Estimation of Monthly Evapotranspiration using NOAA/AVHRR Satellite Images

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Abstract: The purpose of this study is to estimate monthly evapotranspiration (ET) using normalized difference vegetation index (NDVI) obtained from NOAA/AVHRR data sets. Actual evapotranspiration was evaluated by the complementary relationship (Morton, 1978, Brutsaert and Stricker, 1979), and monthly NDVI was obtained by maximum value composite method from daily NDVI images in the Korean peninsula for the year 2001. The monthly actual ETs for each land cover were compared with the monthly NDVIs to determine relationships between actual ET and NDVI for each land cover category. There was a high correlation between monthly NDVI and monthly averaged actual ET. This study presents an alternative approach for land surface evapotranspiration based on remote sensing techniques.

Keywords: evapotranspiration, NDVI, NOAA/AVHRR

1. Introduction

Evapotranspiration (ET) is the process by which water is evaporated from wet surfaces and transpired by plants (Chow, 1984). There are many methods of estimating ET and potential ET such as soil-moisture sampling, lysimeter measurements, water balance, energy balance, groundwater fluctuations and ET equations, but it is very difficult to estimate ET by consideration of regional characteristics of topography or vegetation.

Most methods require various meteorological data and these equations are very complex. Also, these methods are not suitable for estimating of distributed ET.

Factors controlling ET from ground are air temperature, humidity, wind, radiation, soil-moisture and so on. These factors strongly influence the vegetation, and the vegetation influences the ET directly. Therefore, there is a high correlation between the vegetation and the ET. To grasp vegetation condition at any area, NDVI calculated from NOAA/AVHRR data is utilized.

The purpose of this study is to estimate monthly actual ET using high correlation between NDVI from NOAA/AVHRR data and ET

2. NDVI and land cover map

NDVI developed for estimating the state of the vegetation (Rouse et al., 1974), has been widely adopted and applied due to its effectiveness as a surrogate measure of biophysical parameters. NDVI can be represented as follow for application of NOAA/AVHRR data.

$$NDVI = (Ch.2-Ch.1)/(Ch.2+Ch.1) \qquad (1)$$

where Ch.1, 2 are the reflectance in the visible red (channel 1) and near infrared channel (channel 2) of NOAA/AVHRR, respectively. At the cloud covered areas, NDVI is underestimated as compared with non-cloud areas. Therefore, the maximum value composite (MVC) is calculated from a multi-temporal series of NDVI images. Also, imageries in the winter period are not suitable for obtaining ground surface information by reason of snow cover.

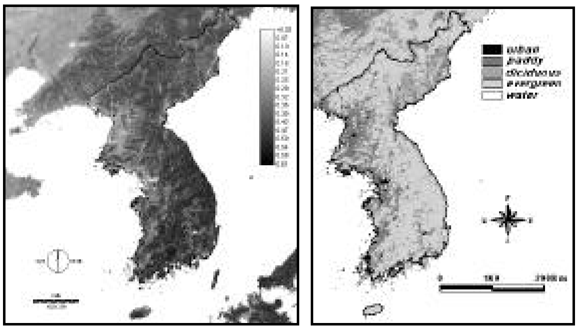
In this study, MVC values were calculated monthly from consecutive NDVI images with the exception of snowing season.

Also, iNDVI (integrated NDVI) can be used as representative NDVI within a given period of time.

$$iNDVI = \sum (NDVI_j \times d_j) / \sum d_j \qquad (2)$$

where $NDVI_j$ is j^{th} NDVI and d_j is observed day of $NDVI_j$.

Land cover map was derived from iNDVI using histogram classification method. This method may categorize vegetation area that takes similar ground characteristics into a land cover class. Land cover map can be used for estimating ET of each land cover classes.



(a) (b)

Fig. 1. a: iNDVI during the period March-December 2001
b: Land cover map from iNDVI

3. Actual ET from meteorological data

Morton (1978) suggested that actual ET can be estimated by the complementary relationship and it was represented by:

$$Ea = 2Ep - Epp \qquad (3)$$

where Ea is actual ET (mm/day), Ep is potential ET by Priestly-Taylor's method (mm/day) and Epp is potential ET by Penman's method (mm/day).

Since, daily meteorological data are necessary to use the complementary relationship, weather elements (e.g., temperature, humidity, wind velocity, sunshine time) are acquired from the 73 meteorological stations in Korea.

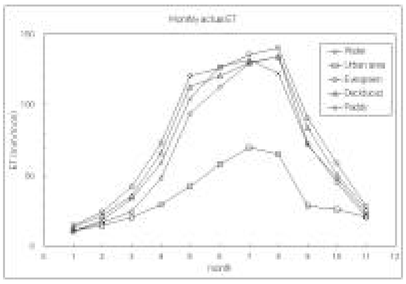


Fig. 2. Estimated actual ET for the Han River basin (2001)

4. Estimation of monthly ET using NDVI from NOAA/AVHRR data

Satellite-derived NDVI is very useful tool for the frequent monitoring of green vegetation cover. The state of vegetation has a correlation with meteorological condition, and meteorological condition also has high correlation with ET. Therefore, it can be considered that ET at a forest region such as the Korean peninsular is linearly proportional to the NDVI.

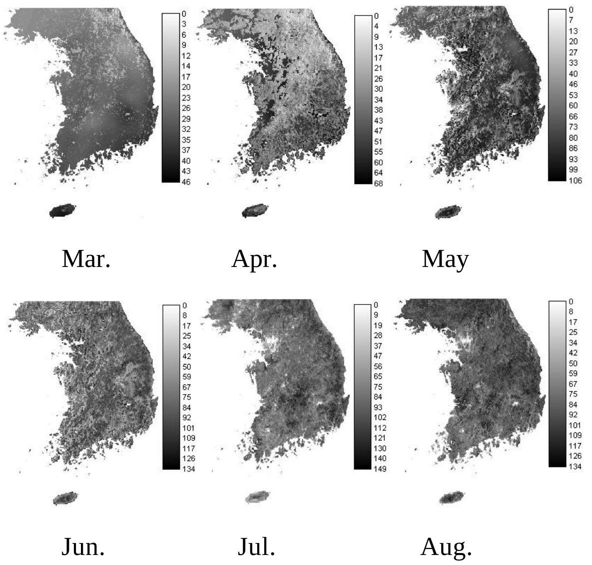
The histogram of NDVI reflects seasonal changes of vegetation very well. NDVI was divided into specific ranges and pixel number of specific ranges was regarded as parameter. Using this parameter, multiple regression analysis was performed on each land cover.

The results of this procedure may offer the method for estimating directly actual ET using NDVI at any point.

$$Ea = \frac{1}{P}\sum_{i=1}^{n} e_i p_i \qquad (4)$$

where e_i is a regression coefficient represented actual ET, p_i is pixel number of each specific range, n is the number of range, and P is total number of pixels. Regression equations, *Ea=aNDVI+b* type, of each land cover class were derived from multiple regression analysis. Using these regression equations,

The actual ET can be estimated simply using these regression equations with only one parameter, NDVI, at any points.



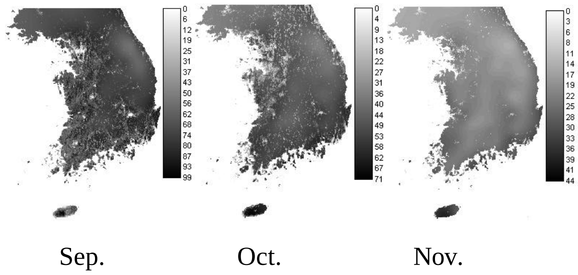


Fig. 3. Monthly ET (mm/day) obtained by NDVI (2001)

5. Conclusions

Developed method in this study is based on high correlation between NDVI from NOAA/AVHRR data and ET from meteorological data. Using this method, areal distribution data set of actual ET can be produced simply using NDVI calculated from NOAA/AVHRR data. This method is applicable to another countries on suitable calibration of relationships between NDVI and ET. This method makes possible to estimate ET of any areas where enough meteorological and hydrological data are unavailable.

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References

[1] Chow, V. T., 1984. Handbook of applied hydrology, McGRAW-HILL Inc..

[2] Morton, F. I., 1978, Estimating evapotranspiration from potential evaporation - practicality of an iconoclastic approach, *J. of Hydrol.*, 38: 1-32.

[3] Rouse, J. W., R. H. Haas, J. A. Schell and D. W. Deering, 1974. Monitoring vegetation system in the great plains with ERTS, *Proceedings, Third Earth Resources Technology Satellite-1 symposium*, Greenbelt, NASA SP-351, 3010-317.