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Monitoring of Forest Burnt Area using Multi-temporal Landsat TM and ETM+ Data

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Abstract : The usefulness of the multi-temporal satellite image to monitoring the vegetation recovery process after forest fire was tested. Using multi-temporal Landsat TM and ETM+ data, NDVI and NBR changes over times were analyzed. Both NDVI and NBR values were rapidly decreased after the fire and gradually increased for all forest type and damage class. However, NBR curve showed much clearer tendency of vegetation recovery than NDVI. Both indices yielded the lowest values in severely damaged red pine forest. The results show the vegetation recovery process after forest fire can detect and monitor using multi-temporal Landsat image. NBR was proved to be useful to examine the recovering and development process of the vegetation after fire. In the not damaged forest, however, the NDVI shows more potential capability to discriminate the forest types than NBR.

Key Words : Iimage Differencing, NDVI, NBR, Vegetation Recovery.

1. Introduction

Nowadays the global environments are becoming hot issues to human beings. It concerned in environmental pollution and vast deforestation caused by the industrialization and urbanization and natural disasters such as flooding, drought, and especially forest fire. Since United Nations Conference on Environment and Development (UNCED) in 1992, also known as the Earth Summit, forest is one of the most important global concerns in aspects of environmental management. Forest absorbs and sinks the carbon dioxide, and has a role to dilute the global warming influenced by the green house effect.

Forest fire is very important and urgent issue in Korea as one of the major disturbances resulting in changes of forest ecosystem and its function. According to Lim(2002) during the period of 1990 to 1999 an average of 336 fires occurred annually and affected an average area of 1399 ha. It was only 238 fires occurred, affecting 1102 ha between 1980 and 1989. Especially in the 1990s a few large forest fires occurred in eastern coastal region of Korea. This region is vulnerable to fire because they have very low rainfall in the spring; and foehn and quasi-foehn winds abruptly interchange many times in a day. Under these meteorological conditions, wildfires spread rapidly over large areas. Moreover, vegetation is mainly composed of *Pinus densiflora* that is inclined to ignite easily.

Satellite image is one of the useful tool for mapping

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The distortions come from not only the sensor being used and earth curvature but topographical condition of the study area. Therefore an orthorectification that corrects terrain displacement is indispensable.

An orthorectification process was performed using Erdas Imagine. The ground control points(GCPs) were selected from the topographic maps in scale 1:25000. DEM is also derived from digital topographic maps. Transverse Mercator projection with eastern origin that adopted in Korea for the study area was used. Nearest Neighbor resampling method was used to determine the new rectified pixel values in a size of 30m by 30m. At first the 2000 image was orthorectified and the other three images were co-registered with image to image registration method.

The total root mean square error (RMSE) between the registered images remain under 0.25 pixel, which is quite low enough to accept for this study. Usually RMSE for the purpose of change detection is less than 0.5 pixel when registering the images.

2) Image Analysis

(1) Normalized Difference Vegetation Index

Vegetation Index is often used to explain the vegetation phenomena and to interpret differences among various vegetation types or between vegetation and artificial objects. Diverse object shows a unique reflectance pattern according to wavelength. For example, spectral reflectance curves for healthy green vegetation almost manifest a "peak-and-valley" configuration. In the visible portion of the spectrum, chlorophyll strongly absorbs energy in the wavelength bands centered at about 0.45(blue) and 0.67μm(red), while highly reflecting green energy. In the near infrared portion of the spectrum at about 0.7 to 1.3μm, healthy vegetation shows very high reflectance value at about 40 to 50 percent of the incident energy. On the other hand, healthy plants show relatively low reflectivity in red band.

Likewise, many plant stress alters the reflectance in both visible and near infrared wavelengths, and so sensors operating in this range are often used for detection of vegetation stress such as forest damaged by fire, insect and disease attack. Therefore, based on the reflectance pattern of vegetation, various models of vegetation indices are developed to explain the health, vigor, vegetation cover, and biomass of the plants. Various algebraic combinations of the Landsat TM channel 3(Red band) and channel 4(NIR band) have been introduced as a vegetation index that explain the presence and condition of green vegetation. Referring to the previous researches (Green *et al.*, 1994 ; Miller and Yool, 2000), NDVI was one of the most effective ways to detect the burnt forest. NDVI is computed from the Eq. (3).

$$NDVI = \frac{NearIR(Band4) - Red(Band3)}{NearIR(Band4) + Red(Band3)} \qquad (3)$$

Vegetated areas generally yield high values for NDVI because of their relatively high reflectance in NIR and low reflectance in visible wavelength. On the contrary, water and bare soil areas have a higher reflectance in visible than NIR wavelength and yield negative (-) and/or near zero (0) index. The NDVI values vary from -1 to +1 according to vegetation conditions. To make easy the data handling, the NDVI data was transformed to 8bit data with 0 to 255 pixel values(Eq. (4)).

$$tNDVI = \left[\frac{NearIR(Band4) - Red(Band3)}{NearIR(Band4) + Red(Band3)} + 1\right] \times 127.5 \qquad (4)$$

(2) Normalized Burn Ratio

Key and Benson(1999) devised the Normalized Burn Ratio, considering the fact that band 4 and 7 exhibited the greatest reflectance change in response to fire. The reflectance value of band 7 is increased while the value of band 4 is decreased after fire. They hypothesized that a ratio of those bands would be most discriminating for burn effects and constructed the Normalized Burn Ratio from their reflectance values. Like NDVI, the NBR value also ranged from -1 to +1. Because of the same reason as the NDVI and to compare with it, the NBR data was also transformed to 8bit data using the Eq. (5).

$$tNBR = \left\{ \frac{NearIR(Band4) - MiddleIR(Band7)}{NearIR(Band4) + MiddleIR(Band7)} + 1 \right\} \times 127.5 \quad (5)$$

(3) Image Differencing

Change detection involves the use of multi-temporal image data sets to discriminate the changes between dates of imaging. There are two ways to detect the changes ; 1) post-classification comparison and 2) pre-classification interpretation. In latter one, numerous change detection methods such as composite analysis, image differencing, principal components analysis (PCA), and change vector analysis are employed. The choice of a most appropriate method depends on the objectives of change detection and status of the image acquired among other things.

Image differencing methode was employed in this study to quantify change from one time to the next. In the image differencing procedure, the pixel value (reflectance) of one date (t1) are simply subtracted from the corresponding pixel value of the other date(t2) as shown in the Eq. (6).

$$DX_{kij} = X_{kij}(t2) - X_{kij}(t1) \quad (6)$$

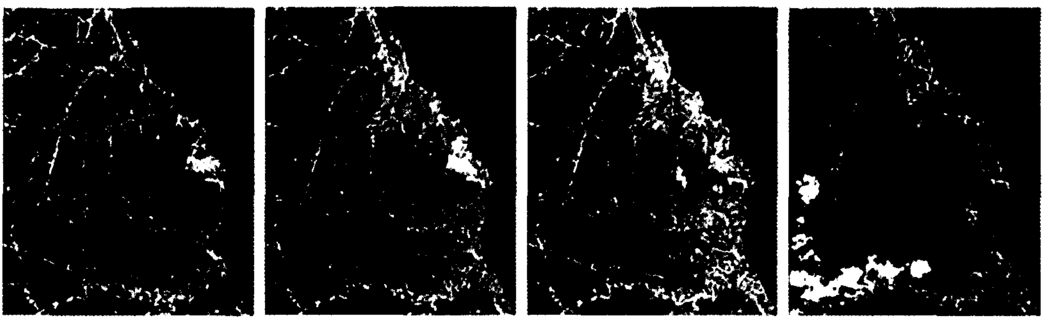
Where X_{kij} is the pixel value(reflectance) of the band k at pixel (i, j)

Theoretically the difference values in no-changed areas shows near zero (0), while the areas of change have relative large negative (-) or positive (+) difference values. When image differencing is employed, the analyst must find a meaningful "change/no-change threshold" within the data.

3. Results and Discussions

1) Interpretation of Forest Damage by Image Differencing

For the visual interpretation of the forest burnt area several band combinations were analysed. The color composite image with band combination of 7, 4 and 3 for RGB color was found as best suitable one. Fig. 1 shows the data sets of Landsat TM and ETM+ images covering the study area. Fig. 1(a) was obtained in May 20, 1998(pre-fire), Fig. 1(b) was acquired in May 25, 2000(a month after fire extinction), Fig. 1(c) was acquired in May 28, 2001(a year after fire), and Fig. 1(d) was acquired in May 23, 2002(two years after fire), respectively. Vegetation covers damaged by fire appeared reddish in the image (b). On the other hand, the post-fire image (c) and (d) vividly show the vegetation recovery over times after forest fire. Typically the vegetation of burnt area appear more



(a) May 20, 1998 (b) May 25, 2000 (c) May 28, 2001 (d) May 23, 2002

Fig. 1. Satellite image data used for change detection.

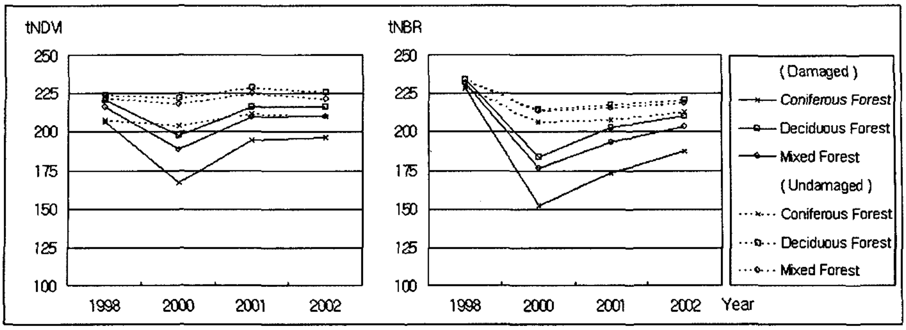


Fig. 5. NDVI and NBR changes according to forest types.

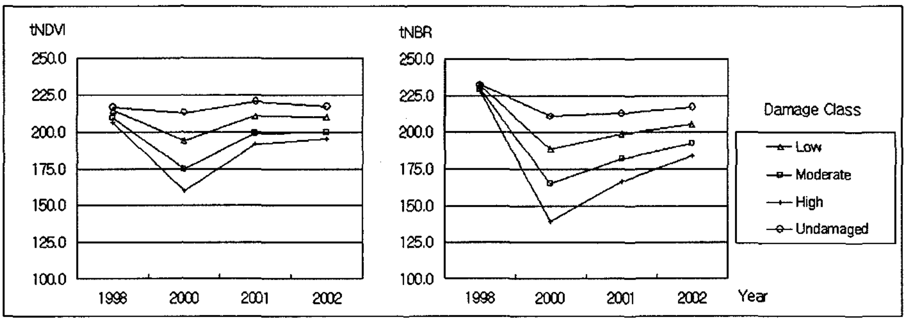


Fig. 6. NDVI and NBR changes according to the damage class.

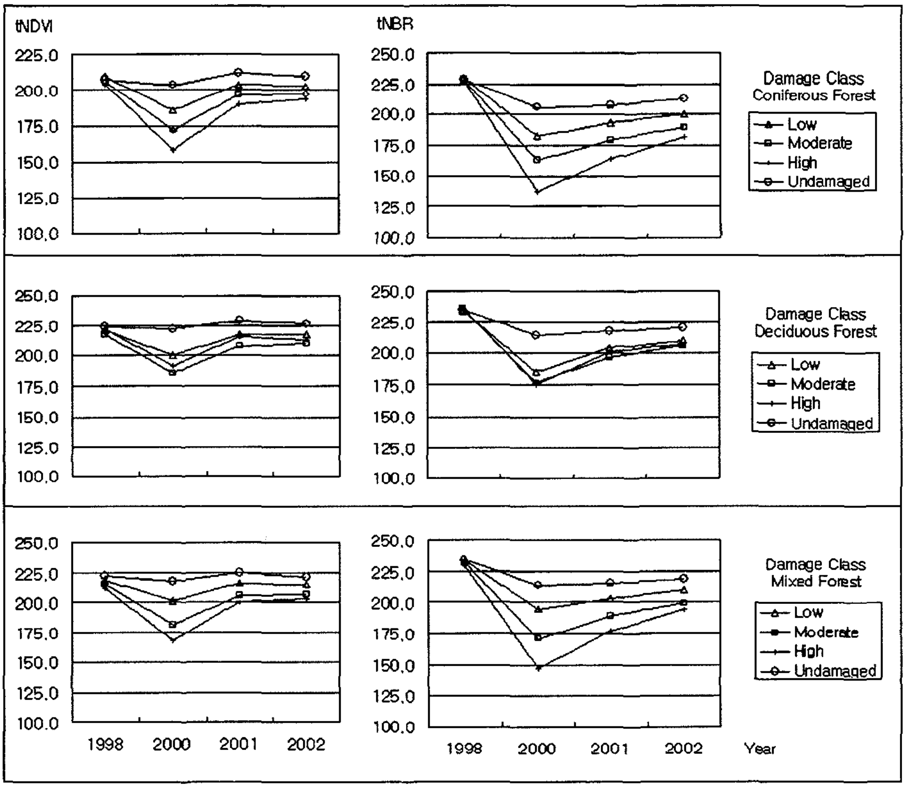


Fig. 7. NDVI and NBR changes according to forest type and damage class.

NBR showed the continuous increasing pattern. Therefore, in order to examine the forest fire effects, it is more useful to introduce the NBR with the infra-red Bands 4 and 7, responding sensitively to soil characteristics rather than NDVI.

4. Conclusions

Multi-temporal Landsat TM and ETM+ data were used to examine and to monitor the vegetation changes in forest burnt area. After radiometric and geometric corrections new component such as the NDVI and NBR were yielded and image differencing algorithm was applied to change detection. The difference of the pixel value in every pair of 6 bands except thermal band, and NDVI and NBR between before- and after fire were computed.

The differences of vegetation change were appeared distinctively in both Band 4 and Band 7 after fire. The fire effect and vegetation recovery were examined based on NDVI and NBR. Both values were rapidly decreased after fire and gradually increased over times. However, NBR curve showed much clearer tendency of vegetation recovery than NDVI. NDVI and NBR changes were analyzed according to forest type and damage class. In coniferous forest composed with red pine stand, both indices yielded the lowest values. In fact, most of the red pine forest in the study area was prone to forest fire and severely damaged. In this study, NBR was proved to be useful to examine the recovering and development process of the vegetation after fire. In the not damaged forest, however, the NDVI shows more potential to discriminate the forest types than NBR.

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