Investigation on the water stress in alpine vegetation using Hyperspectral Sensors

Buho Hoshino [1] ***, Gaku Kudo*** [2] ***, Tetsuo Yabuki*** [1] ***Masami Kaneko*** [1] ***, Sumiya Ganzorig*** [3]

1. Department of Biosphere and Environmental Sciences, Rakuno Gakuen University, Japan
2. Graduate School of Environmental Earth Science, Hokkaido University, Japan
3. Graduate School of Veterinary Medicine, Hokkaido University, Japan

Abstract The effect of global warming may be seen even on the top of the Mt. Daisetsuzan National Park (DNP) in Japan's northernmost island of Hokkaido where communities of alpine plants having been greatly suffered from the expansion of alien species. Alpine of the Mt. Daisetsu is in protected zone of the DNP and has no direct human influence. So far, this happening might indicate the negative effects of global scale climate changes in high mountainous ecosystem. Seriousness of that phenomenon is that it is completely changing the local vegetation. Due to the global warming, increased temperature causes rapid melting of the snow coverage at DNP and soil is quickly losing its moisture. In this study, alpine meadow vegetation in DNP was photographed with aid of the hyper-spectral sensors mounted on the airplane. Simultaneously, ground observations were also made. Hyperspectral sensors are having 60 bands with wavelength from 400 to 1000 nm, and resolution of 10 nm. Ground observations were made using the Field Spec devices for spectral measurement, GPS for mapping. Plant species, coverage, and soil moisture were investigated.

Key word: alpine ecosystem, hyperspectral sensors, Hokkaido Daisetsuzan National Park

1. INTRODUCTION

Alpine ecosystem is the most sensitive terrestrial ecosystem to global climate change. Alpine environments in Japan are generally characterized by cold, snowy winters and warm, wet summers. Micro-scale variation in snow condition is one of the most important environmental factors creating and maintaining the diversity of alpine vegetation [1]. Therefore, changes in snowmelt regime at regional scale should cause serious disturbance of alpine vegetation. Recently, snowmelt time in alpine meadow has been accelerated in the Taisetsu Mountains in the Daisetsuzan National Park (DNP) of northern Japan [2]. Global warming may be a reason of this change. Acceleration of snowmelt time in addition to the increase in temperature may cause soil desiccation during summer in alpine regions, which should promote rapid vegetation change. During the period of last 30 years, several herbaceous species in alpine meadow have been replaced by dwarf bamboo (*Sasa kuriliensis*) in the central part of DNP (G. Kudo, unpublished observation). Because human impact is negligible in this region, this vegetation change may reflect the indirect effects of global climate change on alpine ecosystem. Therefore, the quantification of vegetation dynamics at regional scale is very important to access the global change impact on alpine ecosystem.

In this study, digital imaging of the land cover in DNP has been taken with aid of the hyper-spectral sensors mounted on the airplane. Simultaneously, ground observations were also made. Airborne Hyperspectral sensor (©NEC) has 60 bands with wavelength from 400 to 1000 nm, and resolution of 10 nm, FOV 30 degree. Ground observations were made using the Field Spec device for spectral measurement, and the GPS device for mapping. Plant species composition, their coverage, and soil moisture were also investigated.

2. METHODOLOGY

The Daisetsuzan National Park (DNP) is located in the central part of Hokkaido Island, northern Japan. DNP is the largest national park in Japan and occupies 226,000 ha. In Japanese, "Dausetsuzan" means "Great Snowy Mountain". The Park is the most rugged scenery in Japan, 16 peaks are over 2000 meters with trails and there is many more without trails (see Fig. 1(a)).

2.1 A new method of hyperspectral band selection

Obtained data were analyzed separately for alpine plants, dwarf bamboo (*S. kuriliensis*) and alpine dwarf pine (*Pinus pumila*). The YH index was selected to combine the hyperspectral data for the optimal visualization of bands (RGB). This index is based on the usage of Shannon Entropy including mutual entropy. In previous study (Buhe, 2007) the OIF (Optimum Index Factor) has been used for the optimal combination of the hyperspectral bands. OIF index is given by the following formula [3]:

$$OIF = \frac{\sigma_A + \sigma_B + \sigma_C}{|r_{AB}| + |r_{BC}| + |r_{CA}|} \quad (1)$$

There are two weak points in OIF index: in firstly, the standard deviation, which is used in the numerator of OIF index, cannot always detect how widely the reflection rates of a band are distributed. Especially when the distribution has multiple peaks, standard deviation is not good index to measure dispersion of the distribution.

The Shannon entropy is better dispersion index, because it can detect how wide values of reflection rates are contained in any distribution. Therefore we have used the Shannon entropy instead of the standard deviation in this study; in secondly, the correlation efficient, which is used in the denominator of OIF index, can not always detect the true correlation between the reflection rates of two bands. For example, when the distribution contains two parts with opposite correlation, the correlation efficient can be nearly 0. But in such a case, the distribution has actually a definite correlation and the actual correlation can be detected in our index YH in which mutual entropies are used instead of correlation functions. This means that not OIF but YH can detect low visualization by the combination of two bands having the right scatter diagram.

.In order to solve the above two problems, we have proposed the following new index YH;

$$YH = \frac{1}{2}\left\{\left(1 - \frac{r(A,B) + r(B,C) + r(C,A)}{3}\right) + \left(\frac{S(A) + S(B) + S(C)}{3\log n}\right)\right\} \quad (2)$$

In the above definition each quantity is given as follows. is the entropy of the reflection rate $S(A)$ distribution (spectrum) of band A and is given by , and n is the total number of reflection rates, and is a index we call the entropy correlation index and given by

$$S(A) = -\sum_{i=1}^{n} p(a_i) \log p(a_i) \quad r(A,B)$$

$$r(A,B) = \frac{1}{2} I(A,B) \cdot \left(\frac{1}{S(A)} + \frac{1}{S(B)}\right)$$

where is the mutual entropy of he reflection rate distribution (spectrum) of band A and B which is given by the following formula;

$I(A,B)$

$$I(A,B) = S(A) + S(B) - S(A,B) \quad (3)$$

Where is given by using the simultaneous possibility.

$S(A,B)S(A,B) =$

$$-\sum_{i=1}^{n}\sum_{j=1}^{n} p(a_i, b_j) \log p(a_i, b_j) \quad p(a_i, b_j)$$

In the above formula of our index YH, we have used the entropy instead of the standard deviation $S(A)\sigma$, and used the entropy correlation index instead of the correlation coefficient . We will present that our index YH is superior to OIF (Optimum Index Factor) index in a concrete target field.

$$r(A, B) r_{AB}$$

2.2 DNP Alpine vegetation index

A vegetative index is a value that is derived from sets of remotely-sensed data that is used to quantify the vegetative cover on the Earth's surface. Though many vegetative indices exist, the most widely used index is the Normalized Difference Vegetative Index (NDVI). The NDVI, like most other vegetative indices, is calculated as a ratio between measured reflectivity in the red and near infrared portions of the electromagnetic spectrum. In order to classify alpine vegetation, *S. kurilensis* and alpine dwarf pine (*Pinus pumila*), we used two spectral bands there are green band and red band, calculated Normalized Alpine Vegetation Index (gNDVI). The gNDVI transformation is computed as the ratio of the measured intensities in the Green (G) and red (R) spectral bands using the following formula:

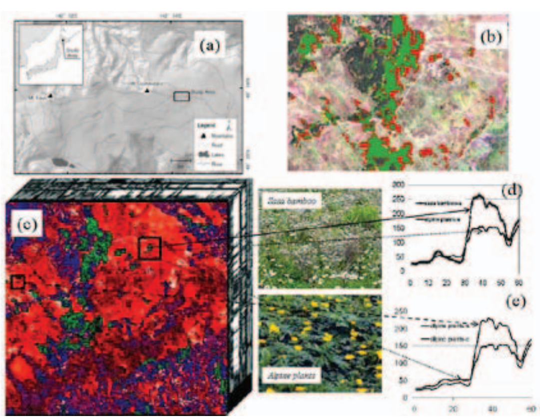

Figure 1. Comparison of water stress levels in alpine vegetation and alien, dwarf bamboo (S. kurilensis) using hyperspectral sensor data ((a)-the study area map; (b)-change detection of sasa bamboo (red color: increased area by during 1978a to 2008a); (c)-gNDVI index map; (d) and (e)-Comparison of water stress levels in alpine vegetation and alien, dwarf bamboo).

$$_{g}NDVI = \frac{Green - \mathrm{Re}d}{Green + \mathrm{Re}d} \qquad (4)$$

These two spectral bands are chosen because they are most affected by the absorption of chlorophyll in leafy green vegetation and by the density of green vegetation on the surface. Also, in red and green bands, the contrast between alpine vegetation, *S. kurilensis* alpine dwarf pine (*Pinus pumila*) and soil is at a maximum.

3. CONCLUSIONS

In this study, the application of newly proposed YH index is more suitable than traditional OIF. Also, application of the gNDVI was very useful to distinguish alpine meadow vegetation from dwarf bamboo and dwarf pine.

ACKNOWLEDGMENT

This work was supported by Grant-in-Aid for Scientific Research (A) 21370005 and the Global Environmental Research Fund (F-092) by the Ministry of the Environment, Japan.

REFLECTANCES

[1] Kudo G. & Ito K. “Plant distribution in relation to the length of the growing season in a snow-bed in the Taisetsu Mountains, northern Japan” ***Vegetatio*** 98: 165-174. 1992

[2] Kudo G. & Hirao A. S. “Habitat-specific responses in the flowering phenology and seed set of alpine plants to climate variation: implications for global-change impacts” ***Population Ecology*** 48: 49-58. 2006.

[3] Aosier, Buh, K. Tsuchiya, M. Kaneko, N. Ohtaishi, H. Mahamut, “ Land cover of oases and forest in XinJiang, China retrieved from ASTER data”, ***Advances in Space Research***, 39: 39-45. 2007.