Forecasting evapotranspiration equation based on Hargreaves Evapotranspiration Method for Semangat Village, Merdeka Sub-district, Karo Regency, North Sumatera Province, Indonesia

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Abstract. Providing water according to plant water requirement is a problem faced by many farmers because it’s related to cost of production and water scarcity. Some methods of calculating evapotranspiration are very difficult for farmers to use because they require some meteorological data. Simplifying the use of calculation equation is needed to make it easier for farmers to determine plant water requirements. The aims of study were to forecast evapotranspiration equation based on Hargreaves Evapotranspiration Method for Semangat Village. The methods divided two steps, they were observing potential evapotranspiration using Hargreaves Evapotranspiration method, and forecasting evapotranspiration equation. The results show potential evapotranspiration (ETo) in Semangat Village were 2.9 – 7.1 mm/days during January until July, 2020. Forecasted evapotranspiration equation for Semangat Village $y = 0.444x - 4.0964$ with $R^2 = 0.435$ for daily average temperature, $y = 0.2265x - 1.9029$ with $R^2 = 0.8518$ for daily maximum temperature, and $y = -0.2137x + 8.6148$ with $R^2 = 0.1361$ for minimum temperature. The conclusion shows that the formula $y = 0.2265x - 1.9029$ where x is daily maximum temperature is the best formula which can be used to forecast evapotranspiration in Semangat Village, Merdeka Sub-district, Karo Regency, North Sumatera Province, Indonesia.

1. Introduction

Semangat Village is one of the villages located in Merdeka district, Karo District, North Sumatra Province, Indonesia. Agriculture is one of the main pursuits of this village community. One of the problems faced is the source of water that must be purchased to meet the needs of plant water [1], so that it becomes one of the production costs that must be incurred by farmers. Provision of water according to plant water needs is a major problem, because currently only providing water is self-taught.

The provision of irrigation water generally corresponds to the evapotranspiration value of the plant, which is based on the evapotranspiration potential value of the area. The method of calculating the potential evapotranspiration of plants can be done by several methods including Penman [2], Penman-Monteith [3] and Hargreaves [4,5]. However, calculations with these methods require some meteorological data including temperature, humidity, solar radiation, and wind speed.
In fact, there was already a technology for automatic water supply according to weather conditions using subsurface irrigation technology [6], but its application to traditional farmers is difficult with limited capabilities and resources. For this reason, it is necessary to simplify the estimation of the potential value of evapotranspiration for local conditions using a simple parameter, namely temperature [5].

2. Materials and methods
The research was conducted during January – July 2020 in Semangat Village, Merdeka District, Karo Regency, North Sumatera Province, located in 02˚50' - 03˚19'N and 97˚55' - 98˚38'E. The used tools were Hobo temperature data logger, USB-Cable, computer, and global positioning system. Whereas the material was daily temperature data.

The method used in this study is an experimental method, divided into two steps. The first is to observe the potential evapotranspiration using the Hargreaves method. In this method the required data are daily average temperature, daily maximum temperature and daily minimum temperature. In the second step is to estimate the potential evapotranspiration for the Semangat Village area by simplifying the calculation of the potential evapotranspiration value, the relationship between temperature and potential evapotranspiration by looking at high determination.

2.1. Observe Hargreaves Potential Evapotranspiration (ETo) Method
The observation of the potential evapotranspiration value of the Hargreaves method [3] is calculated using the equation expressed with:

$$ETo = 0.000939(Tave + 17.8) (Tmax - Tmin)^{0.5} Ra$$

where ETo is potential evapotranspiration (mm / day), Ra is extraterrestrial radiation, Tave is daily average temperature (°C), Tmax is daily maximum temperature (°C) and Tmin is daily minimum temperature (°C). Temperature data collection is done every 15 minutes using a temperature data logger.

2.2. Simplifying the potential evapotranspiration equation
The Hargreaves potential evapotranspiration equation is simplified for the condition of the Semangat village by creating a new equation that is generated by relation both the potential evapotranspiration value and temperature, i.e., average, minimum, and maximum temperatures. After the equation is obtained, forecast-potential evapotranspiration is calculated by entering the daily temperature into each equation. After that, a correlation was made between Hargreaves potential evapotranspiration and forecast-potential evapotranspiration by looking at the coefficient of determination. The equation with the highest determination coefficient value (R^2) will be chosen to be the equation for forecast-potential evapotranspiration for the Semangat village.

3. Results and discussion
From the research that has been done, the potential evapotranspiration value is obtained based on the Hargreaves method and by simplifying the potential evapotranspiration calculation formula so that an estimation of the potential evapotranspiration is obtained as a formula for the Semangat village.

3.1. Potential Evapotranspiration (ETo) based on Hargreaves Method
The results of observing the potential evapotranspiration value based on the Hargreaves method can be seen in Figure 1. Figure 1 shows the potential evapotranspiration in the village of spirit ranges from 2.9-7.1 mm / day during January to July, 2020. From Figure 1 it can also be seen that the monthly peak evapotranspiration from January to July, 2020 are 6.74, 6.31, 7.18, 6.03, 6.28, 5.97, and 5.50 mm / day, respectively.

From Figure 1 it can also be seen that the distribution of potential evapotranspiration values is between 4-6 mm / day. This potential evapotranspiration value is obtained using several data, including
daily average temperature (Tave), daily minimum temperature (Tmin), daily maximum temperature (Tmax), and extraterrestrial radiation, so it is very difficult for farmers to calculate it. To make the calculation easier, the calculation is simplified [5] by looking at the greatest influence between Tave, Tmin, and Tmax.

![Figure 1. Potential evapotranspiration](image)

3.2. Forecasted evapotranspiration equation for Semangat Village

From the simplification of the potential evapotranspiration equation of the Hargreaves method for the Semangat village, the relationship between Tave, Tmin and Tmax can be seen in Figure 2.

![Figure 2. Relation both temperature and potential evapotranspiration](image)

Figure 2 shows the relationship between temperature and the potential evapotranspiration value using the Hargreaves method (ETo). The relationship between temperature (Tave, Tmin, Tmax) and the ETo value results in the formula used to estimate the value of evapotranspiration. From the Tave relationship
with ETo, the equation \( y = 0.4444x - 4.0964 \) is obtained, the relationship between Tmax and ETo is obtained by the equation \( y = 0.2265x - 1.9029 \), and the relationship between Tmin and ETo is obtained by the equation \( y = -0.2137x + 8.6148 \).

By inputting the Tave, Tmin and Tmax values into each equation, it can be seen in Figure 3 that the distribution of the estimated evapotranspiration values with ETo Hargreaves. From Figure 3 it can be seen that the resulting equation from the Tmax relationship with ETo is almost the same as the ETo value obtained by the Hargreaves method [5]. To see the determination of the three equations, the correlation test between Hargreaves-ETo and Forecast-ETo is carried out, it can be seen in Figure 4.

![Figure 3. The distribution of the estimated evapotranspiration values with ETo Hargreaves](image1)

![Figure 4. The correlation both forecasted potential evapotranspiration equation and potential evapotranspiration Hargreaves Method](image2)

From Figure 4, it can be seen that the correlation between forecast-ETo and Hargreaves-ETo shows that the equation \( y = 0.2265x - 1.9029 \) and coefficient of determination \( R^2 = 0.8518 \), higher than the other two equations. The coefficient of determination obtained shows that only by using the daily maximum temperature the ETo value is close to the Hargreaves method. Thus, it can be said that the daily ETo by Hargreaves equation compares closely with ETo calculated using a simplified equation [5], it is \( y = 0.2265x - 1.9029 \), where x is daily maximum temperature, but these equations limited using for Semangat Village, Merdeka District, Karo Regency.
4. Conclusions
The conclusions of the research were: Potential evapotranspiration (ETo) in Semangat Village were 2.9 – 7.1 mm/days during January until July, 2020. Forecasted evapotranspiration equation for Semangat Village $y = 0.444x – 4.0964$ with $R^2 = 0.435$ for daily average temperature, $y = 0.2265x – 1.9029$ with $R^2 = 0.8518$ for daily maximum temperature, and $y = -0.2137x + 8.6148$ with $R^2 = 0.1361$ for minimum temperature. The best formula forecasted-potential evapotranspiration for Semangat Village is $y = 0.2265x – 1.9029$ with $R^2 = 0.8518$ where $x$ is daily maximum temperature and $y$ is potential evapotranspiration.

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