forest land-cover has been fragmented all around the study site for 15 years. Especially, forest denudation is severe near the newly constructed road and Gyungui railway and in the North Korean part of DMZ and vicinity.

Table. 1 Land-cover changes in southern part of DMZ and vicinity('87-'02)

Land-cover		'87 Southern part of DMZ and vicinity					
		forest	bare land	agri.	urban	water-body	**Area**
'02 Southern part of DMZ and vicinity	forest	204.52	16.37	16.33	0.01	0.21	**244.39**
	bare-land	13	17.95	13.33	0.4	0.23	**44.91**
	agri.	25.08	22.93	59.13	0.11	1.37	**108.62**
	urban	0.14	0.12	0.62	0.87	0.04	**1.79**
	water-body	0.67	0.48	2.48	0.11	6.44	**10.18**
	Area	**243.56**	**57.88**	**91.89**	**1.5**	**8.3**	**0**
	Changes	**39.04**	**39.94**	**32.76**	**0.63**	**1.85**	**0**

Table. 2 Land-cover changes in northern part of DMZ and vicinity('87-'02)

Land-cover		'87 Northern part of DMZ and vicinity					
		forest	bare land	agri.	urban	water-body	**Area**
'02 Northern part of DMZ and vicinity	forest	210.49	20.54	11.31	0.06	0.24	**244.64**
	bare-land	23.8	138.89	56.15	0.85	0.38	**220.07**
	agri.	27.99	23.59	53.46	1.03	1.55	**107.62**
	urban	0.02	1.36	2.29	2.62	0.08	**6.37**
	water-body	0.32	0.34	1.67	0.06	3.19	**5.57**
	Area	**262.86**	**184.74**	**124.96**	**4.62**	**5.45**	**0**
	Changes	**52.37**	**45.85**	**71.5**	**2**	**2.26**	**0**

Table 1 summarized the area change of land-covers in southern part of DMZ and vicinity from 1987 to 2002. 10% of forest land-cover changed to agricultural land and 1% to bare-land, and 38% of bare-land changed to agricultural land. That means in the southern CCZ, bare-land and forest have been cultivated to agricultural land. Table 2 shows the area change of land-covers in northern part of DMZ and vicinity from 1987~2002 and the trend of land-cover changes is so similar to southern part. 11% of forest land-cover changed to agricultural lands and 9.1% of forest to barren lands. And 44% of agricultural land changed to bare land. That means in case of North Korea, the drive for production, due to the food shortage, have been increased area of agricultural land. In fact, many forest slopes and hills have been changed to terraced fields across the nation. But difficulties to managing terraced fields, like equipment of irrigation facilities, made them being left and after all changed to barren lands. Due to the energy shortage problem, every trees and shrubs near human settlements, were logged as fuel and food.

Conclusions

This study aims to investigate the land-cover changes of western DMZ and vicinity. For the study of access prohibited area, GIS and RS technique were adopted, and especially SMA was utilized to enhance classification accuracy.

For 15 years, contrary to expectations, land-covers of western DMZ and vicinity have been changed largely. In case of southern part, infrastructure construction for inter-Korean economic cooperation affects to the forest fragmentation. In northern part, increase of agricultural land for solving the food crisis have been changed forest to agricultural and barren land.

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