APPLICATION OF SATELLITE IMAGERY FOR DROUGHTS MONITORING IN LARGE AREA

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ABSTRACT:

Droughts have been an important factor in disaster management in Korea because she has been grouped into nations of lack of water. Satellite imagery can be applied to droughts monitoring because it can afford periodic data for large area for long time.

This study aims to develop a method to analyze droughts in large area using satellite imagery. We estimated evapotranspiration in large area using NDVI data acquired from satellite imagery. For satellite imagery, we dealt with MODIS data operated by NASA. As the result of this study, we improved the usability of satellite imagery, especially in drought analysis.
KEY WORDS: droughts, disaster management, water balances, NDVI, MODIS

1. INTRODUCTION

For the last two decades, many countries in the world have been undergone severe droughts. In Korea, there were a lot of record droughts which was close to 100-year return period event in some local area during 1994 and 1995. Also in 2001, there were very severe droughts in some local area in Korea. Because the water resources in Korea are depending on rivers and dams, the impacts of droughts will befall to a considerable extent.

In water circulation process, evapotranspiration, along with precipitation, is one of the important factors which decide the humidity of earth surface. So, evapotranspiration is closely related with droughts.

Evapotranspiration represents the migration of vapour in air and it can not be directly observed with accuracy. So, evapotranspiration has been indirectly estimated using water balance and energy balance, up to date. However, this kind of methods only estimate evapotranspiration but in a point, not in a large area. Also, it is difficult to estimate the spatial distribution of evapotranspiration.

However, considering the weather condition of Korea that the rate of evapotranspiration in water balance exceeds over 40 %, it's difficult in Korea to investigate the quantitative water balance without evapotranspiration.

Recently, micro-weather observation and precise energy balance model are being used to estimate evapotranspiration in large area. In addition, new attempts are made to include satellite imagery in the estimation. But, it's not easy to apply those methods to the large area, because numerous observations and variables are required in proportion to the size of area.

If satellite imagery is used, it is convenient to interpret the land use and hydrological conditions over large area. So, satellite imagery is useful in the estimation of evapotranspiration according to the various ground conditions.

Evapotranspiration is affected by various factors in the weather, and the vegetation also affected by weather conditions such as temperature and solar radiation. So, it is likely that evapotranspiration is tightly related with vegetation.

Running and Nemane(1988) reported that iNDVI(integrated normalized difference vegetation index) which is integrated value of NDVI(normalized difference vegetation index) is in proportion to annual evapotranspiration. Considering tight relation between NDVI and evapotranspiration, Shin(2004) developed a model equation to estimate evapotranspiration for Korean territory using only NDVI data from NOAA satellite imagery.

The advantage of the above method that it doesn't require weather data turns into a disadvantage that it could not consider the ground conditions because only satellite data are available in the estimation process of evapotranspiration. On the other side, the method which combines satellite data and weather data has the advantage that it can consider the ground conditions. But, in turn, it can't be applied to the area where the ground data can't be acquired and weather data are required in every analysis.

In this study, we used satellite data acquired by MODIS(Moderate Resolution Imaging Spectroradiometer), a payload of Terra satellite and Aqua satellite. Combining MODIS data with weather data, we developed a method to estimate evapotranspiration at Nakdong river area, Korea. For the weather data, we only used temperature data because it can be easily and accurately acquired. So, our method can be easily applied to the drought monitoring and analysis.

2. DATA

2.1 MODIS Imagery and NDVI data

MODIS is a sensor to observe Earth surface which was payloaded in Terra satellite(launched on October, 1999) and Aqua satellite(launched on May, 2002). Both satellites were developed and operated by NASA, USA. MODIS has 36 optical channels to observe Earth surface. Among the 36 channels, band 1 and band 2 covers red spectral band and near infrared spectral band, respectively, with 250 m spatial resolution. Using these 2 channels, NDVI data can be produced.

NASA is offering various MODIS product including atmospheric corrected vegetation indices product without payment via website(http://edcimswww.cr.usgs.gov/pub/imswelcome/index.html). We used the vegetation indices product.

Using the vegetation indices product, NDVI and EVI(enhanced vegetation index) data can be extracted. After we extracted the NDVI data from the product, we performed coordinate transformation into TM coordinates system of Korea, based on Tokyo datum, using MODIS reprojection tool which is provided by NASA. Then, we converted the digital number of NDVI stored as 1 byte unsigned type value into real NDVI value that should be stored as 8 byte float type value, using gain and offset values which can be acquired from MODIS header file.

A MODID NDVI data covers 1200 km x 1200 km on ground and two zones, h27 and h28, in MODIS coordinate zone covers south Korea. So, we set AOI in the two zones to cover entire south Korea and, then, made mosaic image to make NDVI data that covers entire south Korea. These preprocessings are operated using ERDAS Imagine software.

2.2 Weather Data

Weather data including temperature, duration of sunshine, relative humidity, wind speed are required to estimate evapotranspiration through complementary relationship. We acquired the data from 22 weather observatories located around Nakdong river area. We also estimated solar radiation of the area using observations at 6 observatories from 1999 to 2004.

3. ESTIMATION OF EVAPOTRANSPIRATION

Before we develop a method to estimate evapotranspiration from NDVI, we should have reference evapotranspiration data. Although the reference data should be directly and accurately observed, it's impossible in most case to directly observe the evapotranspiration in large area. So, we estimated evapotranspiration using complementary relationship.

While evapotranspiration at an area is computed through potential evapotranspiration in conventional estimation model, Morton(1978) developed a new approach which directly computes evapotranspiration from weather data.

Because Morton's model includes model parameters related temperature, humidity, radiation, its reliability is higher than conventional models.

$$E_a = 2E_p - E_{pp} \tag{1}$$

Where, E_a is actual evapotranspiration; E_p is potential evapotranspiration(mm/day) by Priestly-Taylor; E_{pp} is potential evapotranspiration(mm/day) by Penman.

$$E_p = 1.26\frac{\Delta}{\Delta + r}(R_n + M - G) \tag{2}$$

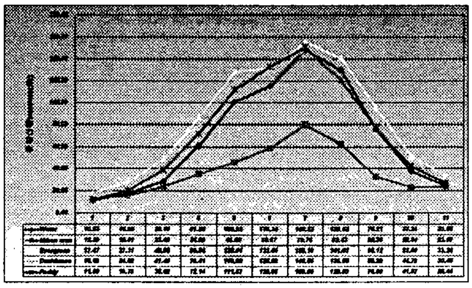
$$E_{pp} = \frac{\Delta}{\Delta + r}(R_n + M - G) + \frac{\Delta}{\Delta + r} f(u)(e_s - e_a) \tag{3}$$

$$M = 0.66L_n - 0.44R_n \tag{4}$$

$$G = C_r \cdot R_n \tag{5}$$

Where, R_n is net radiation(J/m2/d); M is diffusion of radiation(J/m2/d); G is soil heat flux(J/m2/d), Δ is the slope of the saturation vapour pressure curve, (hPa/° C); e_a is actual vapour pressure in air(hPa); L_n is long wave radiation(J/m2/d); C_r is the coefficient of soil heat flux.

Using complementary relationship equation, we estimated monthly evapotranspiration during 2001 and 2002 at five vegetation classes; water area, urban area, cultivated land, deciduous forest, and evergreen forest. Figure 1 shows the results.



(a) 2001

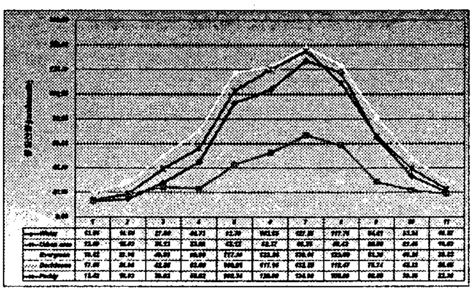


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Figure 1. Estimation of evapotranspiration using complementary relationship equation

4. VEGETATION INDICES AND CLASSIFICATION OF VEGETATION USING MODIS DATA

4.1 Monthly NDVI

MODIS vegetation indices products provided by NASA are derived at 16 day interval. Each cell value indicates the maximum NDVI value during 16 day interval.

To make monthly NDVI data, we grouped each NDVI data at 16day interval by month. Then, we made monthly NDVI data by taking maximum NDVI value for each cell of all NDVI data in a month. In fact, each month group includes two NDVI data except October that had only one NDVI data. By choosing maximum NDVI value at each cell, the atmospheric effects such as cloud, dust, etc. can be removed.

We collected two year MODIS NDVI data from 2001 to 2002. In winter time, NDVI value would not be correct because of snow in Korea. So, we excluded January, February, and December from monthly NDVI data production.

4.2 Vegetation Class from MODIS Data

To estimate evapotranspiration based on NDVI, first, we should group the area into several classes that have similar vegetation property. So, we can estimate the evapotranspiration according to the vegetation properties.

In this study, we classified our study area into 5 classes; water area, urban area, cultivated land, deciduous forest, and evergreen forest.

If we use just a monthly NDVI data, we can investigate but a monthly state of vegetation, not a long term state. So, we generated iNDVI(intergrated NDVI) data by integrating 18 monthly NDVI data from March to November for two years(2001 to 2002). And then, we made classification of vegetation using the iNDVI data. Figure 2 shows iNDVI data that we generated in this study.

We applied supervised classification in the classification of vegetation with iNDVI data. The reference data for the supervised classification was the Land Cover Map made by Ministry of Environment, Korea. But, in the Land Cover Map, we couldn't discriminate deciduous forest from evergreen forest.

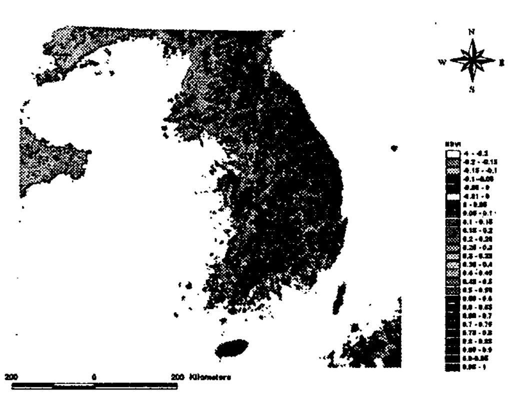


Figure 2. iNDVI data(2001~2002)

At first, we classified iNDVI data into 4 classes; water area, urban area, cultivated land, forest area using the reference map. To make classification between deciduous forest and evergreen forest, we produced iNDVI data for winter season. We used 6 monthly NDVI data(January, February, December in 2001 and 2002) to make the winter iNDVI data. Using the winter iNDVI data, we classified vegetation area and non vegetation area in winter season by applying supervised classification. We set 6 AOIs for the classification on the computer screen where the brightness is the highest. The vegetation area in winter means evergreen forest. Overlaying this evergreen forest data with previous 4 class data, we finally got the vegetation map with 5 classes; water area, urban area, cultivated land, deciduous forest, and evergreen forest. Figure 3 shows our vegetation class map.

Note that the classes of our vegetation map are classified just for the purpose of estimation of evapotranspiration. So, it may be different from general land cover map.

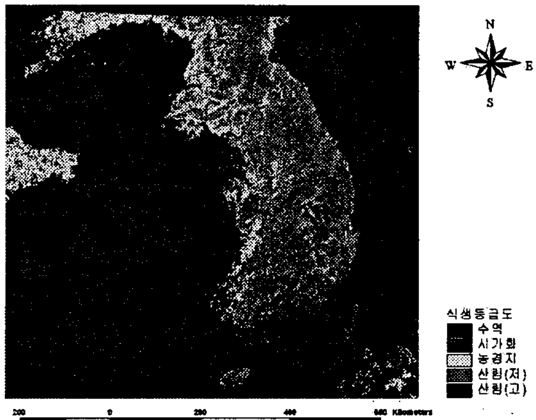


Figure 3. Vegetation classes (2001~2002)

5. ESTIMATION OF EVAPOTRANSPIRATION WITH MODIS NDVI AND TEMPERATURE

NDVI represents the local state of vegetation and evapotranspiration is affected by the state of vegetation. Also, evapotranspiration and NDVI are closely related with weather condition. So, we can suppose that evapotranspiration, NDVI and weather condition are closely related with each other. There are so many factors in weather condition. However, we attempt to use only temperature as a factor of weather condition because it can be easily acquired.

Through multi-regression analysis, we developed a model equation to estimate the evapotranspiration at Nakdong river area with NDVI and temperature data.

There is a correlation between the change of vegetation and the change of evapotranspiration . But, the phase of the correlation may be somewhat different according to the two vegetation period; the growth period and the defoliation period. So, the application of regression analysis should be divided into two periods according to the phase of vegetation to develop more accurate model than the simple model developed with entire vegetation period(Shin, 2004). We defined the growth period as March to August and the defoliation period as September and November and applied multi regression analysis to each period. Table 1 shows the result of our regression analysis.

Table 1. Regression Analysis

Vegetation	Period	Regression equation	R^2
Class2 (urban)	3-8	E=4.658+51.196NDVI+2.028Temp	0.863
	9-11	E=12.007+24.671NDVI+0.587Temp	0.718
Class3 (cultivated)	3-8	E=12.702-129.435NDVI+8.647Temp	0.846
	9-11	E=-10.413+37.916NDVI+2.942Temp	0.924
Class4 (deciduous)	3-8	E=-28.797+149.244NDVI+1.443Temp	0.903
	9-11	E=-67.947+144.869NDVI+1.799Temp	0.907
Class5 (evergreen)	3-8	E=-63.328+179.730NDVI+1.854Temp	0.894
	9-11	E=-94.466+148.767NDVI+2.979Temp	0.922

In table 1, the coefficient of determination (R^2) of each regression equation is fairly high and it means that the regression equation would be suitable. But, in the case of entire period at urban and growth period at cultivated land, the coefficient of determination is relatively lower.

In general, the state of vegetation in urban area would be inconsistent. In cultivated land, the planting time and the growth speed are various according to each plant in spring and the state of vegetation would be inconsistent in that period, too. These would be the reason why the coefficient of determination is relatively lower in entire period at urban area and growth period at cultivated land.

However, in fall, the growth of plants would be stopped and the state of vegetation at cultivated land would be more consistent than spring time. So, the coefficient of determination is higher than the growth period at cultivated land.

In case of deciduous forest and evergreen forest, the coefficients of determination are evenly high. This means the regression equation is generally suitable.

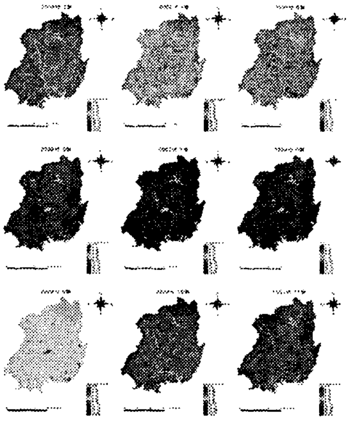
Figure 3 shows the distribution of evapotranspiration at Nakdong river area plotted with regression equation presented in table 1.

6. CONCLUSIONS AND FUTURE WORKS

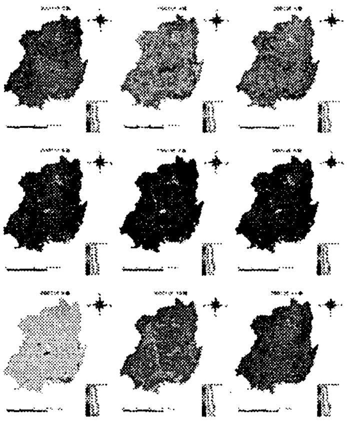
In this study, supposing that evapotranspiration, NDVI, and temperature are closely related to each other, we presented a method to estimate evapotranspiration in large area with NDVI from MODIS data and temperature data.

In practical operation, MODIS data and temperature data are available. So, our method would be available in practical operation.

We just estimated the distribution of evapotranspiration in large area. For the final analysis of droughts, we should estimate climatological water balance using the distribution of potential evaporation and precipitation. In near future, we will estimate the lack of water with climatological water balance and present a method to analyze the droughts in large area.



(a) 2001



(b) 2002

Figure 3. Distribution of evapotranspiration at Nakdong river area

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