Multi-temporal analysis of vegetation indices for characterizing vegetation dynamics

Tsend-Ayush Javzandulam
Center for Environmental Remote Sensing Chiba University
1-33, Yayoi-chou, Inage-ku, Chiba, 263-8522, Japan
javzaa@graduate.chiba-u.jp

Ryutaro Tateishi
Center for Environmental Remote Sensing Chiba University
1-33, Yayoi-chou, Inage-ku, Chiba, 263-8522, Japan
tateishi@ceres.cr.chiba-u.ac.jp

Dong-hee Kim
Center for Environmental Remote Sensing Chiba University
1-33, Yayoi-chou, Inage-ku, Chiba, 263-8522, Japan
kdonghee@graduate.chiba-u.jp

Abstract: An attempt has been in this study to delineate the characteristics of spectral signatures of the vegetation in terms of various VIs, particularly made the Normalized Difference Vegetation Index(NDVI), Modified Soil Adjusted Vegetation Index2(MSAVI2) and Enhanced Vegetation Index(EVI). Multi-temporal SPOT-4 VEGETATION data from 1998 to 2002 have been used for the analysis. They have been compared with each other for their similarities and differences. The correlations between the vegetation indices observed at various degree of vegetation coverage during their different stages of growth were examined. All of the VIs have shown qualitative relationships to variations in vegetation. Apparently, the NDVI and MSAVI2 are highly correlated for all of the temporal changes, representing the different stages of phenology.
Key words: Vegetation Indices, Vegetation dynamic, Mongolia

1. Introduction

Vegetation indices (VIs) are the indicators of spectral transformations of two or more bands of satellite derived data employed to enhance the contribution of vegetation properties. They provide reasonable and reliable inter-comparisons of spatial and temporal information of terrestrial photosynthetic activity and canopy structural variations over a wide range of empirical observations. Investigations have shown that the potential applications of the usage of VIs are highly useful in deciphering the characteristics of phenological stages of vegetation. The seasonal variability of the vegetation dynamics can be estimated easily with the availability of the present database allowing them for a rational correlation with the empirical observation and the controlling of bio-geo-physical parameters. Most of the VIs are called broadband VIs because they are based on algebraic combinations of reflectance in the red and the near infrared spectral bands [1]. These algebraic combinations are designed to minimize the effect of external influences such as solar irradiance changes due to the atmospheric effect or variations in soil background optical properties in the vegetation canopy spectral response.

In this study, we attempted to delineate the characteristics of the spectral signatures of the vegetation in terms of various VIs, such as NDVI, MSAVI2 and EVI. We explored multi-temporal SPOT-4 VEGETATION (VGT) data for the analysis.

2. Data and Study area

1) Multi-temporal SPOT-4 VGT sensor data

In this study, we acquired VGT-S10 data from April 1, 1998 to September 21, 2002 (a time series of observations) which covered Mongolia. The VGT sensor belongs to the a new generation of space-borne optical sensors that were designed for mainly observations of vegetation and land surfaces [2]. The VGT instrument has four spectral bands: B0 (blue, 430–470 nm), B2 (red, 610–680 nm), B3 (near infrared, 780–890 nm) and SWIR (short-wave infrared, 1580–1750 nm). The blue band is primarily used for atmospheric correction. The SWIR band is highly sensitive to soil moisture, vegetation cover and leaf moisture content, that can improve the discrimination of vegetation and other land covers. There are three 10-day composites for 1 month: days 1–10, days 11–20, and day 21 to the last day of the month.

2) Ground truth data

The biomass measurement is cutting all the grass inside an area of $1m^2$ with the hand. Consist of wet grass weight, dry grass weigh and grass height were measured. In this study we used biomass, coverage measurement data from middle of June 1998 to middle of September 2002 used to compare vegetation indices.

3)**Vegetation indices**

In this study, NDVI, MSAVI2 and EVI were calculated for each of the VGT-S10 products.

Vegetation indices:

1. Normalized difference vegetation index (NDVI) is a normalized ratio of the NIR and red bands. NDVI is defined as;

$$NDVI = \frac{NIR - \mathrm{Re}\,d}{NIR + \mathrm{Re}\,d} \qquad (1)$$

2. Huete [3] suggested a new vegetation index which was designed to minimize the effect of the soil background, which he called the soil-adjusted vegetation index (SAVI). [4] developed of an iterated version of this vegetation which is called MSAVI2:

This equation can be described as,

$$MSAVI2 = \frac{2NIR + 1 - \sqrt{(2NIR+1)^2 - 8(NIR - \mathrm{Re}\,d}}{2} \qquad (2)$$

3. Enhanced vegetation index (EVI) was developed to optimize the vegetation signal with improved sensitivity for high biomass regions and improved monitoring through de-coupling of the canopy background signal and reduction in atmospheric influences. The EVI is represented by the following equation:

$$EVI = G\frac{NIR - \mathrm{Re}\,d}{NIR + C_1\,\mathrm{Re}\,d - C_2 Blue + L} \qquad (3)$$

where L is the canopy background adjustment that addresses nonlinear, differential NIR and Red radian transfer through a canopy, and *C1*, *C2* are the coefficients of the aerosol resistance term, which uses the blue band to correct the aerosol influences of the red band. The coefficients adopted in the EVI algorithm are, L=1, *C1*=6, *C2*=7.5, and *G* (gain factor)=2.5 [5,6]

3) Study area

Mongolia is located between N50°00'-50°40' and E106°00'-107°20' latitude and longitude respectively. Total area covers 1,565,000 sq. km. This area is mountainous and has a wide steppe topography. The greater part of highlands consist of mountainous areas with gentle to steep slopes, which are located western, northern and south-western parts of Mongolia. Eastern and southern parts of Mongolia are wide plain steppe and gobi desert areas. The climate of the Mongolia is characterized by short, dry summer and long cold winter season. The growing season lasts from middle of June to the end of August.

3. Method

1) Sampling Procedure

Prior to sampling, we determined the number of samples necessary to detect differences in vegetation indices. We selected 35 sample points would be adequate for all the vegetation indices examined.

2) Analysis

Relationships between vegetation indices observed at various degree of vegetation coverage during their different stages of growth were analyzed using regression and correlation analyses and each vegetation indices of sample points were compared with ground based data. To check the sensitivity of vegetation indices to vegetation dynamics, we examined the differences in VIs over the period of April-September, and we used following equation.

$$VI_{\Delta t} = \left| VI_{t+1} - VI_t \right| \qquad (4)$$

where VI_t, VI_{t+1} is vegetation index values time steps *t*, *t+1*

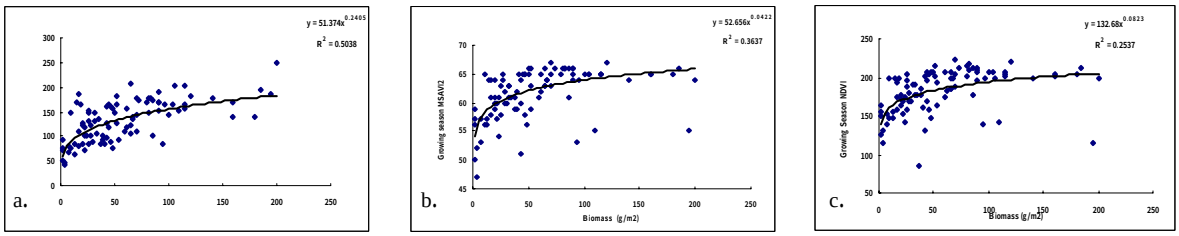

Fig. 1 The relation between biomass(g/m2) and vegetation indices in grassland area:
a. growing season EVI and Biomass, b. growing season MSAVI2 and Biomass, c. growing season NDVI and Biomass

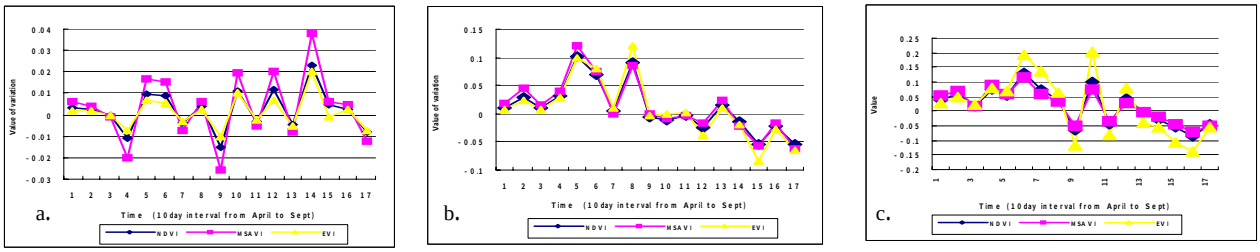

Fig. 2. Variation of VIs at 10 day interval over the period of April-September in different degree of vegetation cover:
a. Desert area, b. Grassland area c. Forest area

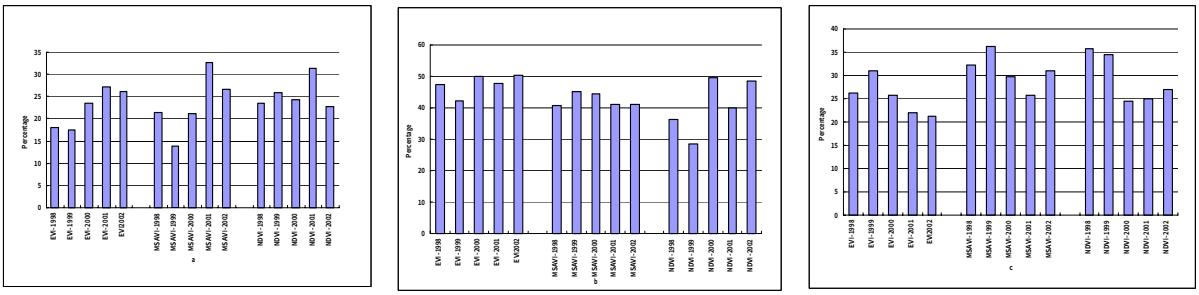

Fig. 3. Percentage of each class from each index: a. desert area, b. grassland area, c. forest area

4. Result

All of the VIs showed a qualitative relationship to variations in vegetation. Apparently, the NDVI and MSAVI2 are highly correlated for all of the temporal changes and in different degree of vegetation coverage. In general, the EVI was least correlated to the NDVI and MSAVI2 in the early stage of growth. Correlation coefficients between vegetation indices for study area are shown in the Table1.

Table 1. Correlation coefficients between VIs for per pixel

	Evi&msavi	evi&ndvi	msavi2&ndvi
April	0.55	0.58	0.98
May	0.88	0.91	0.98
June	0.96	0.91	0.98
July	0.96	0.98	0.99
August	0.94	0.97	0.98
September	0.91	0.96	0.98

The EVI and aboveground biomass were correlated well in grassland area (Fig.1). Where as in forest area NDVI and biomass are correlated better than the other indices. In desert area, MSAVI2 was more sensitivity and in forest area EVI was found to be more sensitive to the vegetation dynamics (Fig. 2). Maximum-likelihood supervised classification was performed on the each index. Each index was classified into four general classes, namely water, forest, grassland, forest compared percentages of each class.

5. Conclusions

According to the theory, EVI is interesting because this index is a discontinuous function by the blue channel. The range is approximately from -1270 to 1240 in continuous range and when greenness is increasing the range become short. For this index differences in land cover type were big. After being converted to 1 byte, similar land cover types became indistinguishable. Therefore it seemed that in 2bytes, this index could show differences in land cover types more clearly. The range of MSAVI2 was between –23 to 0.7. However the VIs were correlated well, classification results were different depending on the vegetation index (Fig3).

Acknowledgement

The authors would like to thank the “ Joint Mongolian Russian Expedition” and specialist M. Erdenetuya of Information and Computer Center National Remote Sensing Center of Mongolia for providing ground truth data.

References

[1] Bannari et al., 1995. A. Bannari, D. Morin, F. Bonn and A.R. Huete , A review of vegetation indices. Remote Sensing Reviews 13, pp. 95–120.

[2] Saint, G. 2000. Proceeding of VEGETATION 2000: 2years of operation to prepare the future. Internationa l Conference of VEGETATION 2000, April 3-6, Lak e Maggiore, Italy.

[3] Tomoaki Miura, Alfredo R. Huete, Hiroki Yoshioka and Brent N. Holben, December 2001. An error and sensitivity analysis of atmospheric resistant vegetation indices derived from dark target-based atmospheric correction, Remote Sensing of Environment 78, pp.284-298

[4] Huete,A.R., 1988. A soil-adjusted vegetation index Remote Sensing and the Environment, 25, pp.53-70

[5] Qi, J., Chehbouni A., Huete, A. R., Kerr, Y. H., and Sorooshian, S., 1994. A modified soil adjusted vegetation index, Remote Sensing and the Environment, 48, pp. 119-126

[6] Huete, A.R. and Liu, H.Q., 1994. An error and sensitivity analysis of the atmospheric- and soil-correctingvariants of the NDVI for the MODIS-EOS. IEEE Transactions on Geoscience and Remote Sensing 32 4, pp. 897–905

[7] Huete, A.R., Liu, H.Q., Batchily, K. and van Leeuwen, W., 1997. A comparison of vegetation indices over a global set of TM images for EOS-MODIS. Remote Sensing of Environment 59, pp. 440–451

[8] Xiangming Xiao, Bobby Braswell, Qingyuan Zhang, Stephen Boles, Stephen Frolking and Berrien Moore., 2003 Sensitivity of vegetation indices to atmospheric aerosols: continental-scale observations in Northern Asia, Remote Sensing and the Environment, 48 pp. 385-392