Research on Estimation of Evapotranspiration using Ecological Map, MODIS NDVI and EVI

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ABSTRACT: The evapotranspiration is related with water and energy circulation, climate change, ecosystem productivity and also it is important process in water and nutrition of ecosystem. The evapotranspiration is closely related with ecosystem services that is defined all kind of benefits from ecosystem, however many studies focused on estimation of evapotranspiration in Korea. In this study, estimates the evapotranspiration using precipitation, plant available water index, potential evapotranspiration. In processing for plant available water index, used ecological map, MODIS(MODerate-resolution Imaging Spectroradiometer) NDVI(Normalized Difference Vegetation Indec) & EVI(Enhanced Vegetation Index) and computed 4 different methods and then conducted accuracy assessment using RMSE(Root Mean Square Error) from comparing with Penman-Monteith Equation. Result of RMSE range of daily evapotranspiration are from 1.3mm to 1.54mm and final result represented Green Water Flux for connecting the ecosystem services. Finally land cover classification using ecological map is the most accurate method for estimation of evapotranspiration.

1. Introduction

Ecosystem services are defined as all benefits from ecosystem to human(MEA, 2005). In the Forest Korea Service, economic value of forest ecosystem services valuated 6,800 million dollars in 2008(KFS, 2010). And also the TEEB(The Economics of Ecosystems and Biodiversity) assessed value of tropical forest as average $6,120/ha, maximum $16,362/ha(EC, 2008). However, these days 15 of 24 ecosystems are decreasing their original functions and this will affect negatively to human being(Canton J., 2006). Because of this effect, most research is studied on prediction changes of ecosystem services(Dominati E. et al., 2010). Trends of the study are emphasizing prediction or changing of ecosystem services but research with respect to quantified assessment of ecosystem services is lacking.

In this study, we conducted quantitative evaluation of ecosystem services using evapotranspiration as one factor. Evapotranspiration(ET) is defined as the sum of evaporation and plant transpiration from the Earth's land surface to atmosphere(Burba G., 2008). The evapotranspiration has important role in water and energy circulation and also it can be used decision making factor for climate change and ecosystem productivity. To assess ecosystem activity, hydrological flux is used and it consists of green & blue water flux especially intensity of each pixel of green water flux means evapotranspiration and degree of ecosystem services (Krishnaswamy, et al., 2009). In this research, we used climatic information by Korea Meteorological Administration(KMA) for estimation of evapotranspiration of the GangWon province, Republic of Korea. We estimated quantitatively forest ecosystem services using evapotranspiration that carried out from climatic information, Ecological Map, MODIS NDVI & EVI(LP DAAC FTP, 2010). Finally, we evaluated quantitative assessment as RMSE between 4 different results.

2. Methodology

2.1 Study Flow

First stage is data collection. This stage acquires dataset: climatic information, MODIS NDVI & EVI. Secondly, data arrangement stage conducts computation of evapotranspiration using acquired dataset. Final stage carries out green water flux through estimated evapotranspiration. In green water flux, dark green pixel means more active area so it has more energy from the ecosystem services. In contrast, light pixel means lower energy from ecosystem services than dark pixel(Krishnaswamy., 2009).

To calculate annual precipitation, we used Annual Report of Automatic Weather Station Data by Korea Meteorological Administration(KMA, 2009). Annual precipitation is conducted using kriging method because Automatic Weather Station collect point form. To arrange plant available water index, we used Ecological Map by Ministry of Environment(MOE, 2010) and MODIS NDVI & EVI. This index basically from 0 to 2.0 and we divided 2 categories: discrete and continuous. Discrete index used Ecological Map and NDVI(Shin, S. C. et al., 1996) through land cover classification and allocated as 0.1(urban area, water), 0.5(agriculture field), 1.0(mixed forest), 2.0(pure forest). Continuous index used average NDVI and EVI of 23 MODIS images. To compute potential evapotranspiration, we used PETP model equation as follows equation 1.(Liang L. et al., 2010).

$$\mathrm{PET} = \frac{8.5\mathrm{P}}{\ln(30\mathrm{P}) - \ln\mathrm{K}}$$

equation 1. PETP model equation(Liang L. ea al., 2010)
where, PET(potential evapotranspiration, mm), P(precipitation, mm), K(constant, 4.259mm/month)

Finally, we applied equation 2. by Zhang's research for computation evapotranspiration.

$$\mathrm{ET} = \left[\frac{1 + \mathrm{w}\frac{\mathrm{E}_0}{\mathrm{P}}}{1 + \mathrm{w}\frac{\mathrm{E}_0}{\mathrm{P}} + \left(\frac{\mathrm{E}_0}{\mathrm{P}}\right)^{-1}}\right]\mathrm{P}$$

equation 2. evapotranspiration equation(Zhang L. et al., 2001)
where, ET(evapotranspiration, mm), w(plant available water index), P(precipitation, mm), E_0(potential evapotranspiration, mm)

2.2 Accuracy Assessment

As abovementioned, we calculated evapotranspiration 4 plant available water indices so we compared with Penman-Monteith evapotranspiration equation(Jung, J. H. et al, 2007). For accuracy analysis, we used RMSE(Root Mean Square Error) as following table 1.

table 1. Accuracy Assessment by 4 Plant Available Water Indices

Category	Discrete		Continuous	
Dateset	Ecological Map	NDVI	MODIS NDVI	MODIS EVI
RMSE(mm)	1.305	1.439	1.540	1.368

3. Results & Conclusions

In this research, we identified surveying-based Ecological Map is more accurate than using MOIDS NDVI & EVI through accuracy assessment. We will apply other factors(not evapotranspiration), satellite images and wide area in the future, it will suggest more reasonable result. This research will connect other surveying based dataset for enhancement of reliability. If we will select other factors like evapotranspiration and combine all together, it can be applied in basic quantitative information for national development and preliminary feasibility study of development projects.

References

Burba G., 2010, Evapotranspiration, The Encylopedia of Earth, http://www.eoearth.org/article/Evapotranspiration

Canton J., 2006, The Extreme Future : The Top Trends that will Reshape the World for the next 5. 10. and 20 years, Dutton Adult.

Dominati E., Patterson M., Mackay A., 2010, A Framework for Classifying and Quantifying the Natural Capital and Ecosystem Services of Soils, Ecological Economics, Vol. 69, No. 9, pp. 1858-1868.

European Communities(EC), 2008, The Economics of Ecosystems & Biodiversity(TEEB) : An interim report.

Jung, J. H., Yoon, Y. N., 2007, Water Resource Design Practice, Goomibook, Korea, pp. 203-210.

Korea Meteorological Administration (KMA), 2009, Annual Report of Automatic Weather Station Data.

Korea Forest Service (KFS), 2010, Economic Value of Biodiversity and Forest Ecosystem Services in Korea, http://www.forest.go.kr

Krishnaswamy J., Bawa K.S., Ganeshaiah K.N., Kiran M.C., 2009, Quantifying and Mapping Biodiversity and Ecosystem Services : Utility of a multi-season NDVI based Mahalanobis Distance Surrogate, Remote Sensing of Environment, 113, 857 - 867.

Land Processes Distributed Active Archive Center(LP DAAC) FTP, 2010, United Stated Geological Survey (USGS), ftp://e4ftl01.cr.usgs.gov/MOLT/

Liang L., Peng S., Sun J., Chen L., Cao Y., 2010, Estimation of annual evapotranspiration at regional scale based on the effect of moisture on soil respiration, Ecological Modeling, 221, pp. 2268-2674.

Millennium Ecosystem Assessment (MEA), 2005, Ecosystems and human well-being: Synthesis, www.millenniumassessment.org

Ministry of Environment (MOE), Republic of Korea, 2010, Environmental Geographic Information System(EGIS), http://egis.me.go.kr/egis

Sherrouse B.C., Clement J.M., Semmens D.J., 2010, A GIS application for assessing, mapping, and quantifying the social values of ecosystem services, Applied Geography, online available.

Shin, S. C., Choi, Y. S., Ahn, K. W., 1996, Land Cover Classification using NDVI in Korean Peninsula, Korean Society of Civil Engineers (KSCE) Journal of Civil Engineering, 16(2), pp. 139- 146.

Zhang L., Dawes W.R., Walker G.R., 2001, Response of mean annual evapotranspiration to vegetation changed at catchment scale, Water Resources Research, 37(3), pp. 701-708.