

Impacts of Climate Change on Agriculture for Local Paddy Water Requirement Irrigation Barito Kuala, South Kalimantan, Indonesia

MAYA AMALIA ACHYADI^{1,2*}, KOICHIRO OHGUSHI¹ AND TOSHIHIRO MORITA³

¹Saga University, Saga, Japan; ²Lambung Mangkurat University, Banjarbaru, Indonesia
³Northern Kyushu River Use Association, Fukuoka, Japan

ABSTRACT

Increasing rice consumption demand in Indonesia has provided serious problems such as food insecurity. Being the major staple food, rice production is the main priority of medium and long term development planning in Indonesia. Local rice production is strongly affected by climate conditions, especially in South Kalimantan. Nowadays, the world must adjust to climate change. One of significant effects of changing climate on agriculture is related to productivity. Evapotranspiration is the major cause of loss of water needed, for agricultural requirements. The crop requires effective irrigation system with adequate water amount. The main objective of this research is to analyze the water requirements for the irrigation units in Barito Kuala, South Kalimantan concerning local rice cultivation under the climate change scenarios. Supposed rainfall during the 2050s and 2090s are obtained from four downscaled circulated models and one model for projected temperature under CMIP5 with RCPs 8.5 scenario. Penman-Monteith method was used to calculate the evapotranspiration value. Based on future effective rainfall water requirement is estimated. The result shows the impact of climate change on the water irrigation requirement of local paddy cultivation are 56% and 25 % higher than current condition in July and September October respectively.

Keywords: *climate change, local rice production, evapotranspiration, water irrigation requirement*

INTRODUCTION

One of the main determinants of food demand in a country is population growth which is positively correlated with food demand (Arifin, et al., 2018). The Indonesian population expected to reach 321.2 million in 2090 (Guilmoto, 2016). One of the main challenges for the Indonesian government is to increase food production to meet population growth. Java island is a national paddy barn that contributes 56.05% of paddy in Indonesia (BPS, 2019). Java island is the most densely populated with 1,163 population per km² in 2017 more than 50% of inhabitants live in Java Island (BPS, 2018).

In the future, area of paddy field in Java island will decrease as a consequence of increasing number of new residents. In contrast, 6% of inhabitants live in Kalimantan islands with 743,300 km² area equal to 28% of the Indonesia land area (Syuaib, 2016). Land reclamation for agriculture around the Barito River in Kalimantan island has traditionally begun in 1935. In 1971 an irrigation network was be built to meet water requirements for 200,000 ha of agricultural land (Hadi, et al., 1999).

Kalimantan island, especially South Kalimantan province has a lot of suboptimal lands located near river with tidal influence. These conditions increased the soil fertility higher compared to other locations because freshwater flowing through irrigation canals networks provides a source of minerals for cultivating paddy (Haryono, et al., 2013).

Correspondence: Maya Amalia Achyadi, Saga University, Departement of Civil Engineering and Architecture, Honjo Campus Saga Japan 840-8502. Email: 17654904@edu.cc.saga-u.ac.jp

About 90% of the farmers choose to grow local paddy varieties rather than superior ones, even though the cultivation index is only once a year (Darsani & Koesrini, 2018). Base on a study more than 750 million inhabitants in the developing country faced insufficient supply. In developed countries, 41 million people suffer from food insecurity (FAO, 2002). The balance between rainfall and evapotranspiration affects soil moisture that will eventually determine the variation in irrigation water requirements. Temperature and rainfall patterns will be affected by global warming (De Silva, 2007). Beside evapotranspiration, other related climate conditions such as air humidity, wind velocity, and cloudiness are possible factors to be associated with these fluctuations in temperature (Gleick, 1987).

Over the past decades, the impact of climate change on agriculture production have attracted great consideration (Gahatraj, 2018). Climate change will result in changes in precipitation patterns, temperature decreases or increases and changes in the hydrological cycle. Rainfall and temperature, which are the most risk-increasing parameters, are positively related to rice yield variability (Kim, 2009). Models of the water resources system can be effective instruments to analyze the effects of climate change and to reconsider policies in the water segment (Andreu, et al., 2011).

Based on the Global Climate Models (GCM) output, in 2070 there is an increase in the value of evaporation as a result of changes in rainfall patterns in countries located in Southeast Asia. Global changes occur around 5-8% but in Southeast Asia the impact of climate change is higher at 15% (Fischer, et al., 2007) (Döll, 2002).

The combination of a large number of population and biological diversity make Indonesia as one of the countries that in higher danger to climate change consequences (Case, et al., 2007).

One of the effective methods to examine the impact of climate change is combine output from GCM under greenhouse gas concentration scenarios, Representative Concentration Pathways (RCP) adopted by Intergovernmental Panel on Climate Change (IPCC) (Awal, et al., 2016) (Safeeq & Fares, 2012). The suitable GCM model considered for Asian regions with monsoon climate classification is Coupled Model Intercomparison Project 5 (CMIP5) (Sperber, et al., 2013). CMIP5 establishes the new scenarios RCP 8.5 the maximum and RCP 2.6 the minimum. Two scenarios for the middle assumption are RCP 4.5 and RCP 6. These kinds of scenarios characterized by the amount of greenhouse gas concentration up to year 2100 (Peters, et al., 2013) (Riahi, et al., 2011). Research in China about changing pattern of precipitation under RCP 8.5 concluded that present global condition slightly above the highest RCP scenario, it means RCP 8.5 will properly simulate the impact of climate change (Zou & Zhou, 2013).

The output from some models from GCM is then downscaled to the research study location and used as inputs to irrigation water requirement analysis. Many GCM models have been established by many research institutions in various countries. The purpose of this research is to evaluate the effects of climate change by taking into consideration irrigation water requirements of the local paddy type in Terantang Irrigation Units, South Kalimantan, Indonesia.

METHODOLOGY

Study Region

The location of the study region in Kalimantan island, Barito Kuala Regency. Lowland region at central of Indonesia with a atachment area of 30 km². Terantang irrigation unit is one of the irri-gation networks located

within the latitude of 3°7'- 3°10' S and longitude of 114°36'- 114°39' E. A lowland region with average gradient 3%. The area of Terantang irrigation units 3000 ha lies in the eastern region of the Barito River. Terantang tidal irrigation unit was built in 1981, whose construction was equipped with 8.9 km primary canal, 47 left tertiary canal and 39 right tertiary canals. The schematic of the irrigation network is shown in Figure 1.

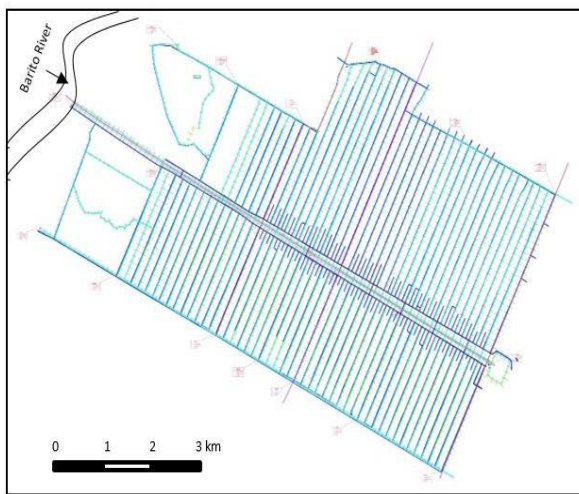


Figure 1. Terantang Tidal Irrigation Units, South Kalimantan, Indonesia (Source: KemenPUPR, 2017)

Terantang Irrigation unit has two types of paddy, local and superior. At present, these two variants of paddy have been cultivated with different intensity; 100 for local and 200 for others annually. Most of farmers at Terantang irrigation unit prefer local variety as Siam with cultivation period can reach up to 10 months. The seeding stage divided into 3 namely *tarandakan*, *ampakan* and *lacakan*.

The first stage of seedbed starts in October for 35-40 days called *tarandakan*. *Ampakan* period is the second stage of seedbed begins in November for 35-45 days, during this period the paddy will be placed at the larger rice field. The final step of seeding period is *lacakan*, 50-70 days period start in January through March (Wakhid &

Syahbuddin, 2016). Paddy cultivation at Terantang area with local variety takes quite a long time from seeding period in October until harvested in early August.

Climate Change Scenario

Historical and projected rainfall and climatology data were obtained from the Data Integration and Analysis System (DIAS). Today GCM's product for water resources at the watersheds scale can be simulated from the CMIP5 tools. We can easily download the projection value by choosing the model and experiment type (Kawasaki, 2017).

In this study downscaled daily rainfall from 4 GCMs models simulated by CMIP5 under high-est scenario RCP 8.5. The outputs of four GCMs such as ACCESS1.0, CNRM-CM5, GFDL-CM3, and MRI-CGCM3 were be used to predict the future rainfall simulation data. Predicted climate data such as temperature, humidity, solar radiation and wind velocity obtained from HadGEM2-CC.

The RCP 8.5 is considered as the highest greenhouse gas scenario. This climate change scenario was downscaled at basin scale by a statistical downscaling simulation model (SDSM) tool. The observed daily rainfall and temperature dataset obtained from two local meteorological stations, Banjarbaru and Syamsuddin Noor station. Projected rainfall with climate change scenarios was used as valuable input as estimated effective rainfall for the future water requirement analysis.

Irrigation Water Requirement

Evapotranspiration is an important value of hydrologic losses in water requirement value, the key to water loss and a principal factor for hydrological and climatological studies (Djaman,

2017). Penman-Monteith method is recommended for calculating

$$ET_0 = \frac{0.408\Delta(Rn - G) + \gamma 900u_2/(t + 273)(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

evapotranspiration value by FAO.

Where:

ET_0 = evapotranspiration (mm/day),

Δ = gradient of saturation vapor pressure vs temperature curve (kPa/°C),

Rn = net radiation (MJ/m²day),

G = ground surface soil heat flux density (MJ/m²day),

t = daily average temperature (°C),

u_2 = daily wind velocity at 2 m (m/s),

e_s = vapor pressure at saturation stage (kPa), e_a = vapor pressure at actual stage (kPa),

$e_s - e_a$ = the saturation vapor pressure deficit (kPa),

γ = constant value of psychometric (kPa/°C).

Water requirement was calculated according to the following equation.

$$\text{Irr Water Req} = Et_0 + \text{Deep percolation} + \text{Runoff} - \text{Peff}$$

Where:

Et_0 = Evapotranspiration (mm)

$Peff$ = the effective rainfall (mm)

RESULTS

Observed rainfall and temperature data

Figure 2 shows the monthly average temperature in South Kalimantan. Minimum

temperature mainly occurs in January and December. The maximum temperature occurs in May. Monthly average temperature is 26.22 °C.

Tropical monsoon is the type of climate in Barito Kuala, climatological conditions throughout the year are hot and humid with a dry season about 2-3 months with rainfall depth less than 100 mm/month. The wet season around 5-6 months, has a rainfall depth more than 200 mm/month (Ar Riza, 1997). The dry season in Indonesia occurs as an effect of the southeast winds pushing dry Australian continental air masses toward the archipelago, while the wet season occurs when the monsoon winds blow from a northwest direction. (Kirono, 2016).

The climate of South Kalimantan, especially in Barito Kuala, is strongly influenced by monsoon. The Monsoon type of rain pattern is U-shaped. The pattern thus has a wet season around October to March this pattern was also strongly influenced by the movement of winds from the northwest towards the southeast starting in October and ending in March. Dry season start April to September as an effect of the wind from southeast to northwest which from April to September. In addition, this pattern is also strongly influenced by extreme wet situations (La-Nina) and extreme dry situations (El-Nino) (Rusmayadi, 2016).

Figure 3 shows the monthly average of rainfall in South Kalimantan, in August is the minimum rainfall value and the maximum is in December. The average monthly rainfall depth is 228.32 mm and the average annual rainfall in South Kalimantan is 2575 mm. Mainly local paddy cultivation begins in March but seeding period start from October in the previous year.

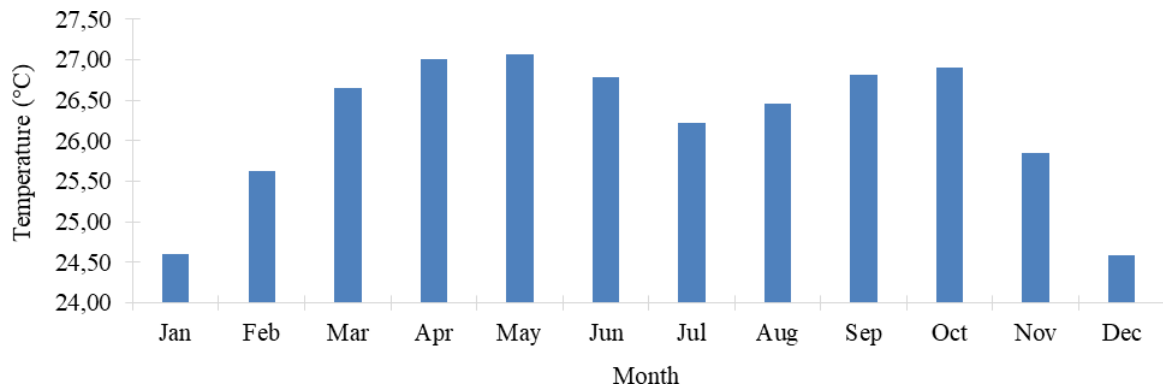


Figure 2. Monthly average of temperature in South Kalimantan

Projected rainfall and meteorological parameter under the climate change scenario

This research is conducted by employing RCP 8.5 scenario. The Representative Concentration Pathways (RCPs) 8.5 parallels to high greenhouse gas emissions pathways. Increased greenhouse gas emissions and concentrations are noticeable over time, leading to a radiative forcing of 8.5 W/m^2 at

the end of the century (Riahi, et al., 2011). RCP 8.5 has been chosen because Indonesia as a developing country with a huge population that leads to high energy demand. Food security is an important subject due to the increase in population. Result of projected rainfall analysis shows in **Figure 4** (a) 2050 and (b) 2090.

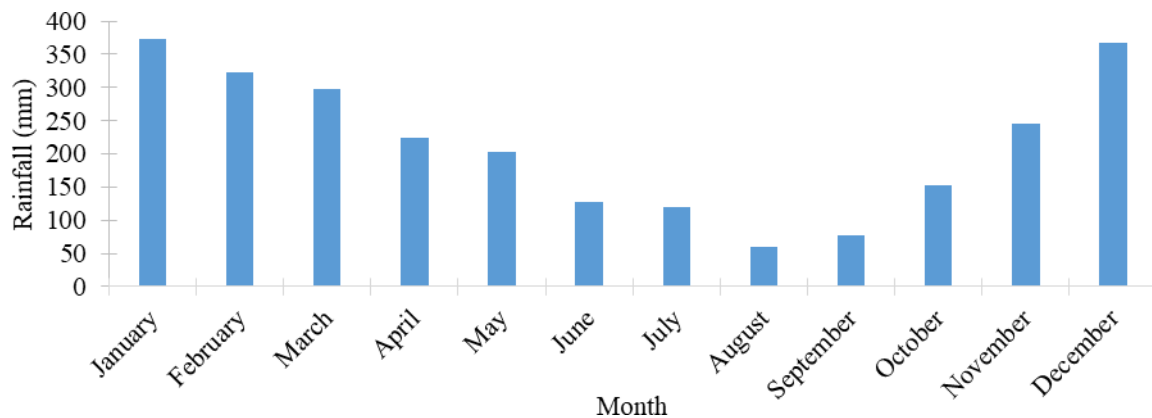


Figure 3. Monthly average of rainfall in South Kalimantan

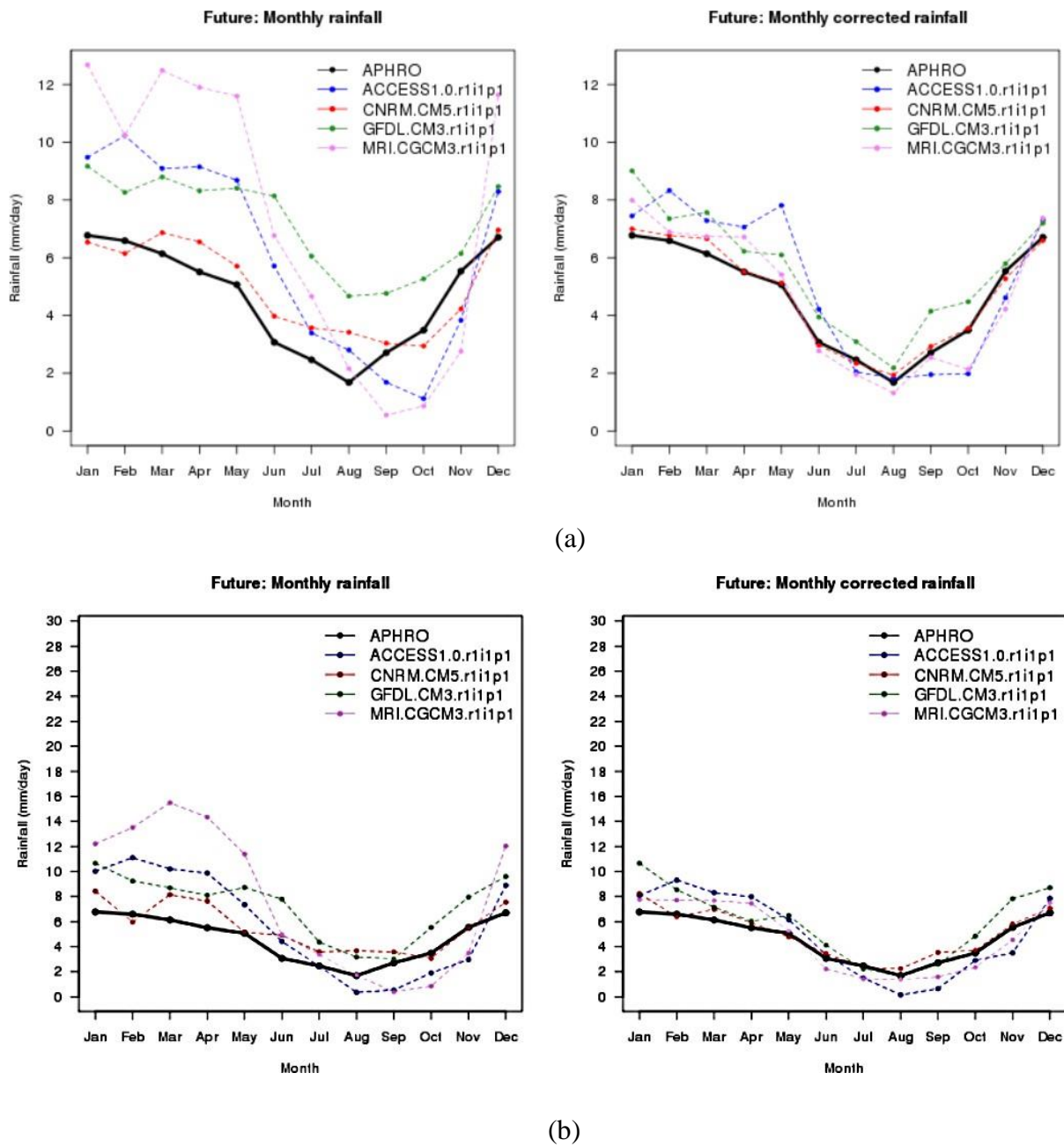


Figure 4. Comparison of projected rainfall before and after bias correction
(a) 2050 and (b) 2090 (Achyadi, et al., 2019)

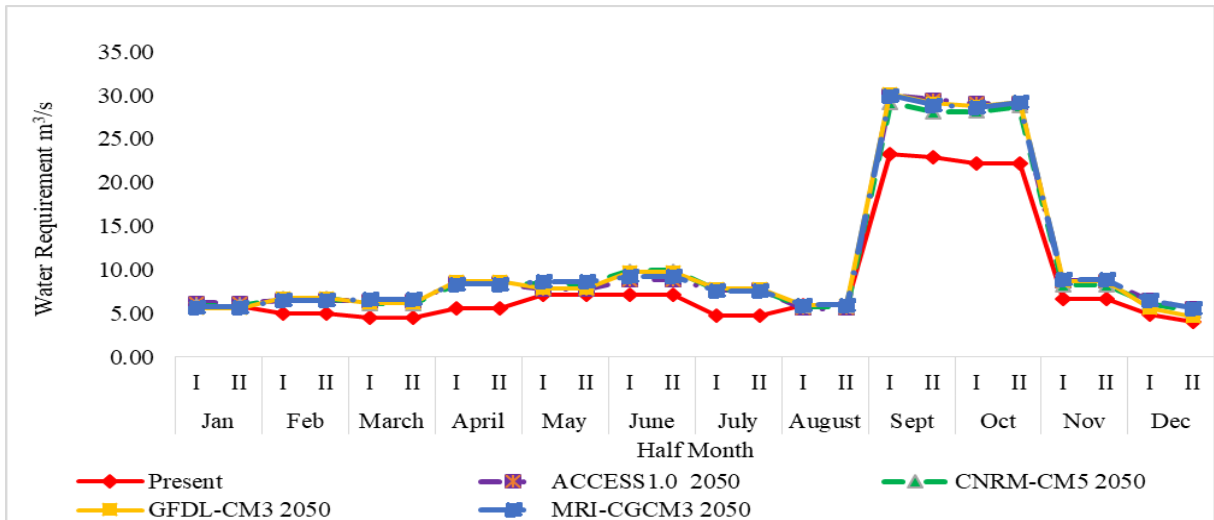


Figure 5. Present and projected (2050) half monthly water requirement relative to local paddy cropping pattern

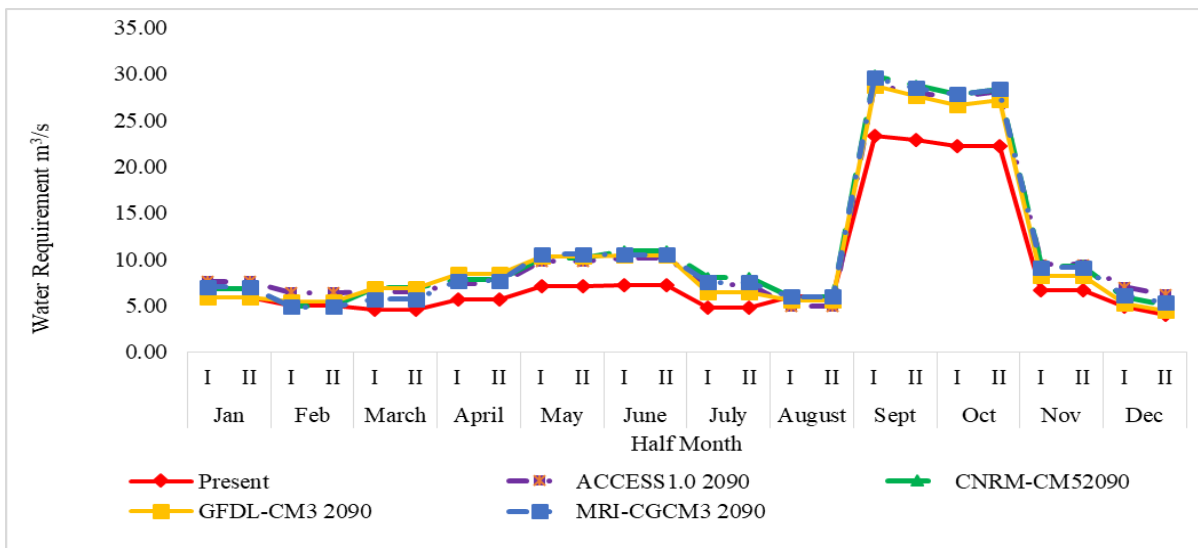


Figure 6. Present and projected (2090) half monthly water requirement relative to local paddy cropping pattern

As seen in **figure 4** (a) and (b), the results of the simulation of four corrected GCM models for 2050 show different patterns from June to December. Each model shows that not all downscaled model data point have similar trends. Two models show the rainfall value compared with observed value (APHRO) such as ACCESS 1.0 and MRI.CGCM3. A similar result came from CNRM.CM5 model, the simulation and

observed value alteration are quite small. Different results can be seen in GFDL. CM3, which is the estimated rainfall overestimation of the observed value.

The predicted rainfall results also varied in the 2090 simulation Figure 4b. All models did not show a similar trend compared to observed data, there are some differences in predictions of future rainfall.

The graph shows the ACCESS 1.0 model underestimated the future rainfall values from July whereas the underestimation of MRI.CGCM3 model started in June. In this case, CNRM.CM5 and GFDL. CM3 gave similar results with observed data. Effective rainfall will determine the evapotranspiration value. Therefore simulation value of rainfall is very influential on the value of future water requirements.

Projected evapotranspiration analysis

The future prediction of temperature, humidity, wind velocity, and solar radiation obtain from GCMs by DIAS CMIP5 data analysis tools on this address <http://apps.diasjp.net/modelvis/cmip5>.

Present data of evapotranspiration provided by Ministry of Public Works and Residential Republic of Indonesia.

Table 1 shows, the monthly average evapotranspiration value increased to 6.53 mm/day in 2050 and 6.62 mm/day in 2090 from the present 4.51 mm. The model projection of monthly average evapotranspiration in wet season (October–March) is slightly decrease 6.17 mm/day in 2050 to 5.97 mm/day in 2090.

Furthermore, during the dry season (April–September), September is the highest value 7.86 mm/day in 2050 and 7.69 mm/day in 2090. Our simulations calculated that October is the highest evapotranspiration value 8.24 mm/day and 7.9 mm/day. October is the cultivation in the larger paddy field starts every year. A higher value of evapotranspiration will obtain more water demand for the paddy field.

Table 1. The evapotranspiration value in the present and future.

Month	Evapotranspiration (mm/day)		
	Present	2050	2090
Jan	4.22	4.66	5.34
Feb	4.05	5.26	3.90
March	4.60	5.72	5.72
April	4.41	6.60	6.43
May	4.57	5.57	7.47
June	4.31	6.43	7.12
July	4.25	7.43	7.43
August	4.93	7.52	7.52
Sept	4.83	7.86	7.69
Oct	4.99	8.24	7.90
Nov	4.73	7.17	7.34
Dec	4.23	5.94	5.61
Monthly Average	4.51	6.53	6.62

Source : Present data from KemenPUPR,2017

Projected water requirement analysis

The impact of climate change is very significant in the agricultural sector because the agricultural sector is very reliant on conditions of temperature for paddy cultivation. Excess or shortage of water and decreasing trend of temperature will greatly affect water requirements for plants. Crop water requirement for local paddy cultivation could be obtained by multiplying evapotranspiration and time-varying crop coefficient (Kc). **Figure 5** and **figure 6** show the simulation of the paddy water requirement between the present condition and future. Because of increasing evapotranspiration value in 2050 and 2090, this condition will generate higher water requirements.

Local paddy type cultivation is 10 months for one period. The cultivation period divided into 4 stages, land preparation, vegetative, generative, and harvesting. Vegetative and generative stages are a period where higher water supply is needed for plant growth. Local farmers begin the cropping time in October or November. Overall, the future water requirement in the vegetative and generative stages will increase by around 56% in dry season (July). Wet season cropping water requirement will increase by 25% in September and October. These conditions will result in the use of water from the irrigation system support increased.

CONCLUSIONS

This study examines the impact of climate change on the water requirement between the present (1981-2009) and future (2050 and 2090). Impacts in terms of 5 GCMs model under the RCPs 8.5 scenario were assessed for the local paddy fields in Terantang Barito Kuala, South Kalimantan, Indonesia. Due to the rising temperature and solar radiation, projected evapotranspiration will increase in the future. As mentioned above, increased evapotranspiration value will increase the water requirement by 56% in July and 25% in September-October. Such conditions will depend on the management of irrigation water use in the future.

ACKNOWLEDGMENT

This research was conducted partially by the River Foundation under the research grant in FY 2019 (research representative: Koichiro Ohgushi). We also acknowledged the Indonesia Ministry of Public Works and Residential, Kalimantan II Region for hydrology data and schematic layout of Terantang Irrigation Unit.

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