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Change Analysis of Forest Area and Canopy Conditions in Kaesung, North Korea Using Landsat, SPOT and KOMPSAT Data

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Abstract : The forest conditions of North Korea has been a great concern since it was known to be closely related to many environmental problems of the disastrous flooding, soil erosion, and food shortage. To assess the long-term changes of forest area as well as the canopy conditions, several sources of multitemporal satellite data were applied to the study area near Kaesung. KOMPSAT-1 EOC data were overlaid with 1981 topographic map showing the boundaries of forest to assess the deforestation area. Delineation of the cleared forest was performed by both visual interpretation and unsupervised classification. For analyzing the change of forest canopy condition, multiple scenes of Landsat and SPOT data were selected. After preprocessing of the multitemporal satellite data, such as image registration and normalization, the normalized difference vegetation index (NDVI) was derived as a representation of forest canopy conditions. Although the panchromatic EOC data had radiometric limitation to classify diverse cover types, they can be effectively used to detect and delineate the deforested area. The results showed that a large portion of forest land has been cleared for the urban and agricultural uses during the last twenty years. It was also found that the canopy condition of remaining forests has not been improved for the last twenty years. Possible causes of the deforestation and the temporal pattern of canopy conditions are discussed.

Key Words : Vegetation Index, Deforestation, Canopy Condition, Change Detection, North Korea, KOMPSAT.

1. Introduction

The condition of forest vegetation can be a responsive indicator of the human activities. This is particularly true for the area which has relatively high population density and the lack of resources, such as food, fuel, and timber, to support their life. Forest is the largest cover type over Korean peninsula and plays an important role for maintaining the environmental condition of the region. About 80% of North Korea had been occupied by forest until the division of north and south in late 1940's. In addition to the large portion of forest land, forests in northern side had more stocking level and healthier canopy condition as compared to the southern part of the peninsular. This was mainly due to the highly undulated topography that made it difficult to

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access. Ever since the separation between north and south after Korean War, there has been virtually no reliable information regarding the extent and condition of forest in North Korea. In recent years, the problem of food shortage in North Korea, which was frequently followed by severe flooding and drought, has brought in a great concern to international community.

Although there was not enough information regarding the possible causes of such catastrophes, the over-exploitation of mountainous forest was considered as one of primary reasons for the disasters. It is not difficult to imagine that the large occupancy of forests can be an alternative for food production and local fuel supply. Large-scale deforestation may have a significant impact to degrade the environmental quality. To clarify the causes of continuing disasters in North Korea, it is necessary to have a pertinent method to monitor the spatial extent and canopy condition of forest over long-term period.

Since the first launch of civilian remote sensing satellite in 1972, satellite imagery has played an important role to monitor and analyze such deforestation problems (Lambin and Ehrlich, 1997). Satellite remote sensor data can be used for monitoring not only the extent of deforested area but also the crown closure and vigor of forest canopy. Remote sensing technology can be a reasonable choice to analyze the forest condition over inaccessible area like North Korea, where in situ survey was almost impossible. Recently, the forest cover change in North Korea has been studied by using multitemporal Landsat MSS and TM data (Lee *et al.*, 1999). Because of very limited sources of information regarding the spatial distribution of forests in North Korea, satellite remote sensing technology can be an only dependable tool for periodic monitoring of forest condition in this region. Land use/land cover change detection has been a major subject in remote sensing ever since the first earth observing satellite was launched (Singh, 1989; Green *et al.*, 1994; Muchoney and Haack, 1994). Using satellite imagery accumulated during the last thirty years, it has become available to analyze long-term change pattern of forest cover in both quantitative and qualitative manner.

The successful launch of the first Korean multipurpose satellite (KOMPSAT-1) has expanded the applications of space remote sensing over Korean peninsula through more frequent and flexible data supply. The electro-optical camera (EOC) is one of the imaging sensors being loaded on the KOMPSAT-1. Like other spaceborne optical sensors, such as SPOT HRV and IRS LISS operating in panchromatic mode, the main application of EOC data is to extract three-dimensional topographic information. The use of panchromatic data for thematic mapping was restricted to the identification of only a few cover classes, such as to delineate forest roads in a harvested forest (Jazouli *et al.*, 1994) and to monitor the annual changes of herbaceous aquatic vegetation (Jensen *et al.*, 1993). Phillipson *et al.* (1988) used SPOT panchromatic data to monitor complicated land cover types over landfill sites. In most cases of using panchromatic data, the information extraction was achieved by visual interpretation of image rather than machine processing. Therefore, the panchromatic data were quite often merged with other multispectral data in the applications related to thematic information extraction.

The primary objectives of this study were to analyze the temporal and spatial characteristics of forest cover changes in Kaesung area and to assess the effectiveness of several sources of satellite imagery data for describing the forest changes in North Korea where no other reliable information was existing. Forest changes would be described by the areal extent and canopy conditions, such as crown closure. EOC panchromatic data were tested for the detection and delineation of the deforested area while Landsat and SPOT multispectral data were applied for the change analysis of forest canopy conditions.

2. Study Areas and Data Used

The study areas were selected as to include diverse land cover types of both natural and man-made features. Kaesung is located in middle of the peninsula and one of the largest urban area in North Korea (Fig. 1). Since this area is also very close to the borderline between North and South Korea, it would be ideal to compare the forest cover in both North and South Korea. During the last fifty years since the division after Korean War, the two countries might have very different land use practices, which could show possible consequences in forest condition. The topography of this area is relatively flat with gentle slopes. The suburban area of Kaesung city had been primarily crop land and forest.

Due to the relatively narrow swath width of EOC per orbit, it was rather limited to obtain nadir-view scene. This study used the EOC image of Kaesung area, which was obtained at off-nadir looking mode with tilt angle of 21.5 degree on May 8, 2000. Therefore, the nominal pixel size is little larger than 6.6m at the normal nadir-view scene. For the analysis of canopy conditions, Landsat and SPOT multispectral scanners data were used. Image data earlier than 1980 were mostly obtained from Landsat Multispectral Scanner (MSS). Table 1 shows the list and

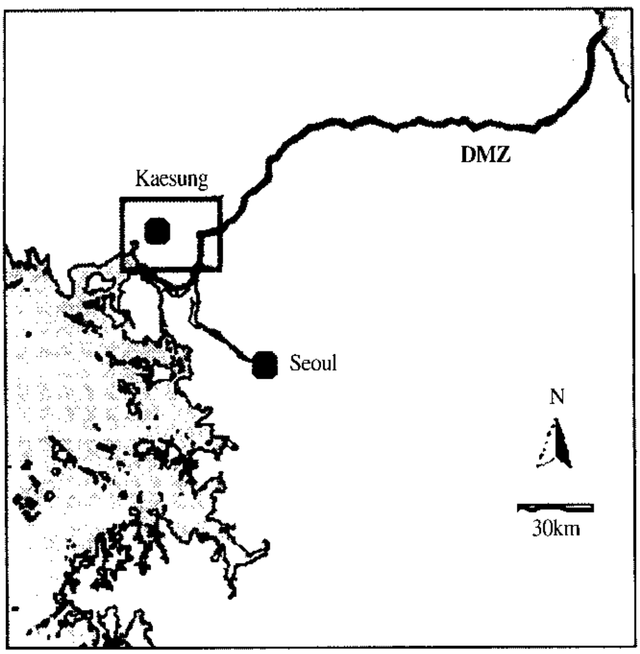

Fig. 1. Location of the study area near Kaesung and its suburban area.

Table 1. List of satellite data used.

satellite - sensor	spectral bands	wavelength (micrometer)	acquisition date	ground resolution	sun angle	
					elevation	azimuth
KOMPSAT1- EOC	panchromatic	0.51-0.73	May 8, 2000	6.6m		
Landsat 1-MSS	1	0.5-0.6	Oct. 31, 1972	79m	35	153.3
	2	0.6-0.7				
Landsat 2-MSS	3	0.7-0.8	Oct. 4, 1979		41.7	141.5
	4	0.8-1.1				
SPOT2-HRV	1	0.50-0.59	Oct. 6, 1995	20m	45.8	160.0
	2	0.61-0.68				
	3	0.79-0.89				

characteristics of satellite images used for the study. In case of analyzing multitemporal satellite data sets in temperate forest area, it is desirable to use image data sets acquired at the same growing stage to exclude the possible misinterpretation caused by different plant phenology. To minimize such seasonal variation due to the leaf growth, the data acquisition dates were selected as close as possible. The only available topographic maps, as ancillary data, in this area were 1: 50,000 scale military maps produced by Russia. Although it is known that these maps were made in 1981 using aerial photographs of late 1970's, the exact time of aerial photos and actual field survey is not quite clear. Fortunately, this map shows the boundaries of forests and even further it shows young plantation stands separated from normal mature stands. In addition, the 1999 scene of Landsat TM data were also used to help the visual interpretation of the EOC image.

3. Methods

1) Delineation of Deforested Area Using KOMPSAT EOC Data

The data analysis for detecting and delineating the deforested area was rather simple. Fig. 2 shows the overall procedure to detect the deforested area using EOC data and 1981 topographic map. The EOC image of the study area was geometrically corrected by using a set of ground control points (GCP). About 30 GCPs selected from the topographic map were used to construct the coordinate transformation functions. The maximum allowable root mean squared (RMS) error of the coordinate transformation function was set to less than 0.5 pixel distance. The boundaries of forest as well as other major features (road, water body, DMZ border, etc.) were digitized from the 1: 50,000 scale map of Kaesung. Once the vector map of forest boundaries on the 1981 map was built, it could be overlaid with the geo-corrected EOC image (Fig. 3).

Segmentation of cleared forest was performed by both visual interpretation and computer classification. Visual interpretation has been an old but still effective way to extracting any thematic information from panchromatic images as well as traditional black and white aerial photographs. As compared to computer classification where pixel's tonal value is perhaps the only clue to separate different features, human eyes can use rather diverse interpretation elements beside tone, which include texture, size,

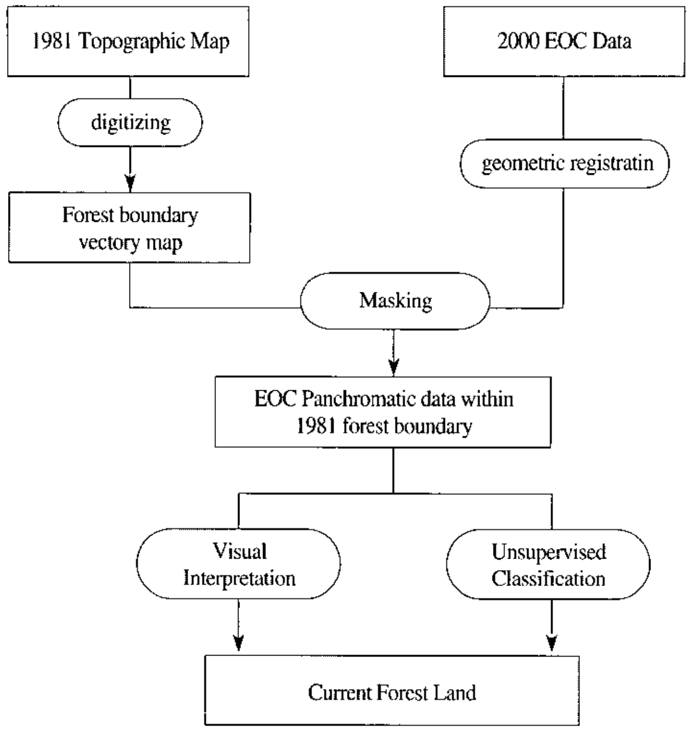

Fig. 2. Data analysis procedure to delineate the deforested area using the 1981 topographic map and the 2000 EOC panchromatic data.

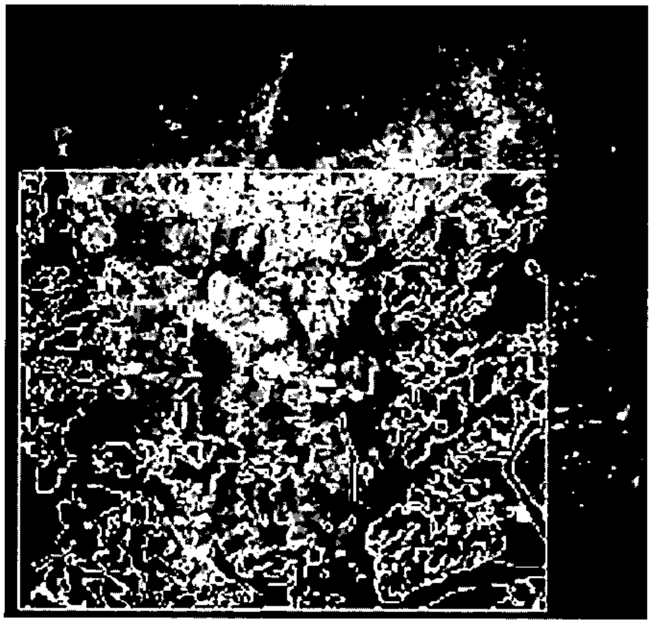

Fig. 3. Geometrically rectified EOC image overlaid with the vector map of forest boundary.

shape, pattern, etc.. After the EOC image was displayed on the monitor screen, the boundary of the cleared forests was directly delineated by screen digitizing. Although it was quite clear to separate between forest and non-forest, TM multispectral color imagery was often used to make sure the interpretation result.

Since only two classes (forest and non-forest) were of interest, it was believed that the normal computer classification scheme might work well with the single band of EOC panchromatic data. To exclude any spectral confusion among several cover types, the 1981 vector map of forest boundary was overlaid to the EOC image and the non-forest areas in 1981 were masked out. Unsupervised classification was applied using the iterative self-organizing data analysis technique (ISODATA) algorithm. Once several spectral clusters were built up, each cluster was assigned to either forest or non-forest by comparing with TM color display.

2) Comparison of Forest Canopy Conditions Using Landsat and SPOT Data

To compare the changes of forest canopy conditions over the last twenty years, three scenes of multitemporal data were obtained. The image data were processed to extract a standardized quantity for representing the forest canopy condition at the time of data acquisition. Landsat MSS and SPOT HRV multispectral scanner data are different in geometric and radiometric distortions. In particular, the Landsat MSS data obtained before 1980 showed the stripping effect. The stripped lines were adjusted by simple linear transformation function that relates to nearby normal scan line statistics (Jensen, 1996). After the correction of stripping effect, the two data sets were then registered into the other reference image by image-to-image registration for each study area. Once all three data sets were matched together, they were registered into a plane rectangular coordinate system using a set of GCP that could be identified on both map and image. About 15 to 20 control points were applied to each study area and the maximum allowable RMS error of the coordinate transformation function was less than 0.5 pixel distance. During the resampling procedure (nearest neighbor), the pixel sizes of SPOT HRV data were degraded into the one of MSS data to reduce the data volume for subsequent analysis.

To compare the condition of forest canopy over years, the digital number (DN) values recorded by various sensor systems should have been an exact representation of the reflected energy from forest canopy. However, since the multitemporal data sets were acquired under the different sensor systems and various environmental conditions, the data sets should have a great amount of radiometric variations from scene to scene. From the viewpoints of sensor system, the gain and offset settings to calibrate the sensor-recorded radiance to DN value were different between sensors and satellites. Atmospheric condition and sun angles at the time of data acquisition could be other critical factors that caused the radiometric discrepancy between the multitemporal data. Radiometric correction requires a lot of supplementary parameters, which include the accurate sensor calibration coefficients, sun angles, and atmospheric data at the time of data acquisition to estimate the atmospheric influences (scattering and absorption) on both incoming solar irradiance and target leaving radiance. In general, the first and the second factors are readily obtainable from various sources. However, it is very difficult to have exact information regarding the atmospheric condition at the time of data acquisition, which is very dynamic in both spatial and temporal scales. Absolute radiometric correction of atmospheric effects is usually based on the radiative transfer functions to calculate all the interactions between electromagnetic energy and atmospheric aerosol and molecules. Although there have been a few attempts to introduce the radiative transfer functions to correct atmospheric effects on satellite images, they were still limited by using a predefined atmospheric model rather than using true atmospheric data (Ritcher *et al.*, 1990).

Since there was no reliable data about the gas and aerosol components of the atmosphere over the study areas at the time of data acquisition, the absolute radiometric calibration could not be performed. Instead, image normalization was applied to reduce the scene-to-scene variation of DN values caused by detector calibration and atmospheric condition (Eckhardt and Verdin, 1990). Once image normalization was performed, the DN values of the same target could be treated to present the forest canopy under the same conditions. For the study area, one scene having the highest sun elevation angle and less obvious atmospheric effects was selected as a reference for the normalization of the other two scenes. Image normalization was performed by applying a simple linear regression model, which related the DN values of the two scenes to the ones in the reference scene. Regression functions for the image normalization were constructed by selecting a set of invariant targets from the registered multitemporal data. These invariant targets were assumed to be no-change over time so that any difference in their DN values could be related to detector calibration, atmospheric condition, and sun angles. About ten invariant targets were selected and they included clear lakes, river and airport runaway. Total four regression functions were developed for two spectral bands of two different scenes to be normalized.

Vegetation index has been frequently used to quantify the relative canopy closure of forest vegetation. Vegetation index is essentially an image transformation technique to enhance the differences in spectral reflectance of green vegetation at visible and near infrared wavelengths and is known to be closely related to many vegetative features, such as the amount of green biomass and leaf area index. After the radiometric normalization of multiple images of different years, normalized difference vegetation indices (NDVI) were derived from each data set. Considering the spectral characteristics of green vegetation, it is very common to use red spectral band that has relatively low reflectance among visible wavelength region. To compare the changes on forest canopy conditions over years, about ten sample forest sites were delineated. The sample forest sites were selected such that they were remained as forests on all three temporal scenes and each sample forest was larger than 100ha. In addition, the sample forests were distributed in two different locations of suburban and remote local areas. The suburban forests were close to not only residential area but also to agricultural areas. Since all three temporal scenes span both North and South Koreas, the sample sites were also selected from the forests near Seoul and the suburban area. After the boundaries of the selected forest stands were delineated, the NDVI values were extracted and compared for each site.

4. Results and Discussions

Image statistics varies by target reflectance, sensor's calibration, atmospheric condition, and solar angles. Although the Kaesung scene of EOC data covers relatively small area of about 17x19km^2, it includes diverse cover type features ranging from bright bare soil to dark water body. Fig. 4 shows the histograms of six different cover types sampled from the Kaesung scene. Among the six cover types, one or two classes (such as water and forest) were readily separable by their DN values. The other classes of soil, crop, urban, and road were spectrally mixing and the classification of these cover types should be very erroneous when the DN values are only used. EOC panchromatic data was primarily designed for topographic mapping and, therefore, did not enough radiometric fidelity to contrast such subtle differences among the several cover types with only a single band data.

Visual interpretation of the deforested area within the boundary of the 1981 vector map was relatively straightforward. Since the EOC data were acquired in early May when the leaf development of deciduous trees was not completely finished, it could be possible to misinterpret the deciduous forest as the deforested area. However, the deforested areas were mostly converted to crop land or abandoned and have different texture and pattern on the image as compared to the deciduous forest stands. The possible misinterpretations could be reduced by incorporating the TM color composite, which was helpful to distinguish between bare soil and deciduous forest. The total area of cleared forest obtained by the visual interpretation was 2,350ha, which is 20.6% of the entire forest (11,380ha) in the 1981 topographic map.

Unsupervised clustering on the single band of the EOC panchromatic data showed similar result to the one obtained from the visual interpretation. From the Fig. 4, the histogram of the forest class is somewhat distinguishable from the other non-

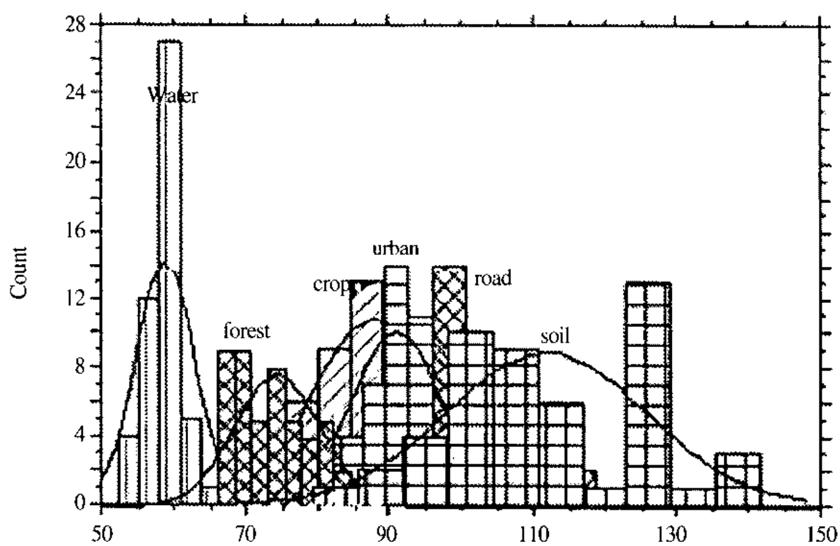

Fig. 4. Histograms of six different cover types selected from the Kaesung scene.

forest classes although it has some overlapping with the crop class. The total deforested area classified by unsupervised classification was 2,860ha, which was larger than the one from visual interpretation. Fig. 5 shows the classification results from both visual interpretation and computer classification. Although there were about 500ha of discrepancy between the two methods, the overall pattern of spatial distribution of the deforested area is similar each other. Because computer classification was entirely based on the pixel's DN value, the under-developed deciduous forest, which had similar spectral characteristics with crop or soil classes, might be misclassified into non-forest class. That could be the reason why the deforested area from the computer classification had larger than the one from visual interpretation.

Fig. 6 shows the mean and standard deviation of temporal NDVI values extracted from the sample forest stands in both Kaesung and Seoul areas. The temporal changes of NDVI values in Kaesung area did not show any significant change from 1972 to 1995, although the remote forest has maintained higher values than the suburban forests. The forest in suburban area shows relatively low values over years, which implies very sparse canopy closure and low level of leaf biomass. The actual appearance of the canopy condition corresponding to such low NDVI value can be imagined by the known forest condition in Seoul area at the same time. In early 1970's, the forest condition near Seoul area was very poor in terms of canopy closure, stand density, stocking level, and tree sizes. Twenty-three years should be long enough for young forest stands to have healthy canopy if they were not disturbed for that period. If the forest had normal growth and was not disturbed, the canopy closure should have much increased and their NDVI values should have been high.

The temporal patterns of NDVI values between Kaesung and Seoul areas showed very interesting results. Ever since the division of North and South Korea, the forest land in Kaesung and Seoul areas might be undergone with different management

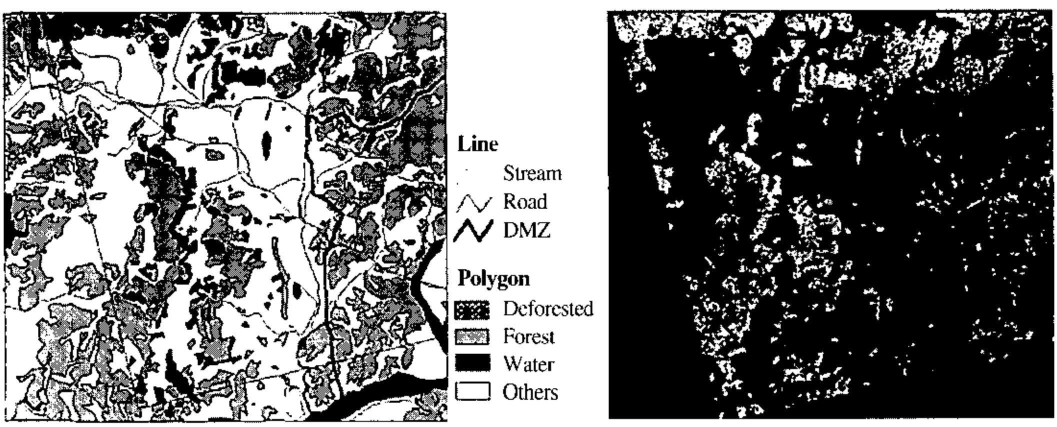

Fig. 5. Delineation of the deforested area using EOC data by visual interpretation (left) and unsupervised computer classification (right). Computer classification was only applied to the forest defined by the 1981 map with two classes of forest (grey) and non-forest (white).

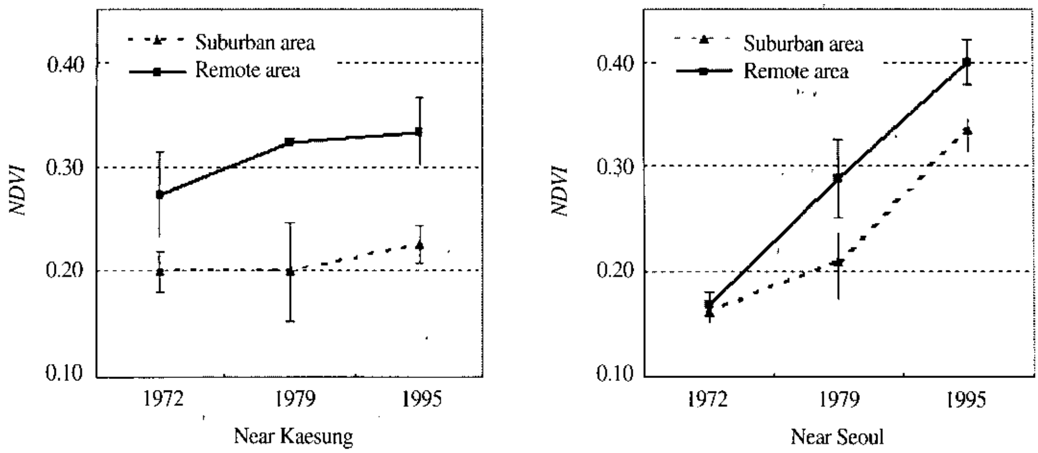

Fig. 6. Temporal changes of the NDVI values between Keasung and Seoul forest areas.

practices and environmental conditions. Although the forest conditions in 1972 was almost similar between Kaesung and Seoul areas, the NDVI values of 1995 showed the dramatic changes after twenty three years. The NDVI values in Seoul area showed rapid increases over the years on both suburban and remote forests. The forest lands near Seoul as well as the other part of the country were so devastated by the war and continuing disturbances. Since late 1960's, the government has maintained very strong forest recovery and protection programs which have resulted in rapid improvement within short period. Such distinct difference of the NDVI changes between Kaesung and Seoul area have shown that an effective management and preservation practices could have very strong influence on forest condition over less than thirty years.

There have been significant changes in both the size of forest area and the canopy condition since the early 1970's. The analysis of the KOMPSAT EOC data along with the topographic map showed that about 20% of the forest land was converted to other land uses. If the forest boundaries on the 1981 topographic map were accurate representation of forest status at that time, such change should be significant enough under the standard land use practices. Two types of deforestation pattern were found from this study. First, large areas of forest had been cleared for urban expansion. This type of deforestation was found near the Kaesung city and its suburban area where the forest land was converted for housing and transportation. Second type of forest conversion was to expand the agriculture land for crop cultivation. As mentioned before, the topography in this area is relatively flat and gentle slope. It has often been reported that North Korea kept a long policy to expand the agricultural land to increase food production. Considering the gentle topography and relatively large population near the urban area, forest could be an easy alternative to be developed. Along with the decrease in the size of forest land, it was also obvious that the remaining forests have suffered continuous disturbances from the temporal pattern of NDVI values extracted from Landsat and SPOT multispectral data.

5. Conclusions

The massive developments and degradation of forest in North Korea have been a great concern related to the frequent flooding disasters. To monitor forest conditions in this region, KOMPSAT satellite can be a practical choice to provide appropriate image data with more frequent time interval. Although EOC data was designed to produce topographic maps and had several limitations to be used for extracting thematic information over wide geographic area, it showed potential to be used for detecting forest changes at local scale. If EOC data is used with other forms of old spatial data, such as the old map in this study, it would be effective to update current condition of forest with rather simple manner. In this study, EOC data were processed to delineate deforested area by visual interpretation and computer classification. Considering the limitation of using a single band of panchromatic data, visual interpretation seems to be better approach although we cannot confirm this without any reliable reference data or on-site verification.

The long-term monitoring of canopy condition can provide valuable information on the effects of human and environmental disturbances. With multitemporal data, it has now become practical to conduct this kind of analysis to characterize the change pattern of forest canopy over long-term period. In addition, satellite images can be effective choice to study the inaccessible area that can not be approached by other means. This study could be a typical case of such situations. In analyzing multitemporal satellite data sets, it can be crucial to minimize the possible effects of the pixel value variations caused by data acquisition environments, such as the atmospheric condition, sensor calibration, different growing stage of vegetation. The comparison of the temporal NDVI values showed that the forests in Kaesung area have undergone continuing disturbances. This was obvious for the forests near the urban areas while the remote local forests showed some improvement in canopy closure. The degradation in the suburban forests was very clear when we compared with the forest canopy changes in Seoul area. Although the consequences of the poor forest condition were not well clarified, the overexploited forest may have great influence on soil erosion, flooding, and water supply. With increasing availability of satellite images including KOMPSAT data, there are better chances to use multitemporal data set, which should give us a more clear description on the forest status in North Korea.

References

Eckhardt, D. W. and J. P. Verdin, and G. R. Lyford, 1990, Automated Update of an Irrigated Lands GIS Using SPOT HRV Imagery, *Photo. Engr. Remote Sens.*, 56(11): 1515-1522.

Green, K., D. Kempka, and L. Lackey, 1994, Using Remote Sensing to Detect and Monitor Land-cover and Land-use Change, *Photo. Engr. Remote Sens.*, 60(3): 331-337.

Jazouli, R., D. L. Verbyla, and D. L. Murphy, 1994, Evaluation of SPOT Panchromatic Digital Imagery for Updating Road Locations in a Harvested Forest Area, *Photo. Engr. Remote Sens.*, 60(12): 1449-1452.

Jensen, J. R., 1996, *Introduction Digital Image*

Processing, Prentice Hall.

Jensen, J. R., S. Narumalani, O. Weatherbee, 1993, Measurement of Seasonal and Yearly Cattail and Waterlily Changes Using Miltidate SPOT Panchromatic Data, *Photo. Engr. Remote Sens.*, 59(4): 519-525.

Lambin, E. F. and D. Ehrlich, 1997, Land-cover Changes in Sub-Saharan Africa (1982-1991): Application of a change index based on remotely sensed surface temperature and vegetation indices at continental scale, *Remote Sensing of Environment*, 61: 181-200.

Lee, K. S., M. R. Joung, and J. S. Yoon, 1999. Content and Characteristics of Forest Cover Changes in North Korea, *J. Korean Forestry Soc.*, 88(3): 352-363.

Muchoney, D. M. and Haack, B. N., 1994, Change Detection for Monitoring Forest Defoliation, *Photo. Engr. Remote Sens.*, 60(10): 1243-1251.

Philipson, W. R., E. M. Barnaba and A. Ingram, V. L. Williams. 1988. Land-Cover Monitoring with SPOT for Landfill Investigations. *Photo. Engr. Remote Sens.*, 54(2): 223-228.

Richer, R., 1990. A Fast Atmospheric Correction Algorithm Applied to Landsat TM Images, *Int. J. Remote Sens.*, 11(1): 159-166.

Singh, A., 1989, Digital Change Detection Techniques Using Remotely-Sensed Data, *Int. J. Remote Sens.*, 10(6): 989-1003.