Change Detection for the Monitoring Ecosystem Changes of DMZ in Korea

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Key words: DMZ, Forest, Satellite Images, Change Detection

Abstract

This study aims to characterize present land cover and to detect its change over time for the Demilitarized Zone (DMZ) of Korea and its vicinity using remotely sensed images. DMZ, a 4 km wide (N-S), 248 km long (W-E) corridor shaped area along the stalemate line has been free from human access for over the last 50 years. The DMZ, however, partly well conserved has been witnessing periodical disturbance continuously due to the army operations and artificial fire clearing the sight. The area surrounding the DMZ has been under the pressure of urbanization and the expansion of dry field and barren land. Land cover changes in DMZ and its surrounding area were mapped by comparing past and present Landsat TM 5 and 7 satellite images. And land-cover maps showing 7 categories of present land cover and its change were developed using supervised classification techniques including calculation of NDVI and GIS overlay between 1987-1989 and 2001. The main category of quite a big change was 'Forest 1 class' of which the stem density and viability were relatively high. The 'Forest 1 Class' area decreased from 640,716 ha to 526,970 ha. The area of changes was larger in North Korea than in South Korea due to the conversion of forests into cropland and barren land for food production and fuel-wood supply. And what is worse, most of the croplands developed on the mountain slopes in North Korea are known to be experiencing increased erosion and decreased soil fertility. Apart from the quality, forests inside the DMZ showed better connectivity than the surrounding area. The results will help decision makers detecting where changes in the ecosystem of DMZ and its vicinity have occurred and determining where to conserve and restore for maintaining the structure and function of DMZ ecosystem.

Introduction

The Demilitarized Zone (DMZ), which was established after Korean War, has divided Korea into two areas since 1953. The DMZ is 4 km wide and 248 km long, and lies across the middle part of Korea along the Military Demarcation Line. Another 10-20 km was added to the width as the Civilian Control Zone (CCZ) that allowed only the military access in the southern part of the DMZ. While preventing public access keeps some area from human disturbances, other areas have been disturbed frequently for military purposes such as the sight clearing. These frequent disturbances have created forests more open than the landscape might naturally have resulting in more diverse landscape mosaic with various habitats from open areas to closed canopy structures (Shin *et al.* 2002, John *et al.* 2003). Most of the ecosystems in this area were destroyed during the Korean war and the nature have transferred the deserted land into the various ecosystems, such as the abandoned rice field became wetlands providing valuable habitats for the wetland organisms, presenting the wonderful model to show how the mother nature restores the land without human beings. However, the ecosystem in this area is a very unique one created by the combination of the frequent disturbances by the army operations such as the forest fire for the sight clearing which is different from the disturbances ordinary ecosystem experiences, and the recovery ability of the nature itself to adapt to these unusual disturbances for last 50 years. The ecosystem of the DMZ may change into other direction in case of Korean unification because the disturbances by the army operations would no longer exist while disturbances by humans may increase because public access is available. For example, the grass field maintained by the frequent fires for the sight clearing may turn into the deep forest resulting in the decrease of the number of deer who use the grass field for food and the increase of the owls or woodpeckers that reside in the deep forest. Therefore, we should keep trying to understand and monitor the DMZ ecosystem and apply the experience for better conservation and/or management of the ecosystem.

Study Area

The DMZ and 20 kilometers buffered area surrounding DMZ belong to the study area. As mentioned above, the DMZ which was established along the stalemate line roughly at latitude 38 degrees extends across the middle part of Korean peninsula from Gyonggi-do province in the west to Gangwon-do province in the east. The buffer area covers a part of Hwanghae-do province and Gaesung city in North Korea in addition to Gyonggi-do and Gangwon-do provinces (Figure 1).

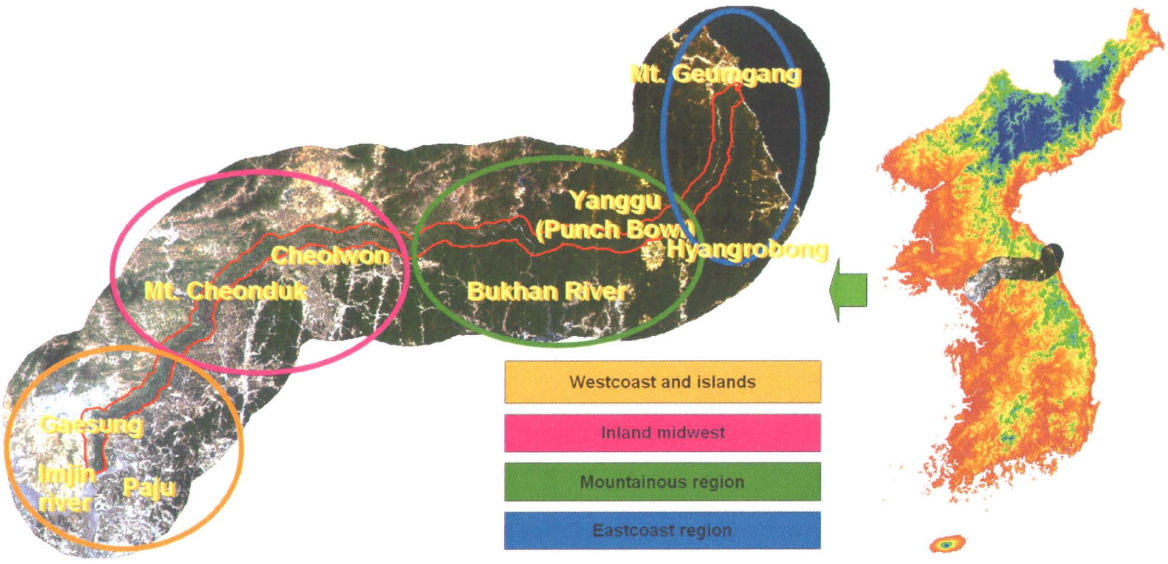

Figure 1. Location map of four regions of DMZ (red outlined area) and buffer area

The DMZ and CCZ include various landforms from the coastline in the east to the islands in the west through mountainous areas around Taebeck mountains in the middle east and plain farm land in the west side. The DMZ is the origin of the Namgang river, Bukhangang river, and Hantangang river and the corridor geographically between Mt. Geumgangsan and Mt. Seoraksan, and biologically between northern and middle Korean species, which makes the DMZ as the representative area of the Korean species (Kim 1997). The DMZ and it's surrounding areas can be grouped as the 1) east coast area which includes lagoons, wetland and valleys in the east coast, 2) mid-eastern mountainous area which includes mountains and highland marshes, 3) mid-west inland area which includes the upper Hantangang river watershed and a lava plateau, and 4) west coast and islands which include salty wetlands and hills, based on the geographical differences. Each area shows its own biological and geographical characteristics.

Materials and Methods

Satellite Image Analysis

A multi-temporal remote-sensing approach was utilized as the spatial basis for mapping the vegetation on the study area. After considering the size and diversity of the study area, the desired time frames, necessary map detail and flexibility, available data, and mapping strategies, it was decided to use LANDSAT Thematic Mapper (TM) 5 and 7 satellite imagery as the foundation for the mapping effort. Four scenes of TM imagery provide complete coverage of the study area. The cost per-area unit of Landsat image is

less than that of high resolution imagery like IKONOS, QUICKBIRD and aerial photography, both in terms of direct costs and the effort for map development. Landsat image has relatively higher spectral discrimination, with six spectral bands and one thermal band, among commercially available space-based sensors. Individual occurrences of trees didn't resolved by the sensor. Therefore, TM is particularly suited for evaluating and quantitatively identifying more generalized vegetation "community" occurrence patterns and their associated surface substrate characteristics.

A surface terrain model created by mosaicking together the US Geological Survey (USGS) 30 arc second Digital Elevation Models (DEMs) that cover the study area. The DEMs were further processed to create hill shade and slope images and to calculate the altitude.

To detect the forest cover change over time more accurately, images of 1987-1989, 2001 taken at the same phenological period were used because phenological differences between two images may cause misclassification of pixels.

Ancillary data like detailed maps, vegetation maps, and aerial photography for study area was not available because of national security purposes. Therefore, given the complexity of the data and the lack of ability to predict what the ideal combination of images for clustering might be, iso-data cluster images were produced first by unsupervised classification. NDVI (Normalized Difference Vegetation Index) was also calculated as a tool to evaluate the forest condition and its viability related to the disturbance regimes in DMZ area, including fire for the control of height growth of vegetation. Supervised classification was then executed based on the iso-data cluster images, NDVI images and ground truth data obtained by field survey.

Post-Classification Comparison involves the classification of each of the images independently, followed by a comparison of the corresponding thematic labels to identify areas where change has occurred. The comparison of separately classified images was carried out visually, or quantitatively to detect such changes as forest to non-forest cropland or non-urban to urban conversion.

Field Survey

Field surveys were conducted over the study period to gather data on the forest condition and pre-clustered spectral classes. Compass and laser distance measuring device were used together with portable GPS to identify the location of a certain characteristic, because it was not easy to access the study area due to military purposes and risk for landmine. Because the study area is quite big, it was not easy to cover all the area with field survey, some sites of easy access were selected.

Results

Image Classification and Change Detection

Classification results were developed into maps showing 7 categories of land cover of 1987-1989 and 2001 (Figure 2).

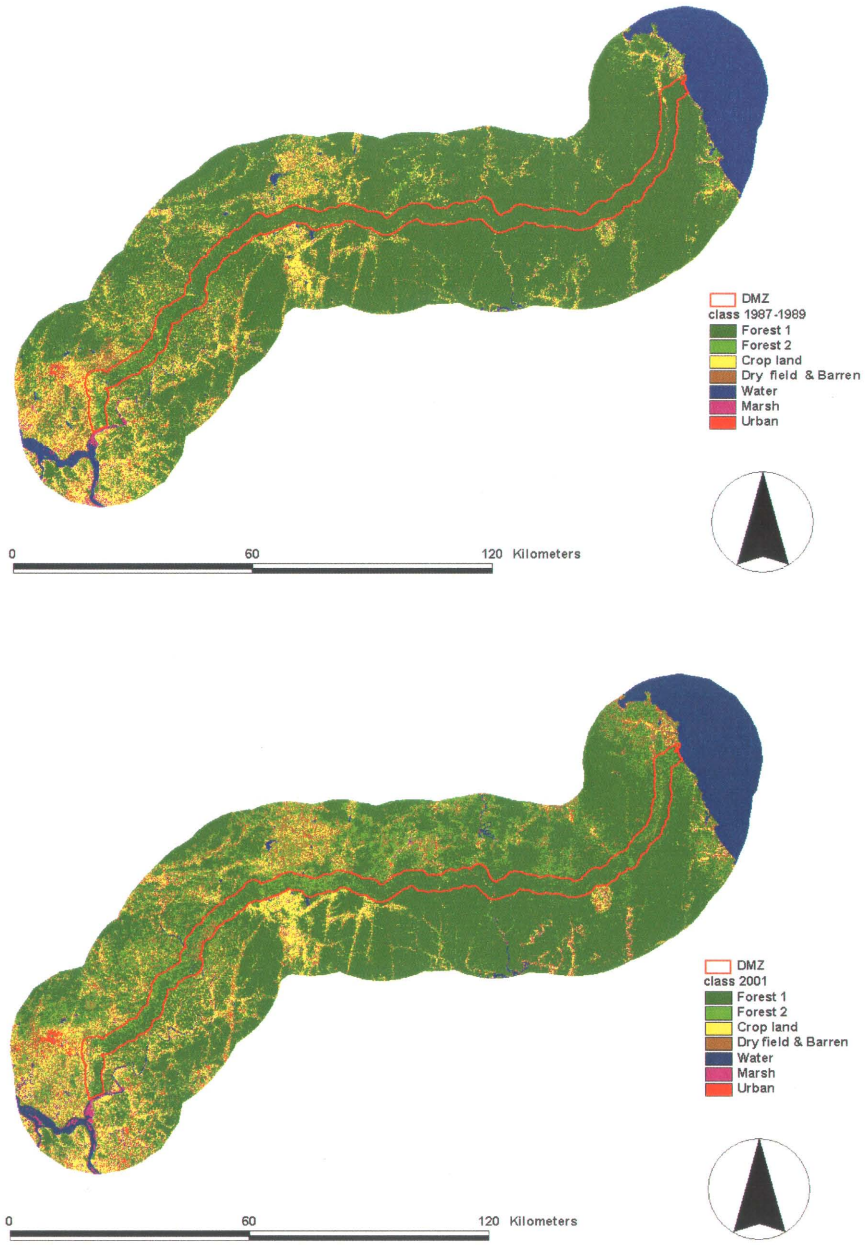

Figure 2. Classified images of study area (upper: 1987-1989 lower: 2001)

Due to the difficulty of separating closely allied categories, such as grasses and bushes, from one another in a single satellite image, it was decided to simplify the classification classes and grassland was included in relatively young forest stand which shows low stem density (Forest 2 Class). As a matter of fact, it is not easy to find grassland without any shrub species and woody species. The change of land-cover pattern and forest area around DMZ area is shown in Figure 3 and Figure 4.

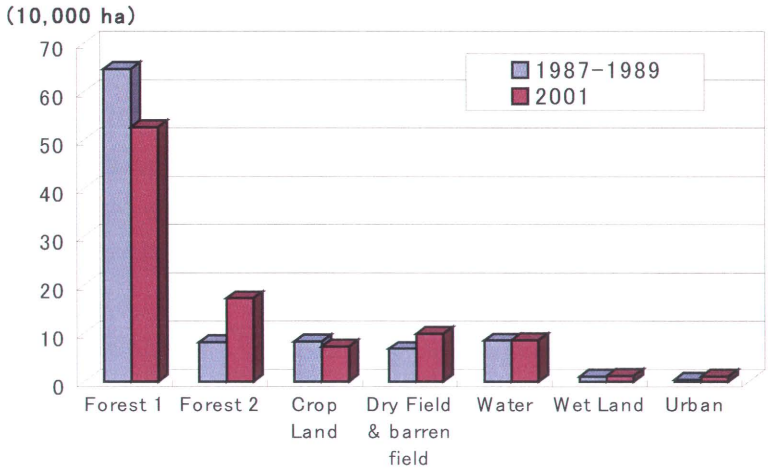

Figure 3. Land-cover change between 1987-1989 and 2001.

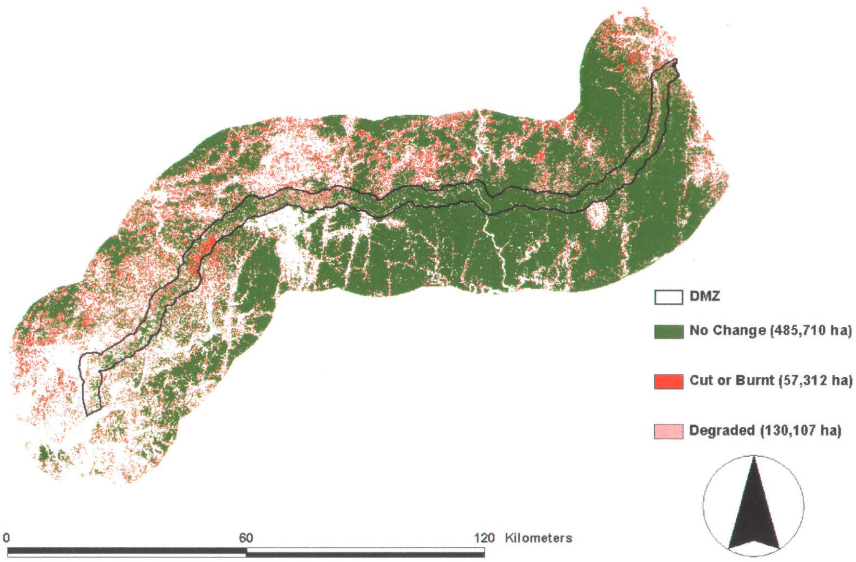

Figure 4. Change of forest area in the DMZ and its vicinity

The main category of quite a big change is 'Forest 1 class' of which the stem density and viability are relatively high. The 'Forest 1 Class' area decreased from about 640,716 ha to 526,970 ha. The double of the 'Forest 2 Class' is presumed to be the increased regeneration stand of young trees followed by the disturbances like fire, insect, and cutting.

The area of changes was estimated to be larger in North Korea than in South Korea mainly due to the conversion of forests into dry field and barren land for food production and supply of fuel wood. And what is worse, most of the croplands developed on the mountain slopes in North Korea are known to be experiencing increased erosion and decreased soil fertility.

Apart from the quality, forests inside the DMZ showed better connectivity than the surrounding area in some of the southern parts. Forest deterioration was severer in western low land than in eastern mountainous area.

In South Korea, decrease of forest area was detected in the eastern part damaged by a couple of forest fires and the vicinity of urban area under the continuous pressure of urbanization and industrialization.

Vegetation

In most areas, oak sprout or secondary growth pine forests were dominated. Secondary oak forest and *Persicaria thunbergii-Salix koreensis* forests were distributed in the west coast, islands and inland mid-west areas. Natural forests such as *Acer pseudo-sieboldianum – Quercus mongolica* forest type were distributed in the eastern and mid-eastern mountainous areas.

Conclusion

Forests in the DMZ and CCZ were generally poor due to frequent disturbances by military operations. Forests were mostly I-II of age class secondary forests of pine or oak sprouts with shallow and poorly developed soils. The DMZ and surrounding area was a unique ecosystem maintained by the combination of military operations and prevention of public access, which did not include human being but mainly controlled by human being, resulting in high biodiversity in particular areas among low

biodiversity areas rather than well reserved ecosystem. The area surrounding the DMZ, however, has been under the pressure for urbanization and the expansion of dry field and barren land according to the results of this study. Building and maintaining network to connect these high biodiversity areas and ecological corridors should come with forest restoration to conserve the surrounding areas to make the forest ecosystem in the entire DMZ fully functioned. Master plan for the rational conservation and management of the DMZ and surrounding areas should be prepared to suggest overall plan to conserve and nature-friendly manage the DMZ and surrounding areas which is the uniquely maintained ecosystem that may be gone soon if Korea is unified. The results of this study will help decision makers detecting where changes in the ecosystem of DMZ and its vicinity have occurred and determining where to conserve and restore for maintaining the structure and function of DMZ ecosystem.

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