The projected water availability on paddy rice based on climate change scenario in Indonesia

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Abstract. Climate change is a crucial issue concern in this century. The increase in temperature and changes in rainfall has a substantial effect on the agricultural sector. This study investigates the impact of climate change on water availability and crop evapotranspiration (ETc) in seven locations. The historical data (1981-2005) and The GCM data (ACCESS1-0) for the CMIP5 project for 45 years (2006-2050) under RCP 4.5 and RCP 8.5 scenarios were used to analyze the trend of temperature, rainfall, crop evapotranspiration, and changes in water availability using The Mann-Kendall test. In this study, crop evapotranspiration is calculated to assess monthly crop water requirement, while deficit rainfall is using to calculate the water deficit on paddy rice. This study shows that the temperature and crop evapotranspiration have a significant positive trend under historical, RCP 4.5, and RCP 8.5 scenarios. Otherwise, rainfall shows a relatively decreasing trend for historical RCP 4.5 and RCP 8.5 scenarios. Crop water requirement is projected to increase in the future. Rainwater would insufficient to crop water requirements in a certain month. Shifting the planting time and adjusting the cropping pattern is a strategy to adapt and mitigate climate change.

1. Introduction
Climate change is a serious problem in the 21st century for the researchers, the government, and the general public, affecting the agricultural sector significantly [1,2]. Climate change causes rainfall variability, frequency, intensity of extreme climate events, and disaster occurrences, such as drought and flood are rising [3,4]. Agriculture is one of the most vulnerable water sectors to climate variability and change, corresponding to water availability for crops in each stage [5]. Climate change has a significant influence on crop production and crop water availability. The rise in temperature and reduction of water availability during crop stages were shown a severe impact on crop production [6–8].

Several studies have investigated rainfall and temperature changes in Indonesia, the temperature is shown a positive trend while rainfall is seen to have a decreased trend [9–12]. Other studies show that the water deficit and crop evapotranspiration for paddy rice are likely to increase in future projections [13, 14]. Changing the cropping date is an alternative to adapt to water availability changes due to climate change effect [8, 14]. One strategy to mitigate the impact of climate change suggested by IPCC is adjusting the crop pattern to the climate condition by shifting the planting time and managing the cropping pattern [15]. The farmer can decide the right time to start sowing based on water availability to minimize yield loss and crop failure.
This study attempts to investigate the impact of the projected climate change on water availability at seven locations over Indonesia, namely Blang Bintang, Tapan, Sukadana, Gantar, Babat, Tolai, and Bengo. In this study, the trend of temperature, rainfall, and crop evapotranspiration, and rainfall deficit are calculated based on data from the general circulation model (GCM) output.

2. Materials and methods

2.1. Study area

The study area is covering some locations over Indonesia, and there are seven locations (table 1) that represent different rainfall patterns in Indonesia. Indonesia has three dominant rainfall regions, namely monsoonal, equatorial, and local. Each region has its characteristics. The monsoon region has one peak and one trough and is highly influenced by two monsoons, i.e., the wet northwest monsoon from November to March and the dry southeast monsoon from May to September. The equatorial region has two peaks, from October to November and March to May. Those two peaks are aligned with the intertropical convergence zone (ITCZ) movement [16]. The local region has one peak in the middle of the year is June to July.

![Figure 1. Location of the study area over Indonesia.](image)

In this study, three locations are taken as a representative monsoonal region (Lampung, West Java and East Java), two sites for equatorial regions (Aceh and West Sumatera) and two locations for local regions (South Sulawesi and Central Sulawesi).

| Station     | Province     | Longitude | Latitude | Elevation (m) |
|-------------|--------------|-----------|----------|---------------|
| Blang Bintang | Aceh         | 95.46     | 5.52     | 50            |
| Tapan       | West Sumatera| 101.08    | -2.16    | 18            |
| Sukadana    | Lampung      | 105.33    | -5.04    | 39            |
| Gantar      | West Java    | 108.00    | -6.48    | 19            |
| Babat       | East Java    | 112.20    | -7.10    | 8             |
| Bengo       | South Sulawesi| 120.04   | -4.62    | 103           |
| Tolai       | Central Sulawesi| 120.22 | -0.89    | 12            |

2.2. Observed data

Monthly observed rainfall data in seven locations (table 1) were obtained from Indonesian Agro-climate and Hydrology Research Institute, Ministry of Agriculture for the period of 1981-2010. Owing to the
lack of air temperature data for observed in site location, gridded air temperature data from the Climate Research Unit (CRU) Ts v4.04 were used in this study and extracted to seven areas of study for a period 1981-2010 [17]. CRU data are available at https://crudata.uea.ac.uk/cru/data. Observed rainfall data were used to correct rainfall GCM data and CRU-air temperature data was used to correct temperature GCM data.

2.3. General Circulation Model (GCM) data
One climate output model of The GCM data from CMIP5 (Coupled Model Intercomparison Project phase 5) experiments developed as a collaboration between the Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organization (CSIRO) of the Australian Government determined for this study is ACCESS1-0 [18]. The ACCESS1.0 is available at the following link https://esgf-node.llnl.gov/search/cmip5/. The data comprises historical data for 25 years (1981-2005) and future data for 45 years (2006-2050) under two future Representative Concentration Pathway (RCP) scenarios viz. RCP 4.5 and RCP 8.5 for rainfall data and air temperature data. ACCESS1-0 is a GCM model with good performance in simulating historical climate, interannual variations, and future predictions consistency [19,20]. There was a significant inconsistency between observed data and GCM data. The bias in GCM data needs to be corrected before use for further analysis. Bias correction of GCM data has been carried out using the cumulative distribution function method for rainfall data [21] and using the ratio of observed to GCM data for temperature [22].

2.4. Methods
2.4.1. Potential evapotranspiration (PET) and crop evapotranspiration (ETc). The potential evapotranspiration was estimated using temperature data. Due to the lack of detailed climate data for the observed and projected time scales, the Thornthwaite method for PET computation [23] has been used here. The Thornthwaite equation is given as:

\[
\text{PET} = 16 \times \left( \frac{10^{T}}{T} \right)^{\alpha} \times \left( \frac{N_{d}}{12} \times \frac{N_{d}}{30} \right)
\]

\[
I = \sum_{i=1}^{12} \left( \frac{T_{mi}}{5} \right)^{1.514}
\]

\[
\alpha = (6.75 \times 10^{-7})I^{3} - (7.71 \times 10^{-5})I^{2} + (1.792 \times 10^{-2})I + 0.49239
\]

PET is the estimated potential evapotranspiration (mm month\(^{-1}\)), T is the monthly air temperature (°C), I is an annual head index which depends on the 12 monthly mean temperatures \(T_{mi}\), \(N_{d}\) is a number of days in the month being calculated, \(\alpha\) is the exponent that also depends on I, and \(N/12\) is the astronomical day defined at 12 hours of the 30-day month at the latitude where PET is calculated. The ETc is obtained as below.

\[
\text{ETc} = \text{PET} \times K_{c}
\]

ETc is the crop evapotranspiration (mm month\(^{-1}\)) for paddy rice. \(K_{c}\) is the crop coefficient for paddy rice, where \(K_{c_{ini}}\) is 1.05, \(K_{c_{med}}\) is 1.20, and \(K_{c_{end}}\) is 0.60-0.90 [24]

2.4.2. Trend analysis of ETc and precipitation. The trend analysis is carried out using a robust trend detection technique, namely the Mann-Kendall (MK) test. This test is applied to rainfall and crop
evapotranspiration for each month over 70 years, historical (25 years) and future projection (45 years). MK test is a ranked non-parametric test and has been used by many researchers to detect trends in precipitation data [10–12]

\[
S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn} (x_j - x_k)
\]

(5)

where \( n \) is the length of the time series \( x_1, \ldots, x_n \), and \( \text{sgn}(\ldots) \) is a sign function, \( x_j \) and \( x_k \) are data values in month \( j \) and \( k \), respectively. Sign function is given as:

\[
\text{sgn}(x_j - x_k) =
\begin{cases} 
1, & \text{if } x_j > x_k \\
0, & \text{if } x_j = x_k \\
-1, & \text{if } x_j < x_k 
\end{cases}
\]

(6)

The positive value of \( S \) is an indication of a rising trend, and a negative value indicates a declining direction. The expected value of \( S \) equals zero (\( E[S] = 0 \)) for series without direction, and the variance is computed as:

\[
\sigma^2(s) = \frac{1}{18} \left[ n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5) \right]
\]

(7)

Here \( q \) is the number of tied groups, and \( t_p \) is the number of data values in \( p \) group. The test statistic \( Z \) is then given as:

\[
Z = \begin{cases} 
\frac{S-1}{\sqrt{\sigma^2(s)}} & \text{if } S > 0 \\
0 & \text{if } S = 0 \\
\frac{S+1}{\sqrt{\sigma^2(s)}} & \text{if } S < 0 
\end{cases}
\]

(8)

A positive value of \( Z \) indicates an upward trend, and a negative value of \( Z \) suggests a downward trend of rainfall and crop evapotranspiration in this study. \( H_0 \) is rejected if the absolute value of \( Z \) is more significant than \( Z_{1-\alpha/2} \), where \( Z_{1-\alpha/2} \) is obtained from the standard normal cumulative distribution tables. The null hypothesis (\( H_0 \)) for this test implies there is no significant trend in the series. The value of \( \alpha \) in this study is tested at 0.05 (95%).

2.4.3. Water availability. In this study, water availability was calculated using rainfall deficit conditions. The rainfall deficit (RD) was estimated by subtracting the monthly precipitation (R) with the monthly PET.

\[
\text{RD} = \text{R-PET}
\]

(9)

This approach has been used previously in evaluating the climate change impacts on evapotranspiration, precipitation deficit, and crop yield in Puerto Rico [13]. Others study also applied this method to assess the effect of climate change to water availability related to shifting the sowing date [14]. A positive value of \( \text{RD} \) indicates water over crop water requirements, and a negative value of \( \text{RD} \) indicates a deficit in terms of crop water requirements.
3. Results and discussion
The method mentioned in the previous section is used to analyze the monthly rainfall and evapotranspiration trends in previous years (historical) and also for future periods (RCP 4.5 and RCP 8.5) in the context of water availability.

3.1. Trend analysis of temperature, rainfall and evapotranspiration
Mann Kendall (MK) test was applied to monthly precipitation and monthly crop evapotranspiration for paddy rice in seven locations over Indonesia (Blang Bintang, Tapan, Sukadana, Gantar, Babat, Tolai and Bengo). Table 2-5 shows the tabulated Z value of MK test for air temperature, rainfall and crop evapotranspiration in seven locations. The Z statistic showing a positive value signifies an increasing trend, while a negative value donates a decreasing trend. The values with no asterisks indicate nominal Z values. Table 2 shows the Z value of temperature for historical (1981-2005) and future scenario RCP 4.5 and RCP 8.5 (2006-2050). The Z value of temperature shows a varying trend, generally show a significant positive trend in any location for all month under RCP 4.5 and RCP 8.5 scenarios. In contrast, the historical scenario shows a more insignificant trend, especially in Blang Bintang show a significant trend in August. In March, temperature shows a significant positive trend in almost all location except for Blang Bintang. The Z value of temperature under the RCP 4.5 scenario is higher than the historical scenario but less than the RCP 8.5 scenario. It indicates that temperature will rise in the future based on the projection of GCM - ACCESS1.0, which is similar to a previous study [25] that demonstrated the increasing temperature under RCP 4.5 is greater than under RCP 4.5. The differences between RCP 4.5 and RCP 8.5 might be associated to different emission scenarios.

Table 2. The Z value of the Mann–Kendall test for temperature.

| Location     | Parameter | Z          |
|--------------|-----------|------------|
|              | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Blang Bintang|      |     |     |     |     |     |     |     |     |     |     |     |
| Historical   | 0.10 | 0.24 | -0.03 | 0.03 | 0.22 | 0.26 | 0.26 | 0.40 | 0.23 | 0.11 | 0.13 | 0.21 |
| RCP 4.5      | 0.48* | 0.46* | 0.46* | 0.35* | 0.45* | 0.47* | 0.52* | 0.56 | 0.59* | 0.50* | 0.59* | 0.51* |
| RCP 8.5      | 0.66* | 0.71* | 0.54* | 0.54* | 0.60* | 0.62* | 0.61* | 0.68* | 0.67* | 0.62* | 0.61* | 0.62* |
| Tapan        |      |     |     |     |     |     |     |     |     |     |     |     |
| Historical   | 0.24 | 0.37* | 0.36* | 0.34* | 0.45* | 0.47* | 0.40* | 0.26 | 0.30* | 0.27 | 0.34* | 0.17 |
| RCP 4.5      | 0.23 | 0.13 | 0.49* | 0.43* | 0.41* | 0.49* | 0.51* | 0.40* | 0.49* | 0.02 | 0.27 | 0.50* |
| RCP 8.5      | 0.31* | 0.45* | 0.43* | 0.56* | 0.57* | 0.51* | 0.54* | 0.38* | 0.31* | 0.38* | 0.53* | 0.41* |
| Gantar       |      |     |     |     |     |     |     |     |     |     |     |     |
| Historical   | 0.17 | 0.15 | 0.48* | 0.29* | 0.48* | 0.46* | 0.47* | 0.36* | 0.43* | 0.49* | 0.39* | 0.12 |
| RCP 4.5      | 0.21 | 0.37* | 0.39* | 0.44* | 0.27 | 0.26 | 0.37* | 0.25 | 0.38* | 0.34* | 0.37* | 0.24 |
| RCP 8.5      | 0.25 | 0.23 | 0.46* | 0.43* | 0.51* | 0.39* | 0.44* | 0.51* | 0.61* | 0.58* | 0.53* | 0.24 |
| Babat        |      |     |     |     |     |     |     |     |     |     |     |     |
| Historical   | 0.27 | 0.27 | 0.40* | 0.27 | 0.44* | 0.24 | 0.39* | 0.49* | 0.43* | 0.37* | 0.29* | 0.08 |
| RCP 4.5      | 0.55 | 0.42 | 0.62 | 0.44 | 0.41 | 0.28 | 0.32* | 0.31* | 0.35* | 0.25 | 0.45* | 0.31* |
| RCP 8.5      | 0.38* | 0.53* | 0.51* | 0.57* | 0.56* | 0.37* | 0.43* | 0.33* | 0.43* | 0.45* | 0.35* | 0.19 |
| Bengo        |      |     |     |     |     |     |     |     |     |     |     |     |
| Historical   | 0.45* | 0.57* | 0.47* | 0.60* | 0.52* | 0.50* | 0.51* | 0.44* | 0.48* | 0.37* | 0.28 | 0.51* |
| RCP 4.5      | 0.65* | 0.61* | 0.51* | 0.55* | 0.41* | 0.55* | 0.50* | 0.47* | 0.40* | 0.47* | 0.21 | 0.49* |
| RCP 8.5      | 0.55* | 0.53* | 0.55* | 0.66* | 0.60* | 0.59* | 0.61* | 0.56* | 0.41* | 0.34* | 0.44* | 0.43* |
| Tolai        |      |     |     |     |     |     |     |     |     |     |     |     |
| Historical   | 0.19 | 0.26 | 0.51* | 0.47* | 0.29* | -0.03 | 0.23 | 0.14 | 0.23 | 0.26 | 0.23 | 0.02 |
| RCP 4.5      | 0.32* | 0.33* | 0.46* | 0.45* | 0.49* | 0.43* | 0.41* | 0.43* | 0.31* | 0.37* | 0.47* | 0.41* |
| RCP 8.5      | 0.29* | 0.35* | 0.35* | 0.51* | 0.50* | 0.50* | 0.58* | 0.53* | 0.42* | 0.35* | 0.35* | 0.31* |
| Sukadana     |      |     |     |     |     |     |     |     |     |     |     |     |
| Historical   | 0.29* | 0.35* | 0.30* | 0.27 | 0.46* | 0.39* | 0.39* | 0.29* | 0.32* | 0.30* | 0.17 | 0.20 |
| RCP 4.5      | 0.09 | 0.23 | 0.63* | 0.45* | 0.52* | 0.43* | 0.51* | 0.21 | 0.29* | 0.31* | 0.12 | 0.19 |
| RCP 8.5      | 0.26 | 0.34* | 0.47* | 0.56* | 0.63* | 0.51* | 0.36* | 0.29* | 0.09 | 0.31* | 0.19 | 0.27 |

*Trend significant at confidence level 95%
Table 3 shows Z statistic value for rainfall in each scenario (historical, RCP 4.5 and RCP 8.5) in seven location. The variations in Z value can be seen in all seven locations. The majority Z value shows an insignificant negative trend, and only a few Z values show a significant negative trend for each month. In all seven location, Z value on April, May, and October show an insignificant trend. In Blang Bintang, a significant rainfall trend is only seen in June (positive trend) and August (negative trend) under RCP 4.5 and December for RCP 8.5. In Tapan, the Z value shows a significant negative trend in September for historical and in February for RCP 4.5, and significant positive value is seen in July and November. The Z value in Sukadana shows a significant trend in March and September under historical, in February under RCP 4.5, in June and December under RCP 8.5. The Z value of Gantar shows the significant value in March and September for historical and in March for RCP 4.5, and rainfall show an insignificant trend under RCP 8.5. In Babat, rainfall only shows a significant trend in March (RCP 4.5), in August (RCP 8.5), and an insignificant trend under the historical scenario for all months. In Bengo, Z value shows a significant trend in June for historical, in March for RCP 4.5, and there no significant trend for RCP 8.5. The Z value shows a significant trend in March under the historical and January under RCP 4.5 and RCP 8.5.

The Z value of the MK test for crop evapotranspiration for paddy rice in seven locations for historical, RCP 4.5, and RCP 8.5 is presented in table 4. Most of the Z value shows a significant positive trend for each month in all seven locations under the RCP 4.5 and the RCP 8.5. In contrast, an insignificant trend is seen in all areas under the historical scenario in several months. Under the historical scenario, a significant positive trend in Blang Bintang only seen in August while in Tolai is seen in March, May, and June. The increasing trend of ETc is in line with the previous study [14], which detected the rising trend of ETc under RCP 8.5 is higher than RCP 4.5. The ETc shows a significant positive trend as the temperature trend. This can happen because the ETc calculation only uses temperature, so the results show the same trend.

| Location  | Scenario | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|-----------|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Blang Bintang | Historical | -0.13 | -0.01 | 0.11 | -0.07 | -0.15 | 0.21 | -0.14 | -0.14 | 0.11 | -0.07 | 0.12 | 0.03 |
| RCP 4.5 | 0.02 | 0.04 | 0.13 | 0.12 | 0.05 | 0.27* | -0.02 | -0.27* | 0.01 | 0.10 | 0.04 | 0.04 |
| RCP 8.5 | -0.11 | -0.03 | -0.05 | -0.08 | -0.06 | -0.03 | -0.05 | 0.12 | 0.16 | 0.00 | 0.09 | 0.26* |
| Historical | -0.18 | 0.09 | -0.19 | 0.02 | -0.07 | 0.01 | -0.18 | -0.23 | -0.29* | -0.17 | -0.19 | -0.04 |
| Tapan | RCP 4.5 | 0.17 | 0.10 | 0.24* | 0.02 | 0.07 | 0.02 | -0.01 | 0.11 | 0.02 | 0.09 | 0.18 | 0.06 |
| RCP 8.5 | 0.04 | 0.09 | 0.17 | 0.15 | 0.17 | 0.13 | 0.23* | -0.05 | 0.01 | 0.06 | 0.28* | 0.13 |
| Historical | -0.24 | 0.01 | -0.47* | 0.24 | -0.05 | -0.17 | -0.06 | -0.08 | -0.32* | -0.09 | -0.11 | -0.25 |
| Sukadana | RCP 4.5 | -0.07 | -0.23* | -0.20 | 0.07 | -0.01 | -0.11 | -0.11 | -0.05 | -0.01 | 0.01 | 0.12 | 0.07 |
| RCP 8.5 | 0.14 | 0.06 | 0.12 | 0.18 | 0.07 | 0.21* | 0.05 | -0.03 | 0.05 | 0.08 | 0.11 | 0.22* |
| Historical | 0.01 | 0.00 | -0.41* | 0.07 | -0.02 | -0.13 | -0.01 | -0.01 | -0.33* | -0.11 | -0.13 | 0.08 |
| Gantar | RCP 4.5 | 0.10 | -0.17 | -0.23* | 0.11 | -0.09 | 0.00 | 0.02 | 0.04 | 0.02 | -0.03 | 0.10 | 0.08 |
| RCP 8.5 | 0.09 | 0.14 | 0.06 | 0.12 | 0.06 | 0.03 | 0.03 | 0.10 | -0.18 | 0.05 | 0.10 | 0.08 |
| Historical | -0.10 | -0.14 | -0.27 | -0.25 | -0.13 | -0.25 | -0.07 | 0.07 | -0.19 | 0.01 | -0.02 | 0.03 |
| Babat | RCP 4.5 | -0.09 | -0.20 | -0.23* | 0.16 | -0.07 | 0.05 | -0.02 | 0.01 | -0.01 | -0.09 | 0.03 | 0.12 |
| RCP 8.5 | 0.02 | -0.10 | -0.18 | 0.14 | 0.05 | 0.09 | 0.00 | -0.24* | 0.14 | 0.16 | 0.09 | 0.19 |
| Historical | 0.11 | 0.28 | 0.07 | -0.12 | 0.13 | 0.33* | -0.02 | 0.02 | 0.07 | 0.22 | 0.20 | 0.07 |
| Bengo | RCP 4.5 | -0.14 | 0.09 | 0.25* | 0.12 | 0.05 | -0.02 | -0.18 | -0.07 | -0.03 | 0.11 | 0.14 | 0.02 |
| RCP 8.5 | 0.09 | -0.02 | 0.03 | 0.07 | -0.03 | -0.20 | -0.13 | 0.07 | -0.07 | -0.03 | -0.01 | -0.12 |
| Historical | 0.01 | -0.05 | -0.34* | -0.03 | 0.05 | 0.09 | -0.03 | 0.00 | -0.03 | 0.17 | 0.13 | 0.17 |
| Tolai | RCP 4.5 | -0.23* | -0.17 | -0.13 | 0.04 | -0.11 | -0.02 | -0.07 | -0.16 | -0.05 | 0.19 | -0.03 | 0.05 |
| RCP 8.5 | 0.26* | -0.08 | -0.09 | 0.08 | -0.03 | -0.06 | -0.08 | 0.19 | -0.05 | 0.03 | 0.07 | -0.03 |

*Trend significant at confidence level 95%
Table 4. The Z value of the Mann-Kendall test for crop evapotranspiration.

| Location       | Parameter | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|----------------|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Blang Bintang  | Historical| 0.10| 0.24|-0.03| 0.03| 0.22| 0.26| 0.26| 0.40*| 0.23| 0.11| 0.13| 0.21|
|                | RCP 4.5   | 0.48*| 0.46*| 0.46*| 0.35*| 0.45*| 0.47*| 0.52*| 0.56*| 0.59*| 0.50*| 0.59*| 0.51*|
|                | RCP 8.5   | 0.66*| 0.71*| 0.54*| 0.54*| 0.60*| 0.62*| 0.61*| 0.68*| 0.67*| 0.62*| 0.61*| 0.62*|
|                | Historical| 0.24| 0.37*| 0.36*| 0.34*| 0.45*| 0.47*| 0.40*| 0.26| 0.30*| 0.27| 0.34*| 0.17|
| Tapan          | RCP 4.5   | 0.56*| 0.57*| 0.75*| 0.71*| 0.69*| 0.73*| 0.72*| 0.65*| 0.68*| 0.57*| 0.66*| 0.68*|
|                | RCP 8.5   | 0.68*| 0.71*| 0.74*| 0.79*| 0.83*| 0.81*| 0.77*| 0.67*| 0.66*| 0.70*| 0.74*| 0.74*|
|                | Historical| 0.29*| 0.35*| 0.30*| 0.27| 0.46*| 0.39*| 0.39*| 0.29*| 0.32*| 0.30*| 0.17| 0.20|
| Sukadana       | RCP 4.5   | 0.50*| 0.59*| 0.69*| 0.46*| 0.45*| 0.43*| 0.21*| 0.25*| 0.46*| 0.57*| 0.59*| 0.58*|
|                | RCP 8.5   | 0.64*| 0.67*| 0.68*| 0.66*| 0.63*| 0.57*| 0.23*| 0.28*| 0.44*| 0.56*| 0.60*| 0.61*|
|                | Historical| 0.17| 0.15| 0.48*| 0.29*| 0.48*| 0.46*| 0.47*| 0.36*| 0.43*| 0.49*| 0.39*| 0.12|
| Gantar        | RCP 4.5   | 0.35*| 0.65*| 0.65*| 0.65*| 0.64*| 0.64*| 0.68*| 0.65*| 0.63*| 0.69*| 0.71*| 0.63*|
|                | RCP 8.5   | 0.63*| 0.70*| 0.73*| 0.69*| 0.77*| 0.76*| 0.70*| 0.76*| 0.80*| 0.78*| 0.77*| 0.62*|
|                | Historical| 0.27| 0.27| 0.40*| 0.27| 0.44*| 0.24| 0.39*| 0.49*| 0.43*| 0.37*| 0.29*| 0.08|
| Babat          | RCP 4.5   | 0.66*| 0.68*| 0.71*| 0.38*| 0.24*| 0.24*| 0.18| 0.39*| 0.64*| 0.64*| 0.66*| 0.63*|
|                | RCP 8.5   | 0.72*| 0.77*| 0.71*| 0.55*| 0.33*| 0.20| 0.32*| 0.55*| 0.75*| 0.73*| 0.67*| 0.60*|
|                | Historical| 0.45*| 0.57*| 0.47*| 0.60*| 0.52*| 0.50*| 0.51*| 0.44*| 0.48*| 0.37*| 0.28| 0.51*|
| Bengo          | RCP 4.5   | 0.82*| 0.80*| 0.78*| 0.77*| 0.71*| 0.78*| 0.75*| 0.70*| 0.68*| 0.75*| 0.63*| 0.72*|
|                | RCP 8.5   | 0.80*| 0.80*| 0.81*| 0.84*| 0.83*| 0.83*| 0.81*| 0.79*| 0.75*| 0.70*| 0.72*| 0.77*|
|                | Historical| 0.19| 0.26| 0.51*| 0.47*| 0.29*| -0.03| 0.23| 0.14| 0.23| 0.26| 0.23| 0.02|
| Tolai          | RCP 4.5   | 0.63*| 0.68*| 0.71*| 0.69*| 0.73*| 0.71*| 0.66*| 0.63*| 0.64*| 0.65*| 0.71*| 0.62*|
|                | RCP 8.5   | 0.70*| 0.74*| 0.73*| 0.77*| 0.78*| 0.77*| 0.79*| 0.75*| 0.70*| 0.73*| 0.72*| 0.70*|

*Trend significant at confidence level 95%

3.2. Analysis of water availability

This section discussed the monthly water availability for historical, RCP 4.5, and RCP 8.5 scenario corresponding to rainfall (R), crop evapotranspiration (ETc) and rainfall deficit (RD). A positive value of RD indicates water overcrop water requirements, and a negative value indicates a deficit in terms of crop water requirements. Three locations (Blang Bintang, Gantar and Bengo) are taken representatively to be elaborated furthermore.

Figure 2 presents the graphical distribution of rainfall, crop evapotranspiration and monthly rainfall deficit for paddy rice in Blang Bintang. Under the historical scenario can be seen that the rainfall in January to October is lower than ETc and RD is negative. It indicates a deficit water availability to crop water requirements, the water is excess in November and December. Due to higher temperature and lower rainfall that relatively is projected in RCP 4.5 and RCP 8.5, the ETc and RD in RCP 4.5 and RCP 8.5 is more elevated than historical, positive of RD (water excess) is shifting to October and November in RCP 4.5, the rainfall is almost entirely below ETc values in RCP 8.5 except October. Hence RD is almost shown negative values.

Figure 3 shows monthly rainfall, monthly crop evapotranspiration and monthly rainfall deficit in Gantar for historical, RCP 4.5 and RCP 8.5 scenario. In can be seen rainfall excess ETc from November to April, so that RD values are positive, the rainfall is below the ETc from May to October as RD values are negative for the historical scenario. In the case of RCP 4.5 and RCP 8.5, ETc values are higher than the historical scenario. Excess rainfall shifting to February and March for RCP 4.5, rainfall is below ETc from April to December, so as RD value is negative. Unlike historical and RCP 4.5, it can be seen that rainfall is always below ETc each month in RCP 8.5 so that RD values are negative for all months.

Monthly rainfall, crop evapotranspiration, and rainfall deficit in Bengo for historical, RCP 4.5, and RCP 8.5 scenarios are presented in Figure 4. In the case of historical, rainfall is excess ETc from December to July, so that RD show positive value, it means that the water availability is excess crop water requirement. RD on May always show positive value for historical, RCP 4.5 and RCP 8.5, water availability is a deficit to crop water requirement. Because the rainfall is lower than ETc, water availability is a deficit to crop water requirement under RCP 4.5. Due to the rainfall is excess ETc in
January and June and RD is positive, water availability in January to June is sufficient to meet the crop water requirement. Hence RD value is negative from July to December. In the case of RCP 8.5, RD value is negative from June to December, while RD value from January to March almost touches zero value, it means rainfall can meet the water requirement for paddy rice.

Figure 2. Monthly rainfall (R), ETc and rainfall deficit (RD) in Blang Bintang for historical (a), RCP 4.5 (b) and RCP 8.5 (c).

Figure 3. Monthly rainfall (R), ETc and rainfall deficit (RD) in Gantar for historical (a), RCP 4.5 (b) and RCP 8.5 (c).
Conclusion

In this study, the effect of climate change on water availability was assessed by the trend. The trend of temperature, rainfall, and crop evapotranspiration for paddy rice in seven locations over Indonesia is estimated by MK test. The result shows that the temperature is demonstrated to increase under the RCP 4.5 and the RCP 8.5 scenarios in almost all locations. The increasing rate under the RCP 8.5 scenario is higher than the RCP 4.5 scenario. Rainfall is projected to decrease relatively under the RCP 4.5 and RCP 8.5. Crop evapotranspiration also shows an increasing value under the RCP 4.5 and RCP 8.5 scenarios. The differences between RCP 4.5 and RCP 8.5 is the different emission pathways.

Crop evapotranspiration for paddy rice is projected to increase in all locations due to the higher temperatures under the RCP 4.5 and the RCP 8.5, which means the crop water requirement will be higher in the future. Deficit rainfall is also projected to increase under the RCP 4.5 and RCP 8.5 scenarios in a particular month. It means that rainwater is a deficit to crop water requirement. Hence water irrigation is needed. The water availability information is required to adjust crop planting time to prevent water shortage during the planting period. The farmer can decide to shift planting time based on crop water availability. Based on this information, the decision maker also can develop agricultural planning such as a cropping calendar and irrigation infrastructure. This is a part of the strategies to reduce the effect of climate change on crop cultivation and minimize crop yield loss even crop failure.

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