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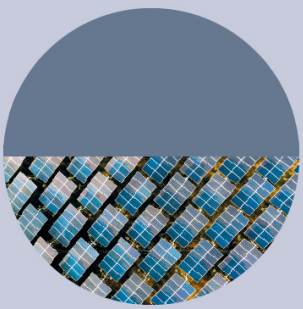

An evaluation of MODIS global evapotranspiration product (MOD16A2) as terrestrial evapotranspiration in East Java - Indonesia

A Faisol[1]*, Indarto[2], E Novita[2],and Budiyono[3]
[1]Faculty of Agricultural Technology – Papua University, JlnGunung Salju Amban – Manokwari – West Papua - Indonesia
[2] Faculty of Agricultural Technology – Jember University, Jln Kalimantan No 37 – Jember – East Java – Indonesia
[3] Faculty of Agriculture – Papua University, JlnGunung Salju Amban – Manokwari – West Papua - Indonesia

*arif.unipa@gmail.com

Abstract.MODIS global evapotranspiration product (MOD16A2) was used widely in the world as terrestrial evapotranspiration. This research aimed to evaluate the performance of MODIS global evapotranspiration products as terrestrial evapotranspiration in East Java – Indonesia. A total of 5 climatological station data and 30 scenes of MODIS global evapotranspiration image recording 2015 – 2018 were used for analysis. Research shows that MODIS global evapotranspiration overestimates compared with climate data analysis with a lower deviation. Generally,MODIS global evapotranspiration can estimate evapotranspiration with 75% accuracy compared with climate data analysis. Besides MODIS global evapotranspiration in East Java has mean error (ME) 0.64 mm/day, mean absolute error (MAE) 0.92 mm/day, root mean square error (RMSE) 1.10 mm/day, relative bias (RBIAS) 0.25, mean bias factor (MBIAS) 1.04, and correlation coefficient (CC) 0.25.

1. Introduction

Evapotranspiration is one of the main parameters in agriculture. Evapotranspiration have been used on water management in irrigation area [1][2][3][4], monitoring agricultural droughts [5][6][7][8][9], and crop yield prediction [10][11][12]. Evapotranspiration (ET) is the amount of water released to the atmosphere from ground surfaces. It intercepts canopy precipitation through evaporation and plant transpiration. Traditionally, evapotranspiration was analyzed using one of 3 methods: (1)measurement, (2) pan evaporation, and (3) climate data analysis [13]. These methods provide a point estimation of evapotranspiration, so it cannot be used to estimateevapotranspiration ina large area.Measurementand pan evaporation methods are suitable to estimates evapotranspiration at field-scale or an area less than 10 hectares[13].Climate data analysis can be use to estimates evapotranspiration atan area less than 5000 km^2 or radius less than40 km from climatology station [14].

Installing the evapotranspiration system and pan evaporation to cover large areas is costly. Several institutions in the world provided evapotranspiration data based on MODIS global evapotranspiration product including National Aeronautics Space Administration (NASA) [15], European Space Agency (ESA) [15], U.S Geological Survey (USGS) [16], and Department of Civil Engineering – Indian Institute of Science [17].Several studies showed that the MODIS global evapotranspiration product can estimate evapotranspiration with reasonable accuracy[18][19][20][21][22]. Besides, research conducted by Abiodun et al shows that the deviation of MODIS global evapotranspiration is 20% compared with observed evapotranspiration in Australia[23]. Furthermore,Obiodun et al report that evapotranspiration data derived from MODIS global evapotranspiration hasa difference of less than 6% compared with the SWAT hydrological model at catchment scale[24].

Based on the above condition, this study evaluates the MODIS global terrestrial evapotranspiration product to estimate evapotranspiration in East Java – Indonesia.

2. Methods

This research was conducted in East Java – Indonesia. Generally the main stages of this research:

1. Data inventory
   This stage aims to collect the MODIS global evapotranspiration product (MOD16A2) for the East Java area as many as 30 scene recordings 2015 – 2018 and climate data were obtained from a meteorological station located at Banyuwangi, Pasuruan, Sidoarjo,Malang, and Nganjuk.
2. Evapotranspiration information extraction
   The purpose of this stage is to extract evapotranspiration information from MOD16A2. The evapotranspiration information extraction process is done by using the HEG Tool released by NASA.
3. Evaluation ofthe MODIS global evapotranspiration
   This stage aimed to compared evapotranspiration information that derived from MODIS global evapotranspiration (MOD16A2) and climate data analysis using 6 (six) statistical parameters including mean error (ME), root mean square error (RMSE), correlation coefficient (CC), relative bias (RBIAS), and mean bias factor (MBIAS) with the following equations:

$$CC = \frac{\frac{1}{n}\sum_{i=1}^{n}(y-\overline{y})(x-\overline{x})}{(S_y)(S_x)} \quad (1)$$

$$M = \frac{1}{n}\sum_{i=1}^{n}(y-x) \quad (2)$$

$$M = \frac{1}{n}\sum_{i=1}^{n}|y-x| \quad (3)$$

$$R = \frac{\sum_{i=1}^{n}(y-x)}{\sum_{i=1}^{n}x} \quad (4)$$

$$M = \frac{\sum_{i=1}^{n}x}{\sum_{i=1}^{n}y} \quad (5)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y-x)^2} \quad (6)$$

Where CC is correlation coefficient, ME mean error (mm.day^{-1}), RB relative bias, MBF mean bias factor, RMSE root mean square error, yi satellite evapotranspiration estimate (mm.day^{-1}), $\overline{y}$ averaged satellite evapotranspiration (mm.day^{-1}), xi climate data processing evapotranspiration (mm.day^{-1}), $\overline{x}$ averaged climate data processing evapotranspiration (mm.day^{-1}), SD_{yi}standard deviation of satellite evapotranspiration (mm.day^{-1}), SD_{xi} standard deviation of climate data processing evapotranspiration (mm.day^{-1}), and n amount of data. The prefect value of correlation coefficient (CC) = 1, mean error (ME) = 0, relative bias (RB) = 0, mean bias factor (MBF) = 1, and root mean square error (RMSE) = 0 [25].

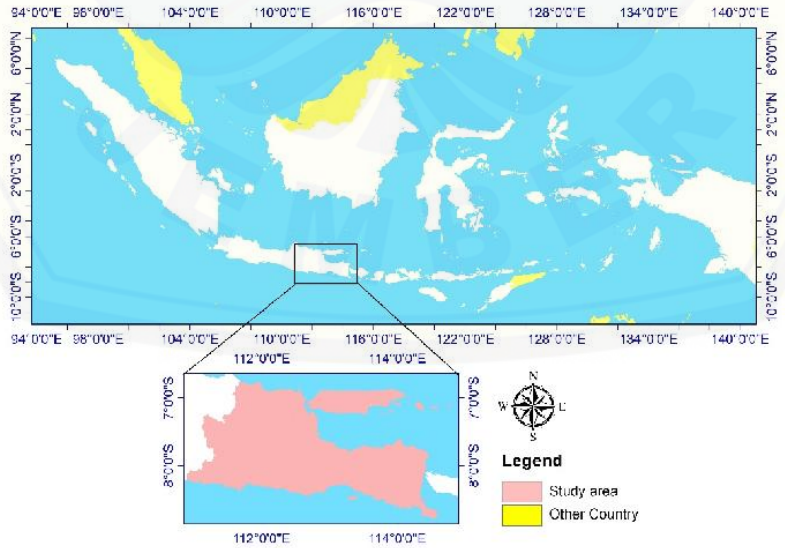

Figure 1 Study area

3. Results and Discussion

Generally, an evapotranspirationthat generated fromMODIS global evapotranspiration product (MOD16A2) ishigher than climate data analysis. The spatial distribution of evapotranspiration inthe study area base on MODIS global evapotranspiration is presented infigure 3 through figure 5. A comparison ofevapotranspiration that derived from MODIS global evapotranspiration and climate data analysis is shown in figure 6 to figure 10.

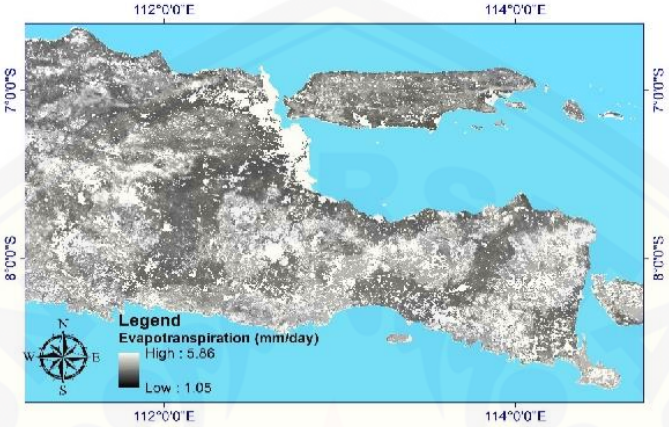

Figure 2. Spatial distribution of evapotranspiration in East Java based on MODIS global evapotranspiration product on 9 May 2015

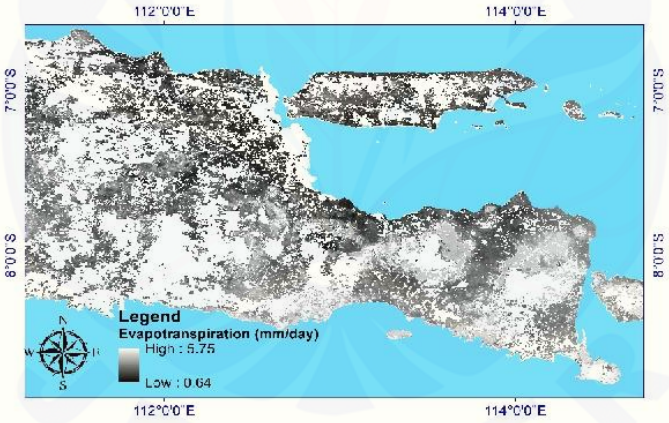

Figure 3. Spatial distribution of evapotranspiration in East Java based onMODIS global evapotranspiration product on 10September 2016

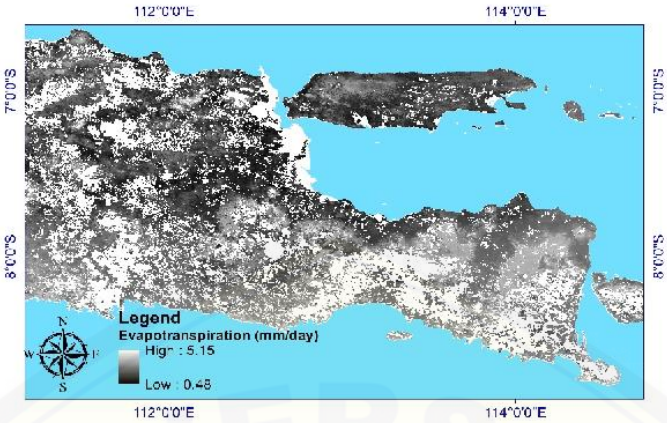

Figure 4. Spatial distribution of evapotranspiration in East Java based on MODIS global evapotranspiration product on 11August 2017

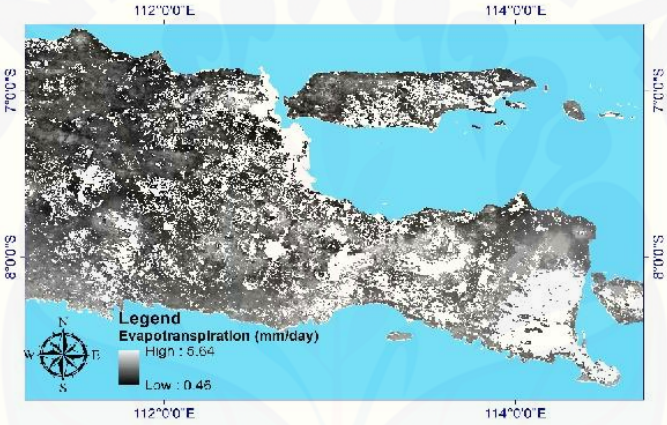

Figure 5. Spatial distribution of evapotranspiration in East Java based on MODIS global evapotranspiration product on 9July 2018

Based on statistical analysis, evapotranspiration that generated fromMODIS global evapotranspiration (MOD16A2) hasan accuracy of 75%compared with climate data analysis, although it has a lower correlation. Statistical performance of the MODIS global evapotranspiration compared with climate data analysis is shown in Table 1.

Table 1. Statistical performance of the MODIS global evapotranspiration product compared with climate data analysis

Station	Correlation Coefficient (CC)	Mean Error (ME)	Mean Absolute Error (MAE)	Relative Bias (RB)	Mean Bias Factor (MBF)	Root Mean Square Error (RMSE)
Banyuwangi	0.09	0.11	0.48	0.04	0.96	0.61
Pasuruan	0.17	1.33	1.38	0.65	0.61	1.53
Sidoarjo	0.40	1.09	1.11	0.32	1.47	1.36
Malang	0.52	0.50	0.92	0.17	1.21	1.20
Nganjuk	0.09	0.14	0.73	0.06	0.95	0.82
Average	0.25	0.64	0.92	0.25	1.04	1.10

Source: Analysis

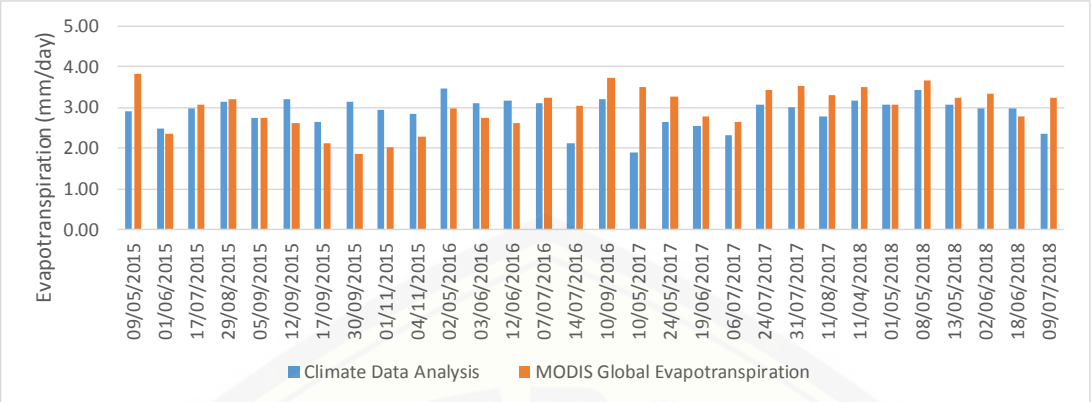

Fig. 6 Comparison of the MODIS globalevapotranspiration with Banyuwangi station climate data analysis

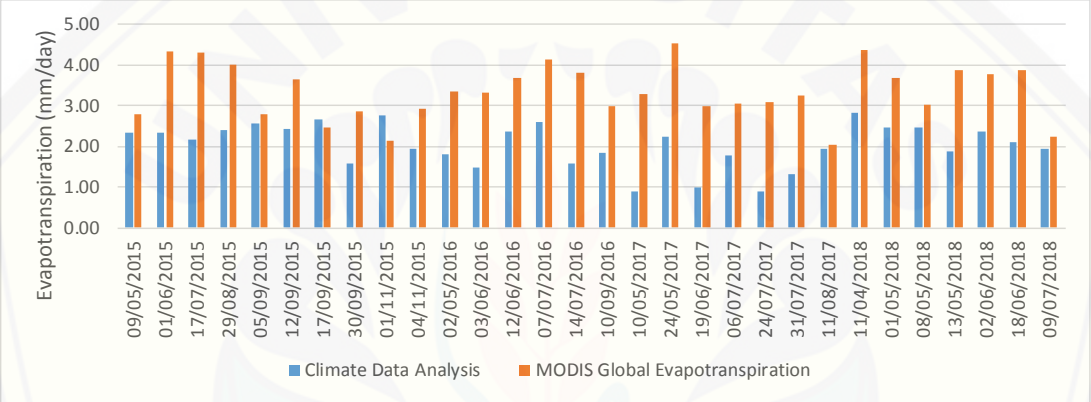

Fig. 7 Comparison of the MODIS globalevapotranspiration with Pasuruan station climate data analysis

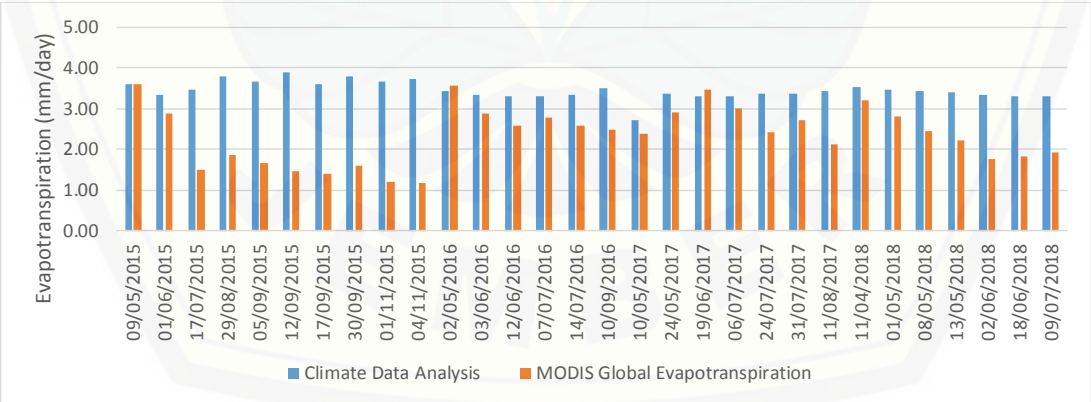

Fig. 8 Comparison of the MODIS global evapotranspiration with Sidoarjo station climate data analysis

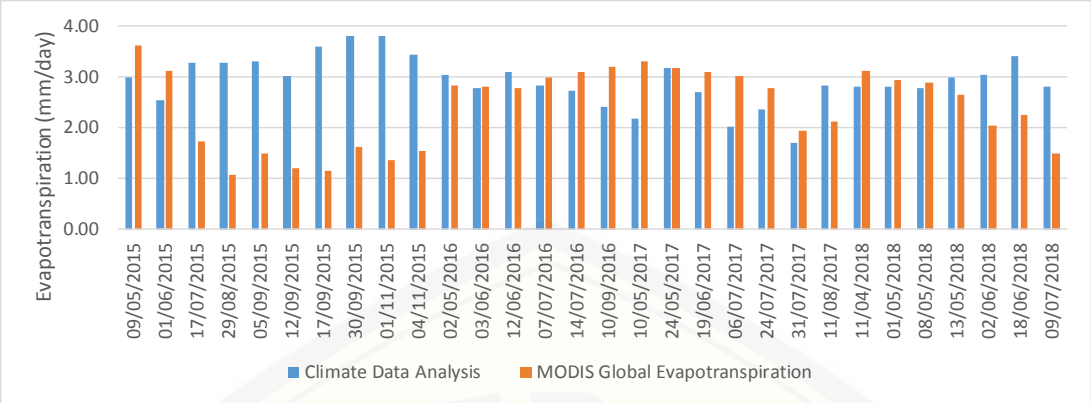

Fig. 9 Comparison of the MODIS global evapotranspiration with Malang station climate data analysis

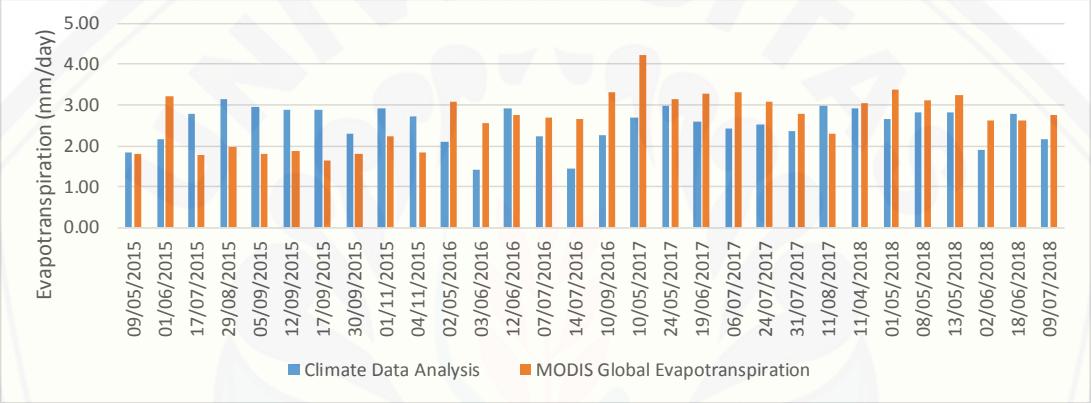

Fig. 10 Comparison of the MODIS globalevapotranspiration with Nganjuk station climate data analysis

Previous research shows that evapotranspiration generated fromthe MODIS satellite imagehas an accuracy of 84%compared with climate data analysis in Manokwari – West Papua[26] and 83% compared with pan evaporation in Situbondo – East Java[3].Research conducted by Kim et al showed that MODIS global evapotranspiration product can estimate evapotranspiration with reasonable accuracy in Asia compared with ground measured evapotranspiration [21].Ncube et al reported thatMODIS satellite image has an accuracy of 90% to derive evapotranspiration at sub-catchment in Zimbabwe compared with climate data analysis[27], and Ruhoff et al show that the deviation ofMODIS global evapotranspiration is 19% compared with evapotranspiration measurement and 21% compared with the hydrological model in Brazil [28].

4. Conclusions

MODIS global evapotranspiration has a good performance to derive an evapotranspiration information with accuracy 75% compared with climate data analysis, so MODIS global evapotranspiration product can be used as an alternative solution to generate evapotranspiration information in East Java – Indonesia.

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