Change of Tree Types and Estimation of Tree Ages in a Research Forest from Two-decade Archive of Landsat Images

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ABSTRACT:

We used a series of Landsat images acquired from 1984 to 2001 to observe decadal changes of the research forest of Kangwon National University. Tree NDVI images of November in 1984, 1986 and 2001 were displayed in RGB color composite. This image enabled us to identify historical change of conifer types and their approximate ages. Conifers were classified into 'old conifer aged more than 25 years', 'young conifer aged 20-25 years' 'very young conifer aged less than 20 years', and recently deforested areas. The results coincide with *in situ* data very well. Archives of higher resolution images should be used to monitor the change of area for various tree types.

KEY WORDS: Tree age, Tree type, NDVI, conifer, deciduous tree.

1. INTRODUCTION

1.1 Backgrounds

Forest is a very important natural resource that affects our daily life. However, detailed investigation of the forest has always been a challenging task. The resolution of forest maps of Korea is currently limited to the scale of 1:25,000. A long-term archive of satellite images can complement the current forest maps. In this study, we will show that mid-resolution (30m) satellite images such as Landsat TM and ETM+ can help to classify tree types and tree ages when a series of images acquired over decades are available.

1.2 Study Area and Data

The study area is the research forest of Kangwon National University (Fig 1). Geographic centre location of the study area is 37º48´ latitude, 127º52´ longitude, and its area is 3,058ha. The area of deciduous tree is about 2,293ha and conifer tree about 77ha over the research forest. Its administrative district includes Dongsan-myeon, Chuncheon city and Bukbang-myeon, Hongcheon-gun. The research forest has various species of conifer and deciduous trees. As a research forest, there are plenty of *in situ* data such as Stock Map of Research Forest[1], Planting Records[2], The 6th Forest Management Planning of Research Forest[3], which can be used as both a ground truth and an object of for the results from the satellite images. The resolution of *in situ* data of research forest is comparable to that of Landsat images. We used a series of Landsat images acquired from 1984 to 2001 to observe decadal changes of the research forest. Landsat TM, ETM+ images used in this study were six from PATH-ROW 115-034 as shown in Table 1.

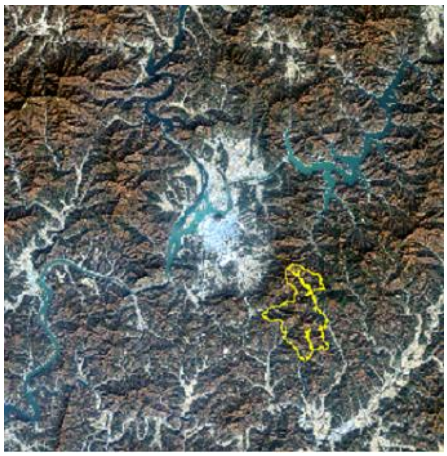

Figure 1. The study area outlined in yellow contour. (whole image: 54km x 54km)

Acquisition date	path	row	sensor
1984-11-12	115	034	TM
1986-11-16	115	034	TM
1987-04-27	115	034	TM
1999-03-27	115	034	TM
2001-11-19	115	034	ETM+
2002-03-11	115	034	ETM+

Table 1. List of Landsat satellite data

2. DATA PROCESSING

2.1 NDVI

We detected vegetation by using NDVI (Normalized Difference Vegetation Index) of Landsat TM, ETM+:

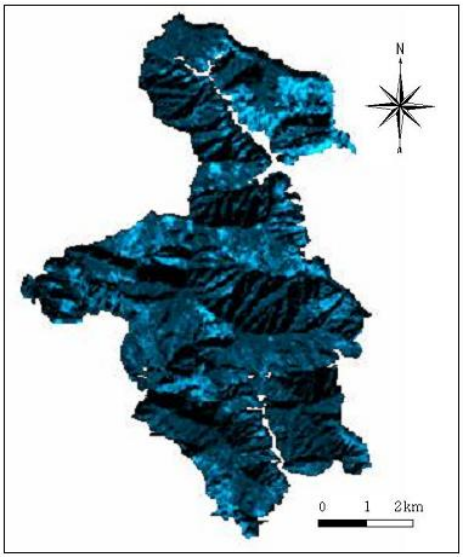

Figure 2. NDVI image of Landsat TM (1984/11/12)

NDVI= (Band4-Band3) / (Band4+Band3), (1)

and transformed it using the following formula

if NDVI<1 then 1 else NDVI*255 (2)

We used NDVI value from 1 to 255 and assigned 0 to null value during image processing. Winter-time NDVI of conifer threes is much higher than that of deciduous tree as the deciduous tree fall its leaves. Identifying the tree types using Landsat winter-time image is much more efficient and accurate than that using summer-time image. Therefore, we focused on six winter-time images only. The light blue area in the Fig. 2, shows high NDVI value of conifers in an image acquired on 12 November 1984. Dark area indicates low NDVI over deciduous trees.

2.2 Classification

We applied supervised classification with *in situ* data obtained from field works and several reference data [1]. Fig 3 shows examples of training sets for classification collected from field survey. We have three major training sets: conifer, deciduous, deciduous_shadow.

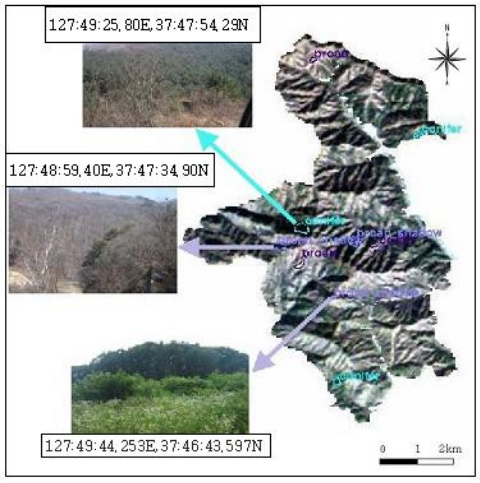

Figure 3. Training set

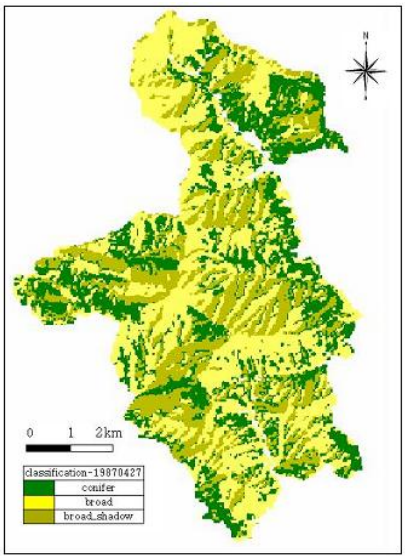

Figure 4. Result image of classification

The deciduous_shadow is for north-facing slopes with limited light which shows different spectral characteristics from deciduous tress of south-facing slopes. We tried several classification methods, but there was no major difference between these methods. We chose the Minimum Distance classification method for its simplicity and high accuracy especially in the boundary region.

Fig. 4 shows a result of classification using Landsat-5 TM acquired on 27 April 1987. Bright and dark yellow regions stand for deciduous trees on south-facing and north-facing slope, respectively, and the green pattern is the conifer trees. The similarity between Fig. 3 and Fig. 4 indicates that classification was successful and the vegetation can be well presented by both the classified image and the NDVI image.

3. DATA ANALYSYS

3.1 Tree Types and Ages

We displayed RGB color composites with NDVI winter-time images obtained from 1984 to 2001 to see the change of tree types. "The 6th forest management planning of Research Forest" and "Stock map of Research forest" were used for comparison and analysis. Fig. 5 shows a color composite image of November-NDVIs acquired on 12 November 1984 to Red, 16 November 1986 to Green, 19 November 2001 to Blue. The climate of November can change on yearly base, but its effect is assumed negligible in this study.

White area in Fig.5 is conifer forests that haven't changed significantly from 1984 to 2001. Tree age of this forest is more than 25 years because the tree age on 1984 must have been more than 5 years to show such high NDVI. Reference data shows that these areas are mainly cone pine (*Pinus koraiensis*) or some pine trees aged more than 70 years. We call this area 'old conifer' aged more than 25 years.

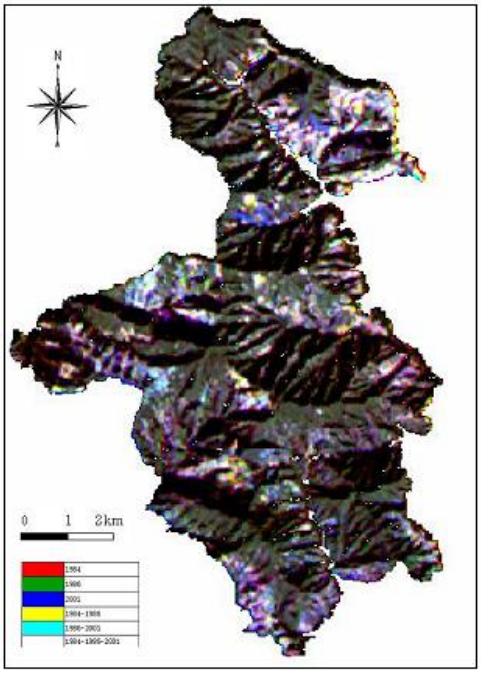

Figure 5. RGB-NDVI composite image

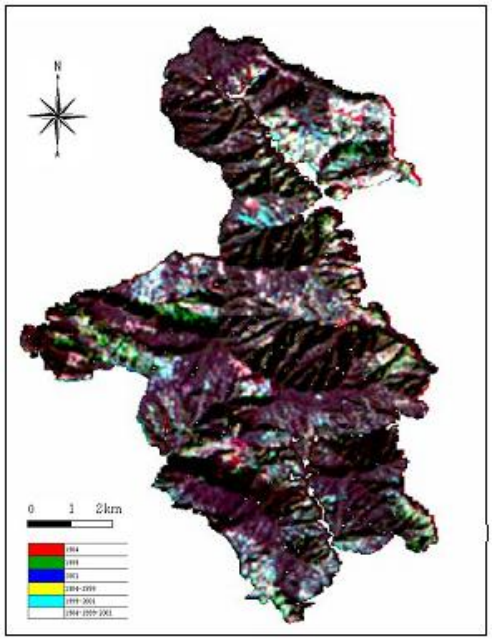

Figure 6. RGB-NDVI composite image.

Cyan colour means that conifer was absent in 1984, but it began to appear from 1986 NDVI. This means that the trees are planted in early 1980s. For this reason, we call it 'young conifer' aged 20 to 25 years.

Blue part means that the area is afforested after 1986 or the growth was not very good. Anyway, the NDVI-age of this blue region is younger than the light-blue young conifer. Therefore we named it 'very young conifer' aged less than 20 years or perhaps less than 10 years.

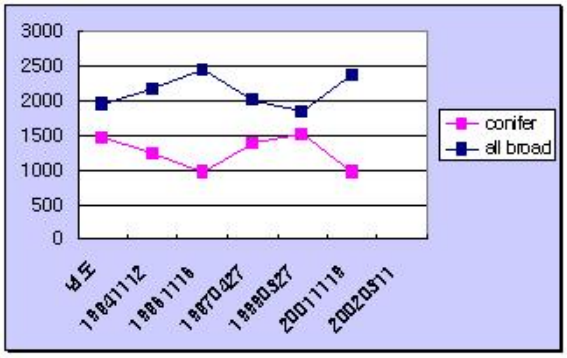

Figure 7.Changs of conifers and deciduous size

Yellow colour indicates deforestation occurred after 1986,where there were conifers 1984 and 1986 but disappeared before 2001. Red to purple indicates deforestation during 1984-1986.

As shown above, three November images used for Fig. 5 are acquired in 1984, 1986 and 2001, and there are large gap of data during 1986 to 2001. To overcome this limitation, we used March 1999 image for Green instead of 1986 image for colour composite, which was shown in Fig 6. Green colour means that high NDVI only temporary in 1999, and over the deciduous or mixed region according to the in situ data. This is because we used the March image when weeds, grass or some deciduous begin to reflect near-infrared to the sensor. Therefore we need to be careful to interpret this image.

White colour of Fig. 6 confirms the locations of 'old conifer' area similar to Fig. 5. The blue area in Fig 5. appears cyan in Fig. 6, which indicates that the conifer in this region were 'very young' during 1986, but it has grown enough to show high NDVI on 1999.

3.2 Area Change of Tree Types

We tried to trace the change of area of conifers and deciduous trees. Fig. 7 shows changes of conifer and deciduous area in time sequence. Deciduous trees increased dramatically on April 1987 and March 2002. The result can not be accepted because of classification error which fluctuates season to season.

To avoid this error, we have interpreted November images only. In November 1986, 200 ha of conifer seem to have been replaced by deciduous trees compared to 1984, and again increased again in 2001. However, the record from "Planting Records(book)" shows the afforest area of deciduous is 21ha, and deforest size of conifer is 13ha. The discrepancy of two result is mainly due to the resolution of satellite and classification error. Decadal archive of higher spatial and spectral resolution image, such as Kompsat-2 or IKONOS will enable accurate monitoring of the forest changes.

4. CONCLUSION

Using archive of November images obtained from 1984 to 2001, we can positively estimate the age of conifers such as 'old conifer aged more than 25 years', 'young

conifer aged between 20-25 years', 'very young conifer aged less than 20 years', 'deforested area'. This interpretation was confirmed by detailed *in situ* data and field work in this research forest. However, it was impossible to classify and measure the area of conifer and deciduous trees due to limitation of spatial, spectral, temporal resolution of Landsat images. Accumulative acquisition of satellite images with higher resolution can save time and effort for forest management

5. REFERENCE

[1] Stock Map of Research Forest in the Kangwon National University.

[2] Research Forest of Kangwon National University, *Planting Records of Research Forest (From 1972 to 2002)*, unpublished document.

[3] Research Forest of Kangwon National University, *Planting Records of Research Forest (From 1972 to 2002)*, unpublished document. Research Forest of Kangwon National University, *6th Forest Management Planning of Research Forest*, Kangwon Publication Co., 1999.

6. ACKNOWLEDGE

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