Monitoring the decline of Abies koreana forest in Mt. Halla

Monitoring the Decline of *Abies koreana* Forest in Mt. Halla

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Abstract

Korean fir (*Abies koreana*) is endemic in Korea and valuable for ornamental use. Korean fir forest in Mt. Halla has been reported that are declining recently. Some causes of declining had been proposed without concrete evidences. To reveal the early symptoms, spatial pattern, and speed of declining, we set permanent plots and sensors of air temperature and relative humidity on 3 locations in 2003 around the peak of Mt. Halla to monitor tree deaths and microclimate, and assessed the degree of tree decline by some characteristics of leaf conditions including leaf length, amount of leaves and leaf folding. And then we drew tree maps and monitored the changes in tree mortality and climatic variables. We found that air temperature of winter and spring time increased highly during last 40 years. Tree mortality was higher in 2003 than in 2004, and also air temperature in spring time was higher in 2003 than in 2004. Using Landsat TM images, we made the vegetation map of the Mt. Halla, assessed the changes in NDVI of Korean fir stands from 1994 to 2003. Korean fir distributed on the relatively flat and abundant in soil moisture regime. There were significant changes in south-west region, while no significant change in north-east region. We found that there were differences of degree of Korean fir decline by location, e.g. mortality, leaf conditions and so on. South and west regions were severer than Northeast. Plant physiological characteristics including photosynthesis rate, water use efficiency, Na contents in needles and antioxidant enzymes contents such as Ascorbate peroxidase (APX) and GR (Glutathione Reductase) were measured at the three sites. Photosynthesis rate of healthy Korean fir was higher than those of unhealthy individual, and could see the symptoms of high temperature stress at spring time while no symptoms at summer and autumn season. As resistance mechanism to physiological stresses, water use efficiency and Na contents in the needles of unhealthy individuals were higher than healthy individuals. APX and GR activities of healthy individuals were higher than those of healthy individuals. We proposed hypothetical causes of Korean fir decline in Mt. Halla. The main cause of the Korean fir decline and its difference by locations were thought to be water balance problem between requirement at canopy and supply from root in winter and early spring, which was triggered by climatic warming.

Key words: Forest decline, Landsat TM satellite Images, NDVI change detection, Korean fir, Climate change, physiological characteristics

Introduction

Mt. Halla is located at Jeju island and the highest mountain (1,950m a.s.l.) in Korea. It possess diverse vegetation types by altitude from evergreen broadleaved forest to sub-alpine forest. The mountain peak area played a role of providing the habitats for remnant species after last glacial era, including Korean fir (Koo *et al*, 2001; Chung *et al.,* 1996).

The earth's climate has warmed by 0.6±0.2℃ over the past 100 years with the about 31% increase of carbon dioxide content in the air, compared with that of pre-industrial era (IPCC, 2001). Besides so many worldwide recent natural disasters due to catastrophic weather events, Korea also has been facing with them frequently, i.e. a big forest fire in east-coastal region in 2000, severe drought in spring time in 2001, heavy rainfall accompanying landslides by typhoon Rusa in 2002, warm winter in 1988, and so on. In this year, two extreme weather events were recorded already, the one was the heaviest snowfall in Busan on March, and the other was the hottest air temperature in April at 40 cities after beginning of meteorological measurement in 1904 in Korea.

Nowadays, annual mean temperature of Korea has risen about 1.5℃ after 1912, and Korean climate has warmed about 0.9℃ when we assume that the urbanization effect is about 30% and offset it. In particular, low temperatures in winter increased more than summer highs, and the intensity of precipitation (the amount per event) increased while precipitation frequency decreased (Kwon, 2003). We feel that the alpine and sub-alpine forests should be vulnerable to global warming, and would like to pay attention to monitor and conserve the communities. There have been reported that dieback of montane trees (Hamburg and Cogbill, 1988; Fisher, 1997) were consistent with the effects of warmer climate.

Mean air temperature of Jeju island has also been increased recently, especially in winter and spring season. Recently, there have been several reports on the decline of Korean fir forest in Mt. Halla. However, no reports provided evident mechanism of decline symptoms, systematic observations and monitoring system. Objectives of this study were to figure out the mechanism of Korean fir dieback in Mt. Halla, to establish of a monitoring system for detection of the changes of Korean fir stand, to assess the degree of decline using remote sensing data.

It is well known that the satellite imagery can provide an important tool to monitor the vegetation change over a long period as well as the transitory disasters like fires or floods in natural landscapes. The synergy between field survey or measurement and time serial satellite data may improve the satellite based vegetation monitoring, offering more accurate spatial data on vegetation parameters such as the viability or mortality of a certain tree species.

Site Description

On the Korean fir forests near the top of Mt. Halla, we set three permanent plots of 10m x 20m in 2003. The first one, Site 1: YS was on the way from Youngsil is located at southwest, second one Site2: WS at Witseoreum in the west, and the other Site3: JD at Jindallebat on the way to Sungpanak in the northeast of the peak (Figure 1, Table 1).Mt. Halla is volcanic, and most of the parent rock in this study area is trachyte basalt, and soil type is volcanic ash forest soil with pebbles (Va-gr) or wet volcanic ash forest soil (Va-w).

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 real time differential GPS (HDOP < 1.5) to identify the location of a certain characteristic. Survey points and the site description data were constructed into spatial coverage and utilized for combining the isodata classes and supervised classification.

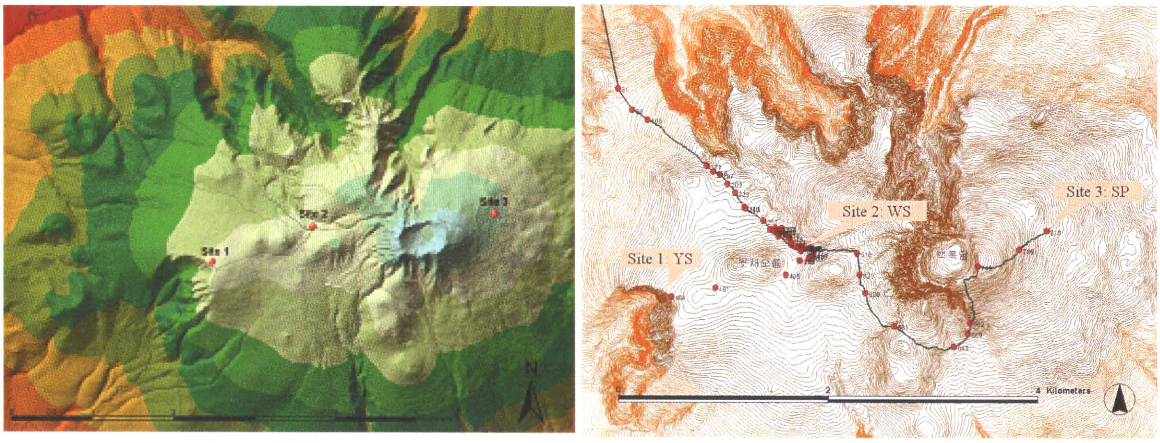

Figure 1. Lacation map of three permanent plots (left), and routes and field check points for vegetation classification (right).

Table 1. Site description of the permanent plots

Site Name	Altitude (m)	Topographical position	Aspect	Slope (°)	DBH (cm)	Height (m)	Age (year)
Site 1:YS (Youngsil)	1,633	Near cliff	SWS	< 3	10.0 (2.9-27.5)	3.0 (1.7-3.6)	40-60
Site 2: WS (Witseoreum)	1,672	Small ridge	SWS	< 3	9.8 (3.1-22.1)	4.0 (1.7-5.6)	40-60
Site 3: JD (Jindallebat)	1,748	Flat area	SES	< 3	12.7 (3.6-26.4)	3.4 (2.0-4.8)	40-60

Climate and Meteorology of Jeju Island

We collected monthly meteorological data of two meteorological stations near the study area, the one was Seoguipo located at the south of, and Jeju at the north of Mt. Halla. During the past 40 years, annual mean temperature increased by1.56℃ at Seoguipo station, and 0.72℃ at Jeju station. Seasonally, increasing rate was highest in winter (from Nov. to Feb.), followed by spring, autumn and summer. Seasonal temperatures of 2003 were higher than those of 2004 at both stations (Figure

2). Prevailing wind direction is WNW at both stations and NWN at Jeju high stratum (Kang, 2001; Figure 3).

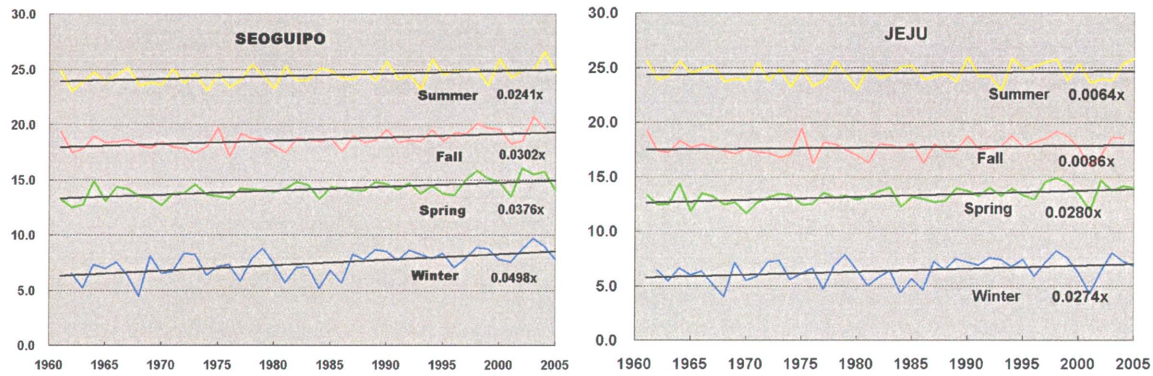

Figure 2. Changes of seasonal mean air temperature of Seoguipo and Jeju city. We assumed spring is from Mar. to May, summer from June to Aug. autumn from Sep. to Nov. and winter from Nov. to Feb.

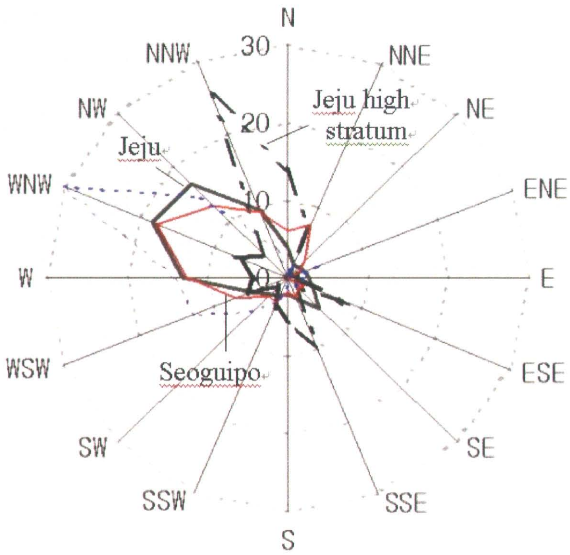

Figure 3. 30 years averaged wind-rose of Jeju island, redrawn from Kang (2001).

Tree Mortality and Vitality

To assess and quantify the degree of vitality (or degree of declining), we developed the assessment guideline as shown in Table 2 using leaf characteristics. At three permanent plots of 10m x 20m, we labeled and drew the stemmap of the all trees lager than 2cm in DBH. Using the vitality assessment guideline, we applied it for the Korean fir trees in the plots by foliage layers and aspects in 2003. As shown in Figure 4, at canopy and middle layer Site 3: JD plot showed more vigorous status than Site 1 and 2. At lower level, it was low because of deep shading by dense foliage of higher levels.

Table 2. Vitality assessment using leaf characteristics for Korean fir

Vitality degree		Leaf characteristics		
		Amount of leaves	Leaf length	Oldest leaf age
0	Dead	-	-	-
1	Almost dieing	Less than 10%	Mostly shorter than 1 cm	Mostly 2-3years
2	Very unhealthy	10-40%	Mostly shorter than 1 .5cm	Mostly 3years
3	Unhealthy	40-60%	About 1.2-1.6 cm	Mostly 3-4years
4	Vigorous	60-90%	Mostly longer than 1.5 cm	Mostly 4 years, some 5 years
5	Full vigor	More than 90%	Mostly longer than 1.5 cm	Mostly more than 5 years

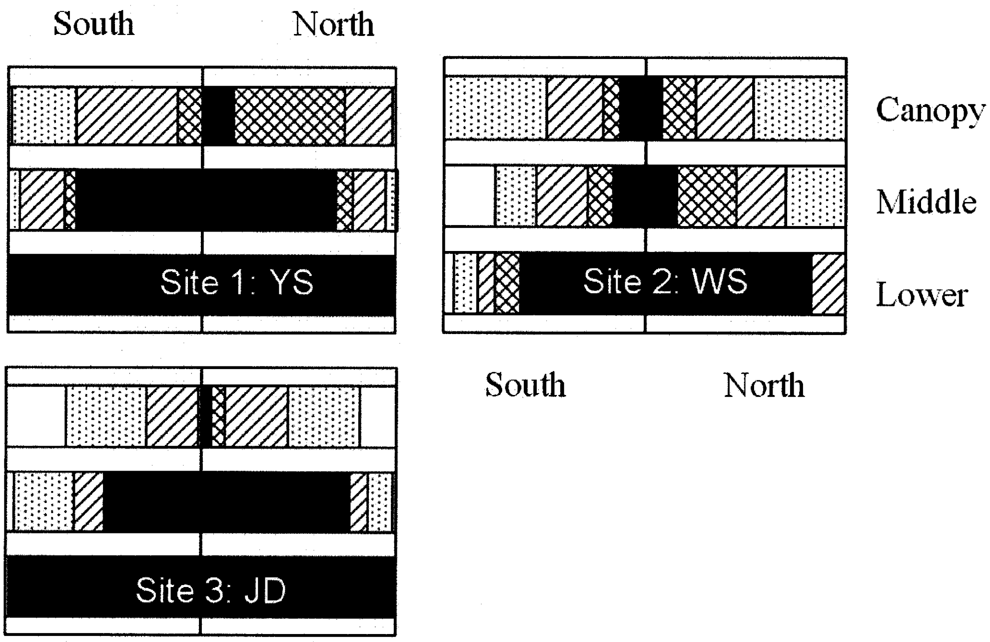

Figure 4. Mean vitality profile of the three sites by foliage layers (canopy, middle and lower), and crown aspect (north and south). Vitality grade ranged from 0 to 5 expressed as black to blank continuum.

At the plots, we monitored the dieback of Korean fir trees on June in 2004 and 2005. As shown in Table 2, the number of dead tree in 2004 was greater than 2005. The cause of yearly difference may be correlated with the differences in winter and spring time air temperature.

Among the sites, the number of dead trees or stems was bigger at Site 1 and 2 than Site 3. The trees at Site 3 were dead because of suppression by higher trees, while at Site 1 and 2 were because of physiological stress when we assessed it by physiognomic symptoms, such as leaf characteristics and crown position.

Table 2. Number of dead trees (trees/year/plot) and of leaf folding symptoms (trees/plot)

Site	Dead trees (number of trees and stems)			Leaf folding symptoms
	2004	2005	Total	(No. of trees, %)
Site 1:YS	3(3)	2(2)	5(5)	10 (50%)
Site 2: WS	5(6)	0(1)	5(7)	18 (28%)
Site 3: JD	3(3)	0(0)	3(3)	1 (2%)

As an indicator of vitality of Korean fir, we measured lengths of 2 years old leaves of 20 leaves x 4 braches x 5 trees per plot. The result is shown in Figure 5, and the length was the shortest in Site 1, and the longest in Site 3.

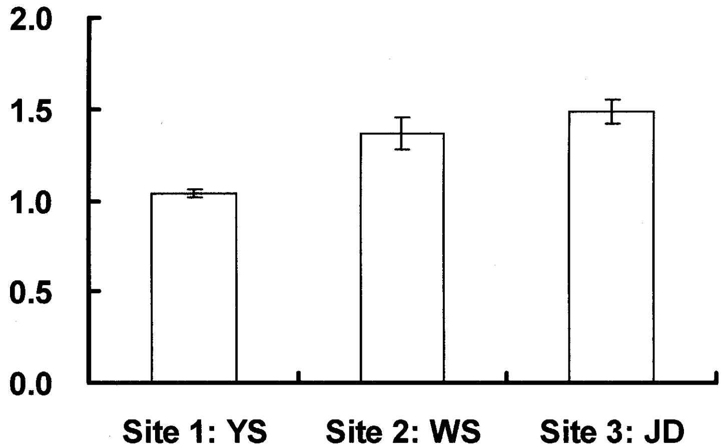

Figure 5. Lengths of 2-year old leaves (mean ± standard error)

According to the observations of field monitoring, Korean fir stands in Site 1 and 2 were stressed, while in Site 3 didn't. Even though we need more future temporal observations and analysis of past data, the main cause of the decline of Korean fir may be clued by warming of winter and spring season.

Physiological Characteristics

To compare the physiological characteristics including net photosynthesis rate, water use efficiency, enzyme activity, we selected 2 trees per site. The one was relatively healthy and the other was unhealthy at each site. Those characteristics were measured at three times, August in 2004, June and September in 2005.

Net photosynthesis rates (A_n) were measured using Licor-6400 Portable Photosynthesis System (Li-cor Inc., USA), and drew the light curve by air temperatures. Transpiration rate (mmol H_2O $m^{-2}s^{-1}$) and water use efficiency calculated at the light intensity of 1,000μmol m^{-2} s^{-1} (Woo *et al.,* 2004).Enzyme activities of Ascorbate peroxidase (APX) and Glutathione reductase (GR) were analyzed using UV spectrophotometer (UV-2100, Shimadzu, Japan) after treatments at laboratory. Contents of chlorophyll a and b in leaves were analyzed using spectrophotometer (UV/Visible Diode Array, Walden Precision Apparatus Ltd., UK) after extraction by 80% of acetone.

Net photosynthesis rates of healthy individuals were greater than unhealthy individuals at all sites. Responses of net photosynthesis rate on June 2005 by air temperature were very interesting. As shown in Figure 6, there was a tendency of decreasing of net photosynthesis rate by increasing of air temperature, while no differences among them were found on September 2005.

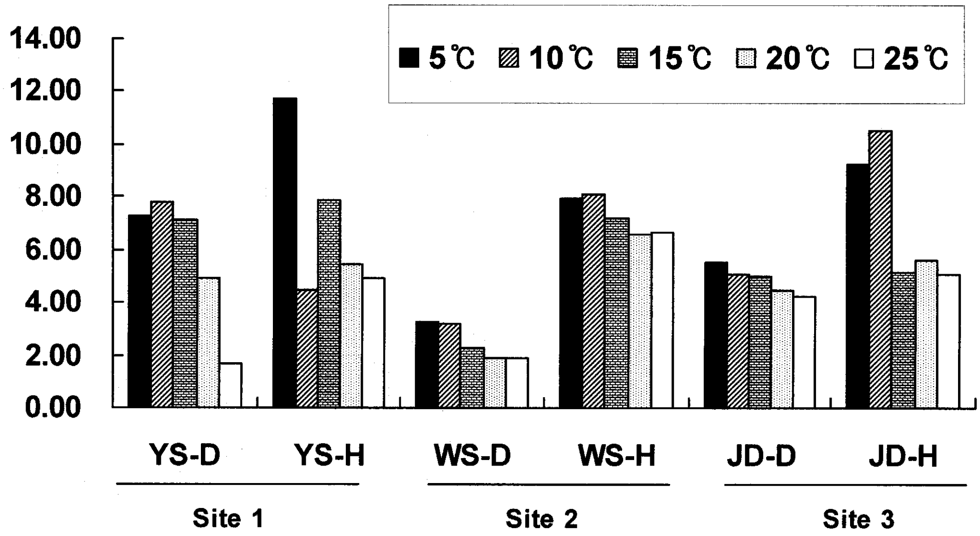

Figure 6. Net photosynthesis rates on June 2005 by air temperature at 1,000 PPFD (μmole m^{-2} s^{-1}). D means damaged or unhealthy individual, and H is healthy individual.

Chlorophyll contents of healthy individuals were greater than unhealthy individuals, and of Site 3 than Site 1 and 2. Water use efficiency of unhealthy individuals was greater than healthy individuals at Site 1 and 2, and no difference at Site 3. This might be the results of small amount of transpiration rate by closure of stomata at the unfavorable moisture condition. However, water use efficiencies were lower at higher temperatures on June 2005 (Figure 7). This implies that high air temperature in spring time make stress on Korean fir tress even until June.

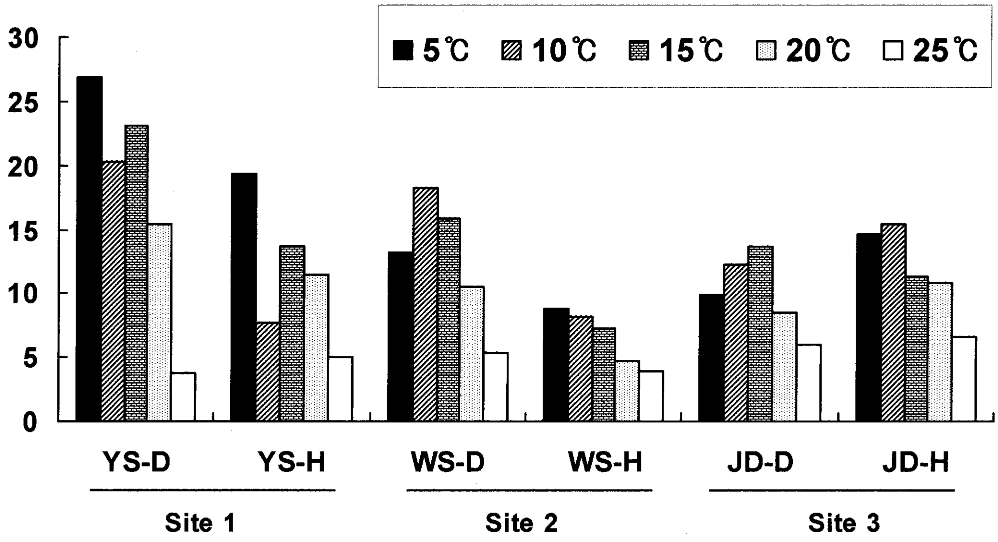

Figure 7. Water use efficiencies on June 2005 by air temperature. D means damaged or unhealthy individual, and H is healthy individual.

Anti-oxidation enzymes, GR and APX are inside of chloroplast and play a role of removal of active oxidants through Ascorbate-glutathione cycle. APX activities of unhealthy individuals of Site 2 and 3 were higher than healthy ones. But GR did not show any tendency.

Image Classification and Change Detection

The aim of this remote sensing and GIS works is to identify the present Korean fir stands remained around the peak of Mt. Halla, to describe species composition and map the pattern of the vegetation communities across the study site for continued monitoring in the future, and to detect the change over time. The results will provide support for the habitat analysis of Korean fir, research on ecosystem structure and dynamics in the context of climate change, and conservation planning of the Mt. Halla ecosystem. To meet the diverse objectives, it was needed to draw a vegetation map defined well and detailed, yet could save on cost to produce. Therefore, the map was developed using moderate resolution Landsat Thematic Mapper(TM) 5, 7 satellite imagery because it is relatively inexpensive to obtain, and because it lends itself to following comparative analysis and map production, further lowering costs. Even though TM has limitations on spatial resolution, and hence a limit on the precision of any given map, TM was still seen as meeting the objectives most efficiently to produce a time serial map of major dominance types.

115 – 37 Landsat image spatially provides full coverage of the study site. Other ancillary data like forest type maps or aerial photos were not used because both of them were too old and unreliable. A surface terrain model for ortho-rectifcation was generated by acquiring and mosaicking together 1:5,000 topographical maps produced by National Geographic Information Institute that cover the study area. Single Landsat 7 image of 21 March 2002 was selected to produce vegetation map. Images available were limited because the site is located around the

mountain peak (1,950m) and hence most of the images were not free of clouds or snow. To detect the change of viability and dieback area of Korean fir, 14 April 1994 Landsat 5 image and 15 April Landsat 7 image were selected even though some parts of images were not snow-free, because the image quality was relatively good and free of noise and most of all, two images belonged to the same phonological period of a year.

All the images were geometrically ortho-rectified to the Transverse Mercator (Tokyo-Korea datum) coordinate system to less than 0.5 pixel RMS error, utilizing ground control points identifiable in the imagery. Radiometric calibration and subsequent transformation to at-satellite reflectance was performed by utilizing standard procedures published in Markham and Barker (1986). Finally, two images for change detection were converted to NDVI grid data using the standard NDVI formula for TM data. The single image for vegetation classification was first fused together with band 8 pan layer to enhance the spatial resolution and converted to NDVI and PCA grid data to stack into a single 8-layer image file including original bands except for thermal layers.

Due to an initial lack of field data, an unsupervised approach to image classification was employed in this work. In order to recognize the spectral characteristics of the diverse plant communities represented in the satellite imagery, an unsupervised training algorithm (isodata) was run on the 8-layer image to generate appropriate spectral clusters and corresponding signatures.

NDVI grid data of 1994 and 2003 were compared for the change detection of Korean fir stands. The NDVI comparison for whole area of Korean fir stands was impossible because there was remaining unmelted snow partly on the ground. Therefore, the differences of NDVI between two periods were compared only on the survey points where site status could be described.

Classification result was quite reliable according to the comparison with the known survey points. Figure 8 depicts the NDVI of 1994 and 2003. Not much change was detected on the whole except for upper-right area showing low NDVI due to the remained snow. But on the survey points in snow free area of Korean fir stands, significant difference between two images were detected (Figure 11). Small window in Figure 10 shows the attribute of survey point where all the trees in the plot were standing completely dead and the pixels around were classified into other classes (grassland or bush).

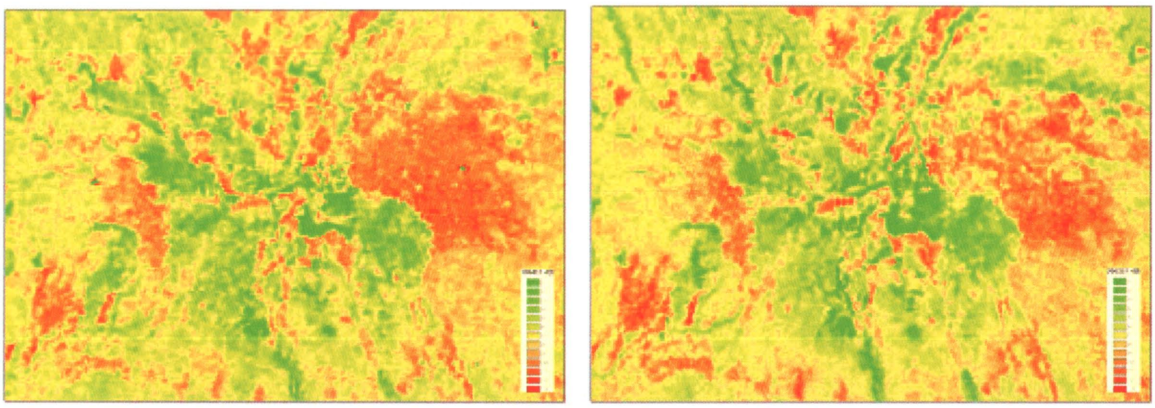

Figure 8. NDVI of 1994 and 2003 at Mt. Halla.

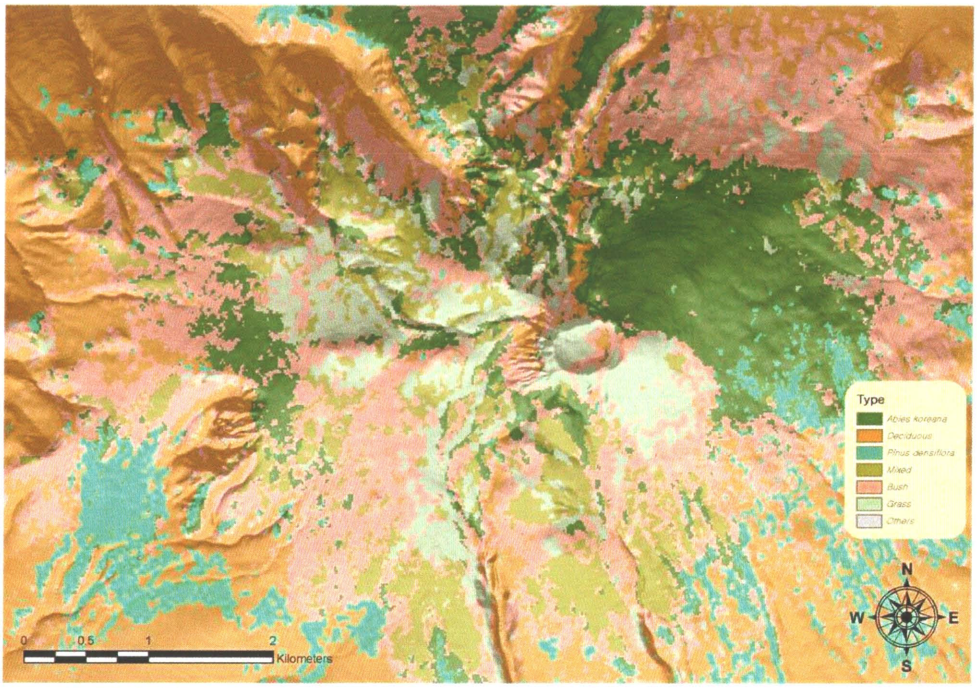

Figure 9. Vegetation map produced from the Lansat TM around the peak of Mt. Halla.

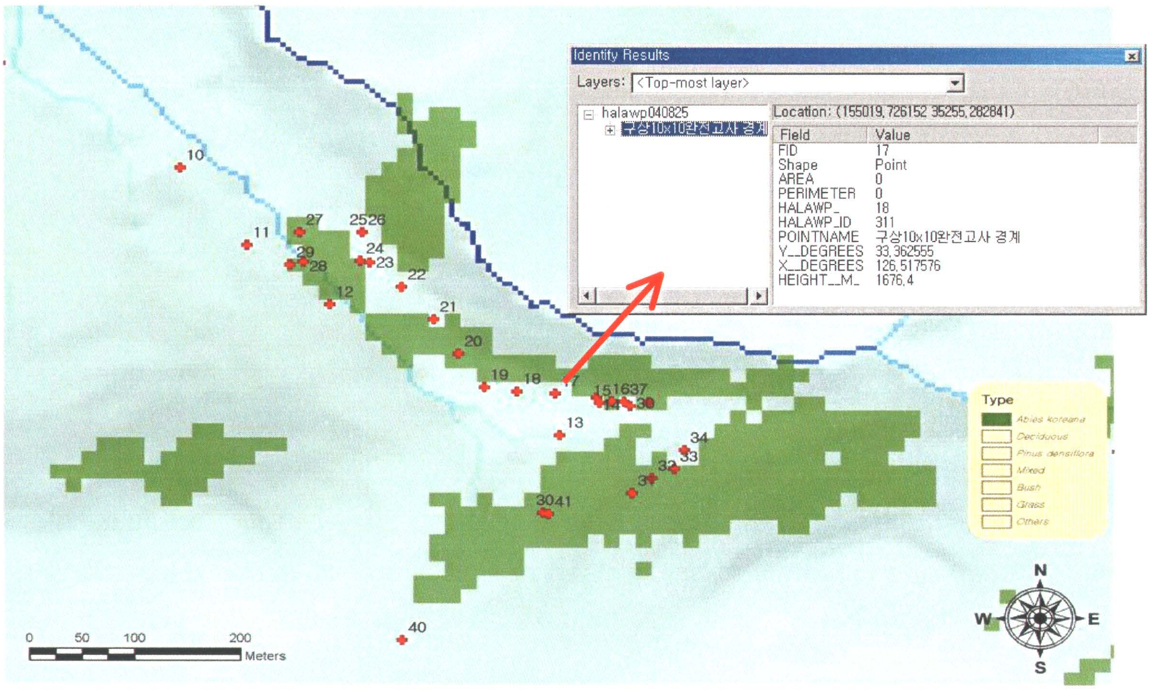

Figure 10. Classification result of Korean fir and matching with field survey data

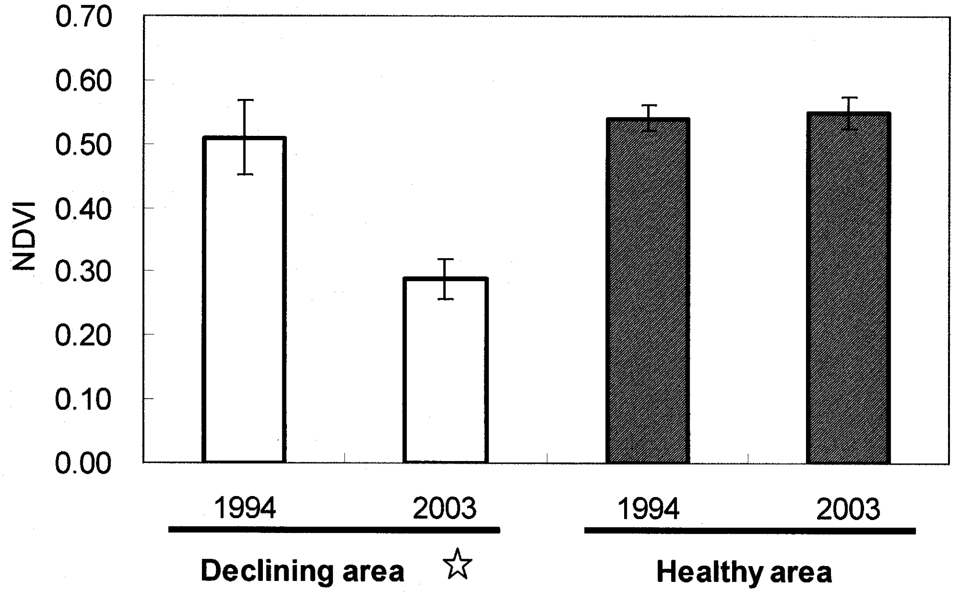

Figure 11. NDVI changes between 1994 and 2003 by

However unfortunately, Landsat 7 Enhanced Thematic Mapper Plus (ETM+) experienced the loss of its scan line corrector (SLC) in 2003. That' s why the most recent image used in this study is the product obtained in 2003. Similar operational alternative to Landsat 7 such as Spot or Aster is under consideration for future works.

Conclusions

We established a monitoring system for detection of the dynamic changes of Korean fir stands in the field of Mt. Halla, and assessed the usefulness of remotely sensed data using Landsat TM imaginary. We made reliable vegetation distribution maps from the imaginary and could see the possibility of Korean fir decline using remotely sensed data.

Evidences from field observations including spatial patterns and temporal changes of Korean fir dieback, climatic data, and physiological characteristics showed that the cause of decline could be warming of winter and spring time in this area. Warmer climate should have affected on the water balance regime of Korean fir trees in case available soil moisture was not enough. Continued observation would be required to see the long-term changes of Korean fir forest and competition with other tree species according to the global warming effects.

References

Chung, J.M., S.W. Lee and K.N. Lee. 1996. Vegetation structure, seedling establishments and growth of Korean fir forests in Mt. Jiri. J. of Korean Forestry Society 85(1): 34-43. (*in Korean*)

Fisher, M. 1997. Decline in the juniper woodlands of Raydah Reserve in southwestern Saudi Arabia: a response to climatic change? Global Ecology and Biogeography Letters 6: 379-386

Hamburg, S.P. and C.V. Cogbill. 1998. Historical decline of red spruce populations and climatic warming. Nature 331: 428-431

IPCC. 2001. Technical Summary - Climate Change 2001: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses. 73pp.

Koo K., W.K. Park and W.S. Kong. 2001. Dendrochronological study on Korean fir forests in Mt. Halla. Korean J. of Ecology 24(5): 281-288. (*in Korean*)

Kwon, W.T. 2003. Changes of Korean climate of last 100 years and future prospects. Korea Meteorological Administration News Letters 2(1): 1-8.

Markham B.L. and J.L. Barker. 1986. "Landsat MSS and TM post-calibration dynamic ranges, exoatmospheric reflectances and at satellite temperatures", EOSAT: Landsat Technical Notes, 1: 3-5.

Woo, S. Y., H. D. Kang, S. H. Lee, S. H. Yoon, B. H. Cho, J.H. Kim, H. J. Youn, and C. Y. Lee. 2004a. Photosynthesis, water use efficiency and chlorophyll contents of the introduced American poplar clones grown in China. J. of Korean Forestry Society 93(4): 307-314.