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Utility of METRIC model for estimating actual monthly evapotranspiration of Vanak Basin using MODIS sensor images

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Abstract

Background and Objective Nowadays, in order to logical use of water for agricultural products, an accurate understanding of the evapotranspiration process is needed. Evapotranspiration is one of the most significant components of water balance hence it is a key variable for the optimal management of water resources. In this paper, we aim to the analysis of the temporal and spatial distribution of actual evapotranspiration (AET) at monthly time scale using the METRIC approach, driven by MODIS satellite observations over the Vanak Basin and check the accuracy of the METRIC results with (SEBAL, Surface Energy Balance Algorithm for Land).

Materials and Methods There are many methods for correct estimation of point evapotranspiration, such as weighing lysimeters, the Bowen ratio, and the eddy correlation methods. The weakness of the mentioned methods is that these techniques only provide evapotranspiration for a specific site and they can't estimate regional evaporation. The METRIC model was developed by Allen et al., (2007) based on the well-known SEBAL model (Bastiaanssen, 1998). METRIC model is a remote sensing-based method that estimates actual evapotranspiration as a residual of the surface energy balance. Herein, the spatial and temporal distribution of actual evapotranspiration of the Vanak Basin from April to November 2013–2014 was estimated using the METRIC model and using MODIS satellite data, the feasibility of using METRIC was investigated. Vanak Basin is located in the southeastern part of the Northern Karoon Basin. It is geographically placed between Chaharmahal va Bakhtiari and Isfahan provinces. 60 MODIS products of Leaf Area Index (MOD15A2), land surface temperature LST (MOD11A2) and surface reflectance (MOD09A1) in 8-day time step were extracted. The mentioned images were downloaded from the USGS website and the images were re-projected from the Sinusoidal projection to UTM projection. The scale factor for LAI, LST and Surface Reflectance were 0.1,0,02 and 0.0001, respectively. Estimation of ET with the METRIC model begins with energy balance. Data sets such as MODIS observations and weather data from the stations in and near the Vanak Basin are used to calculate instantaneous surface energy fluxes including net radiation flux (Rn), soil heat flux (G) and sensible heat flux (H) in the processing technique. ET at the instant of the satellite image is computed for each pixel by dividing LE values by latent heat of vaporization and density of water.

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Results and Discussion Throughout this research, the upper limit of the variation of AET showed a gradual increase from April to July in both 2013 and 2014. According to the results, the maximum amount of actual evapotranspiration in 2013 and 2014 for the July month was obtained 244 and 263 mm per month respectively. In general, the results of this paper will help us better understand the variations of regional AET. Comparison of the spatial distributions of AET, LAI and LST in the study area showed that the spatial distribution of AET was affected by two factors, LAI and LST, that Pearson correlation test was used to assess the relationship between two variables LAI and LST with actual evapotranspiration. Based on the results, the regions which had dense vegetation and low land surface temperatures had high AET rates, while in the regions with sparse vegetation and high land surface temperatures, the AET rate was low. The results showed that the trend of changes in the mean monthly temperature is in line with the monthly actual evapotranspiration; the same trend was observed in the case of albedo and net radiation flux. It should be noted that the absence of ground measurements for comparing them to the modelled AET amounts was a potential limitation of the current study. However, our approach of evaluating AET estimates derived from the METRIC model with the AET estimates derived from SEBAL model is a widely used (as standard approach) approach to tackle such limitations. In the second step of the analysis, this paper compares the estimated monthly AET using the equations of the METRIC versus the SEBAL, for the Vanak Basin in 2014. The outcome of the SEBAL model was used as a reference to compare the results obtained from the METRIC model. The statistical analysis was performed to determine the differences between monthly AET derived from METRIC vs. monthly AET derived from SEBAL. The Nash–Sutcliffe model efficiency coefficient (NSE), Coefficient of Determination (R^2) and Mean absolute error (MAE) are used, that the results showed high R2 values and NS coefficients and low MAE values indicate that METRIC is closely related to SEBAL Model in the most of the months. The monthly AET values estimated by the METRIC model versus the monthly AET values estimated from the SEBAL model were evaluated and compared for the Vanak Basin from April to November 2014. Based on the overall results the scatter of estimations is in an acceptable range. In 2014, there was good agreement between METRIC and SEBAL models (R^2=0.96–0.99, NSE = 0.93–0.99 and MAE = 1.3–7.53 mm month−1). In 2014, other results indicated that in both models, the upper limit of the variation of AET showed a gradual increase from April to July.

Conclusion According to the results, the regions with high leaf area index (LAI) and low land surface temperature have more evapotranspiration than other regions with low leaf area index and high land surface temperature. The trend of the time series of LAI index and evapotranspiration in this study was consistent with the trend of changes in the parameters mentioned in the study, which was described by Reyes-González et al (2019) that use of the METRIC model in Dacota.

Keywords: Actual evapotranspiration, Spatial-temporal variation, Remote sensing, Energy balance, Vanak Basin