Potential of Drought Monitoring with Multi-Temporal Normalized Difference Vegetation Index in North-East Asia

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Abstract: This study attempts to analyze the potential of global scale NDVI data archive to monitor regional scale droughts. Ten-days maximum value NDVI composite data of the northeast Asia region were acquired for the growing seasons from 1993 to 2003. Two NDVI-derived drought indices (SVI, VCI), reported from previous studies, were applied to the study area. Although the SVI and VCI are mainly developed for monitoring the drought condition at the agriculture crop and grasslands, it turned out that they were also effective to reveal the drought condition over the temperate mixed forest. The drought symptom lasts at least one or two months even after the normal raining begins.
Keywords: Drought Monitoring, NOAA, NDVI, SVI, VCI, northeast Asia

1. Introduction

For many years, Normalized Difference Vegetation Index (NDVI) has been widely used to estimate vegetation growth and health, crop yield assessment, and drought monitoring [1, 2]. Until recently, NOAA AVHRR-derived NDVI data have been a primary source of information product of satellite remote sensing for analyzing vegetation conditions at global and/or continental scales.

Since NDVI data have been accumulated for more than 20 years or so, a typical temporal pattern of vegetation phenology could be derived from the average value of multiyear NDVI value. Several studies have used the multi-temporal NDVI data to assess the drought conditions over large geographic areas [1, 2, 3]. Throughout the years, a few drought indices were developed from the multi-temporal NDVI data. These drought indices, a standardized from of NDVI values to compare multiple year datasets, have tested for large geographic areas of agriculture crop and pasture areas, such as Great Plains and cornfield of Zimbabwe and spring wheat field of Kazakhstan [1, 2, 3]. Although the NDVI-based drought monitoring could be an effective alternative to monitor drought conditions over agricultural crop and grass, it has not been applied to forest vegetation. The objective of this study is to evaluate the multi-temporal NDVI and other related drought indices for monitoring drought condition over the northeast Asia where the land cover is rather diverse and forest is a primary land cover type.

2. Multi-temporal NDVI Data

For this study, we have obtained 219 scenes of 10-day NDVI data for the growing season (March – October) from 1994 to 2003 over the study area the Korean peninsula, Japan, and northeastern part of China. The 10-day cloud free NDVI data, originally prepared by the United State Geological Survey (USGS), were obtained from the Japan Agriculture, Forestry and Fisheries Research Information Center [5]. The cloud free NDVI data were made by the maximum value composition of 10 daily NDVI data. The standard NOAA NDVI products were made using the two channels (visible and near-infrared) of AVHRR data after the radiometric calibration of converting digital number values to radiance and the solar illumination correction [6].

As a reference data, we have used the climate data, corresponding to the multi-temporal NDVI datasets, that were collected at about 70 weather stations throughout the South Korea.

3. Drought Indicators

1) NDVI and Drought Indices

As an initial approach, we have compared each temporal NDVI dataset to the 10 year average NDVI of the same date. Overall statistics of NDVI values excluding water surface were extracted and compared for the selected time period. Beside NDVI, other related drought indices were also derived from the ten years multi-temporal NDVI datasets. The standardized vegetation index (SVI), developed by Peters et al. [3], is a simple normalized value of NDVI obtained by the following equation.

$$SVI = \frac{NDVI_{ijk} - \overline{NDVI}_{ij}}{s_{ij}} \qquad (1)$$

where i = pixel location, j=date, k = year.

The vegetation condition index (VCI) is another form of drought index of normalized NDVI value [4]. For each pixel location i at a particular date during the 10 years, VCI is calculated as follows.

$$VCI = \frac{(NDVI_i - NDVI_{\min})}{(NDVI_{\max} - NDVI_{\min})} \times 100 \qquad (2)$$

Probably, drought damage is most prevailing during the growing season of spring and summer in this temperate northeast Asia. Figure 1 shows two different types of drought pattern observed in Korea during the last ten years. Average annual precipitation is 1,300mm while the total precipitations of 1994 and 2001 were 959mm and 1,064mm, respectively. The spring drought was apparent in 1994 while the summer drought rather clear in 2001.

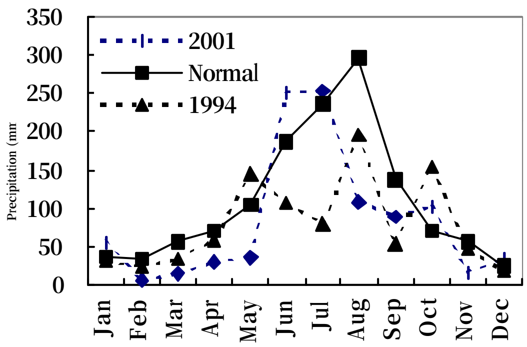


Figure 1. Monthly precipitation of two drought years (1994, 2001) in S. Korea.

Figure 2 shows temporal profile of NDVI, SVI, and VCI of June 21-30 for each year. As compared with the 10-year average value, we can see that the drought year has certainly low values. In this temporal profile, the 1994 values are significantly lower than the average values in all three indices. Among the three indices, however, SVI and VCI show much clear difference between drought years and the other normal precipitation years while the NDVI has a minimal variation between years.

As a matter of the fact, the monthly precipitation during the spring (March to May) of 2001 was only one half of normal precipitation and the record-low during the last 90 years. However, from the NDVI value of 2001 was not very different from the 10-year average while the SVI and VCI values show slight decline in 2001.

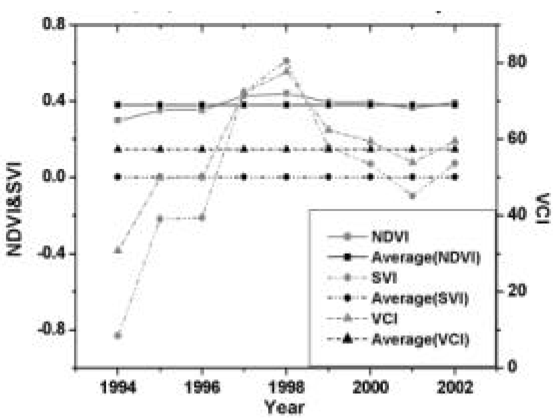
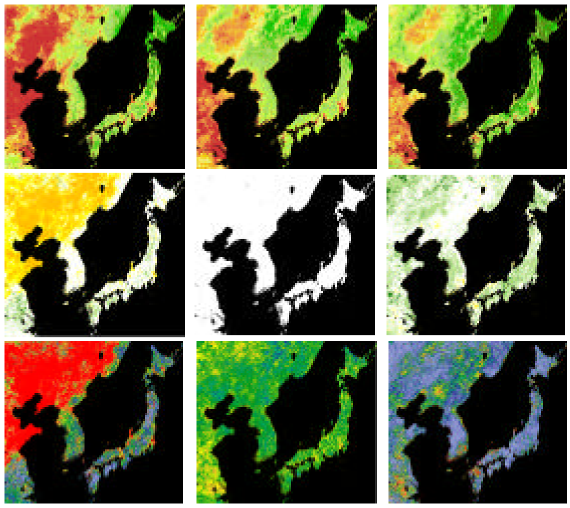


Figure 2. NDVI, SVI, and VCI of June 21-30 for each year



(a) (b) (c)

Figure 3. The minimum (a - 1994), the average (b) and the maximum (c - 1998) of NDVI (top), SVI(middle) and VCI (bottom) of the June 21-30 during the last 10 years.

It is clear that the NDVI itself is not quite effective to show the drought condition as compared to other drought indices. As seen in Figure 3, the NDVI images of the June 21-30 in 2001, when the spring drought was most severe, is not very different from the 10-year average image. On the other hands, the images of SVI and VCI were certain distinction from the average image. Although NDVI has been widely used to monitor the vegetation condition in several cases, it is not very sensitive to show a subtle difference in drought condition.

2) Drought Index by Land Cover Type

The two drought indices (SVI, VCI) were mainly used for the areas of agricultural crop and grasslands. To see the effect of these drought indices over other land cover types (forest and urban), a comparative analysis among the three indices was conducted by land cover type. Using the land cover map of South Korea was overlaid to the NDVI and two drought index images. The land cover map is a part of MODIS product, which was produced in June 2001, has approximately been equal to the spatial resolution of the NDVI data [7]. Three land cover types of forest (both broadleaf and coniferous forests), agriculture (grasses/cereal and broadleaf crops) and urban were extracted among the several land cover classes.

Table 1 shows the statistics of NDVI, SVI, and VCI by three cover types during the drought season in 2001. Among the four datasets, the drought condition was most obvious at the dataset of June 21-30 when the relatively enough rainfall started. In Figure 1, the actual monthly precipitation of June is higher than normal year and the lower precipitations were found from February to May. Although there was very low precipitation in May, the NDVI and the two drought indices were not very different from the 10-year average. The leaf development of forest and crop begins around May and the canopy condition/closure of June was also not very different from May. This implies that it may take a few weeks until the drought symptom begins to show up. May and early June, having the record-low precipitation, might be a drought endurance period.

Although the absolute magnitude of NDVI value of forest is higher than cropland and urban, the difference from the 10-year average is not very significant. When we compare the SVI and VCI of 2001 to the 10-year average, there was not clear difference between forest and crop. The differences between the 2001 and the 10-year average of SVI and VCI were -1.10, -1.02 and -37.06, -34.77 for forest and crop. Effect of the drought condition had about the equal impact on the leaf growths of the temperate forest and the agricultural crops. The predominant cover type in Korea as well as in Japan is forest. The multi-temporal NDVI based drought indices were still effective to find the drought condition in forest.

Table 1. NDVI and drought indices of three land cover types during the drought months in 2001

Index	cover type	21-30 May		1-10 June		11-20 June		21-30 June	
		2001	10 year mean	2001	10 year mean	2001	10 year mean	2001	10 year mean
NDVI	Total	0.50	0.49	0.49	0.46	0.39	0.45	0.25	0.42
	forest	0.53	0.51	0.52	0.48	0.42	0.47	0.27	0.45
	Crop	0.47	0.46	0.44	0.42	0.36	0.42	0.24	0.39
	urban	0.36	0.37	0.34	0.33	0.27	0.33	0.14	0.18
SVI	Total	0.09	0.00	0.50	0.00	-0.57	0.00	-1.07	0.00
	forest	0.15	0.00	0.60	0.00	-0.56	0.00	-1.1	0.00
	Crop	0.10	0.00	0.24	0.00	-0.60	0.00	-1.02	0.00
	urban	-0.09	0.00	-0.11	0.00	-0.67	0.00	-0.91	0.00
VCI	Total	55.9	52.0	67.1	51.2	57.2	52.5	24.4	60.4
	forest	57.2	51.6	71.0	51.6	39.3	57.7	22.9	66.1
	crop	53.8	51.3	59.7	51.2	37.3	75.2	25.1	59.9
	urban	45.5	48.6	41.0	45.1	27.8	50.1	21.1	51.9

4. Conclusions

From this preliminary analysis on the NDVI based drought indices over the last ten years in Korea and surrounding northeast Asia, the major results can be concluded as follows;

- SVI and VCI are more effective to find the drought condition than NDVI itself. As compared with the average NDVI value over ten years, it turned out NDVI is not as sensitive as SVI and VCI to spatially depict the drought condition.
- Although the drought indices has been used for agriculture crop and grasslands, they are also effective to monitor the drought conditions over the temperate forest.
- The lowest precipitation time may not be correspond to lowest drought index. The optimum time to find the drought condition can be varied by the drought endurance period and the vegetation phenology.

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