SPRING DROUGHT MONITORING USING NDVI-BASED VCI AND SVI

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ABSTRACT : In this study, the MODIS NDVI for the period of 2000~2007 was collected and processed to obtain VCI and SVI which are the quantitative indexes of drought. The VCI and SVI based on NDVI can be used for understanding seasonal pattern of vegetation, drought identification and quantitative analysis of drought. VCI and SVI compared with monthly precipitation ratio to average, Standardized Precipitation Index(SPI), and etc., which are used to identify spring drought, to analyze drought region, similarity and difference in drought severity. In addition, frequency of Spring droughts were calculated for the period of 2000~2007, and the usability of the MODIS images as a tool for establishing countermeasures against drought was presented by analyzing drought frequently areas.

Key Word: Spring Drought, MODIS, NDVI, VCI, SVI

1. INTRODUCTION

The study for drought detection using satellite images were started in early 1980s through monitoring plant growth in dry region using multi-temporal Landsat MSS image and vegetation index(Jackson et al. 1983). NDVI(Normalized Difference Vegetation Index) has been used since the mid 1980 to monitor growth of crops by area and season. It also has been used to estimate bio-physical factors of vegetation such as seasonal photosynthesis, growth cycle, and time of leaf change, as well as analysis on the indirect influence of drought by comparing vitality of vegetation. However, the NDVI of which range is -1~1 has limit in quantization of vegetative reaction to water shortage. To this end, Vegetation Condition Index(VCI) and Standardized Vegetation Index(SVI) were developed in order for quantitative presentation of present water shortage using NDVI (Kogan, 1995; Peters et al. 2002). The VCI and SVI can be used for understanding seasonal pattern of vegetation, drought identification and quantitative analysis of drought.

In this study, VCI and SVI were produced by using the MODIS NDVI collected during 2000-2007, and compared with monthly precipitation ratio to average, Standardized Precipitation Index(SPI), and etc., which are used to identify spring drought, to analyze drought region, similarity and difference in drought severity. In addition, the usability of the MODIS images as a tool for establishing countermeasures against drought was presented by analyzing frequency of spring droughts for the period of 2000~2007.

2. VCI AND SVI

VCI(Kogan, 1995) was suggested on the basis of NDVI to detect the changes in weather elements which have influence on vegetation. That is, VCI limited the factors affecting the changes in vegetation by weather conditions, assuming that the vitality of vegetation is maximum under optimal weather conditions, and minimum value of vegetation stand for serious weather condition involved in drought.

$$VCI = 100 \times \frac{NDVI_i - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \quad (1)$$

VCI can be calculated with Equation (1) using the maximum(NDVImax) and minimum(NDVImin) of the NDVI in the same period and the NDVI(NDVIi) of the target period for which the VCI is to be calculated. VCI has value range of 0 to 100, of which less value represents lowered vegetation vitality. Kogan(1995) has analyzed the correlation between VCI and crop productivity to present the influence of drought quantitatively. According to the analysis result, vegetation is stressed at the VCI value of 50 or less, and crop productivity decreases by 20% by drought at the VCI value of 0 to 35. On the basis of this analysis results, VCI of 35 or less is recommended as the indicator of drought(Shin S. C., Kim C. J. 2003).

Peters et al.(2002) has applied NOAA AVHRR NDVI of the Great Plane, for 12 years from 1989 to 2000, in standard normal distribution, and developed a drought index by normalizing each variance with average value by the deviation in vegetative conditions.

$$z_{ijk} = \frac{NDVI_{ijk} - \overline{NDVI_{ij}}}{\sigma_{ij}} \quad (2)$$

SVI can be expressed with Equation (2), where, Zijk is the z value of year k, week j, pixel i, NDVIijk is the NDVI of year k, week j, pixel i, $\overline{NDVI_{ij}}$ is the average NDVI of pixel i for j weeks of the entire n years, and σij is the standard deviation of pixel i for j weeks of the entire n years. The zijk which has continuous probability distribution assumes a standard normal distribution of which standard deviation is 1 and average is 0. Therefore, the probability density function of zijk is given by the Equation (3).

$$SVI = P(Z < z_{ijk}) \quad (3)$$

The SVI which has standard normal distribution has a value between 0 to 1, where, 0 represents the condition to be smaller than all the NDVI pixels of the same period, on the other hand, 1 represents the probability of being larger than all the NDVI pixels comparing the same time NDVI of multi-period. SVI can be classified into 5 classes; very bad(0~0.05), bad(0.05~0.25), average(0.25~0.75), good(0.75~0.95), and very good(0.95~1).

3. COLLECTING MODIS NDVI DATA

The MODIS sensor is one of the 5 sensors on the TERRA satellite launched on Dec. 1999. It has been operated for monitoring wide range changes in biosphere. the MODIS NDVI used in this study was collected through the EOS Data Gateway of NASA which is provided by sinusoidal projection having 250m resolution.

MODIS NDVI was produced using daily surface reflectance of RED and near infrared. Once each surface reflectance was generated by 16 day unit and it produced 16 day composite NDVI through band ratio and optimized composite algorithm. In this study, MODIS NDVI was collected from April 07, 2000 to June 25, 2007. Assuming that from March 6 to June 25 is the Spring season which is the target period of the study, VCI and SVI were constructed.

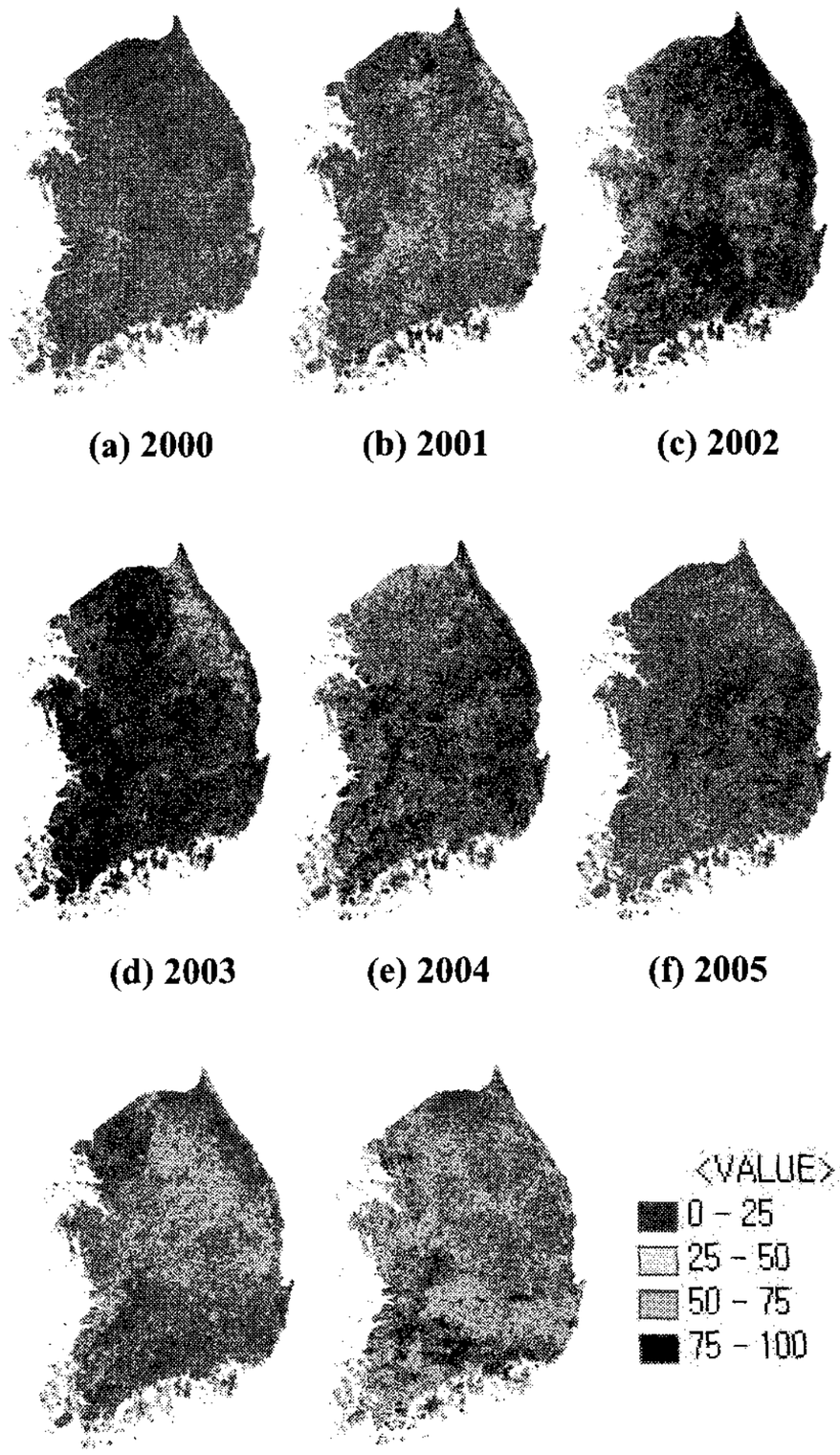
Table 1. MODIS NDVI Product Data Details

	MODIS NDVI
File Name	Vegetation Indices 16-Day L3 Global 250m
Spatial Resolution	250 m
Spectral Resolution	16 bit
Input Image	Surface Reflectance (MOD09)
Composit period	16 day
Projection	Sinusoidal Projection
Data period	04/07/2000 ~ 06/25/2007

4. EXTRACTION OF DROUGHT AREA AND SEVERITY ANALYSIS

Since the MODIS NDVI used in this study is a composite data at 16 days' term, VCI and SVI also were prepared by 16 days' term. Considering the frequency and severity of Spring droughts obtained from references, and vitality of vegetation, the VCI and SVI during April 23 to May 8 were selected for the extraction of drought area and severity analysis, which are shown in Figures 1 and 2.

In this study, the degree of drought was classified into 4 steps with reference to the VCI value of 50 which is known to be the criteria of stress to vegetation by drought, and SVI was classified into 5 steps according to the criteria suggested by Peter et al.(2002). According to the VCI analysis, droughts have occurred in 2000, 2001, 2006 and 2007, as shown in Fig. 1. During April 23 to May 8, the drought in 2000 was the severest, resulting in the productivity decrease in all South Korea. In 2006, severe drought had occurred in the southern region including Jeolla-do and Ulsan and eastern Gangwon-do region. In 2007, drought had occurred in the middle region of Korea, though not in wide area. SVI showed similar results with those of VCI analysis, however, the area where the SVI was 0.05 or lower, which represents severe drought, was not widely distributed. As shown in Figures 1 and 2, it was found out that VCI and SVI are effective for the identification of seasonal drought severity and spatial distribution by quantifying the severity of drought.

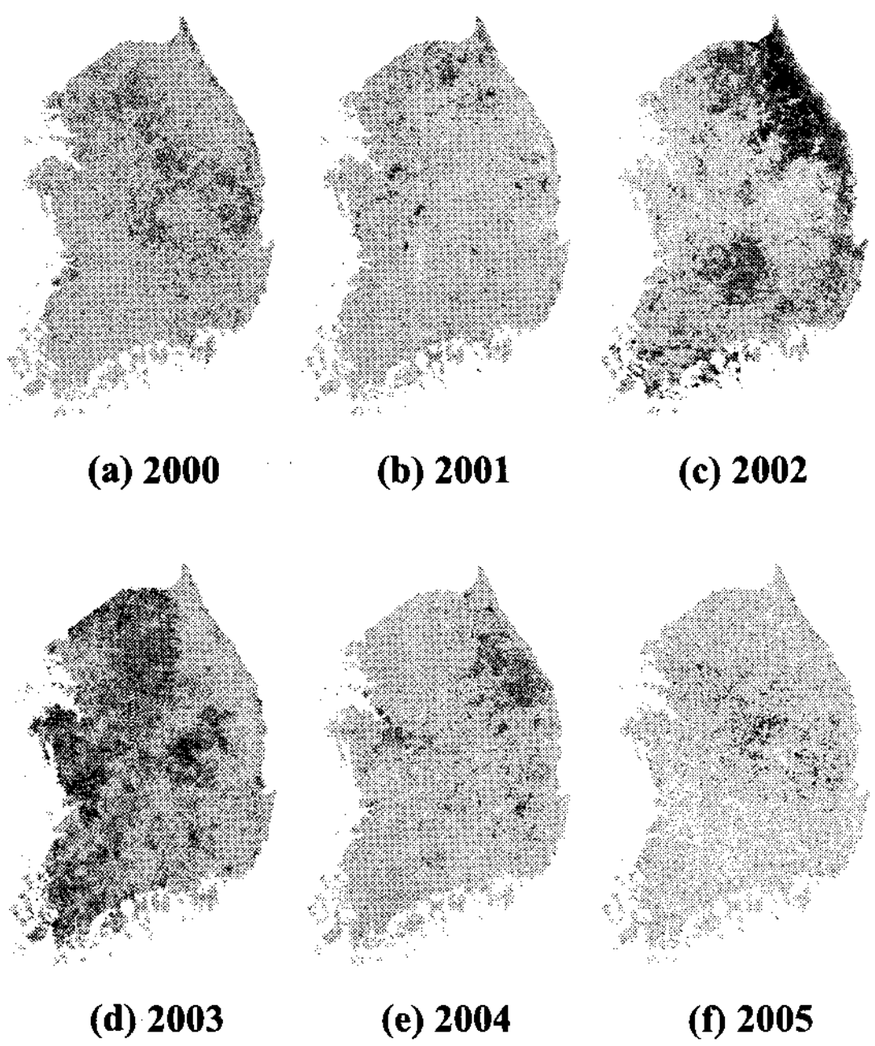


(a) 2000 (b) 2001 (c) 2002

(d) 2003 (e) 2004 (f) 2005

(g) 2006 (h) 2007 (i) Legend

Figure 1. Extraction of Drought Area by VCI (April 23~May 8)



(a) 2000 (b) 2001 (c) 2002

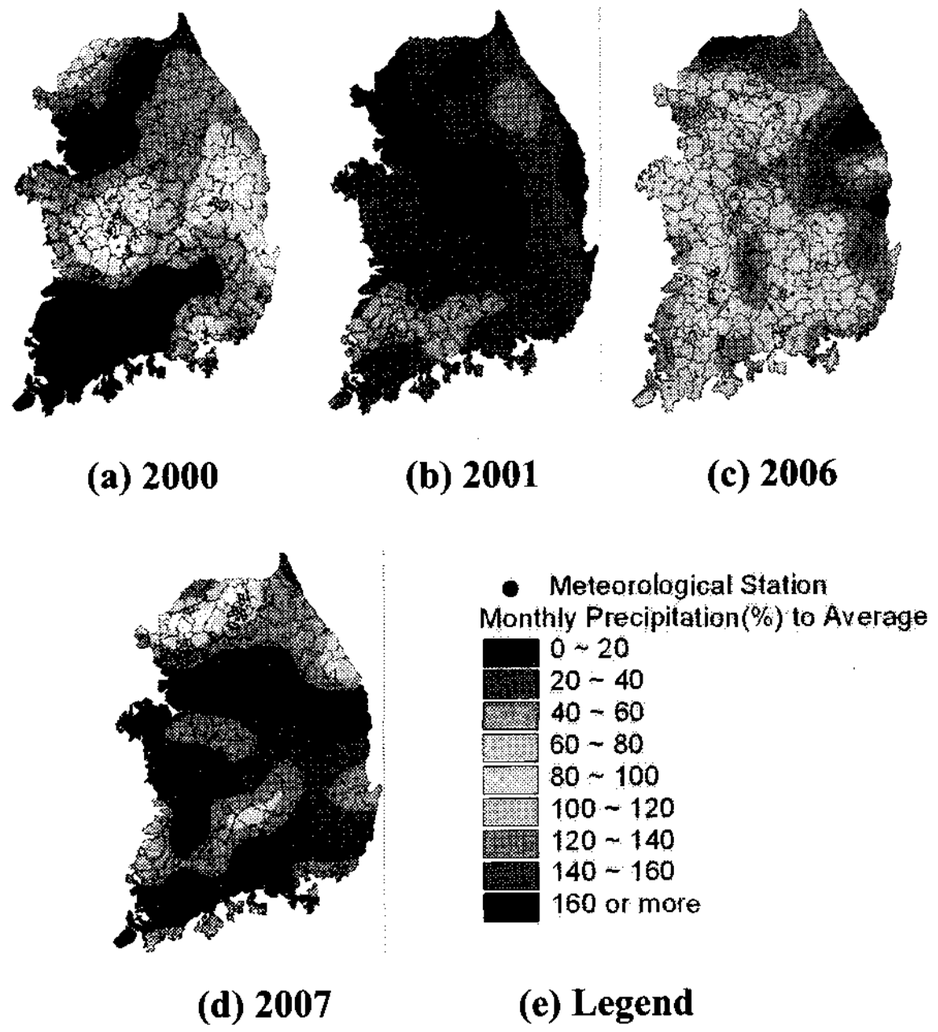
(d) 2003 (e) 2004 (f) 2005

(g) 2006 (h) 2007 (i) Legend

Figure 2. Extraction of Drought Area by SVI (April 23~May 8)

In this study, the similarity and difference of the VCI and SVI which are used to identify the areas and severity of drought from existing drought indicator like SPI, accumulated rainfall were analyzed. Fig. 3 shows the data of 2000~2001 and 2006~2007, the period when droughts were analyzed to have occurred by VCI and SVI, in monthly precipitation rate(%) to average. the most distinctive difference is that the monthly precipitation rate in 2006, which was identified to have suffered from drought by VCI and SVI, monthly precipitation ratio in April is higher than average. In addition, it could be seen that the severities of the drought in 2000 and 2001 differ between VCI and SVI.

According to the reference reports, the Spring drought in 2006 was severest in Jeolla-do region and also occurred in Ulsan and Gangwon area. Especially, the water level of the Juam Dam, Suncheon, recorded lowest level until the drought ended by the rainfall on April 1st. In other words, though the Spring drought in 2006 had continued until March, and the vegetation index had reflected it with delay time, which can also be noticed in the comparison of drought severity between 2000 and April 2001. When comparing the Spring droughts of 2000, which had been severe from Nov. 1999 until April 18, 2000, and that of 2001 which had caused social disorder by extremely low precipitation during March to June, in spite of large precipitation in January and February, the severity by VCI and SVI based on vegetation index was larger in 2000, while the SPI 3-months drought index and the precipitation ratio to average was larger in 2001. From these results, it could be understood that the VCI and SVI based on vegetation index depend upon the accumulated precipitation over a long time.

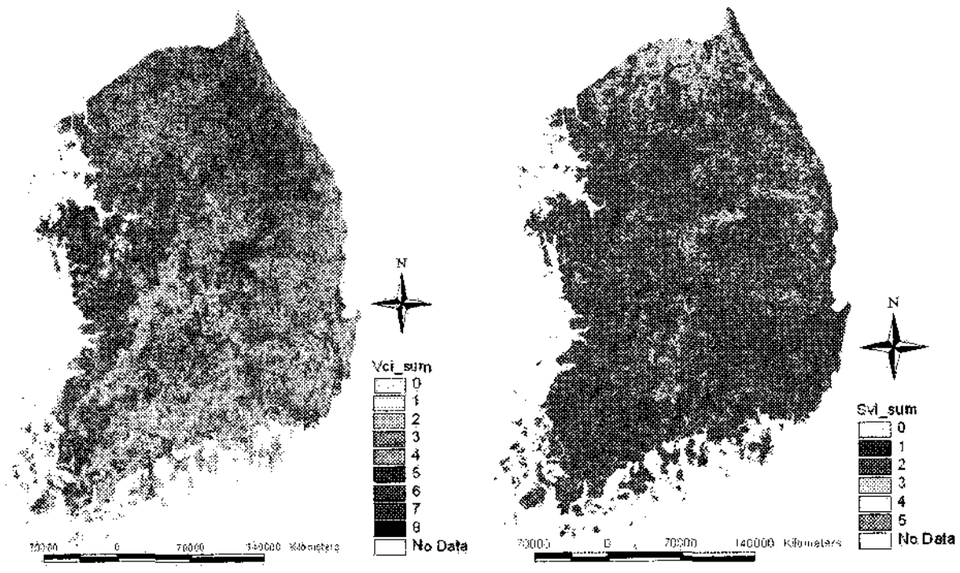


(a) 2000 (b) 2001 (c) 2006

(d) 2007 (e) Legend

Figure 3. Precipitation Ratio(%) in April to average

In this study, the frequency of the spring droughts in 2000~2007 were obtained and shown in Fig. 4 from the results of the VCI and SVI shown in figures 1 and 2. As shown in Fig. 4, in the analysis using VCI, distribution of drought frequently areas was wider and frequency of droughts was larger than those of SVI. In addition, the drought-prone areas were concentrated in Gyeonggi, Chungnam, and Gangwon Provinces where countermeasures are required urgently.



(a) VCI (b) SVI

Figure 4. Areal Distribution and Frequencies of Spring Droughts in 2000~2007

5. CONCLUSION

In this study, the MODIS NDVI for the period of 2000 ~ 2007 was collected and processed to obtain VCI and SVI which are the quantitative indexes of drought. For the objective period, Spring drought was identified, spatial distribution of drought areas was analyzed, and he severities of droughts were compared. it was identified that Spring droughts have occurred in 2000 ~ 2001 and 2006~2007, and their severities could be compared. By comparing the analysis results of VCI and SVI with the precipitation ratio(%) to average and SPI drought index, it was verified that the VCI and SVI which are based on vegetation index depend upon the accumulated precipitation over a long time. In this study, spring drought areas for the 8 years from 2000 were extracted and processed to identify drought frequently areas. The information obtained from these areas would be able to be used in developing countermeasures against droughts.

For the drought analysis with VCI and SVI, long-term data collection has to be conducted. To this end, the MODIS satellite image which has been providing calibrated data since 2000 is a highly effective tool for drought control. Further studies will be conducted to provide basic data to setup countermeasures against drought by further analyses on the drought areas where droughts have occurred after 2000. More reliable data would be available by collecting and utilizing VCI and SVI data continuously.

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ACKNOWLEDGEMENTS

This study was conducted by the sponsorship of the General Research Program of the Korea Research Council of Public Science & Technology (Project name: Public Applications Research of Satellite Data-A Study of River Information Production and Application Using Satellite Images) and Sustainable Water Resources Research Program, which is one of the 21st Century Frontier Research and Development Program(Project name: Development and Application of HyGIS (1-2-3)).