ASSESSMENT OF SPRING DROUGHT USING MODIS VEGETATION INDEX AND LAND SURFACE WATER INDEX

Jung-Sool Park *, Kyung-Tak Kim *, Kyo-Sung Lee**

* Korea Institute of Construction Technology, {parkjs, ktkim1}@kict.re.kr
** INHA University, ksung@inha.ac.kr

ABSTRACT:

In order for the evaluation and analysis of the spring drought which has been periodically occurring in Korean peninsula since 2000, the use of satellite image data is increasing to investigate temporal and spatial characteristics of the drought areas. The recent spring droughts in south Korea have some characteristics. It last for short period in spring when the activity of vegetation is not lively and it have large areal deviation in the severity of drought. In this study, considering the characteristics of the spring drought in Korean peninsular, the MODIS satellite image data which has superior spatial and radiometric resolutions was used for the analysis of the spring drought. In two basins having different spatial characteristics, the drought events were selected and their severities were analyzed using the MODIS NDVI, LSWI, and daily rainfall data since 2000, and the spatial characteristics of the drought area were analyzed using the DEM, land cover, and digital forest map of the study areas.

Key Word: Spring Drought, MODIS, NDVI, LSWI

1. INTRODUCTION

The use of satellite image data for the detection and monitoring of drought is implemented with the vegetation index and surface temperature obtained from the satellite image data. The NDVI(Normalized Difference Vegetation Index) produced from NOAA(National Oceanic and Atmospheric Administration) AVHRR(Advanced Very High Radiometric Resolution) enables investigation of seasonal patterns of vegetation and quantitative detection of changes, with its data accumulated for more than 20 years. Especially, the VCI(Vegetation Condition Index) and SVI(Standardized Vegetation Index) based on the NOAA AVHRR NDVI provide quantitative data on the severity of present drought, for which a number of studies have been conducted centering at the arid areas(Kogan, 1997; Peter et al, 1998).

Since the countrywide spring drought in 2001 south Korea, studies aimed at extracting drought area and investigating the correlations with drought index using NOAA AVHRR NDVI and VCI, SVI, etc., have been conducted(Chul-Jun Kim, 2003; Su-Hyun Shin, 2005).

In this study, the MODIS image data which has improved spatial, radiometric, and spectral resolutions than the NOAA AVHRR was used as the tool for the analysis of spring drought.

Since the recent spring droughts are meteorological droughts caused by short-term water shortage, in this study, the relationship between the MODIS image data and the accumulated rainfall was compared, and the usability of satellite image data taking the spatial variation into consideration with the spatial data and change detection method was proposed.

2. MODIS NDVI and LSWI

The MODIS NDVI used in this study was the data produced by band operation with the daily surface reflectance, synthesized in 16 days cycle, in the red and near-infrared bands of the 250m resolution data of the MODIS Vegetation Index Product provided by the EOS data gateway. The MODIS NDVI which is a tool for effective detection of temporal and spatial changes in vegetation is being used for the monitoring of earth climate, modeling of interactions between biospheres, and resources management(Huete et al, 1999).

LSWI is calculated by combination of near and mid infrared bands. In this study, the surface reflectance, atmospherically corrected, was synthesized in 16 days cylcle, to calculate the LSWI with the equation (1). The short wave infrared band is sensitive to the moisture content of landcover and soil, and the combination of near and short wave infrared bands is useful for the estimation of the moisture content in the canopy.

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}, \quad LSWI = \frac{\rho_{NIR} - \rho_{SWIR}}{\rho_{NIR} + \rho_{SWIR}} \qquad (1)$$

Where ρ_{RED}, ρ_{NIR}, ρ_{SWIR} is surface reflectance values from RED, NIR and SWIR bands.

3. METHOD

This study aimed at the evaluation of the usability of the MODIS satellite data for the evaluation of spring drought and the drought analysis taking the surface characteristics into consideration. To this end, the Ansung River basin and Upper Namhan River basin which have different topographical characteristics were selected. The elevation, land cover, and the severity of drought since 2000 differ in the two areas, suitable for the comparison of the usability of the satellite image data according to the rainfall and spatial characteristics.

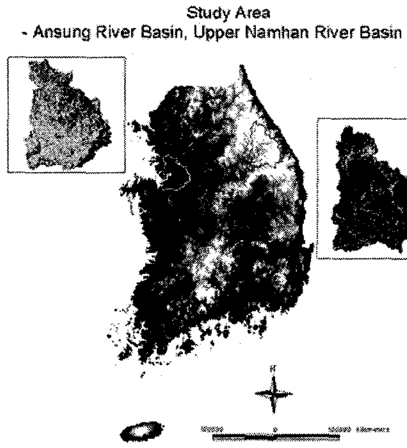


Figure 1. Study Area

For the study, the NDVI and LSWI data of March through June from 2000, when the MODIS data began to be provided, through 2005 was processed. The daily rainfall data of the meteorological stations was accumulated in 16 days unit to match with the period of the NDVI and LSWI data. In addition, the rainfall data of the stations accumulated for 16 days was interpolated with inverse distance weighted method to calculate the average rainfall in the basins.

The 16 day average rainfall so calculated was accumulated in 16 days unit into 32, 48 days and so forth to compare the correlation with the MODIS image data. In addition, the average basin rainfall in March through June and the average rainfall in same period of 2000 through 2005 were compared to classify normal and drought years, and these were compared to evaluate the duration and severity of drought.

Finally, change detection method was applied to produce the variation distribution of the vegetation indexes in normal year and drought period. The distribution was compared with DEM, land cover, and digital forest map to analyze the spatial characteristics of severe drought area.

4. DROUGHT ANALYSIS WITH MODIS NDVI AND LSWI

By comparing the MODIS NDVI and LSWI with the average rainfall of basin that accumulated in 16 day unit, the correlation coefficient was found to be the highest with that of the 64 day accumulated rainfall. The correlation coefficient of the Ansung River basin was 0.76~0.78, and that of the Upper Namhan River basin was 0.56~0.58. Such results mean that the present NDVI and LSWI represent the accumulated rainfall of about two months. In Figure 2, it can be verified that the NDVI and LSWI have similar patterns of accumulated rainfall with that of the 64 days.

For the drought evaluation using the MODIS image data, on the basis of the relationship with the accumulated rainfall, the drought years and normal years were selected since 2000. By reviewing the drought event on the basis of rainfall in spring, droughts have occurred in 2000 and 2001, as shown in Table 1, while the rainfall in 2002 was similar with that of normal year.

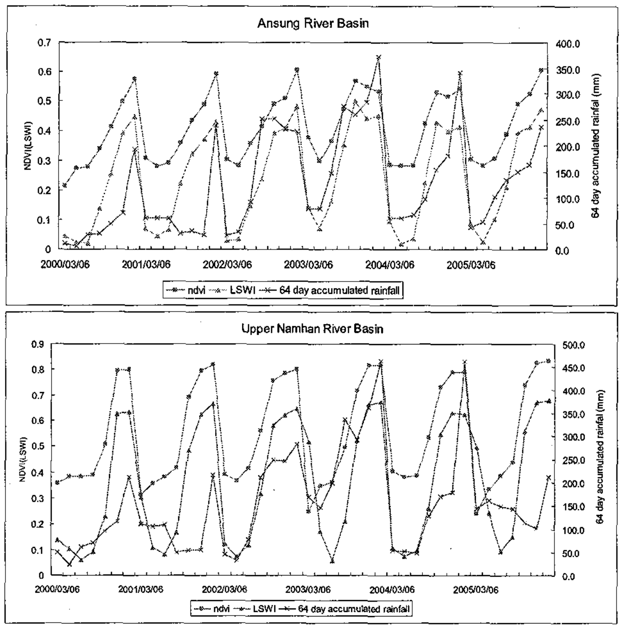


Figure 2. Comparison of 64 Day Accumulated rainfall and NDVI, LSWI

year	Ansung River Basin		Upper Namhan River Basin	
	rainfall (march~may)	percent to average year	rainfall (march~may)	percent to average year
2000	76.6 mm	31.49 %	134.2 mm	54.07 %
2001	37.4 mm	15.44 %	77 mm	31.02 %
2002	262.7 mm	108.42 %	270.9 mm	109.15 %

Table 1. Selection of Drought and Normal Year

In this study, the NDVI and LSWI of 2000, 2001, and 2002, prepared in 16 days unit in accordance with the data providing period of MODIS and the 64 days accumulated rainfall which was found to have the highest correlation were compared, as in Figure 3.

The result of the comparison showed that NDVI and LSWI effectively represent the change in vegetation and moisture deficiency caused by drought. While the NDVI has values larger than LSWI, however, in March and early April when the vegetation is not active, the difference between drought period and normal year was not significant. Since the LSWI is sensitive to drought and provides larger difference according to the severity of drought, it was thought to be an appropriate index for the evaluation of spring drought. In the comparison using the 64 days accumulated rainfall, the drought in 2001 was severer than 2000 at around May 9th in the Ansung River basin and around April 23rd in the Upper Namhan River basin, however, NDVI and LSWI were found to properly reflect the drought severity after May 25th. Therefore, it could be concluded that the MODIS image data is useful for the classification of drought period and normal year but limited for the comparison of the severity by drought event.

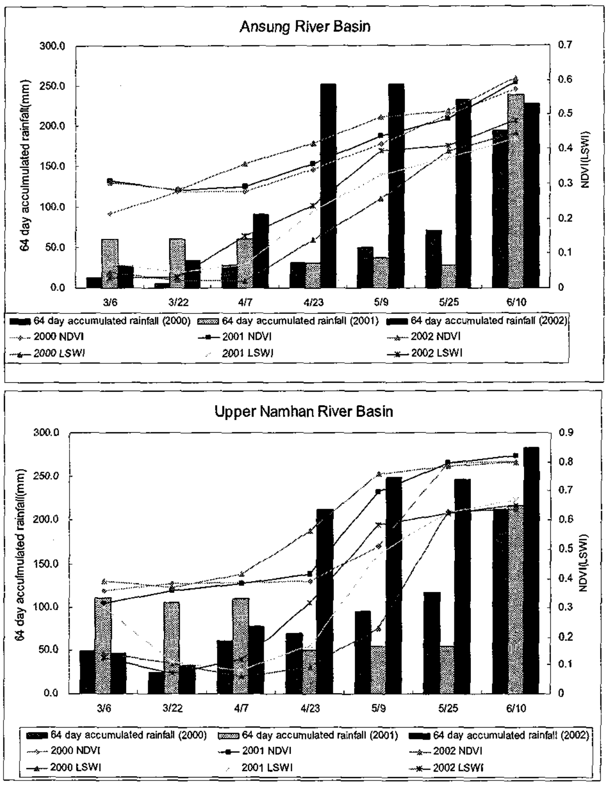
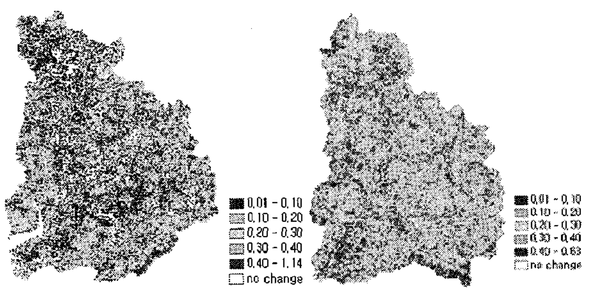


Figure 3. Changes in 16day Accumulated Rainfall and NDVI, LSWI

5. ANALYSIS OF SPATIAL CHARACTERISTICS IN DROUGHT REGION



(a) Ansungg River Basin (b) Upper Namhan River Basin

Figure 4. LSWI Image Differencing (2002-2000)

Figure 4 is a distribution map showing the LSWI changes in normal year and drought year. The data of Ansung River Basin at April 7th and Uupper Namhan River Basn at April 23rd was processed by image differencing method. The changes in LSWI were classified into 6 class. In this study, the change distribution maps of the NDVI and LSWI by basin were processed in this method. The change classes were calculated with the DEM class and land cover class shown in Tables 2 and 3 to analyze the changes in the NDVI and LSWI according to the elevation and land cover.

DEM Class	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Height (m)	4-93	94-182	183-271	272-361	362-450	451-540
percent to basin area	76.2 %	15.9%	5.3%	1.9%	0.6%	0.1%

Landcover Class	paddy fields	dry fields	orchard	grass	conifer	deciduous	mixed forest	etc
percent to basin area	30.8%	9.5%	3.2%	2.4%	14.7%	6.6%	11.0%	21.8%

Table 2. DEM Classification and Landcover Ratio in Ansung River Basin

DEM Class	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Height (m)	190-417	418-646	647-874	875-1102	1103-1331	1332-1560
percent to basin area	8.9%	25.0%	39.0%	22.0%	5.5%	0.5%

Landcover Class	paddy fields	dry fields	other farming land	conifer	deciduous	mixed forest	etc
percent to basin area	1.0%	8.8%	0.9%	38.2%	28.1%	19.4%	3.6%

Table 3. DEM Classification and Landcover Ratio in Upper Namhan River Basin

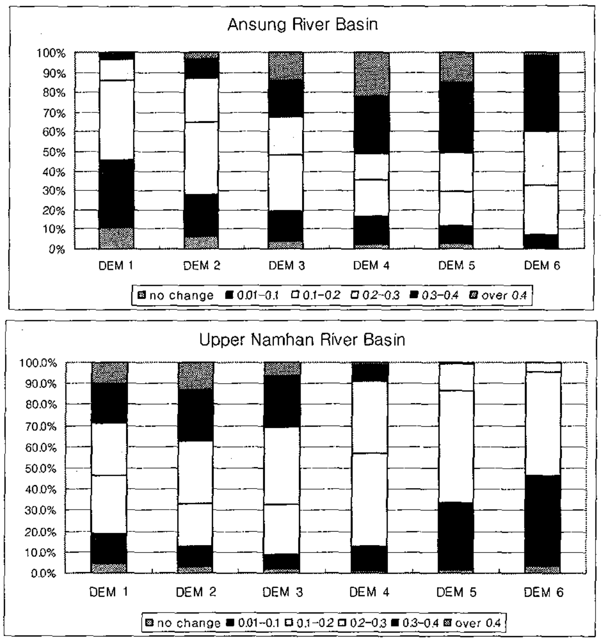


Figure 5. Change Ratio of LSWI according to DEM

The average value of the LSWI change distribution in 2002-2000 in the Ansung River basin was 0.13 at April 7th, while that in the Upper Namhan River basin was 0.2 at April 23rd. In this study, analyses were conducted on the classification that the range of no change~0.2 is the area having small change and the range of 0.2~0.4 is the area having large change.

Considering the change ratio of LSWI in accordance with elevation, the LSWI changes largely according to the elevation in the Ansung River basin of which the average elevation is about 70m, and in the Upper Namhan River Basin of which the average elevation is about 745m, the change of LSWI increase largely according to the elevation to a certain elevation(DEM class 3), however, in the high elevation area of DEM class 4 or higher, the change of LSWI decreases according to the elevation.

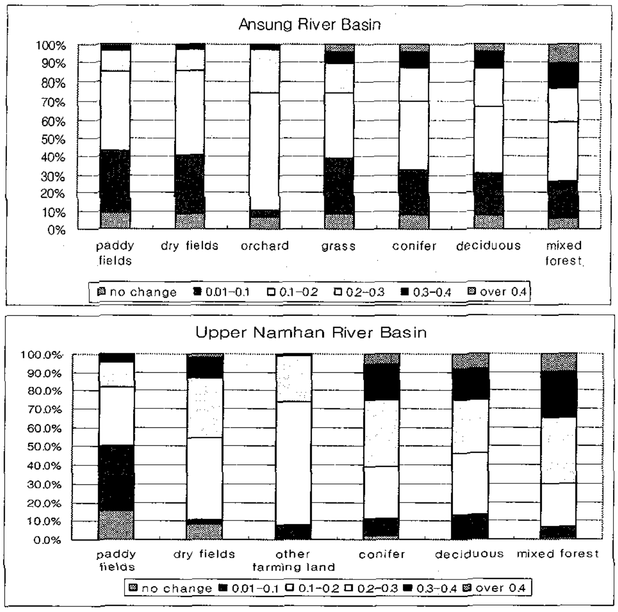


Figure 6. LSWI Change Ratio according to Landcover

The analysis on the landcover showed the least change ratio in paddy fields in both basins and the largest change ratio in forest. In the Ansung River basin which has diverse land cover elements, the order of the influence of drought was forest>orchard, grassland >paddy fields and dry fields, however, the change by landcover was not significant when compared with that by the elevation. On the other hand, in the Upper Namhan River Basin, the order of the influence by drought was forest>dry field>other farming land>rice field. The changes in mixed forest and deciduous forest were large.

In Figure 7 and 8, the LSWI was classified simply into large change and small change areas and its changes were displayed according to the elevation and landcover.

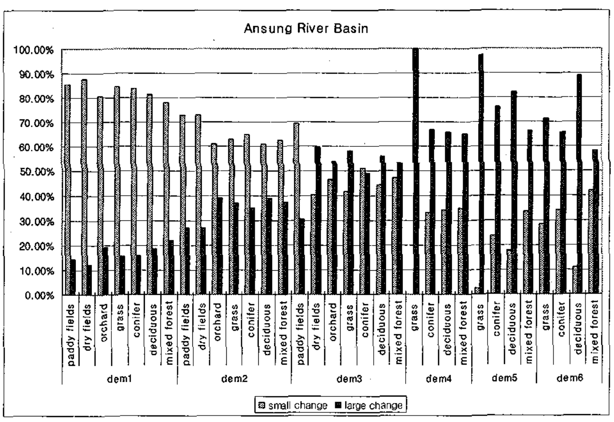


Figure 7. LSWI Change Ratio according to the DEM and Landcover (Ansung River Basin)

In the Ansung River basin, changes by landcover factor in LSWI increased according to the elevation, especially in grass land and deciduous. In the Upper Namhan River Basin, the influence by drought decreased in the lands higher than a certain elevation. Especially, the changes in deciduous and mixed forests were greater in high lands.

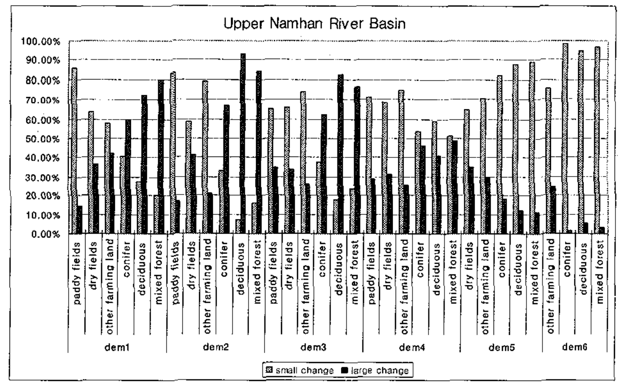


Figure 8. LSWI Change Ratio according to the DEM and Landcover (Upper Namhan River Basin)

6. CONCLUSION

In this study, spring droughts since 2000 were detected, drought events were compared and also compared with topographical spatial data, using the MODIS satellite image data. The results obtained can be summarized as follows;

Firstly, the MODIS NDVI and LSWI is useful for the detection of the spring drought caused by short-term rainfall deficiency, and has the largest correlation with the 64 days accumulated rainfall.

Secondly, the classification of drought period using time series satellite image data is effective, but additional studies are required for the comparison of the severity of drought events.

Thirdly, LSWI has faster response to drought than NDVI and has larger variance according to the severity of drought. Therefore, it can be used as an appropriate indicator for the evaluation of spring droughts.

Fourthly, NDVI and LSWI are affected significantly by the spatial characteristics such as landcover and DEM in addition to the rainfall. It can be concluded that the satellite image data is useful for the evaluation of droughts in the same space.

7. REFERENCE

1. Huete A.R., Didan K., Miura T., Rodriguez E.P., Gao X., Ferreira L.G., (2002) Overview of he radiometric and biophysical performance of the MODIS vegetation indices, Remote Sensing of Environment, 83:195-213
2. Kim Chul Jun (2003) Drought Watch with Vegetation Index, Andong University Master Paper.
3. Kogan F. N. (1997) Global drought watch from space, Bulletin of the American Meteological Society. 78: 621-636
4. Peters, A.J., Walter-Shea, E.A., Lei, J., Vina, A;, Hayes, M., Svoboda, M. R., (2002) Drought monitoring with NDVI-based standardized vegetation index. Photogrametric Engineering and Remote Sensing 68 (1), 71-75.
5. Shin Su Hyun, (2005) Analysis on Drought Index Application on Korea with NDVI, Inha University Master Paper.

ACKNOWLEDGEMENTS

This research was supported by the project: Public Application Research of Satellite Data –A Study of River Information Production and Application Using Satellite Images.