The dominant factor causing potential evapotranspiration in Malang raya using geographic information systems

T Rahayuningsih 1, G Idfi 1, A Anindyasari 1 and Sukriyadi 2
1 Lecturer in Civil Engineering Universitas Negeri Malang
2 Civil Engineering Students Universitas Negeri Malang
titi.rahayuningsih.ft@um.ac.id

Abstract. The water resources management in Malang Raya is very important, because this area still has a lot of agricultural land. Agricultural land needs evapotranspiration maps. By now, there has been no research on the dominant determinant of the value of potential evapotranspiration in the Malang Raya area. Therefore research on the main factors that determine the value of potential evapotranspiration is needed. Purpose research: 1). Discovering the irrigation area that has the lowest and highest potential evapotranspiration value in Malang Raya; 2). Determine the dominant factors that affect the potential evapotranspiration value of irrigation areas in Malang Raya. The method to predict and calculate the amount of Potential Evapotranspiration (ETo) is Penman Method. The main determinants of potential evapotranspiration are mapped using Geographic Information Systems (GIS). Determination of the dominant factors that influence potential evapotranspiration was tested using SPSS. Conclusion: 1). The lowest potential evapotranspiration value were in Blimbing and Kedungkandang Districts from 3.46 to 3.61 mm / day. While, the biggest values were in Batu and Junrejo Districts with values of 6.32 to 6.33 mm / day; 2). The dominant factor affecting the potential evapotranspiration value is the air humidity (RH) factor of 46.4%.

1. Introduction
The rain water that falls to the surface of the earth does not entirely fall to the ground, some of it fall into the plants. Water that falls on plants, partially will be held up by plants where some of it will evaporate and some will fall or flow through branches to the ground

In managing evapotranspiration water resources, evapotranspiration is a very important process because it requires total water loss data caused by total evaporation. The value of evapotranspiration is affected by various factors found in nature. The factors that affect evaporation and evapotranspiration are water temperature, air temperature (atmosphere), humidity, wind speed, air pressure, solar radiation and others which are interconnected one another [1].

There are various potential evapotranspiration measurement methods, one of them is the Penman Modification method. The needed data to determine potential evapotranspiration is by measuring temperature, wind speed, average relative humidity and the relative duration of solar radiation.

Malang Raya consists of Malang Municipality, Batu Municipality, and Malang Regency. The Malang Raya region spreads from the coast to the mountains. Its height starts from 0 meters to 2000 meters above sea level. Its topographical condition causes the Malang Raya is a potential agricultural
area to plant, rice, fruit, flowers, and vegetable. The water resources management in Malang Raya is very important, because this area still has a lot of agricultural land. Agricultural land needs evapotranspiration maps. Evapotranspiration becomes one of the parameters needed in calculating irrigation water requirements for plants. The various determinants of evapotranspiration, there is one dominant factor that affects the value of evapotranspiration [2].

By now, there has been no research on the dominant determinant of the value of potential evapotranspiration in the Malang Raya area. Therefore research on the main factors that determine the value of potential evapotranspiration is needed. The main determinants of potential evapotranspiration are mapped using Geographic Information Systems (GIS) [3-4].

2. Purpose of research
- Discovering the irrigation area that has the lowest and highest potential evapotranspiration value in Malang Raya
- Determine the dominant factors that affect the potential evapotranspiration value of irrigation areas in Malang Raya

3. Methods
The data which used were taken from meteorological, climatology and geophysics stations in Karangploso, Karangkates and AR. Saleh Military Airport. The method to predict and calculate the amount of Potential Evapotranspiration (ETo) is Penman Method. The Penman method can be used if climatology data is available. The potential evapotranspiration based on the Penman formula that has been modified for calculation in Indonesia are as follows [5]:

\[
ETo = C \left( W \cdot Rn + (1 - W)(ea - ed) \cdot f(U) \right)
\]

As:

ETo = potential evaporation (mm/day)
C = An adjusted factor of day and night conditions (correction number).
W = The Factors that depend on average temperature (temperature) and altitude (elevation).
Rn = The total of net radiation (mm / day)

\[ Rn = 0.75 \cdot Rs - Rn1 \]

Rs = The amount of shortwave radiation reaching the earth's surface

\[ Rs = (0.25 + 0.5 \frac{n}{N}) Ra (mm/hari) \]

Ra = Shortwave radiation that fills the outer of the Earth's atmosphere (Angot value), in (mm/day).

n = The average of actual length of the sun (mm/day)
N = The maximum possible amount of sunlight (mm/day)

\[ Rn1 = \text{Net long wave radiation (mm/day)} \]

\[ f(t) = \text{temperature function of the table of relation between temperature (t) with a value of } f(t). \]

\[ f(ed) = \text{the function of steam pressure.} \]

\[ f(n/N) = 0.34 - 0.044 \times ed^{0.5} \]

\[ f(n/N) = \text{the function of sun brightness} \]
\[ f(U) = (0,1 + 0,9 \times n/N) \] ............................................................... (6)

\[ f(U) = \text{The function of average wind speed during the day time at an altitude of 2 meters (m/second)} \]

\[ = 0,27 \cdot (1 + U/100) \] ............................................................... (7)

\[ U = \text{The average of wind speed (m/second)} \]

\[ ea - ed = \text{The saturated vapor pressure with actual vapor pressure at average of air temperature (mbar)} \]

\[ ed = ea \times RH \] .................................................................................... (8)

\[ ea = \text{The actual vapor pressure.} \]

\[ RH = \text{The relative humidity (%)} \]

\[ Rns = \text{The shortwave radiation that goes reflected} \]

\[ = (1-\alpha) \times Rs \] .................................................................................... (9)

After obtaining data calculated using formulas (2) through (9), the data is entered into a table in the Geographical Information System (GIS). GIS is a system designed to capture, store, manipulate, analyze, organize and display all types of geographic data. (Irwansyah, E, 2013). The process of calculating the potential evapotranspiration value of formula (1) is conducted in the GIS table. The next is making a map of potential evapotranspiration patterns using GIS. The data interpolation method from the three climatology and geophysics stations using the Inverse Distance Weighted method (IDW).

The potential evapotranspiration of temperature (T), humidity (RH), solar radiation (n/N), and wind speed (u) Determination of the dominant factors that influence potential evapotranspiration was tested using SPSS [6].

4. Similar research

Similar studies are in Table 1

| No. | Name                  | Year | Title                                                                 |
|-----|-----------------------|------|----------------------------------------------------------------------|
| 1   | Herianto, et al [7]   | 2016 | Evapotranspiration using two regions in West Java as references to analyze of irrigation water needs planning. |
|     |                       |      | Analysis of the changes of estimated value of potential evapotranspiration affected by climate change in the Eucalyptus Pellita plantation forest area. |
| 2   | Supangat, A.B. [8]    | 2016 | Study on the Development of Potential Evapotranspiration Maps with Geographic Information Systems for the East Java Region |
| 3   | Singal, R.Z. [9]      | 2017 |                                                                      |

5. Research result

In this research was used data from 3 Climatology and Geophysics Stations, namely the Karangploso Climatology Station, Karangkates Geophysical Station, and the AR Saleh Military Airport
Climatology Post. The coordinate data consists of latitude, longitude, and altitude above sea level are shown in Table 2.

**Table 2.** Position of climatology and geophysics stations

| No | Name of Station | Coordinate latitude | Coordinate longitude | Altitude (m) |
|----|----------------|---------------------|----------------------|--------------|
| 1  | Karangploso Climatology Station | -7.90080 | 112.59790 | 590 |
| 2  | Karangkates Geophysical Station | -8.15000 | 112.45000 | 285 |
| 3  | AR. Saleh Military Airport Climatology Post | -7.92639 | 112.71444 | 526 |

The data used as a parameter in the calculation of potential evapotranspiration was data with 11 years span starts from 2007 to 2017. The data consists of air temperature, humidity, solar radiation, and wind speed of Karang ploso Station are shown in Table 3. The Table 4 and 5 contain about data from the Karangkates climatology station, and AR Saleh Military Airport climatology post.

**Table 3.** Climatology data and potential evapotranspiration at Karangploso Station

| Month  | Air Temperature | Humidity | Solar radiation | Wind speed | Potential Evapotranspiration |
|--------|----------------|----------|-----------------|------------|------------------------------|
| January | 23.72          | 80.95    | 41.84           | 6.01       | 4.79                         |
| February | 23.75         | 80.52    | 44.20           | 5.12       | 4.83                         |
| March   | 23.78          | 80.51    | 46.94           | 4.95       | 4.33                         |
| April   | 23.93          | 79.50    | 58.56           | 6.32       | 4.12                         |
| May     | 23.84          | 75.87    | 72.22           | 6.10       | 4.16                         |
| June    | 23.15          | 74.82    | 70.43           | 4.93       | 3.77                         |
| July    | 22.27          | 74.00    | 71.96           | 6.08       | 3.94                         |
| August  | 21.96          | 72.30    | 76.45           | 6.70       | 4.91                         |
| September | 23.16        | 69.13    | 79.71           | 7.81       | 6.42                         |
| October | 24.46          | 71.02    | 71.83           | 6.34       | 6.35                         |
| November | 24.40        | 75.97    | 60.74           | 6.32       | 5.79                         |
| December | 24.05         | 80.35    | 41.60           | 4.24       | 4.63                         |

**Table 4.** Climatology data and potential evapotranspiration at Karangkates Station

| Month  | Air Temperature | Humidity | Solar Radiation | Wind Speed | Potential Evapotranspiration |
|--------|----------------|----------|-----------------|------------|------------------------------|
| January | 25.67          | 83.68    | 50.19           | 5.14       | 5.05                         |
| February | 25.39         | 80.30    | 50.26           | 4.51       | 5.17                         |
| March   | 25.75          | 83.80    | 55.26           | 3.51       | 4.55                         |
| April   | 25.61          | 81.90    | 58.97           | 3.23       | 4.01                         |
| May     | 25.75          | 81.70    | 66.39           | 2.91       | 3.80                         |
| June    | 24.89          | 79.70    | 74.00           | 3.24       | 3.72                         |
| July    | 24.31          | 79.30    | 75.63           | 4.29       | 3.86                         |
| Month    | Air Temperature | Humidity | Solar Radiation | Wind Speed | Potential Evapotranspiration |
|----------|-----------------|----------|-----------------|------------|-----------------------------|
| August   | 24.37           | 77.90    | 80.43           | 4.23       | 4.86                        |
| September| 24.81           | 75.29    | 74.13           | 4.20       | 5.76                        |
| October  | 26.37           | 76.30    | 73.56           | 3.99       | 6.20                        |
| November | 25.95           | 80.40    | 54.11           | 3.60       | 5.25                        |
| December | 25.90           | 84.53    | 49.89           | 3.65       | 4.90                        |

**Table 5.** Climatology data and potential evapotranspiration at AR Saleh Climatology Post.

| Month    | Air Temperature | Humidity | Solar Radiation | Wind Speed | Potential Evapotranspiration |
|----------|-----------------|----------|-----------------|------------|-----------------------------|
| January  | 24.37           | 85.40    | 27.00           | 8.48       | 4.31                        |
| February | 23.89           | 85.40    | 31.00           | 7.40       | 4.34                        |
| March    | 23.99           | 85.90    | 52.00           | 7.03       | 4.44                        |
| April    | 24.17           | 85.90    | 51.00           | 6.46       | 3.70                        |
| May      | 24.17           | 84.30    | 85.00           | 5.91       | 4.16                        |
| June     | 23.41           | 83.30    | 64.00           | 11.33      | 3.88                        |
| July     | 22.62           | 82.30    | 46.00           | 5.44       | 3.12                        |
| August   | 22.52           | 80.10    | 66.00           | 5.84       | 4.32                        |
| September| 23.48           | 76.44    | 71.00           | 6.62       | 5.67                        |
| October  | 24.56           | 77.33    | 71.00           | 7.12       | 6.15                        |
| November | 24.60           | 84.44    | 49.00           | 6.36       | 4.98                        |
| December | 23.91           | 87.00    | 31.00           | 66.87      | 4.16                        |

**Figure 1.** The potential evapotranspiration chart of Karang Ploso, Karangkates, and AR Saleh Climatology Station areas.
Based on the potential evapotranspiration data in Tables 3, 4, and 5, a potential evapotranspiration chart can be made from the three climatology stations, namely Karangploso Station, Karangkates Climatology Station, and AR Saleh Climatology Post. The potential evapotranspiration chart can be made as shown in Figure 1.

The results of the calculation of the SE values to the Temperature (T), humidity (RH), solar radiation (n/N), and wind speed (u) using SPSS are shown in Table 6.

| Variable         | Regression Coefficient (Beta) | Correlation Coefficient | R Square | Se  |
|------------------|--------------------------------|--------------------------|----------|-----|
| Temperature      | 0.514                          | 0.261                    |          | 13.4% |
| Humidity         | -0.888                         | -0.522                   |          | 46.4% |
| Solar radiation  | -0.270                         | 0.238                    | 52.2%    | -6.4% |
| length           |                                |                          |          | -1.2% |
| Wind speed       | 0.125                          | -0.094                   |          |      |

6. Discussion

From Table 3, the highest potential evapotranspiration value was in September with an Eto value of 6.42 mm / day and the lowest was in June with an Eto value of 3.77 mm / day. In September, the position of the sun was in the equator and not too far from the research location so that the research area had a relatively large solar irradiation time of 79.71%. The lowest potential evapotranspiration value was in June, when the position of the sun was around the northern turning line and that was the farthest position from the research area and was in the dry season. This condition affected the air temperatures turned relatively low, and humidity was also relatively small. The highest potential evapotranspiration value was in October with an Eto value of 6.15 mm / day and the lowest was in July with an Eto value of 3.12 mm / day.

Figure 1 shows that the three climatology stations have the same potential evapotranspiration pattern, which was the lowest in July and was in the dry season. The highest potential evapotranspiration was in September for Karangploso climatology station. Karangploso Station has an altitude of 529 m above sea level, so the area has entered the rainy season earlier compared to Karangkates and AR Saleh stations.

7. The value of potential evapotranspiration of irrigation areas

Malang Raya Region has several irrigation areas, such as Donomulyo District, Turen District, Gondanglegi District, Pagelaran District, and Kepanjen District. The irrigation in Malang City covers Sukun District, Blimbing District, Lowokwaru District, and Kedungkandang District. Batu City covers Batu District, Junrejo District and Bumiaji District. The following are the coordinates and area of irrigation land in several regions in Malang Raya. Data of Malang Raya irrigation area is shown in Table 7.

| No | District     | Coordinate Latitude | Longitude  | Irrigation (Hectare) |
|----|--------------|---------------------|------------|----------------------|
| 1  | Donomulyo    | -8.321968           | 112.405305 | 2017                 |
| 2  | Turen        | -8.176870           | 112.697335 | 2248                 |
| 3  | Gondanglegi  | -8.155192           | 112.631784 | 2969                 |
| 4  | Pagelaran    | -8.197451           | 112.607946 | 2650                 |
| No | District      | Coordiante          | Irrigation (Hectare) |
|----|--------------|---------------------|---------------------|
| 5  | Kepanjen     | -8.159373 112.560269| 2152                |
| 6  | Batu         | -7.883065 112.533449| 650.78              |
| 7  | Junrejo      | -7.910549 112.542389| 1062                |
| 8  | Bumiaji      | -7.794130 112.536429| 687.2               |
| 9  | Sukun        | -7.993945 112.613905| 251                 |
| 10 | Blimbing     | -7.953594 112.649578| 87                  |
| 11 | Lowokwaru    | -7.937013 112.613906| 241                 |
| 12 | Kedungkandang| -8.011014 112.655622| 591                 |

Source: *Google Earth*

** Central Bureau of Statistics of Malang Regency 2017, CBS of Batu City 2017 dan KMDA (a set of statistic data named Kabupaten Malang Dalam Angka/ Malang Regency in Numbers) of Malang City 2016

The map which shows the lowest potential evapotranspiration conditions for irrigation areas is Figure 2. Figure 3 shows the highest potential evapotranspiration map (September) for each irrigation area.

![Figure 2. The Map of potential evapotranspiration in July](image-url)
Figure 3. The map of potential evapotranspiration in September. The value of potential evapotranspiration of the irrigation area for January to June is shown in Table 8, while for July to December is shown in Table 9.

**Table 8.** The value of potential evapotranspiration of irrigation areas for January to June

| No | District | Jan | Feb | Mar | Apr | May | Jun |
|----|----------|-----|-----|-----|-----|-----|-----|
| 1  | Donomulyo| 4.91 - 4.97 | 5.01 - 5.09 | 4.52 - 4.53 | 3.96 - 3.99 | 3.88 - 3.91 | 3.74 - 3.75 |
| 2  | Turen    | 4.69 - 4.75 | 4.76 - 4.84 | 4.45 - 4.47 | 3.92 - 3.95 | 4.03 - 4.05 | 3.79 - 3.80 |
| 3  | Gondanglegi | 4.76 - 4.82 | 4.85 - 4.92 | 4.48 - 4.49 | 3.92 - 3.99 | 3.95 - 4.02 | 3.77 - 3.78 |
| 4  | Pagelaran | 4.83 - 4.90 | 4.93 - 5.00 | 4.50 - 4.51 | 3.96 - 3.99 | 3.92 - 3.94 | 3.76 - 3.77 |
| 5  | Kepanjen | 4.91 - 4.97 | 5.01 - 5.09 | 4.50 - 4.53 | 3.96 - 3.99 | 3.88 - 3.91 | 3.74 - 3.75 |
| 6  | Batu     | 4.69 - 4.82 | 4.76 - 4.84 | 4.33 - 4.38 | 4.05 - 4.12 | 4.14 - 4.16 | 3.78 - 3.79 |
| 7  | Junrejo  | 4.76 - 4.82 | 4.76 - 4.84 | 4.33 - 4.38 | 4.05 - 4.12 | 4.14 - 4.16 | 3.78 - 3.79 |
| 8  | Bumiaji  | 4.69 - 4.75 | 4.68 - 4.84 | 4.36 - 4.40 | 4.00 - 4.04 | 4.14 - 4.16 | 3.79 - 3.80 |
| 9  | Sukun    | 4.61 - 4.68 | 4.68 - 4.75 | 4.36 - 4.40 | 3.92 - 3.99 | 4.10 - 4.16 | 3.79 - 3.82 |
| 10 | Blimbing | 4.47 - 4.60 | 4.51 - 4.67 | 4.39 - 4.42 | 3.84 - 3.95 | 4.14 - 4.16 | 3.81 - 3.83 |
| 11 | Lowokwaru | 4.69 - 4.82 | 4.68 - 4.84 | 4.33 - 4.38 | 4.00 - 4.12 | 4.14 - 4.16 | 3.78 - 3.80 |
| 12 | Kedungkandang | 4.61 - 4.68 | 4.51 - 4.67 | 4.41 - 4.42 | 3.84 - 3.91 | 4.10 - 4.16 | 3.83 - 3.84 |

**Table 9.** The value of potential evapotranspiration of irrigation areas for July to December

| No | District | Jul | Aug | Sep | Oct | Nov | Dec |
|----|----------|-----|-----|-----|-----|-----|-----|
| 1  | Donomulyo | 3.79 - 3.86 | 4.80 - 4.85 | 5.76 - 5.82 | 6.20 - 6.23 | 5.24 - 5.31 | 4.76 - 4.83 |
| 2  | Turen    | 3.54 - 3.70 | 4.62 - 4.73 | 5.91 - 5.97 | 6.22 - 6.23 | 5.24 - 5.31 | 4.54 - 4.60 |
The highest potential evapotranspiration value for Batu District was in October of 6.32 - 6.33 mm / day and the lowest was in June was 3.78 - 3.79 mm / day. The highest potential evapotranspiration value for Kepanjen district was in October at 6.20 - 6.23 mm / day and the lowest was in June was 3.74 - 3.75 mm / day. The highest potential evapotranspiration value for Lowokwaru district was in October at 6.30 - 6.35 mm / day and the lowest was in June was 3.78 - 3.80 mm / day. The lowest potential evapotranspiration value were in Blimbing and Kedungkandang districts at 3.46 to 3.61 mm / day. While, the biggest value were in Batu and Junrejo districts at 6.32 to 6.33 mm / day.

The results of the dominant factor test on potential evapotranspiration from elements of Temperature (T), humidity (RH), solar radiation (n / N), and Wind Speed (u) obtained data.

From Table 6, it is known that the largest effective contribution to the Eto Value is given by the Air Humidity Parameter (RH) which is 46.4% or 0.464. Beside that, there are two parameters that have a negative value, namely Solar Radiation (-6.4%) and Wind Speed (-1.2%), but for the used effective contribution is the absolute value.

8. Conclusion
- The lowest potential evapotranspiration value were in Blimbing and Kedungkandang Districts from 3.46 to 3.61 mm / day. While, the biggest values were in Batu and Junrejo Districts with values of 6.32 to 6.33 mm / day.
- The dominant factor affecting the potential evapotranspiration value is the air humidity (RH) factor of 46.4%

9. Suggestion
For research on potential evapotranspiration values in other areas, it should be conducted using a Geographic Information System so that the results will be more precise and easier to interpret because the research location has spatial data (coordinate)

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| No | District          | Jul    | Aug    | Sep    | Oct    | Nov    | Dec    |
|----|------------------|--------|--------|--------|--------|--------|--------|
| 3  | Gondanglegi      | 3.62   | 4.68   | 5.83   | 6.22   | 5.32   | 4.61   |
| 4  | Pagelaran        | 3.71   | 4.74   | 5.76   | 6.22   | 5.24   | 4.69   |
| 5  | Kepanjen         | 3.79   | 4.80   | 5.76   | 6.20   | 5.24   | 4.76   |
| 6  | Batu             | 3.79   | 4.80   | 6.28   | 6.32   | 5.64   | 4.61   |
| 7  | Junrejo          | 3.79   | 4.80   | 6.28   | 6.32   | 5.64   | 4.61   |
| 8  | Bumiaji          | 3.71   | 4.74   | 6.13   | 6.30   | 5.56   | 4.61   |
| 9  | Sukun            | 3.61   | 4.74   | 6.06   | 6.26   | 5.40   | 4.54   |
| 10 | Blimbing         | 3.46   | 4.60   | 5.91   | 6.22   | 5.24   | 4.32   |
| 11 | Lowokwaru        | 3.79   | 4.74   | 6.21   | 6.30   | 5.56   | 4.61   |
| 12 | Kedungkandang    | 3.46   | 4.56   | 5.91   | 6.22   | 5.24   | 4.32   |
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