Cropping Calendar Scenario Based on Climate Projections Against Regional Climate Change in the Southern Part of Indonesia

Bayu Dwi Apri Nugroho, Chusnul Arif, and Rizki Maftukhah

Abstract Although there have been many studies in climate projection and cropping calendar, but a little evidence in relationships with climate change in the southern part of Indonesia, especially in East Nusa Tenggara. East Nusa Tenggara (NTT) Province, a province with consists many islands, typical monsoon climate with low annual rainfall. The aims of this study is to predict potential rainfall that can be used for agriculture, to calculate crop water requirement (especially for rice and corn), and to decide planting schedule for rice and corn during 2016–2020 in Kupang, East Nusa Tenggara Province as the southern part of Indonesia. As the results, for climate projection, temperature during period 2015–2040 will be increased around 0.4 °C, and rainfall will be fluctuated during that period. Data rainfall prediction is used to predict water balance during 2016–2020. Water balance for each beginning of planting season was used as basic to decide planting schedule of rice and corn. The result shows that water potential from rainfall is 838.9 mm year^{-1}. The amount of crop water requirement for rice on December and January (2016–2020) are 605.73 mm per planting season and 611.56 mm per planting season, respectively. Further, crop water requirement of corn (December and January) are 344.78 mm per planting season and 348.19 mm per planting season, respectively. Planting schedule scenarios during 5 year (2016–2020) for rice and corn are dominates in December and January.

Keywords Climate change · Climate projections · Crops calendar · Rainfall · Water balance

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Abbreviations

ENSO El Nino/Southern Oscillation
CWR Crop water requirement

1 Introduction

Rice, the primary staple food for Indonesia's 250 $\times$ 10^{-6} people, provides seasonal income and employment for a large segment of the country's rural population. Significant growth in rice production has bolstered rural development since the early 1970's, but climate change has affected rice production in Indonesia with El Nino/Southern Oscillation (ENSO) events as reported in previous studies [1, 2]. Climate change caused the increased scarcity of and competition for water resources that have changed the planting pattern in Indonesia.

East Nusa Tenggara (NTT) is known as a province with typical monsoon climate with low annual rainfall. Increasing population and reducing arable area have increased the challenges to raise rice productivity. In addition, climate change has affected on any sectors including agriculture. Changes in rainfall patterns and extreme climate events such as El Nino and La-Nina are some indicators of climate change that can be felt directly current time. It caused by increasing the average air temperature by increasing concentrations of greenhouse gases in the atmosphere. Climate change also has affected on the water resources for rice farming [3]. Sustainability of rice farming is depending on water resource, when its scarcity became increasing due climate changes [4]. Water saving technology for rice farming is essential.

Based on Statistical Bureau of Republic Indonesia [6], productivity of maize in NTT influenced by El Nino and La Nina events. During 2012–2015, productivity of maize was decreased due to El Nino events. Aims of this study is to predict potential rainfall that can be used for agriculture, to calculate crop water requirement (especially for rice and corn), and to decide planting schedule for rice and corn during 2016–2020 as one of the southern part of Island in Indonesia.

2 Methods

2.1 Study Area

Our study area is East Nusa Tenggara Province which is located in 8° to 12° S and 118° to 125° E (Fig. 1). East Nusa Tenggara Province consists 21 districts and 285 sub districts with area 47,349.90 km^2. Climate condition is typical monsoon climate with low annual rainfall.

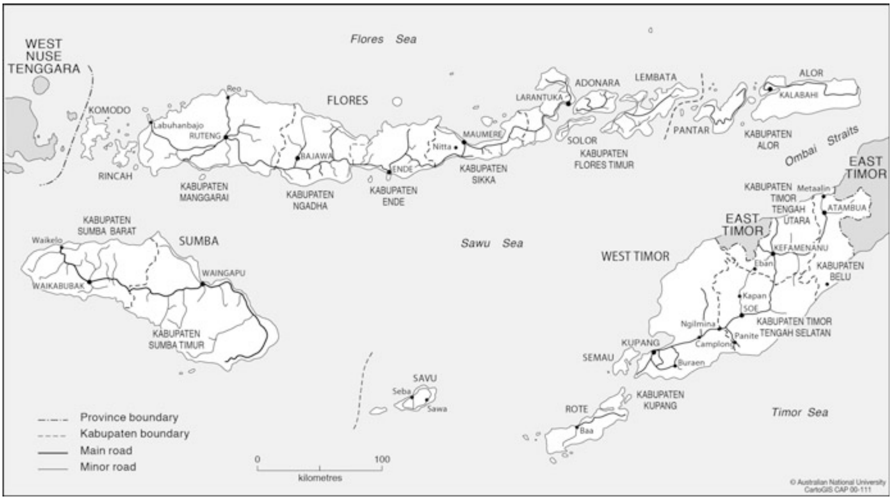

Fig. 1 Map of East Nusa Tenggara Province, Indonesia [5]

2.2 Data

Precipitations data (2001–2015) was collected from the Bureau of Climatology and Geophysics, Republic of Indonesia. Rice, rain-fed rice, and maize productivity of East Nusa Tenggara Province from 2001 to 2015 were collected from Regional Development Institution of East Nusa Tenggara Province [7] and Meterological, Climatological and Geophysical Agency of Republic Indonesia [8].

2.3 Data Analysis

2.3.1 Analysis of Rainfall

Run test and Rescaled Adjusted Partial Sums (RAPS) were used in this study. Time series data of rainfall during 15 year (2001–2015) have been analyzed for their consistency data through standard deviation and cumulative deviation test. Then. Thomas-Fiering equation was used to predict rainfall. For this analysis, model calibration is used to get high correlation value of generated data and observation data. Clarke [9] stated that Thomas-Fiering equation can be determined by calculate mean value of monthly rainfall, deviation standard, correlation coefficient, slope regression equation, and random variant of normal distribution. Thomas-Fiering regression equation was follow:

$$x_{i+1} = \bar{x}_{j+1} + b_j\left(x_i - \bar{x}_j\right) + t_i s_{j+1} + \sqrt{\left(1 - r_j^2\right)} \tag{1}$$

where x_i and x_{i+1} are generated hydrological variables during the i'th and i + 1'st month. respectively; x_j and x_{j+1} are mean of the hydrological variable in months j and j + 1; b_j is regression coefficient; t_i is a random normal variable with zero mean and unit variance; s_{j+1} is standard deviation of the hydrological variable in the j + 1'st month; and r_j is correlation coefficient between the hydrological variables in months j and j + 1.

2.3.2 Model Validation

Model validity was used to determine compability of theoretical distribution model with the observed data. The t test paired data was used for validation of rainfall data in 2006 compared with observed data in 2006. Then the correlation coefficient test (r) at a certain level of trust is used to know the closeness of the relationship between the two data. The correlation coefficient value of r-count is compared with r-table. This test is follow Eqs. 2 and 3.

$$t = \frac{D}{SD/\sqrt{n}} \approx t_{n-1} \tag{2}$$

$$\text{With } D = \sum_{i=1}^{n} Di \text{ and } SD\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(Di - \bar{D}\right)^2} \tag{3}$$

where n is amount of data and d is data.

Coefficient of correlation is calculate by:

$$r = \frac{n\sum_{i=1}^{n} X_i Y_i - \left[\sum_{i=1}^{n} X_i\right]\left[\sum_{i=1}^{n} Y_i\right]}{\sqrt{n\sum_{i=1}^{n} X_i^2 - \left[\sum_{i=1}^{n} X_i\right]^2}\sqrt{n\sum_{i=1}^{n} Y_i^2 - \left[\sum_{i=1}^{n} Y_i\right]^2}} \tag{4}$$

If r count > r table then show the correlation between Xi dan Yi.

2.3.3 Analysis of Crop Water Requirement and Effective Rainfall

Crop water requirement (ETc) was determined by evapotranspiration (ETo) multiply with crop coefficient (Kc). ETo calculated through Cropwat 8.0. Mean climate data (2001–2015) including maximum and minimum temperature (°C); relative humidity (%); wind velocity (m s^{-1}); and sunshine duration (%) were used to calculate ETo. Crop coefficient (Kc) of rice and corn was different during their growth (Table 1).

Table 1 Crop coefficient of rice and corn [10]

Crop age (month)	Crop coefficient (Kc)	
	Rice	Corn
0.5	1.05	0.5
1	1.05	0.59
1.5	1.1	0.96
2	1.1	0.96
2.5	1.1	1.05
3	1.2	1.02
3.5	1.2	–
4	1.05	–

Effective rainfall also determined through Cropwat 8.0 software from FAO by using prediction data of rainfall (2016–2020).

2.3.4 Analysis of Water Balance and Planting Schedule

Water balance and planting schedule is determined based on ETo and effective rainfall calculation. Planting schedule for rice and corn (2016–2020) during a year is using water balance concept with monthly interval. Water balance will determine surplus and deficit month.

3 Results and Discussion

3.1 Rainfall Prediction

In this study, rainfall prediction is using Thomas-Fiering to predict rainfall during 5 year (2016–2017). Rainfall with high intensity was predicted during rainy season (November to March). Peak of rainy season in Kupang regency were February and March. Rainfall intensity was decreased in October (Table 2).

3.2 Water Balance and Planting Schedule

3.2.1 Crop Water Requirement

Crop water requirement (CWR) of rice was higher than corn (Tables 3, 4, 5 and 6). Rice is crop with cultivation period about 4 months. In general, planting season in Kupang will starts if available rainfall is about 200 mm per month. Wairata [11] stated that planting season in Kupang was divided into three periods. First planting season was in rainy season (November to February) and main crop was rice. Second

Table 2 Rainfall prediction (2016 to 2017) in Kupang Regency

Month	Rainfall prediction (mm)				
	Year				
	2016	2017	2018	2019	2020
January	481.8	281.4	322.1	661.1	358.4
February	534.1	696.9	450.8	349.7	315.8
March	315.7	353.9	327.2	401.0	367.5
April	86.3	65.0	64.8	131.2	80.1
May	8.8	18.9	2.5	13.7	7.7
June	12.8	4.2	11.7	12.0	12.4
July	0	0	0	0	0
August	0	0	0	0	0
September	0	0	0	0	0
October	66	0	90	0	0
November	68	57	149.6	0	66.4
December	566.3	339.2	383.0	264.5	290.7

Table 3 Crop water requirement of rice for December to March

Planting schedule	ETo (mm per month)	Kc	ETc (mm per month)	Total ETc (mm)
December[a]	148.55	1.05	155.98	605.73
January	138.81	1.1	152.69	
February	124.9	1.2	149.88	
March	140.17	1.05	147.18	

[a]Start planting

Table 4 Crop water requirement of rice for January to April

Planting schedule	ETo (mm per month)	Kc	ETc (mm per month)	Total ETc (mm)
January[a]	138.81	1.05	145.75	611.56
February	124.9	1.1	137.39	
March	140.17	1.2	168.20	
April	152.59	1.05	160.22	

[a]Start planting

Table 5 Crop water requirement of corn for December to April

Planting schedule	ETo (mm per month)	Kc	ETc (mm per month)	Total ETc (mm)
December[a]	148.37	0.59	87.54	348.19
January	138.81	0.96	133.26	
February	124.9	1.02	127.40	

[a]Start planting

season was started from March to June with corn as main crop. However, some area, which has good irrigation system will cultivate rice. Third season was July to October with no crop production.

Table 6 Crop water requirement of corn for January to March

Planting schedule	ETo (mm per month)	Kc	ETc (mm per month)	Total ETc (mm)
January[a]	138.81	0.59	81.90	344.78
February	124.9	0.96	119.90	
March	140.17	1.02	142.97	

[a]Start planting

Table 7 Water balance of rice in Kupang Regency

	Rice	
Periods	Deficit (mm year^{-1})	Surplus (mm year^{-1})
January 2016–April 2016	28.96	–
December 2016–March 2017	–	61.37
December 2017–March 2018	–	42.57
January 2019–April 2019	–	8.34
December 2019–March 2020	–	27.57

Table 8 Water balance of corn in Kupang Regency

	Corn	
Periods	Deficit (mm year^{-1})	Surplus (mm year^{-1})
December 2016–February 2017	–	185.01
January 2017–March 2017	–	163.42
December 2017–February 2018	–	142.41
January 2019–March 2019	–	171.42
January 2020–March 2020	–	134.42

CWR and effective rainfall was used to determine planting schedule. For 2016–2020, we choosen two different scenarios based on water balance calculation. First scenario was December to March and second was January to April for rice cultivation. The amount of crop water requirement for rice on December and January (2016–2020) are 605.73 mm per planting season and 611.56 mm per planting season, respectively. Further, crop water requirement of corn (December and January) are 344.78 mm per planting season and 348.19 mm per planting season, respectively (Tables 3, 4, 5 and 6).

3.2.2 Water Balance

Water balance of rice and corn cultivation was derived from effective rainfall and CWR. For rice cultivation, will have deficit about 28.96 mm year^{-1} if planting time was start in January 2016. However, in other planting schedule have no problem with water availability from rainfall (Table 7). In case of corn cultivation, there was also have no problem with water (Table 8). Effective rainfall during planting season both in rice and corn was adequate.

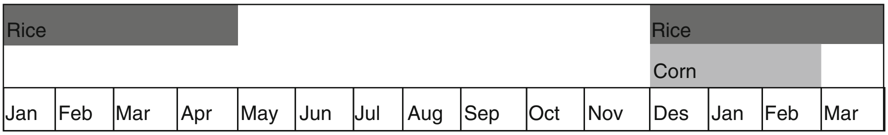

Fig. 2 Planting schedule of rice and corn in Kupang Regency 2016–2017

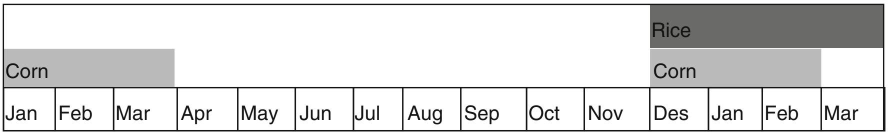

Fig. 3 Planting schedule of rice and corn in Kupang Regency 2017–2018

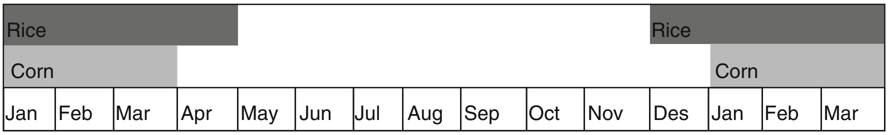

Fig. 4 Planting schedule of rice and corn in Kupang Regency 2019–2020

3.2.3 Planting Schedule

Planting schedule in Kupang Regency commonly was in November, but as mention before, this study shows different result. Based on water balance prediction, planting schedule was change. Planting schedule starts from December and January (Figs. 2, 3, and 4).

4 Conclusion

This study present rainfall prediction during 5 year (2016–2020) shows that water potential from rainfall is 838.9 mm year^{-1}. The amount of crop water requirement for rice on December and January (2016–2020) are 605.73 mm per planting season and 611.56 mm per planting season, respectively. Further, crop water requirement of corn (December and January) are 344.78 mm per planting season and 348.19 mm per planting season, respectively. Based on water balance analysis, planting schedule scenarios during 5 year (2016–2020) for rice and corn are dominates in December and January.

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