International Journal of Environment, Agriculture and Biotechnology
Vol-8, Issue-4; Jul-Aug, 2023
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Water Balance Analysis for Determination of Time Shift in Rice (*Oryza sativa* L.)

Based on Climate Projection Scenarios

Didik Hariyono[1], Rifka Auliasasti Putri[1], Akbar Saitama[1], Yohana Avelia Sandy[1], Akbar Hidayatullah Zaini[2]

[1]Faculty of Agriculture, Universitas Brawijaya, Malang, Indonesia,
[2]Lampung State Polytechnic, Bandar Lampung, Lampung, Indonesia

Received: 29 Jun 2023; Received in revised form: 31 Jul 2023; Accepted: 07 Aug 2023; Available online: 13 Aug 2023

***Abstract*— *Rice production in East Java has decreased, which is related to climate change. Uncertain climate results in a shift in planting time. Climate projection scenarios are a solution to see future climatic conditions. One of the analyses used is the water balance. This study aims to study the water balance to determine the rice (Oryza sativa L.) planting time shift based on climate projection scenarios. The research was conducted from March to July 2022 in four districts of East Java. The materials used are average rainfall data and average temperature data for 2000-2020, climate projection data from the CNRM-CM5 and HadGEM2-ES models for 2025-2050, field capacity data, and permanent wilting point data. This study uses a selected sampling technique and the location is chosen as one of the rice production centers in East Java. This research uses exploratory descriptive analysis, statistical descriptive analysis, and the Thornthwaite and Mather method of water balance analysis. The research results show a shift in the planting time of rice plants in four districts in East Java for the years 2025-2050. Malang District experienced a change in the planting time of rice plants of 2 basics, Gresik District experienced a shift in the planting time of rice plants of 2-6 basics, Banyuwangi District experienced a change in planting time of 3-5 basics of rice and Pasuruan District experienced a shift in planting time of rice plants of 1-4 basics.*

***Keywords*— Water Balance, shifting planting time, rice plants, climate projection scenario.**

I. INTRODUCTION

There are several parameters or climate factors that influence such as rainfall, air temperature, humidity, sunlight intensity, air pressure, and wind direction (Aditya et al., 2021). One important factor to support plant growth is water. Plants themselves have different water needs, including rice plants. Rice plants are plants that require a lot of water and are very sensitive to drought.

East Java is one of the provinces or regions in Indonesia which contributes to agricultural production with good results, one of which is rice. East Java is also one of the rice production centers. Based on BPS data for 2021, East Java is the largest producer by contributing 17.99% of rice production to total national production. However, over time, rice production has decreased due to several factors such as climate change. The impact of climate change that is clearly visible is the availability of water which is not enough to determine the right planting time. According to Apriyana et al., (2016) the impact of climate change resulted in a shift in planting time for rice plants ranging from 10-20 days from the normal planting time.

One of the efforts that can be made to reduce the impact of the shift in planting time is to develop a plan to see future climate conditions, namely with a climate projection scenario. Climate projections are the result of data processing from several modelling activities to determine future climate conditions based on the climate scenarios that will be used. The scenario used is an emission scenario with several levels such as low, medium to high (Surmaini and Faqih, 2016). The water balance is one of the analyzes that can be used for this climate projection scenario. The water balance is able to see the availability of water needed by plants and water balance such as shifts in planting time. This research is to study the water balance to determine shifts in the planting time of rice (Oryza sativa L.) based on climate projection scenarios.

II. MATERIALS AND METHODS

The research was conducted from March to July 2022 at the locations of Malang Regency, Pasuruan Regency, Gresik Regency and Banyuwangi Regency, East Java Province. The research was conducted in an exploratory descriptive manner. This research was conducted by identifying data, classifying secondary data based on research objectives, analyzing data and interpreting it. In this study the type of data used is secondary data which includes (1) BMKG rainfall and temperature data for 21 years, (2) climate projection scenario data from the CNRM-CM5 RCP 45 and RCP 85 models and the HadGEM2-ES RCP 45 and RCP models 85 for 26 years and (3) field capacity and permanent wilting point data.

The research location was determined using a purposive sampling method, namely choosing a location based on specific conditions (based on production centers, rainfall diversity and temperature). From this category, the research sample locations were Malang, Gresik, Banyuwangi and Pasuruan districts.

This study uses Explorative Descriptive Analysis and Statistical Descriptive Analysis. In addition, this research also uses water balance analysis, where the calculation of the water balance in this study uses the method developed by Thornthwaite and Mather (1957) with time per basis (10 days) with additional water surplus and deficit (loss).

III. RESULTS AND DISCUSSION

Rainfall and Temperature BMKG Data and Climate Projection Scenario Data

BMKG data results (observation) the highest rainfall in Malang Regency on the 3rd or January III, the CNRM RCP 45 model data results from the highest rainfall on the 36th or December III, the CNRM RCP 85 model data results from the highest rainfall on the 36th or December III, the results of the HadGEM RCP 45 model data have the highest rainfall on March 9 or III, the highest HadGEM RCP 85 model data results on March 9 or III. While the average temperature in Malang Regency from BMKG data (observations) is 23.6°C, the average temperature for CNRM RCP 45 data is 21.5°C, the average temperature for CNRM RCP 85 data is 21.7°C, the average temperature of the HadGEM RCP 45 data is 24.1°C and the average temperature of the HadGEM RCP 85 data is 24.3°C (Figure 1). This is in accordance with research conducted by Bagçaci et al., (2021) that the temperature results in the HadGEM2-ES model have a better rating when compared to the CNRM-CM5 model.

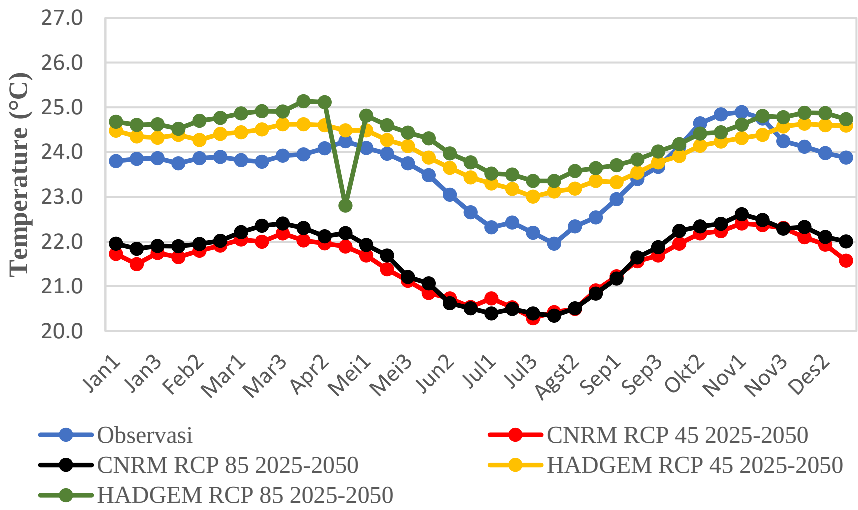

Fig.1. Average Temperature of Malang Regency

BMKG data results (observation) the highest rainfall in Gresik Regency on December 36 or III, the CNRM RCP 45 model data results the highest rainfall on December 36 or III, the CNRM RCP 85 model data results the highest rainfall on January 1 or I , the results of the HadGEM RCP 45 model data have the highest rainfall on the 3rd or January

III and the HadGEM RCP 85 model data results have the highest rainfall on the 4th or February 1st. Meanwhile, the average temperature in Gresik Regency from BMKG data (observation) is 28.1 °C, the average temperature of CNRM RCP 45 data is 27.8°C, the average temperature of CNRM RCP 85 data is 27.8°C, the average temperature of HadGEM RCP 45 data is 29.1°C and the average temperature -The average HadGEM RCP 85 data is 29.3°C (Figure 2). Thorndahl and Andersen (2021) stated that the temperature and rainfall results for RCP 85 would be more extreme when compared to RCP 45 due to an increase in greenhouse gases and no mitigation for reducing greenhouse gases.

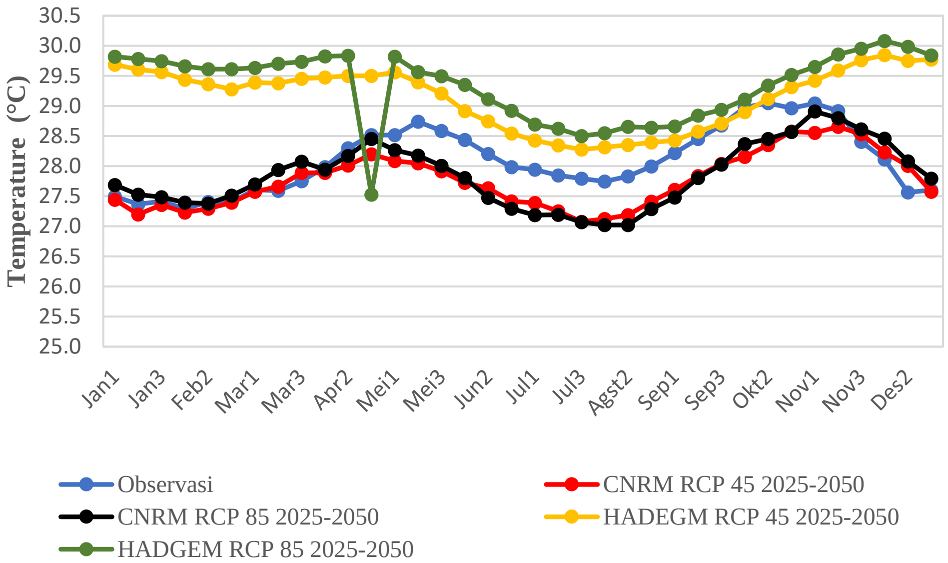

Fig.2. Average Temperature of Gresik Regency

BMKG data results (observation) the highest rainfall in Banyuwangi Regency on the 3rd or January III, the CNRM RCP 45 model data results the highest rainfall on the 11th or April II, the CNRM RCP 85 model data results the highest rainfall on the 8th or March II , the results of the HadGEM RCP 45 model data have the highest rainfall on the 12th or April III and the HadGEM RCP 85 model data results have the highest rainfall on the 14th or May II. While the average temperature in Banyuwangi Regency from BMKG data (observations) is 27.4°C, the average temperature for CNRM RCP 45 data is 24.0°C, the average temperature for CNRM RCP 85 data is 24.1°C, the average temperature of the HadGEM RCP 45 data is 27.3°C, the average temperature of the HadGEM RCP 85 data is 27.5°C (Figure 3). Based on research conducted by McSweeney et al., (2015) stated that the HadGEM2-ES model has good performance and is suitable for application in Southeast Asia.

BMKG data results (observation) the highest rainfall in Pasuruan Regency on the 3rd or January III, the CNRM RCP 45 model data results the highest rainfall on the 36th and 7th month or December III and March I, the CNRM RCP 85 model data results the highest rainfall on December 36 or III, the highest rainfall data for the HadGEM RCP 45 model is on March 8 or II and the highest rainfall for the HadGEM RCP 85 model data is on March 9 or III. While the average temperature in Pasuruan is BMKG data (observation) which is 21.8°C, the average temperature for CNRM RCP 45 data is 22.2°C, the average temperature for CNRM RCP 85 data is 22.4°C, the average temperature of the HadGEM RCP 45 data is 25.0°C and the average temperature of the HadGEM RCP 85 data is 25.2°C (Figure 4). Meng et al., (2017) stated that extreme shifts in rainfall and temperature can affect plant growth and yield.

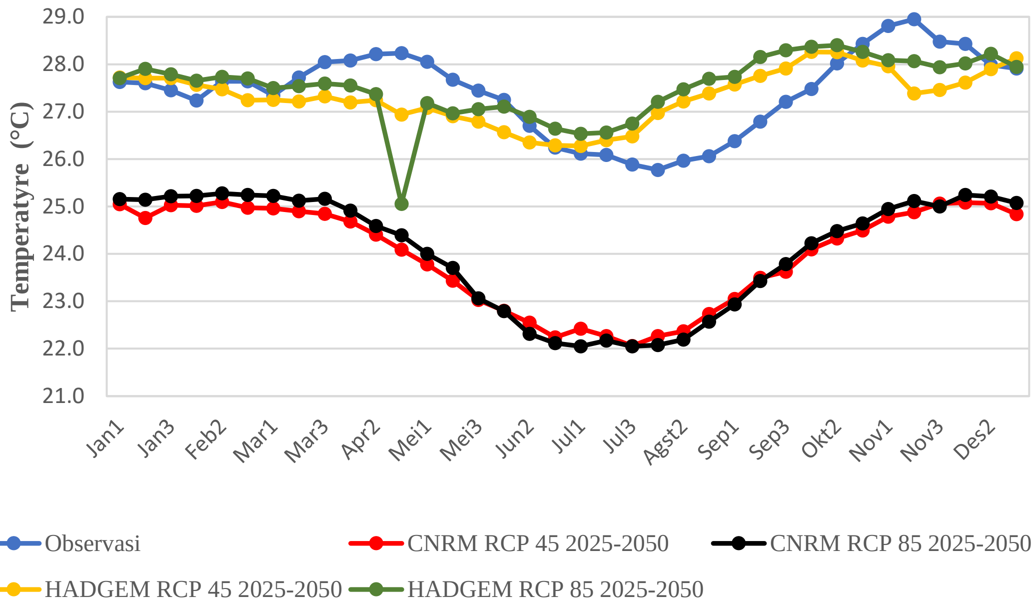

Fig.3. Average Temperature of Banyuwangi Regency

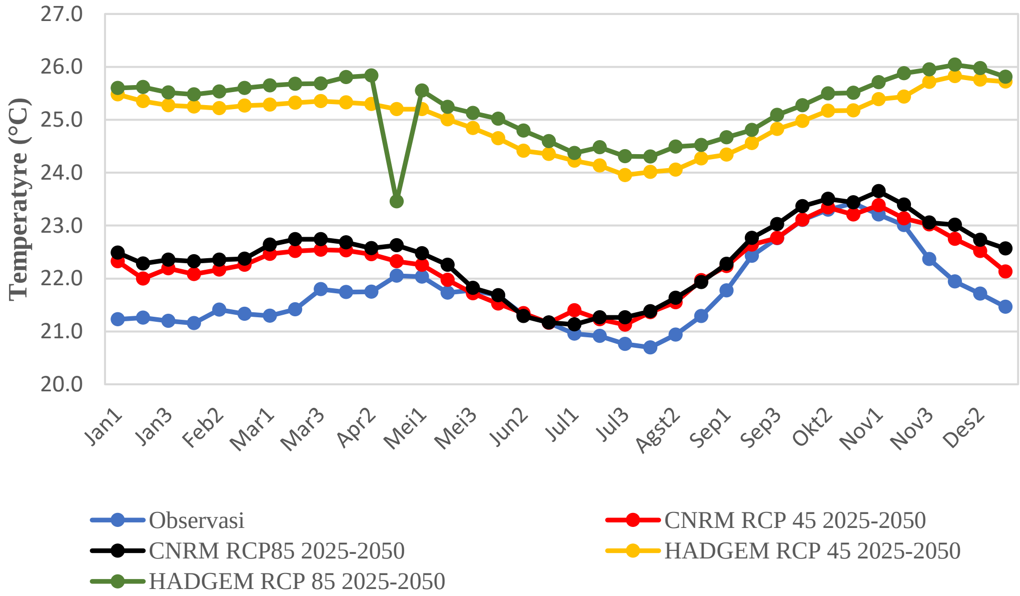

Fig.4. Average Temperature of Pasuruan Regency

BMKG Data Water Balance and Climate Projection Scenario Data

The results of the water balance in Malang Regency BMKG data (observation) experienced a surplus of 19 basis and a deficit of 16 basis (Figure 5), the results of the water balance of the CNRM RCP model data 45 experienced a surplus of 22 basis and a deficit of 13 basis (Figure 6), the result of the water balance of the data model CNRM RCP 85 experienced a surplus of 22 basisan and a deficit of 13 basisan (Figure 7), the water balance results of the HadGEM RCP 45 model data experienced a surplus of 28 basisan and a deficit of 7 basisan (Figure 8) and the results of the water balance data of the HadGEM RCP 85 model experienced a surplus of 30 basisan and 6 basis deficit (Figure 9).

The results of the water balance in Gresik Regency BMKG data (observation) experienced a surplus of 20 basis and a deficit of 14 basis (Figure 10), the results of the water balance of the CNRM RCP model data 45 experienced a surplus of 13 basis and a deficit of 20 basis (Figure 11), the result of the water balance of model data CNRM RCP 85 experienced a surplus of 13 basis and a deficit of 22 basis (Figure 12), the water balance results of the HadGEM RCP 45 model data experienced a surplus of 12 basis and a deficit of 24 basisan (Figure 13), the water balance result of the HadGEM RCP 85 model data experienced a surplus of 10 basisan and deficit 25 basisan (Figure 14).

The results of the water balance in Banyuwangi Regency BMKG data (observation) experienced a surplus of 9 basis and a deficit of 26 basis (Figure 15), the results of the water balance of the CNRM RCP model data 45 experienced a surplus of 12 basis and a deficit of 24 basis (Figure 16), the result of the water balance of the data model CNRM RCP 85 experienced a surplus of 12 basisan and a deficit of 23 basisan (Figure 17), the water balance results of the HadGEM RCP 45 model data experienced a surplus of 23 basisan and a deficit of 11 basisan (Figure 18) and the water balance result of the HadGEM RCP 85 model data experienced a surplus of 23 basisan and deficit 11 basisan (Figure 19).

The results of the water balance in Pasuruan Regency BMKG data (observation) experienced a surplus of 27 basis and a deficit of 7 basis (Figure 20), the results of the water balance of the CNRM RCP model data 45 experienced a surplus of 21 basis and a deficit of 14 basis (Figure 21), the result of the water balance of model data CNRM RCP 85 experienced a surplus of 22 basisan and a deficit of 13 basisan (Figure 22), the water balance results of the HadGEM RCP 45 model data experienced a surplus of 34 basisan and a deficit of 2 basisan (Figure 23) and the water balance result of the HadGEM RCP 85 model data experienced a surplus of 29 basisan and a deficit of 6 basisan (Figure 24).

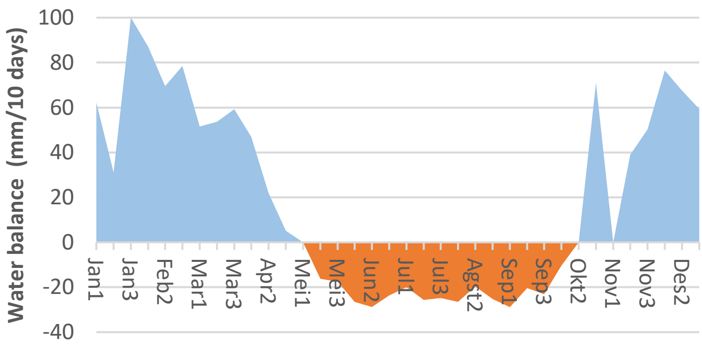

Fig. 5. Observation data water balance of Malang Regency

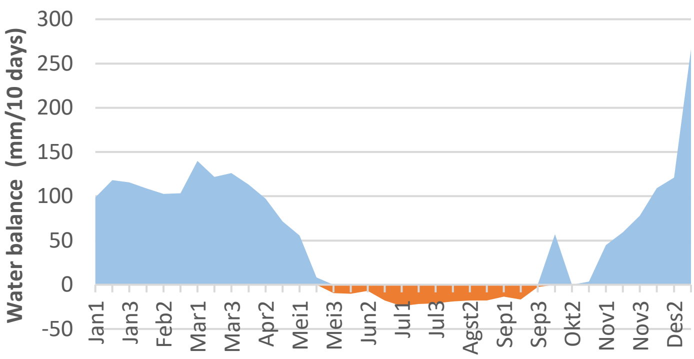

Fig. 6. Water balance data from the CNRM RCP 45 Model in Malang Regency

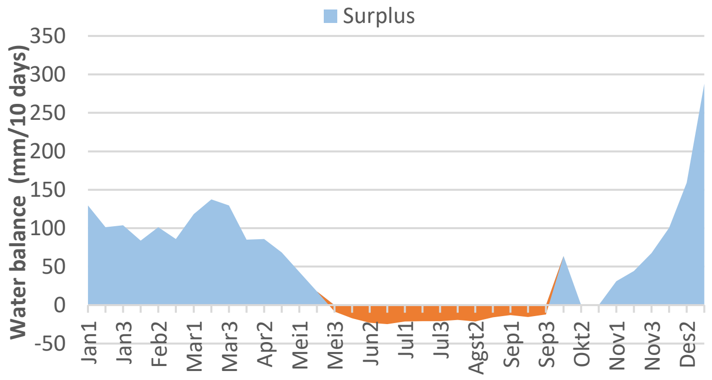

Fig. 7. Water balance of the CNRM RCP 85 Model data for Malang Regency

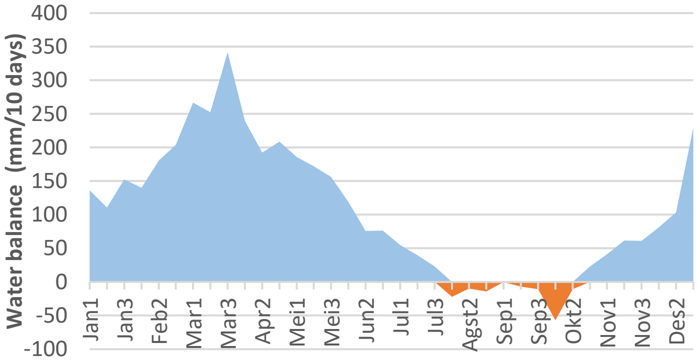

Fig. 8. Water balance of the HadGEM RCP 45 Model data for Malang Regency

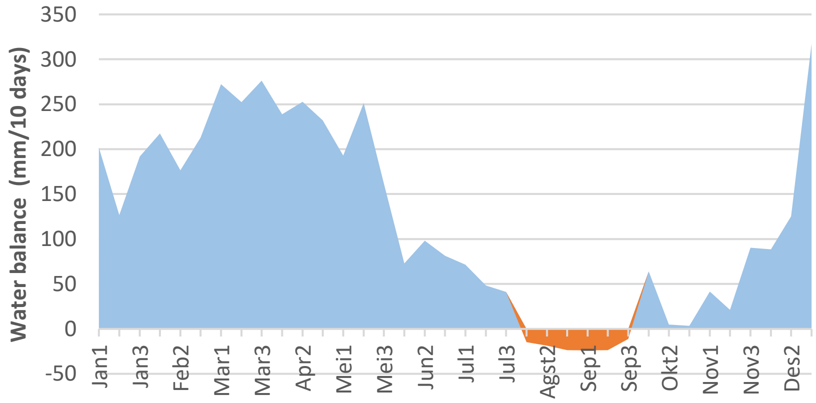

Fig. 9. Water balance of the HadGEM RCP 85 Model data for Malang Regency

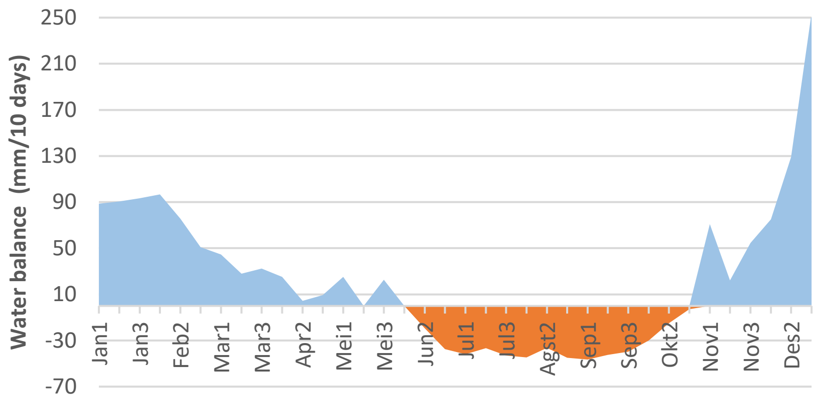

Fig. 10. Water balance Observation data of Gresik Regency

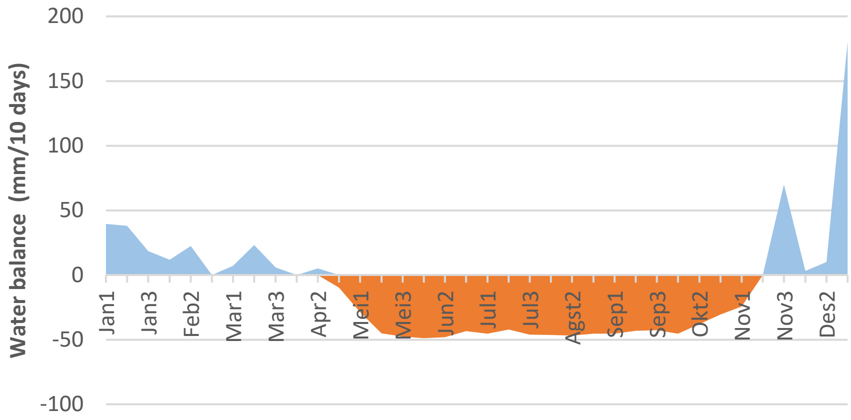

Fig. 11. Water balance data from the CNRM RCP Model 45 Gresik Regency

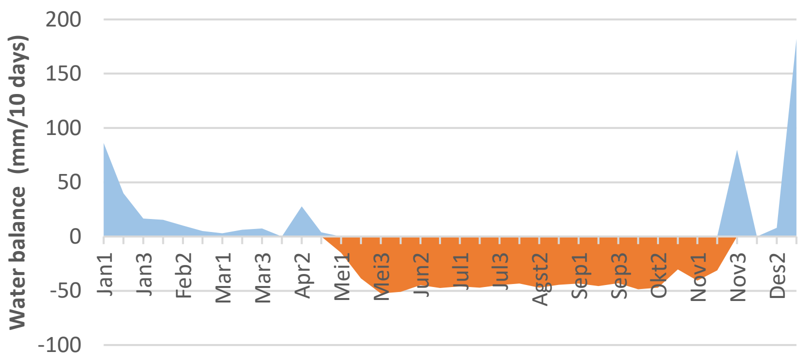

Fig. 12. Water balance data from the CNRM RCP 85 Model, Gresik Regency

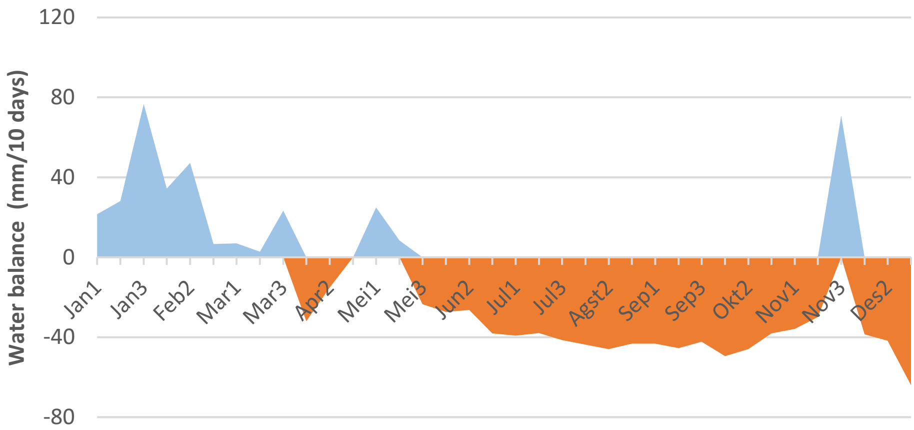

Fig. 13. Water balance data from the HadGem RCP 45 Model in Gresik Regency

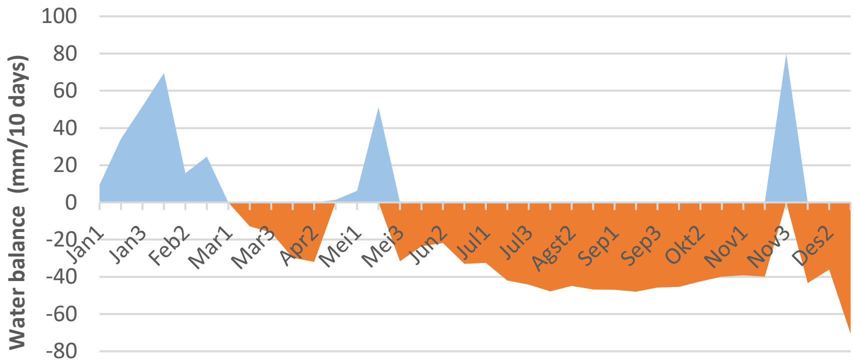

Fig. 14. Water balance data from HadGem RCP 85 Model Gresik Regency

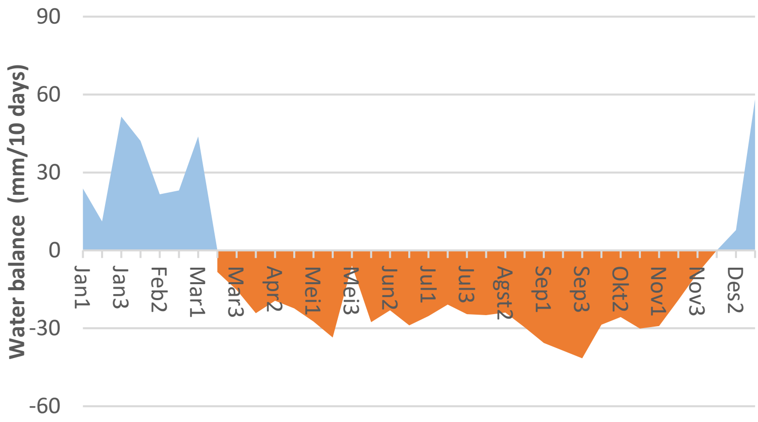

Fig. 15. Observation data water balance of Banyuwangi Regency

ISSN: 2456-1878 (Int. J. Environ. Agric. Biotech.)
https://dx.doi.org/10.22161/ijeab.84.14

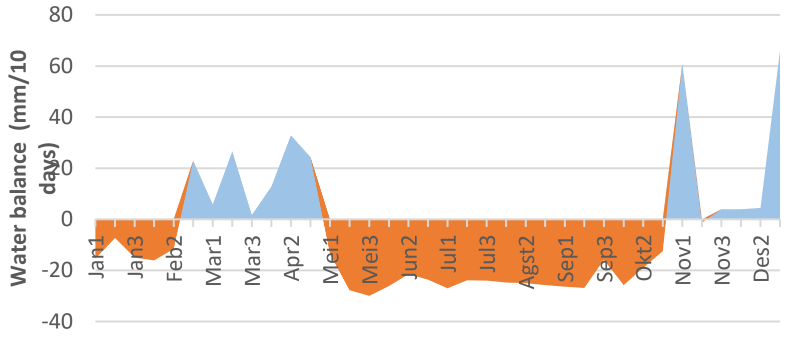

Fig. 16. Water balance data from the CNRM RCP 45 Model, Banyuwangi Regency

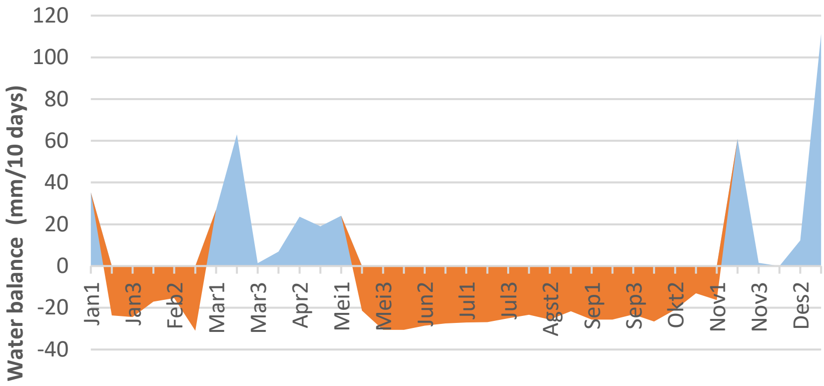

Fig. 17. Water balance data from the CNRM RCP 85 Model, Banywangi District

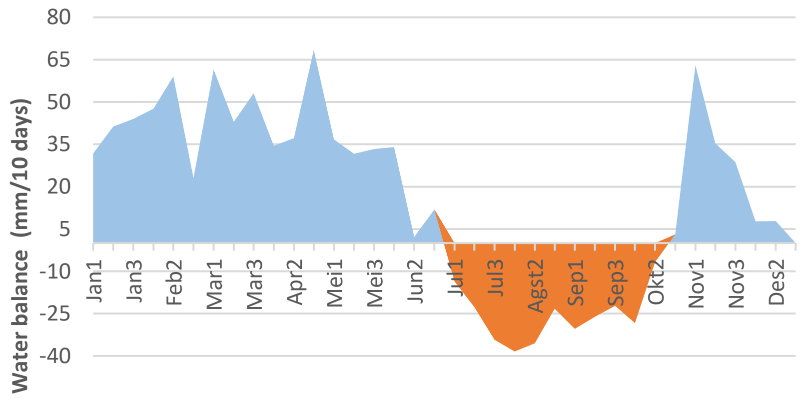

Fig. 18. Water balance data from the HadGEM RCP 45 Model of Banyuwangi Regency

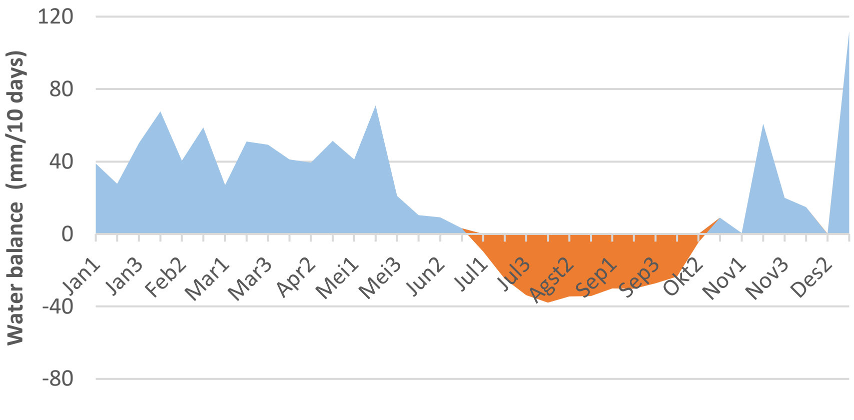

Fig. 19. Water balance data from the HadGEM RCP 85 Model of Banyuwangi Regency

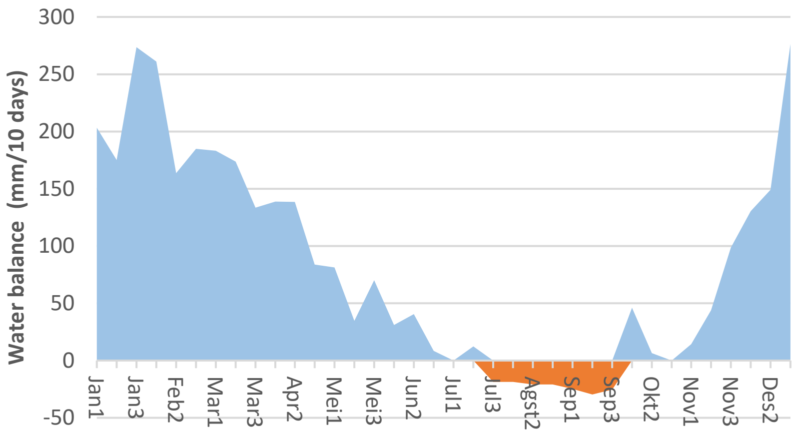

Fig. 20. Observation Data Water Balance Pasuruan District

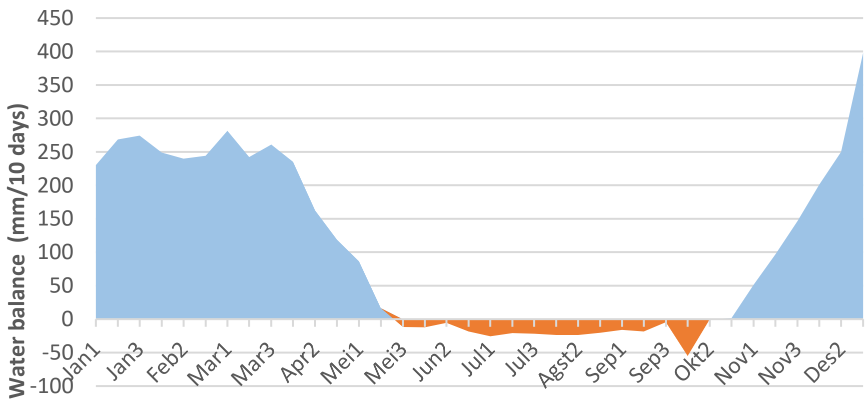

Fig. 21. Water balance data from the CNRM RCP 45 Model, Pasuruan Regency

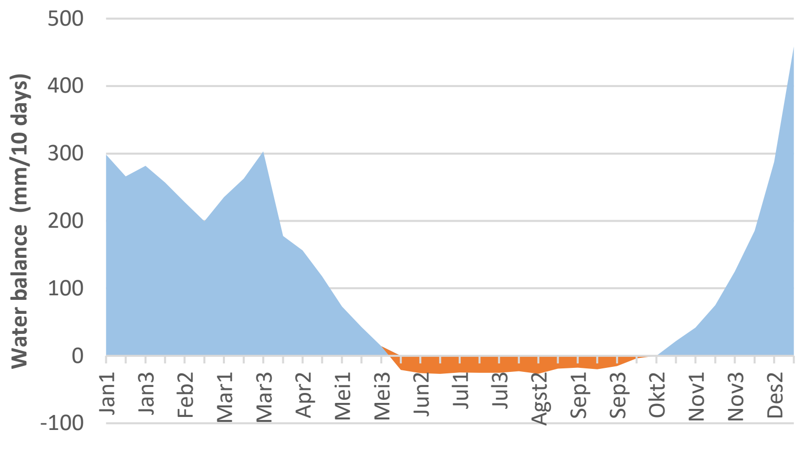

Fig. 22. Water balance data from the CNRM RCP 85 Model, Pasuruan Regency

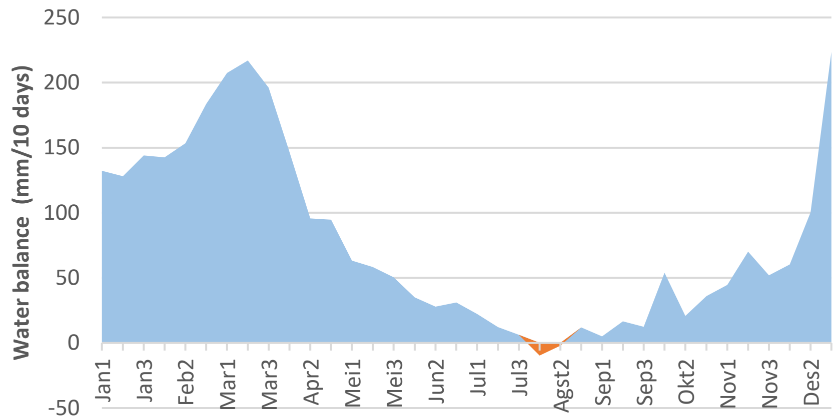

Fig. 23. Water balance data from the HadGEM RCP 45 Model, Pasuruan Regency

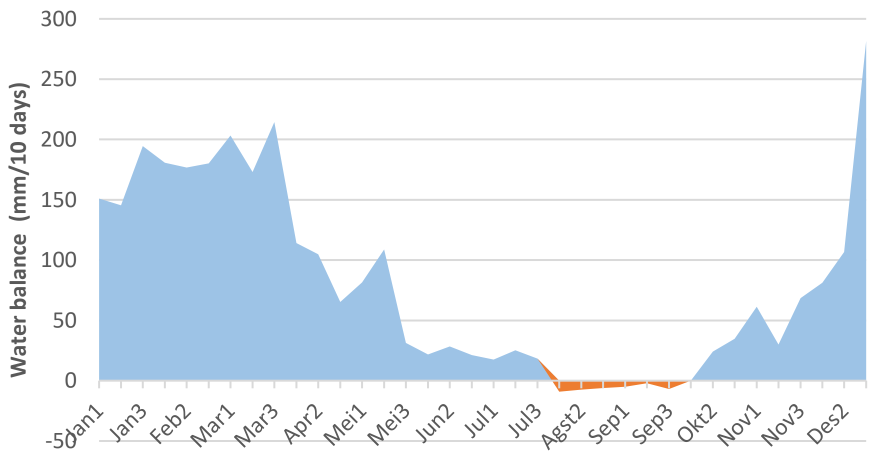

Fig. 24. Water balance data from the HadGEM RCP 85 Model, Pasuruan Regency

Shift in Rice Planting Time in Each Regency in East Java

rice planting time in Malang Regency BMKG data (observation) can be done in October III – February I, rice planting time CNRM RCP 45 model data can be done in October I – January II (experiencing a shift of 2 bases), rice planting time CNRM RCP model data 85 can be done October I – January II (experiencing a shift of 2 basis), rice planting time of the HadGEM RCP 45 model data can be done in October III – February I (no shift) and rice planting time of the HadGEM RCP 85 model data can be done October I – January II (experiencing a shift of 2 basis). According to Rahman (2018), climate change that occurs indirectly has an impact on water availability, when the total amount of rainfall decreases by around 10% and extreme temperature increases will result in more dry seasons.

Paddy planting time in Gresik Regency BMKG data (observation) can be done on November I – February II, rice planting time for CNRM RCP 45 model data can be done on November III – March I (experiencing a shift of 2 basis), rice planting time for CNRM RCP model data 85 can be done November III – March I (experiencing a shift of 2 basis), rice planting time of the HadGEM RCP 45 model data can be done January I – April II (experiencing a shift of 6 basis) and rice planting time of the HadGEM RCP 85 model data can be done January I – April II (experiencing a 6 basis shift). According to Mayasari and Anna (2020) stated that a shift in planting time that occurs, even if only for one basis (10 days), has the potential to reduce crop yields by up to 40%.

Paddy planting time in Banyuwangi Regency BMKG data (observation) can be done in December II – March III, rice planting time for CNRM RCP 45 model data can be done in November I – February II (experiencing a shift of 4 basis), rice planting time for CNRM RCP model data 85 can be done in November II – February III (experiencing a 3-difference shift), the HadGEM RCP 45 model rice planting season can be done in October III-February I (experiencing a 5-difference shift) and the HadGEM RCP 85 model paddy planting season can be done October III- February I (experiencing a shift of 5 basis). Rahman (2018) states that rainfall decreases over a long period of time and temperatures that increase by only 1% will result in a decrease in rice crop yields by 80%.

Paddy planting time in Pasuruan Regency BMKG data (observation) can be done on October I – January II, rice planting time for CNRM RCP 45 model data can be done on October III – February I (experiencing a shift of 2 basis), rice planting time for CNRM RCP model data 85 can be done in October III – February I (experiencing a shift of 2 basis), the rice planting time of the HadGEM RCP 45 model data can be done in August III – December I (experiencing a shift of 4 basis) and the rice planting time of the HadGEM RCP 85 model data can be done in October II – January III (experiencing a shift of 1 basis).

IV. CONCLUSION

1. Two model scenarios from the climate projection scenario that have been used and compared, namely the HadGem2-ES model and the CNRM-CM5 model, produced the right model and can be applied to Malang, Gresik and Banyuwangi districts, namely the HadGem2-ES model, while for the district The appropriate model for Pasuruan is the CNRM-CM5 model which refers to the results of rainfall, temperature and water balance.

2. There has been a shift in the timing of rice planting in four districts in East Java for 2025-2050 based on BMKG data (observation), CNRM-CM5 RCP 45 model data, CNRM-CM5 RCP 85 model data, HadGEM2-ES RCP 45 model data and HadGEM2-ES RCP 85 model data.

REFERENCES

[1] Aditya, F., E. Gusmayanti dan J. Sudrajat. 2021. Pengaruh Perubahan Curah Hujan terhadap Produktivitas Sawah di Kalimantan Barat. Jurnal Ilmu Lingkungan. 19(2): 237-246. DOI: 10.14710/jil.19.2.237-246

[2] Apriyana, Y., E. Susanti., Suciantini., F. Ramadhani dan E. Surmaini. 2016. Analisis Dampak Perubahan Iklim Terhadap Produksi Tanaman Pangan Pada Lahan Kering dan Rancang Bangun Sistem Informasi. Jurnal Informatika Pertanian. 25(1): 69-80.

[3] Bagçaci, S. C., I. Yucel., E. Dunzenli and M. T. Yilmaz. 2021. Intercomparison of the expected change in the temperature and the precipitation retrieved from CMIP6 and CMIP5 climate projections: A Mediterranean hot spot case, Turkey. Journal Atmospheric Research. (256): 1-17. DOI: https://doi.org/10.1016/j.atmosres.2021.105576.

[4] Mayasari, V and A. Hairani. 2020. Preliminary Prediction of Rice Planting for Planting Season 2019, 2020, and 2021, Based Water Balance in Freshwater Swampland. Journal BIO Web of Conferences. (20): 1-5. DOI: https://doi.org/10.1051/bioconf/20202001004

[5] McSweeney, C. F., R. G. Jones., R. W. Lee and D. P. Rowell. 2015. Selecting CMIP5 GCMs for downscaling over multiple regions. Journal Clim Dyn. (44): 3327-3260. DOI: 10.1007/s00382-014-2418-8

[6] Meng, T., R. Carew., W. J. Florkowski and A. M. Klepacka. 2017. Analyzing Temperature and Precipitation Influences on Yield Distributions of Canola and Spring Wheat in Saskatchewan. Journal of Applies Meteorology and Climatology. (56): 897-913. DOI: 10.1175/JAMC-D-16-0258.1

[7] Rahman, H. A. 2018. Climate Change Scenarios In Malaysia: Engaging The Public. International Journal of Malay-Nusantara Studies. 1(2): 55-77

[8] Surmaini, E dan A. Faqih. 2016. Kejadian Iklim Ekstrem dan Dampaknya Terhafap Pertanian Tanaman Pangan di Indonesia. Jurnal Sumberdaya Lahan. 10(2): 115-128

[9] Thorndahl, S and C. B. Andersen. 2021. CLIMACS: A method for stochastic generation of continuous climate projected point rainfall for urban drainage design. Journal of Hydrology. (602): 1-14. DOI: https://doi.org/10.1016/j.jhydrol.2021.126776