MULTI-VIEW REMOTE SENSING MONITORING THE HEALTH-CONDITION AND ACID RAIN ISSUE WITH *Chamaecyparis formosensis* IN YI-LAN AREA OF NORTHERN TAIWAN

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ABSTRACT: Nowadays, acid rain issue and the damage to forests are critical problems in ecological discipline. Herbaceous and woody plants are damaged not only directly by anthropogenic acid rain but also indirectly caused by changes in the soil chemistry and soil-dwelling microorganism. The study was intended to evaluate the health-condition of Taiwan red cypress (*Chamaecyparis formosensis*) and acid rain issue with the species over Yi-Lan study area in northern Taiwan by using multi-stage, multi-temporal, multi-spectral remote sensing. This study took a multiple-view approach with following steps: (1) to collect SPOT and acid-rain data and build a GIS database; (2) to correct multi-date SPOT images using relative radiometric normalization; (3) to produce NDVI from relatively corrected SPOT images; (4) to perform a change detection on multi-date NDVI images; (5) to compare the distribution map of health-condition deteriorating Taiwan red cypresses (TRC) with acidic intensity distribution map; (6) to confirm the comparison results by high resolution ortho-rectified images. The result indicated that health-condition TRC in the study area had a slightly rising tendency based on multi-date NDVI images. Through the entire imagery change detection on a pixel-by-pixel base, the area of TRC health-condition promotion was about 2.3 times more than that of the health-condition degradation. Importantly, the health-condition distribution map disagreed with the acidity tendency. Therefore, acid rain was not a key factor causing deterioration of the part of TRC in the study area. In this area, the most probable reason was intensive land exploration. Hence, Long-term monitoring acid rain on the ground and by remote sensing should be continued to obtain the detail of acidity tendency gradient in Yi-Lan area and to compare with the results at present stage. The results will eventually provide useful information for related government office making a decision on forest management policy in this area.

1. INTRODUCTION

Because of the advance of remote sensing (RS) technology and geographic information system (GIS), the application in forestry become more and more diversified. It also maybe approaches precision forestry eventually. We can reduce the cost of traditional forestry inventory by using RS technology and GIS. Therefore, RS and GIS allows long tern monitoring to become more and more convenient and efficient. Indeed, we can extrapolate field survey data to other areas over which are inconvenient to approach or to survey. It is useful to acquire more information for forest management decision-making and other related fields.

Water content and pigment structure in vegetation will vary when plants are under either seasonal senescence or environmental stress, which result in spectral reflectance difference (Jensen, 2005). The spectral difference is useful to evaluate vegetation health-condition by calculating several different vegetation indices. The widely used indices are normalized differential vegetation index (NDVI) (Rouse *et al*., 1974) and simple ratio (SR) (Cohen, 1991). We can also utilize the specialty of red edge effect in vegetation and vegetation indices to distinguish vegetation from other features.

More and more pollutions emerge due to burning fossil fuel. One of the serious pollution issues to forest is acid rain. The main acid molecules are sulfuric oxidate and nitric oxidate, and these molecules refer to acid deposition when depositing to ground surface. When dissolving in raindrops, the acid molecules will cause decreasing pH value. The acid molecules may deposit not only on the area of pollution source but also farther area due to long distance transportation effect of air pollution (Lin *et al*., 2005). Acid rain may destroy the nutrition balance and cycle, and then lead forest degradation and health-condition deterioration (Veneklaas, 1990; Abrahemse *et al*., 1994; Horntvedt, 1995; de Wit, 2000; Shang *et al*., 2000; Nallemann and Thomsen, 2001; Schroth *et al*., 2001; Lomsky´ *et al*., 2002).

The objective of this study was to detect forest health-condition change by using multi-date SPOT images and calculating NDVI images. Indeed, we perform NDVI change detection in a GIS and overlapped NDVI-change-detection pattern with high-resolution orthophotos. And we used the overlaid map to compare with slope map and rainfall acidity tendency map. Finally, we provided an overall evaluation in Yi-Lan study area.

2. MATERALS AND METHODS

2.1. Study area and target species

We selected Yi-Lan area in northeastern Taiwan as study area, where is the primary habitat of Taiwan red cypress (*Chamaecyparis formosensis*). We chose Taiwan red cypress (TRC) to be the target tree species.

2.2. Data collection

The datasets of this study contained: (1) four-date SPOT images, (2) digital elevation model (DEM), (3) 0.5 m × 0.5 m high-resolution orthophotos, and (4) data of third forest recourses and land use inventory in Taiwan. The basic information of the SPOT images we used is shown in table 1.

2.3. Relative radiometric correction of SPOT images and topographic analysis

We inputted the DEM into ERDAS image program and used topographic analysis module to produce the slope image layer. Then we inputted SPOT images into ERDAS image program and selected the imagery that was acquired in 2005 as the base image. The other three images were corrected by histogram matching (HM) with respect to the base image.

2.4. NDVI calculation and generation

NDVI is sensitive to canopy background variations. Generally, NDVI value of canopy is higher than the value of background, especially bare soils and rocks (Huete *et al.* 2002). According to the NDVI values, we can evaluate the health-condition of vegetation. Rouse *et al*. (1974) developed the general NDVI function:

$$NDVI = (R_{NIR} - R_R) / (R_{NIR} + R_R)$$

We inputted the post-HM SPOT images into ERDAS image program to obtain four-date NDVI images, and the four-date NDVI images are used for calculate NDVI change detection patterns.

2.5. Select TRC habitat pattern

We extracted the habitat patterns of TRC from the data of third forest resources and land use survey in ESRI ArcView 3.2 edition. We clipped the TRC NDVI patterns from NDVI images according to the TRC habitat pattern by using ERDAS image program.

2.6. Pixel-by-pixel change detection

We conducted NDVI image change detection by subtracting the 2009 image from the 1994 image on the pixel-by-pixel base for TRC habitats. The rule of pixel-by-pixel change detection is expressed as follows:

NDVI change = NDVI value of TRC habitat patterns in NDVI image of 2009 for each pixel – corresponding pixel value in NDVI image of 1994.

If the change detection result is positive, it means the TRC health-condition was ameliorating. Conversely, if the result is negative, it means the TRC health-condition was deteriorating. We converted the NDVI change detection into percentage to make it brief:

$$(\text{Positive NDVI change} / \text{Maximum positive NDVI change}) \times 100\%, \text{ or}$$

$$(\text{Negative NDVI change} / \text{Minimum negative NDVI change}) \times 100\%$$

According to change in percent, we can set a particular percentage as a threshold. And we can evaluate the deteriorating degree by this process.

2.7. Explanation of composite map

We overlaid the slope image with TRC change detection patterns and clipped TRC polygons. And then we calculated the slope statistics of TRC change detection patterns. Finally we overlaid the TRC polygons with high-resolution orthophotos and compare with the prior results.

3. RESULTS AND DISCUSSION

3.1. NDVI images and HM relative radiometric correction

The mean of full NDVI image values is shown in table 2. According to the means of NDVI image, there was not obvious difference in four-date post-HM NDVI images. The standard deviations of the post-HM NDVI images are lower than those of the pre-HM NDVI images.

3.2. Distributions of NDVI change and acid rain

Figure 1a shows both NDVI ameliorating and deteriorating TRC habitat patterns. The NDVI deteriorating patterns concentrated on southeastern Yi-Lan study area. The tendency of NDVI deteriorating patterns was opposite to the acidic intensity tendency of acid rain (figure 2a and 2b). The tendency is descendent from northwest to southeast direction. This result indicates that acid rain may be not the key factor result in NDVI deteriorating.

3.3. Relationship between intense change pattern of NDVI and slope

We set 30% as threshold to select intense change patterns of NDVI. Figure 1b shows that patterns remained under the threshold set at 30%. And the calculation of slope statistics of TRC NDVI change patterns under threshold setting at 30% was 28.28° and 25.99° for ameliorating and deteriorating patterns (table 3), respectively. In general, the greater the slope, the soil erosion and nutrition loss is more serious. But the slope of TRC health-condition amelioration was higher than that of TRC health-condition deterioration. The result indicated that slope was not the key factor causing TRC health-condition deterioration.

3.4. Comparison between change detection results and orthophotos

When overlaying the high resolution orthphotos and NDVI deteriorating patterns of threshold setting at 30% (figure 3a and 3b), we found that TRC health-condition deteriorating area was located in the Taipingshan national forest recreation area and concentrated upon the areas surrounding with roads and parking lots and buildings. The anthropogenic exploration and increasing load in traffic resulted in TRC health-condition deteriorating. The most probable reason may be the intensive land exploration.

4. CONCLUSIONS

The results indicated that acid rain issue was not the key factor resulting in TRC health-condition deterioration. But these reasons of damaging TRC still cannot be eliminated fully at present. We plan to set a certain number of field rainfall collecting stations to obtain field-measured rainfall acidity. And we can extract more detailed information about acid rain detriment to TRC from the detail field-measured rainfall acidity. Anthropogenic detriment to TRC in Lan-Yan study area significantly exceeded that of acid rain, thereby probably disguising the small influence of acid rain. Long-term monitoring acid rain on the ground and by remote sensing should be continued along the axis from Dan-Suie River to Lan-Yan Stream, expanding the extent to Taipei, Tao-Yuan, and Hsin-Chu Area.

Table 1. Basic information of four-date SPOT images over Yi-Lan area.

Date	View Angle (°)	Ave. Cloud (%)	Sun Azimuth (°)	Sun Elevation (°)	Geometric Rectification
1994/03/28	2.3	1	136.9	60.7	Level 3 NN
2002/03/08	-12.4	8	140.7	52.4	Level 3 NN
2005/03/20	-26.5	3	132.2	55.0	Level 3 NN
2009/02/11	3.3	1	145.0	43.1	Level 3 NN

Table 2. Mean of full NDVI image.

Area/Process		1994/03/28	2002/03/08	2005/03/20	2009/02/11	NDVI mean
Full image	Pre-HM	180.51	171.61	182.73	165.26	8.09
	Post-HM	188.60	188.94	188.70	189.55	0.43

HM: Histogram Matching

Table 3. The slope statistic of TRC of the threshold set at 30%.

TRC		Minimum (°)	Maximum (°)	Mean (°)	Medium (°)	Mode (°)
Threshold 30%	Increase	1	88	28.28	29	27
	Decrease	1	88	25.99	26	38

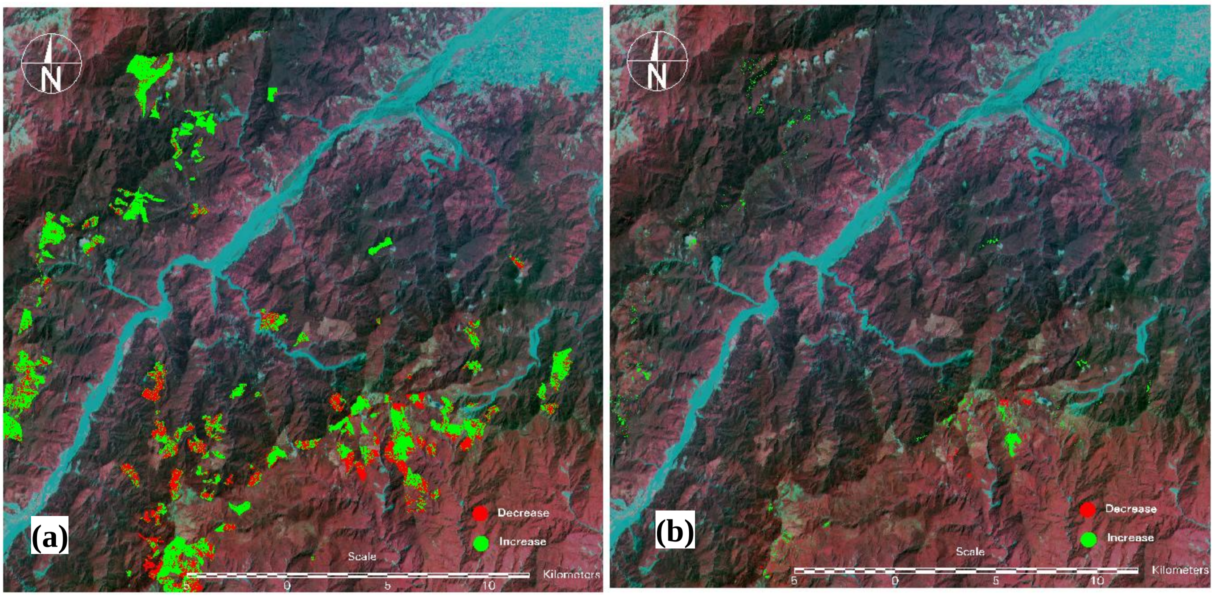

Figure 1. Area of TRC change detection patterns in Yi-Lan area: (a) threshold is set in 0%, (b) threshold is set at 30%.

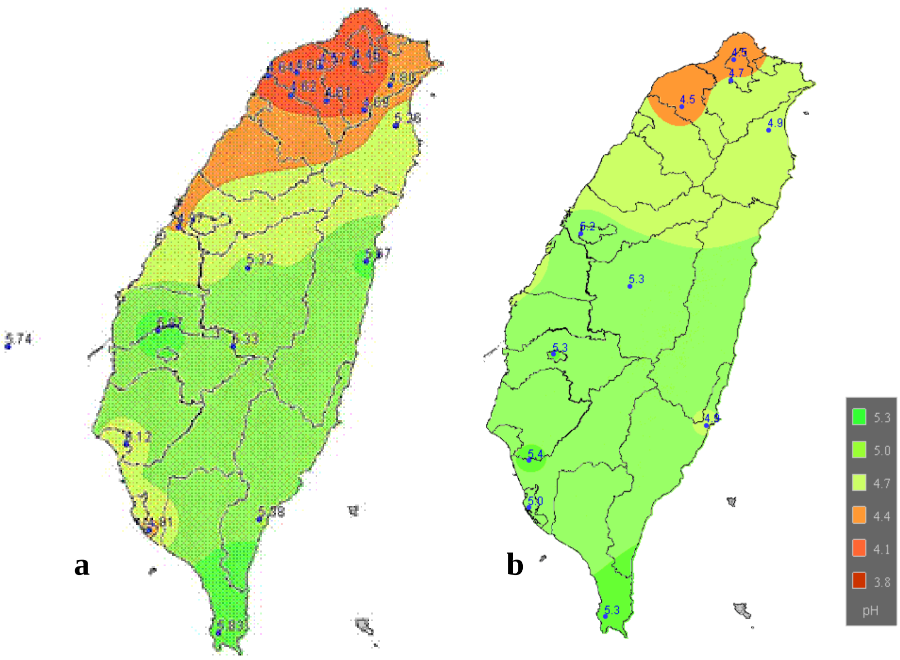

Figure 2. The rainfall acidity tendency in Taiwan: (a) in 1990s, (b) 2003-2009 (Acquired from: the website of acid rain in Taiwan http://acidrain.epa.gov.tw/research/07.htm).

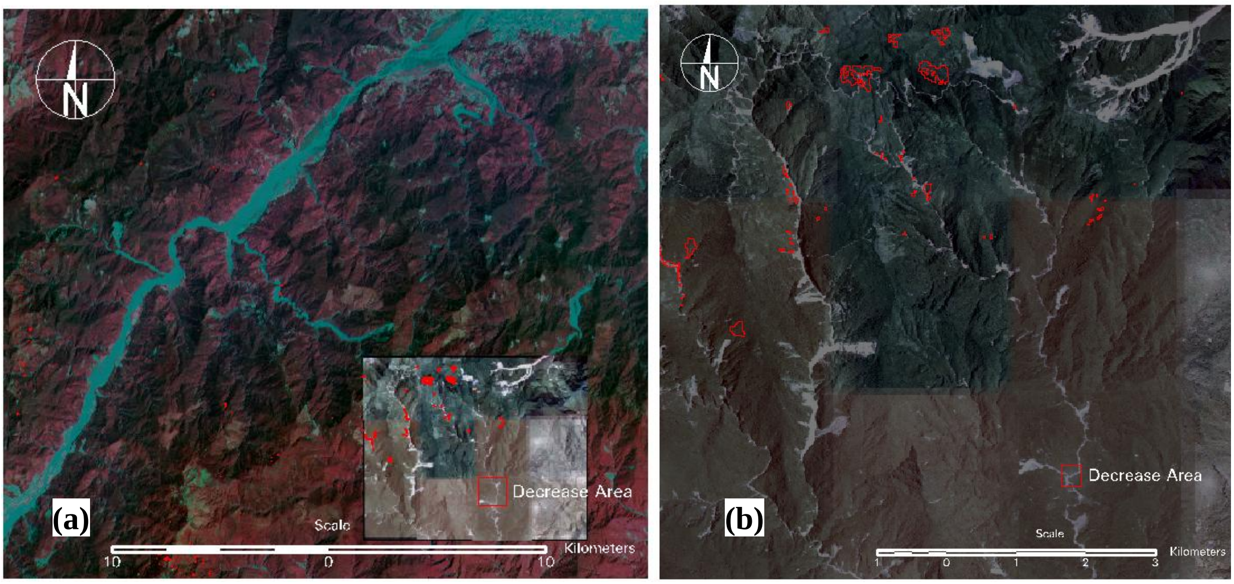

Figure 3. (a) The overlapped map between NDVI intense deteriorating and high resolution orthophoto and (b) the inset of high-resolution orthophoto area.

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