An Evaluation of MODIS Global Evapotranspiration Product as Satellite-Based Evapotranspiration Data for Supporting Precision Agriculture in West Papua - Indonesia

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ABSTRACT

Precision Agriculture has been a significant issue since the middle of the 1980s. Evapotranspiration is one of the main parameters in precision agriculture to analyze real water needs in the agriculture area and managing water resources. Traditionally evapotranspiration estimates by directly measured methods, i.e., lysimeter, pan-evaporation, eddy covariance, Bowen ratio, soil water, and climate data analysis. These methods are expensive techniques with low spatial representativeness. The utilization of remote sensing technology is expected to be an alternative solution for providing evapotranspiration data with a cost-effective and high spatial representative. This research aims to evaluate the MODIS global evapotranspiration as satellite-based evapotranspiration in estimating evapotranspiration in West Papua. Four (4) statistical parameters, i.e., mean error (ME), root mean square error (RMSE), relative bias (RB), and mean bias factor (MBF), are using for evaluation. The research showed that MODIS global evapotranspiration was overestimated in estimating evapotranspiration in West Papua. However, MODIS global evapotranspiration has an acceptable accuracy in estimating evapotranspiration in West Papua indicated by ME = 0.66 mm/day, RMSE = 0.94 mm/day, RB = 0.27, and MBF = 0.81. Therefore, MODIS global evapotranspiration can be used as an alternative solution for providing evapotranspiration data in West Papua with a cost-effective.

Keywords: Evapotranspiration, MODIS global evapotranspiration product, satellite-based evapotranspiration, precision agriculture

INTRODUCTION

The precision agriculture issue was introduced in the middle of the 1980s. The concept of precision agriculture is to identify within-field variability and manage that variability (Zhang 2016). Precision agriculture aims to improve site-specific agricultural decision-making through collection and analysis of data, formulation of site-specific management recommendations, and implementation of management practices (Thenkabail 2016) to increase the profitability of crop production reduce the negative environmental impact (Pierce and Nowak 1999).

Evapotranspiration is one of the main parameters in precision agriculture. It uses to analyze real water needs in the agriculture area. Therefore accurate and detailed evapotranspiration information is crucial to managing water resources. Traditionally evapotranspiration estimates by directly measured methods, i.e., lysimeter, pan-evaporation, eddy covariance, Bowen ratio, soil water balance (Allen et al. 1998), and climate data analysis. However, these methods are expensive techniques with low spatial representativeness (Allen et al. 1998). Direct-measurement methods are suitable to estimate ET at field-scale or an area of fewer than 10 hectares (Allen et al. 1998), and climate data analysis suitable to estimate evapotranspiration for an area of ± 5000 km² or equivalent to a region having a radius of ~ 40 km from the climatology station (WMO 2008).

The utilization of remote sensing technology is expected to be an alternative solution to estimate evapotranspiration with cost-effective and high
Spatial coverage. Guzinski and Nieto’s research shows that remote sensing technology can be used to estimate high-resolution evapotranspiration at the field scale with 85% accuracy compared with local meteorological observation and 81% accuracy compared with climate data analysis (Guzinski and Nieto 2019). Other studies show that remote sensing technology can estimate evapotranspiration at acceptable results (Nouri et al. 2017; Li et al. 2017) and do the goodness of fit compared with meteorological data analysis (Bonemberger et al. 2018). Ceron et al. 2015 reported that the evapotranspiration estimation based on remote sensing is better during the critical dry season when cloud cover is low (Ceron et al. 2015). However, evapotranspiration estimation based on remote sensing technology overestimated during the rainy season and underestimated for the dry season (Junior et al. 2013).

MODIS global evapotranspiration product is a satellite image-based evapotranspiration released by the National Aeronautics Space Administration (NASA) with 500 m of spatial resolution and 8-day temporal resolution. Several institutions in the world using MODIS global evapotranspiration for providing evapotranspiration data, i.e., The European Space Agency (ESA), US Geological Survey (USGS), and Department of Civil Engineering – Indian Institute of Science.

Some studies conducted by Mu et al. (2011); Kim et al. (2012); Shekar and Nandagiri (2016); Miranda et al. (2017); and Aguilar et al. (2018) show that MODIS global evapotranspiration product can estimate actual evapotranspiration with reasonable accuracy. Furthermore, Jiang et al. (2004), Courault et al. (2005), and Kalma et al. (2008) show that deviation of MODIS global evapotranspiration is between 10% - to 30% compared to measurement and observation.

This research aims to evaluate the MODIS global evapotranspiration product in estimating evapotranspiration in West Papua based on the above conditions.

**MATERIALS AND METHODS**

This research was conducted in West Papua – Indonesia. Figure 1 shows the research location. The main stages of this research are data inventory, evapotranspiration data extraction, and data evaluation.

**Data Inventory**

As many as 188 scenes, MODIS global evapotranspiration products periods of 2010 to 2019 were collected. Furthermore, daily climate data recording periods of 2010 to 2019 from meteorological stations located at South Manokwari, Sorong, and Fakfak are also collected.

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**Figure 1. Research location. Study area: □, other country: □, meteorological station: ●.**
Evapotranspiration Data Extraction

The evapotranspiration data is extracted using point to pixel methods. Figure 2 shows the procedure to extract evapotranspiration data from MODIS global evapotranspiration.

MODIS global evapotranspiration using Penman-Monteith methods in estimating evapotranspiration (Mu et al. 2013). Daily meteorological data and 8-day remotely sensed vegetation is used as inputs. Figure 3 shows the general computation of MODIS global evapotranspiration product.

Evaluation of MODIS Global Evapotranspiration

The purpose of this stage is to compare evapotranspiration data from MODIS global evapotranspiration with climate data analysis. The four (4) statistical parameters, i.e., mean error (ME), root means square error (RMSE), relative bias (RB), and mean bias factor (MBF), are using for evaluation with the following equations:

\[
\text{ME} = \frac{1}{n} \sum_{i=1}^{n} (y_i - x_i) \quad (1)
\]

\[
\text{RB} = \frac{\sum_{i=1}^{n} (y_i - x_i)}{\sum_{i=1}^{n} x_i} \quad (2)
\]

\[
\text{MBF} = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i} \quad (3)
\]

\[
\text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (y_i - x_i)^2} \quad (4)
\]

Where:

CC is correlation coefficient, ME mean error (mm.day\(^{-1}\)), RB relative bias, MBF mean bias factor, RMSE root mean square error (mm.day\(^{-1}\)), yi satellite

Figure 2. Procedure to extract evapotranspiration data from MODIS global evapotranspiration

Figure 3. General computation of MODIS global evapotranspiration product (Mu et al. 2013).
evapotranspiration estimate (mm.day\(^{-1}\)), \(\bar{x}_1\) averaged satellite evapotranspiration (mm.day\(^{-1}\)), \(\bar{x}_i\) climate data evapotranspiration (mm.day\(^{-1}\)), \(\bar{y}_i\) averaged climate data evapotranspiration (mm.day\(^{-1}\)), SD\(_{x_i}\) standard deviation of satellite evapotranspiration (mm.day\(^{-1}\)), SD\(_{y_i}\) standard deviation of climate data evapotranspiration (mm.day\(^{-1}\)), and \(n\) amount of data. The perfect value of mean error (ME) = 0, relative

Figure 4. Evapotranspiration data distribution in West Papua based on MODIS global evapotranspiration: (a) 10 June 2017, (b) 14 September 2018, (c) 13 August 2019.

Figure 5. Sunshine duration recording in Ransiki stations - South Manokwari.

Figure 6. Sunshine duration recording in Seigun stations - Sorong.
bias (RB) = 0, mean bias factor (MBF) = 1, and root mean square error (RMSE) = 0 (Omranian et al. 2018).

RESULTS AND DISCUSSION

Generally, evapotranspiration data in West Papua extracted from MODIS global evapotranspiration product is not well distributed. Besides, evapotranspiration data from MODIS global evapotranspiration is overestimated compared to climate data analysis. The high cloud cover throughout the year in West Papua affects solar radiation duration. Figure 4 shows the spatial distribution of evapotranspiration derived from MODIS global evapotranspiration. Figure 5 to figure 7 shows the sunshine duration in West Papua from 2010 to 2018.

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

| Index             | St. Ransiki | St. Seigun | St. Torea | Average |
|-------------------|-------------|------------|-----------|---------|
| Mean Error (ME)   | 0.85        | 0.08       | 1.05      | 0.66    |
| Relative Bias (RB)| 0.29        | 0.03       | 0.48      | 0.27    |
| Mean Bias Factor (MBF)| 0.77    | 0.97       | 0.68      | 0.81    |
| Root Mean Square Error (RMSE)| 1.06 | 0.46       | 1.29      | 0.94    |

Figure 7. Sunshine duration recording in Torea stations - Fakfak.

Figure 8. Comparison of MODIS global evapotranspiration with st. Ransiki climate data analysis. MODIS Global Evapotranspiration: , Climate Data Analysis: .
Based on statistical analysis, MODIS global evapotranspiration has low error in estimating evapotranspiration in West Papua indicated by $\text{ME} = 0.66 \text{ mm/day}$, $\text{RMSE} = 0.94 \text{ mm/day}$, $\text{RB} = 0.27$, and $\text{MBF} = 0.81$. It is relevant to a previous study in generating evapotranspiration data in East Java and Monokwari using MODIS global evapotranspiration (Faisol, Budiyono, et al. 2020; Faisol, Indarto et al. 2020). Statistical performance of MODIS global evapotranspiration is shown in Table 1.

Furthermore, a comparison between evapotranspiration from MODIS global evapotranspiration and climate data analysis is shown in Figure 8-10.

CONCLUSIONS

MODIS global evapotranspiration product can be used as an alternative solution in providing evapotranspiration data in West Papua. The product has a low error and low deviation in estimating evapotranspiration in West Papua compared with climate data analysis.

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