ANALYSIS OF SATELLITE BASED EVAPOTRANSPIRATION FOR SELECTED CLIMATE STATIONS OF BANGLADESH

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ABSTRACT

Evapotranspiration (ET) is one of the important components of hydrological cycle. An accurate estimation of ET is of vital importance in planning, designing and operation of irrigation and water resources system. However it is difficult to measure ET directly. In this study, the usefulness of evapotranspiration product from the Moderate Resolution Imaging Spectroradiometer (MODIS) was assessed. For this purpose, several meteorological data of temperature, humidity, sunshine hour, wind speed of Rajshahi, Bogra and Rangpur climate stations were collected from Bangladesh Meteorological Department (BMD) to estimate evapotranspiration. Daily reference evapotranspiration (ET_0) was calculated by using FAO Penman-Monteith (P-M) method then converted into eight days cumulative ET_0. MODIS evaptranspiration product (MOD16) was collected from the Oak Ridge National Laboratory. Then the Eight days cumulative ET from the P-M method was compared with the eight days MOD16 products over a period 10 years from 2001 to 2010. This comparison shows that the MODIS ET values match well with the actual ET values throughout the year except for Kharif-I (March to June) season. This study also demonstrates that MODIS Enhanced Vegetation Index (EVI) can be used as a useful predictor of evapotranspiration. From the results it is found that EVI values are very small (around 0.2 to 0.3) in Kharif-I (March to June) season, which indicates very little vegetation. So it is noticed that, excluding Kharif-I (March to June) season, comparison shows a significant relation between Penman ET and Satellite ET.

Keywords: Evapotranspiration; Penman-Monteith method; Enhanced Vegetation Index (EVI); Moderate Resolution Imaging Spectroradiometer (MODIS); MOD16

INTRODUCTION

Apart from precipitation, the most significant component of the hydrologic budget is evapotranspiration. Evapotranspiration varies regionally and seasonally according to ambient environmental conditions, such as climate condition, land cover, land use, soil moisture, and available radiation etc. Because of this variability, research for integrate water resources modelling, dynamic crop-weather modelling and drought monitoring, a thorough understanding of the evapotranspiration process and knowledge about the evapotranspiration is needed. As precipitation falls and soaks into the soil, a plant absorbs it and then transpires it through its leaves, stem, flowers, and/or roots. When this is combined with the evaporation of moisture that was not directly absorbed by the soil, a significant amount of water vapor is returned to the atmosphere. Through evapotranspiration and the hydrologic cycle, forests or other heavily wooded areas typically reduce a location’s water yield. Knowledge of evapotranspiration is important for irrigation scheduling but it is also an important factor for other land use applications such as septic tank drain fields, water shed water budgeting, and climate and weather models. ET can be used as a historical tool but usually it is predicted or used in a forecast to help irrigators optimize irrigation.

Evapotranspiration calculations based on the remote sensing data have been developed rapidly for the last 20 years, and several methods have been adopted by different research groups and used in related study area successfully. By far, we got no information on any undertaken research on MODIS product (MOD16) in Bangladesh yet. So in this study we tried to make comparison between this MODIS product (MODIS ET) and actual ET so as to determine the appropriateness of using this MODIS product. The great advantage of satellite based evapotranspiration is that where there is no climate stations, satellite image gives us evapotranspiration data of this place. Satellite image gives continuous data of any place and it is low cost and easily accessible.

Objectives of the Study

The main objective is to analyze the evapotranspirtaion for selected climate stations of Bangladesh through combination of remotely sensing and meteorological observations. The specific objectives are given below:

- To calculate the evapotranspiration from the climate data for selected climate stations of Bangladesh using Penman-Monteith method.
- To extract the evapotranspiration data from the MODIS satellite for the same climate stations.
- To compare the evapotranspirations from Penman-Monteith method and satellite based method.
- To assess the possibility to improve the satellite based evapotranspiration estimation.

Study Area

The study area is the divisional climate stations of Bangladesh. Rajshahi, Bogra, Rangpur are the climate stations under this study area. Latitude, Longitude and elevation above mean sea level of each station are given in the Table 1.

Table 1: Latitude, Longitude, and Elevation of the selected study area

Station Name	Latitude	Longitude	Elevation (Above mean sea level)
Rajshahi	24°22'N	88°40'E	23m
Bogra	24°51'N	89°22'E	26m
Rangpur	25°42'N	89°22'E	36m

METHODOLOGY AND DATA

Meteorological data of selected climate stations were collected from Bangladesh Meteorological Department (BMD). Daily data of the following variables are collected from BMD for the period of 2001 to 2010: i) Minimum Temperature, ii) Maximum Temperature, iii) Relative Humidity, iv) Sunshine hours, v) Incoming Solar Radiation, vi) Wind Speed, and vii) Wind Direction

MODIS satellite images acquired by TERRA instrument is used. For each climate stations evapotranspiration data has been downloaded from the Oak Ridge National Laboratory (ORNL) during the periods of 2001 to 2010. The resolution of the satellite data is 1 km. For the validation purpose Enhance Vegetation Indices (EVI) data also download from the Oak Ridge National Laboratory (ORNL) during the same periods of 2001 to 2010.

Meteorological Data Processing

The FAO Penman-Monteith method is maintained as the sole standard method for the computation of ET_o from meteorological data. Equation [1] is used for calculating ET_o from meteorological data.

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + .34u_2)} \quad (1)$$

Where

$ET_{o=}$ reference evapotranspiration [mm day^{-1}], R_n =net radiation at the crop surface [MJ m^{-2} day^{-1}], G =soil heat flux density [MJ m^{-2} day^{-1}], T =mean daily air temperature at 2 m height [°C], u_2 =wind speed at 2 m height [m s^{-1}], e_s =saturation vapour pressure [kPa], $e_{a=}$ actual vapour pressure [kPa], e_s -e_a =saturation vapour pressure deficit [kPa], D =slope vapour pressure curve [kPa °C^{-1}] g=psychrometric constant [kPa °C^{-1}]

RESULTS AND DISCUSSIONS

The focus of this study is on the comparison of satellite (MODIS) and actual (Penman-Monteith) ET. For this the time series of actual and satellite ET for Rajshahi station has been plotted during periods of 2001 to 2010 [Fig. 1]. As MODIS satellite provides ET per 8 day so the daily penman ET has been converted into 8 day basis.

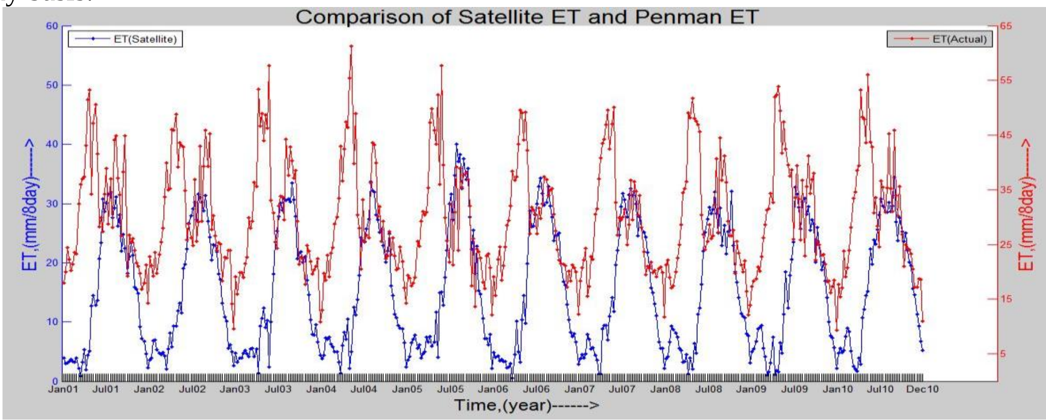
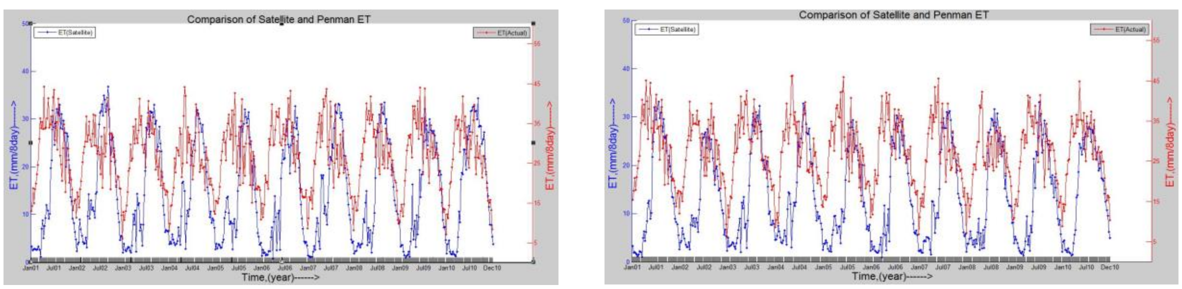


Fig. 1: Comparison of satellite and actual ET of Rajshahi station

From the time series plot it is observed that MODIS ET always lowers than the Penman (Actual) ET [Fig. 1]. At the beginning of the year MODIS gives very low ET when actual ET is high.

In this study the time series of satellite and actual ET of Bogra and Rangpur stations has been also plotted to compare with each other throughout the year of that area. It is noticed that Bogra and Rangpur stations also follows similar pattern of comparison [Fig.2].



Bogra Rangpur

Fig. 2: Comparison of satellite and actual ET

Comparison of Satellite and Actual ET in Kharif-II Season

As the whole cycle does not match, it has been tried to find out the comparison season by season. As far as it is understand that the study area may be cultivated with one crop and it was Kharif-II (July to October). In the Kharif-II (July to October) season, comparison gives very good correlation. In this season actual ET gives very close value with satellite ET. When green vegetation present in the field they provide good correlation than the other period. It is observed that correlation between satellite and actual ET is 0.138 in the Kharif-II season [Fig. 3]. Also the observed root mean square error is 4.37 mm/8day. Other stations i.e Bogra, Rangpur also gives similar pattern of result.

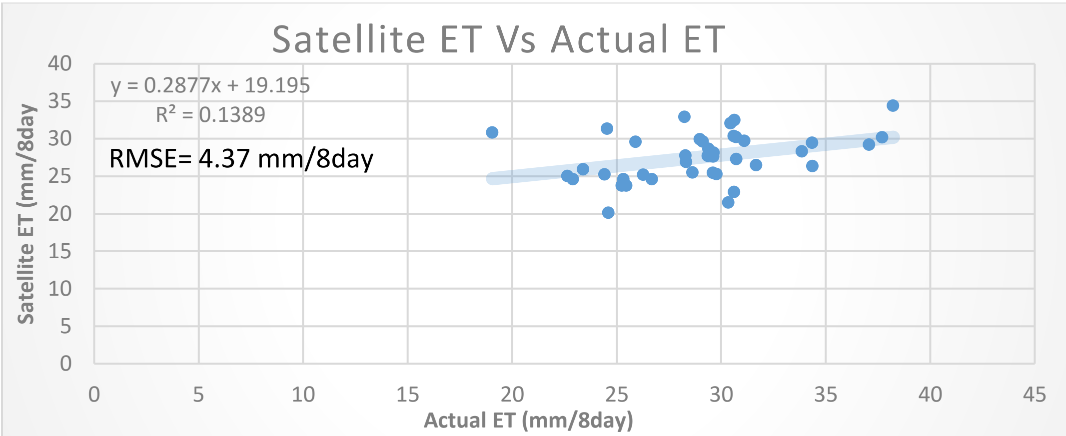


Fig. 3: Satellite ET Vs Actual ET in Kharif-II Season for Rajshahi station

Satellite and Actual (Penman-Monteith) ET Improvement

Three types of rice are grown in Bangladesh. Aus, Aman, Boro. Aus is grown in Kharif-I season (March to June) and it is grown in very small area in Bangladesh nowadays and are not irrigated. From the results it is found that EVI values are very small (around 0.2 to 0.3) in that period which indicates very little vegetation. So probably in that area no Aus crop is cultivated. So excluding Kharif-I period it is observed a notable increase in R^2 between Penman ET and Satellite ET.

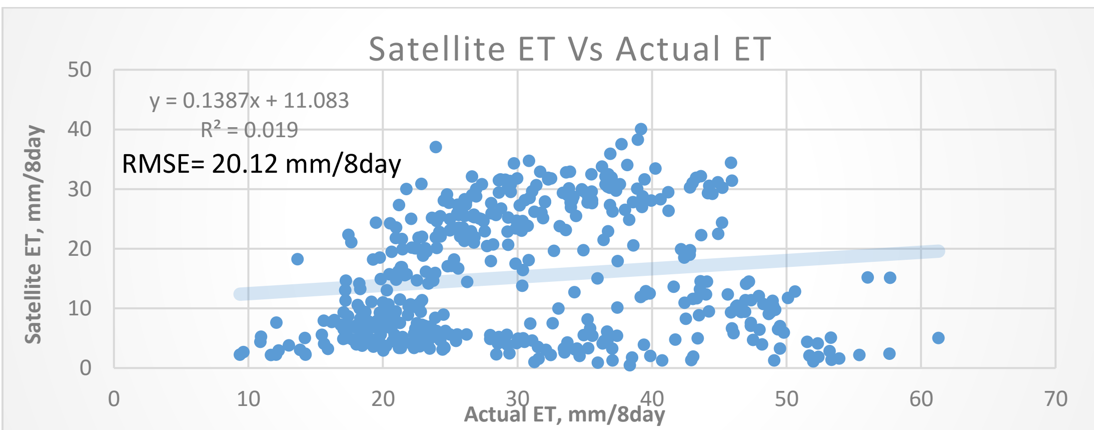


Fig. 4: Regression of Actual and satellite ET (including all season) for Rajshahi station

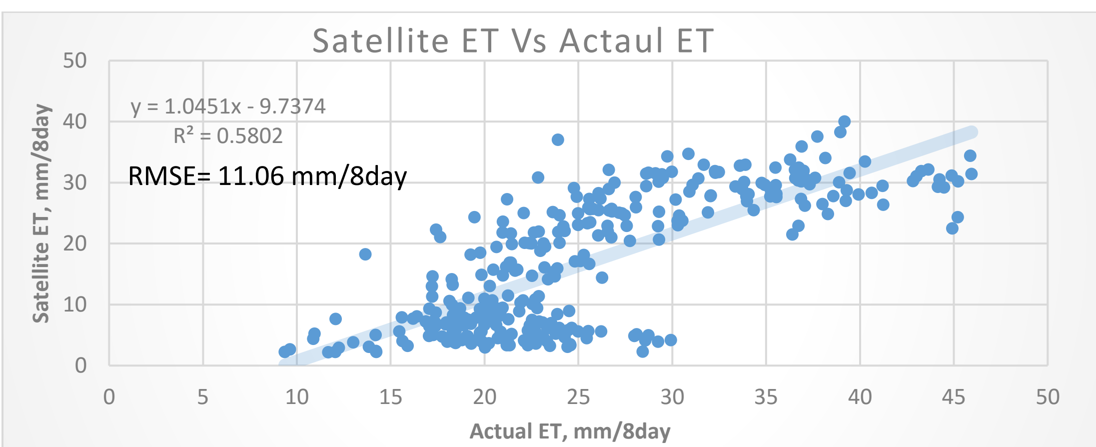


Fig. 5: Regression of Actual and satellite ET (Excluding Kharif-I season) for Rajshahi station

From the regression analysis between satellite and actual ET including Kharif-I season it has been observed very poor correlation (R^2 value is 0.019) [Fig. 4]. But excluding Kharif-I period it has been observed a notable increase in R^2 between satellite and actual ET [Fig. 5]. After excluding Kharif-I season R^2 value is 0.58. Here only Rajshahi stations result have been shown but Bogra and Rangpur stations also follows similar pattern.

Estimation of Penman ET from EVI

Kharif crops are grown in the spring or summer season and harvested in late summer or in early winter. Kharif season is divided into Kharif-I (March to June) and Kharif-II (July to October). Since the EVI values are very small (around 0.2 to 0.3) in that period which indicates very little vegetation. As the comparison does not perfect match, it has been tried another procedure, which is to estimate the penman ET by using EVI. There is a good correlation between penman ET and satellite ET (excluding Kharif-I season), which indicates that EVI value can be used to calculate penman ET [Fig. 6].

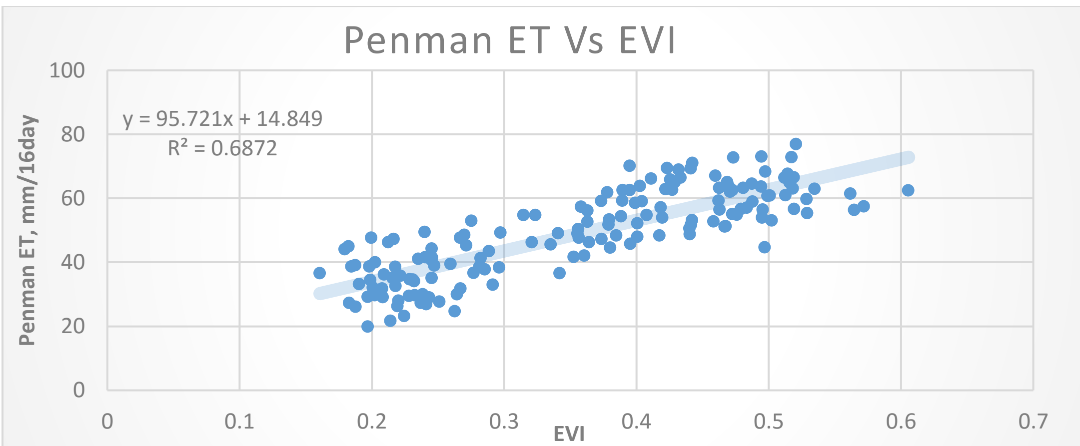


Fig. 6: Estimation of Penman ET from EVI (Excluding Kharif-I season)

CONCLUSIONS AND RECOMMENDATIONS

The main objective of this study was to assess the performance of MODIS ET product for estimating Penman ET for the agricultural areas of Bangladesh. To accomplish this objective, first actual ET was calculated by Penman-Monteith method from some selected stations and then satellite ET was obtained from the same climate stations. After comparing calculated actual ET with satellite ET, it is noticed that there are slightly shifting between the patterns of these two ET's. It is also noticed that actual ET is always higher than satellite ET, since it is not found enough information on crop pattern of the selected areas or due to the limitation of MODIS ET or Penman ET.

From the results it is found that EVI values are very small (around 0.2 to 0.3) in that period which indicates very little vegetation. So probably in that area no Aus crop is cultivated. It is noticed that excluding Kharif-I period there is a notable increase in R^2 between Penman ET and Satellite ET. As the comparison does not show perfect match, it has been tried another alternative procedure, which is to estimate the penman ET by using EVI.

The results showed that satellite ET does not perfectly match with the Penman ET. This can be due to the limitation of MODIS ET algorithm. Moreover Penman method also has some limitation. This method does not incorporate other stresses such as moisture stress, so slight mismatch is expected. Therefore further study is necessary to estimate actual ET by field experiment. In this study the performance of MODIS ET was evaluated for three stations. Future study is necessary to evaluate the applicability of MODIS ET for other areas and for other land use type of Bangladesh. This study shows that EVI can be used to estimate Penman ET. However further validation is necessary to determine whether Penman ET can be computed from EVI for other areas of Bangladesh

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