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CHANGE IN SPATIAL AND TEMPORAL CHARACTERISTICS OF RAINFALL IN EAST JAVA PROVINCE IN RELATION TO GLOBAL CLIMATE CHANGE

Perubahan Karakteristik Curah Hujan Menurut Ruang dan Waktu di Provinsi Jawa Timur dalam Kaitannya dengan Perubahan Iklim Global

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ABSTRACT

This study aims to analyze spatial and temporal variation of rainfall in the year 1971 until the year 2007 that is divided into two (2) periods ie 1971-1989 and 1990-2007 in relation to climate global change. The research was conducted in the area of East Java province from July until December 2008. The secondary data used in the research were: 1) Rainfall monthly data from 106 stations located in East Java within the period of 1971-2007 obtained from the Agency for Meteorology and Geophysical Karangploso Malang, 2) Sea Surface Temperature Nino 3.4 (http ://www.cpc.ncep.noaa.gov.), 3) Soil map scale 1: 250,000 obtanined from the Center Institute for Environmental Resource Management of Agriculture, and the map of Agroecological Zone (AEZ) of East Java scale 1: 250,000 from Assessment Institute for Agricultural Technology East Java. The analysis of rainfall characteristic consists of a) the changes of climate type Oldeman, b) the changes of the early dry and rainy season, c) the changes in of rainfall amount in dry and rainy season. The results showed that in 1971-1989 periods, the type of Oldeman climate in East Java vary from B1 to E, but after the 1990s the type of Oldeman climate change varied from C1 to D4 meaning that a part of East Java area (16.7%) become drier and 17.8% area of East Java became wet. The analysis of rainfall stations (106 stations) showed that some of rainfall stations (58.49%) have decreased the number of dry season rainfall about 3 - 500 mm/season. 56 stations (52.8%) have increased the number of rainy season rainfall in the range 1-600 mm /rainy season, while the 49 rainfall stations (46.22%) have decreased the number of rainfall in the range of 1-500 mm/season. Changes in the characteristics of rainfall in East Java, which occurred within the period of 1971-1989 and 1990-2007 was caused by the ENSO phenomenon.

Keywords : agroecological zone, climate global change, rainfall characteristic, Spatial, temporal

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INTRODUCTION

One of the obstacles faced in achieving the target of food crops' production is the climate factors especially rainfall conditions that are difficult to predict. In addition, the global climate has changed, as is feared by many meteorologists in the world since 1980. Results of observation done by the Inter-governmental Panel on Climate Change (IPCC) (1996) showed that the increase of global temperature since the late 19th century up to now has ranged between 0.3 to 0.6^{O}C, and an increase of 0.2 to 0.3^{O}C occurred in 40 years within the period of 1954 to1994. The main cause of the increasing global temperature is the increasing concentrations of greenhouse gases (especially CO_2) in the atmosphere due to the increased rate of gas emissions from fossil burning activities and industries, especially in developed countries (IPCC, 2000).

Global climate change will affect the behavior of the elements of climate such as rainfall, temperature, radiation, and evaporate transpiration. Las (2007) stated that in the period of 2005-2035 the average air temperature in Indonesia will increase 1-1,5^{O}C. In addition, results of a research by Kaimuddin (2000) divided the historical monthly rainfall data (1931-1990) into two period i.e. 1931-1960 and 1961-1990, and also the trend of the rainfall in the rainy season in the area of South Indonesia, especially in Lampung, Java, and part of the Eastern Indonesia region will be wetter than usual, and drier in the dry season. On the other hand, the rainfall in the North Indonesia (North Sulawesi, North Kalimantan and Sumatra) will decrease, while that in the dry season will increase.

Ratag et al. (1998) and Las (2007) estimated that the existence of global climate change caused by the increased effect of greenhouse gases, has caused the changes in frequency of ENSO (El Nino-Southern Oscillation) occurrence from once in 3-7 years into once in 2-5 years. Observations in some rain stations in Java, Lampung and Bali showed that the influence of ENSO events on rainfall is evident, especially in the dry season. During the El-Nino, rainfall in the dry season II (July to October) can go down to 57% of yearly normal rainfall (Las et al., 1999). On the other hand, during the La-Nina, the rainfall in MK-II increased up to 152% of normal rainfall.Besides affecting high rainfall, El-Nino can influence the beginning of the dry season. In the 1982/83 El-Nino, the starting entry of the dry season in Java and Sulawesi did not change but the end of the season which should have ended in October has extended at least one month up to November (Malingreau, 1987).

Rainfall over Indonesia is governed by the austral-Asian monsoon, whose onset progresses from northwest-to southeast during the austral spring (Aldrian and Susanto, 2003; Naylor et al., 2007). This is also the season when the El Niño - Southern Oscillation (ENSO) exerts its strongest influence on Indonesian rainfall, particularly during the September–December monsoon onset season (Hamada et al., 2002). The impact of ENSO then diminishes during the core of the rainy season in December–February (Haylock and McBride, 2001; Hendon, 2003; Aldrian et al., 2005, 2007; Giannini et al., 2007), suggesting that the timing of monsoon onset may be

potentially predictable.The date of onset of the rainy season is of particular importance for the agriculture sector over Indonesia (Naylor et al., 2002, 2007). It determines the suitable time for planting crops, while delayed onset during El Niño years

(Hamada et al., 2002; Boer and Wahab, 2007) can lead to crop failure. For irrigated rice farmers in Java, information on onset timing is also important for developing strategies (Boer and Subbiah, 2005; Naylor et al., 2007) to avoid exposure of the second rice crop to higher drought risk at dry season planting

(April–July), particularly for farmers located at the tail-end of the irrigation system. Farmers in Indonesia often suffer from "false rains" in which isolated rainfall events around the expected onset date do not signal the sustained onset of the monsoon. Such false starts occurring in September prompt potato farmers in Pengalengan in West Java to start planting. In the eastern part of Indonesia, such as East Nuna Tenggara, multiple false starts can cause multiple failures, with farmers sometimes planting up to four times in a season.

This study aims to analyze the changes spatial and temporal characteristics of rainfall in East Java from 1971 until 2007 that is divided into 2 observation periods ie the period of 1971-1989 and 1990-2007, and to discuss the spatial and temporal changes in relation to global climate change.

METHODOLOGY

The research was conducted in the area of East Java starting from June until December 2008. Spatial and temporal analysis was performed on the data obtained from 106 climate stations in all districts in East Java with 2-4 of climate station/district. The secondary data used in this research namely: 1) monthly rainfall data for 106 climate stations located in East Java within the period of 1971-2007 from Agency for Meteorology and Geophysical Karangploso Malang, 2) the data of Sea Surface Temperature Nino 3.4 (http ://www.cpc.ncep.noaa.gov.), 3) Soil map scale 1: 250,000 obtained from the Center Institute for Environmental Resource Management of Agriculture, and the map of Agroecological Zone (AEZ) East Java scale 1: 250,000 from Assessment Institute for Agricultural Technology East Java. The geographical position of the climate station observed is in Figure 1. The analysis of changes in spatial and temporal rainfall characteristics was conducted by comparing the changes in rainfall characteristics between the years of 1971-1989 and 1990-2007. The division of the two periods was based on the results of previous research (Oldeman, 1975) using climate data in prior to 1980 and Naylor et al. (2007) and Boer (2007) who have created a pattern of hypothetic changes in rainfall after the 1990s. The characteristics of rainfall analyzed include: 1) type of climate change (Oldeman method), 2) Start the rainy season and dry season, and 3) the amount of wet season rainfall and dry season rainfall.

Th analysis of Oldeman climate type change used the monthly rainfall data from January-December in the period of 1971-1989 and 1990-2007. Oldeman have created a new climate type classification using the monthly rainfall data associated with the agricultural practices. The criteria of the climate type based on the calculation of wet months (WM) and the dry months (DM) that consider the limitations in opportunity of rainfall, effective rainfall, and the plants water need.

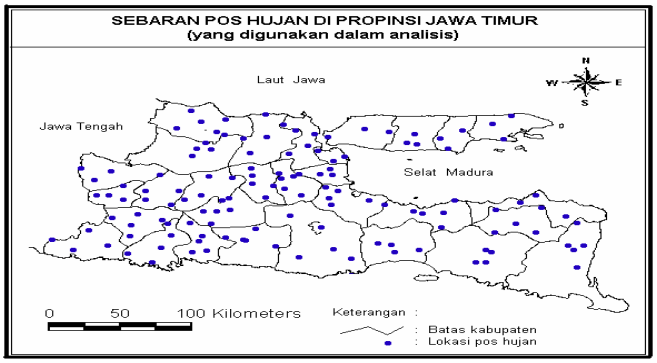


Figure 1 Geographical position of climate stations in East Java

The concept raised by Oldeman (1975) is as follows:

a. Rice will need water in an average of 145 mm per month during the rainy season.
b. Secondary crops will need water in average of 50 mm per month during the dry season.
c. Monthly rainfall is expected to have 75% chance of occurrence or equal to 0.82 times of the average monthly rainfall reduced by 30.
d. The effective rainfall for rice is 100%.
e. The effective rainfall for secondary crop, at the stage of tightly closed lid, is 75%.

In determination of climate type classification, Oldeman used the period length of the wet and dry months in the following orders:

a. Wet month (WM): Month of the average rainfall> 200 mm

b. Humid month: Month with an average rainfall of 100-200 mm c. Dry months (DM): Month of the average rainfall <100 mm

The main types of Oldeman classification are grouped into 5 types which are based on the number of wet months (WM). While subdivision climate type are grouped into 4 types based on the number of dry months (DM) (Table 1).

Table 1 The Oldeman Climate Type Classification Criteria

Main Type	Wet Monhts (WM)	Sub Division	Dry Monts (DM)
A	> 9	1	< 2
B	7 – 9	2	2 – 3
C	5 – 6	3	4 – 6
D	3 – 4	4	> 6
E	< 3		

Source : Oldeman (1975)

The beginning of dry season is determined based on the months that have rainfall intensity <100 mm during the period of dry season, whereas that of rainy season is set in the month which has rainfall intensity of 100-200 mm during the period of rainy season. The tropical climate in East Java is divided into two seasons; the rainy season which lasts between October and

March and the dry season that occurs in April-September. The amount of rainy season rainfall and dry season were calculated by totaling the amount of rainfall during the period of rainy season (October-March) and dry season (April-September). The amount of rainfall in both seasons is observed each year from 1971 until 2007. Changes in spatial characteristics of rainfall analysis above were determined using the Arcview GIS 3.2 software, while the change in temporal characteristic was obtained by comparing the results of spatial characteristics of rainfall period between 1971-1989 and 1990-2007.

RESULTS AND DISCUSSION

Changes Spatial and Temporal in Climate Type Oldeman Period 1971-1989 and 1990-2007

The analysis of rainfall using Oldeman methods on the two (2) periods has resulted in different climate changing types. The differences in type of climate occured in 3 types of climate changes, namely 1) 20 stations (18.87%) changed to be more dry climate type according to Oldeman's criteria, 2) 67 stations (63.21%) did not change, and 3) 17 stations (17.92 %) changed to be more wet climate according to Oldeman's criteria. The results showed that about 36.79% of the 106 rainfall stations observed changed in the type of climate within the 37 years period.

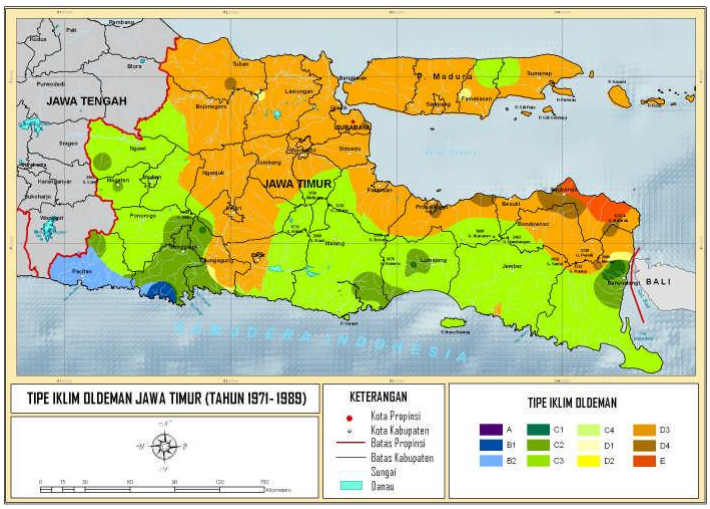


Figure 2 The Spread of Oldeman's Climate Type in East Java Province Period 1971-1989

Figure 3 The distribution of Oldeman's Climate Type in East Java Province Period 1990-2007

The spatial temporal changes of the Oldeman climate type in two (2) periods of 1971-1989 and 1990-2007 were different for all Districts in East Java (Figure 2 and 3), while the area distribution of the climate types in each regencies were showed in Figure 4 and 5. Figure 2 and 3 also showed that Trenggalek and Pacitan districts that experienced significant climate change become much drier, while Kediri and Situbondo become much wetter. The change of climate type for other regencies are not significant, because the changes in area are relatively small (Figure 4 and 5). In addition, the change of climate type shown in Figure 2 and 3 are not so clearly seen on the map, because the only change is in the sub-divisions or change in the number of dry months (e.g., the type of climate C1 into C2). The change of climate type will be significant when the change is taken place in the divisions or in the number of wet months (eg, the type of climate B2 into C2 or C2 into the D3).

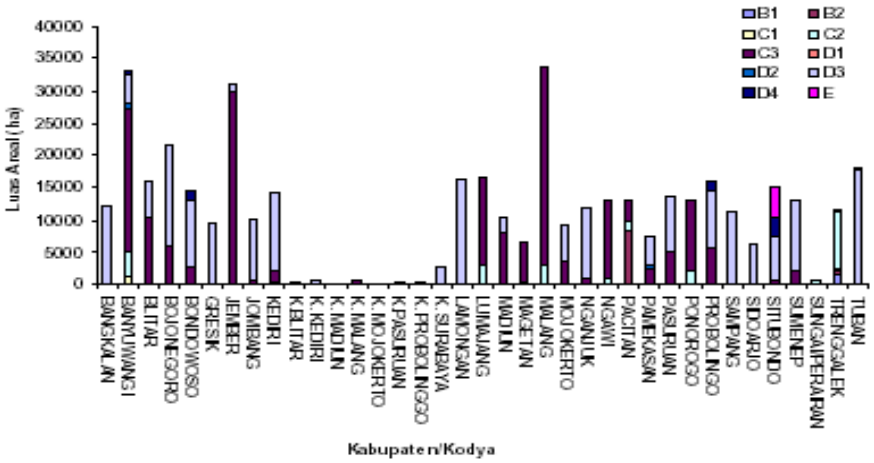


Figure 4. The Area of Climate Type for each Regencies in East Java Province Period 1971-1989

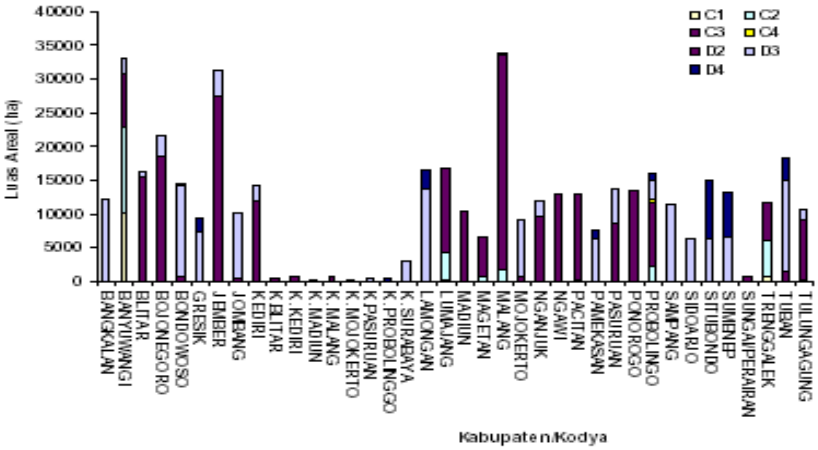


Figure 5. The Area of Climate Type for each Regencies in East Java Province Period 1990-2007

Trenggalek and Pacitan Regency that is very wet (climate type B1 and B2) in period 1971-1989 has changed to the climate type C1 and C3 in period 1990-2007, likewise Situbondo Regency that is very dry (climate type E) has changed into type D4.

Table 3. Changes in Area of Climate Type Within Period 1971-1989 and 1990-2007

No	Climate Type	Area (ha) Period 1971-1990	Area (ha) Period 1990-2008	Changes in Area (%)	Regency
1	B1	1,581.3	-	-0.37	Trenggalek
2	B2	7,600.2	-	-1.76	Pacitan, Trenggalek
3	C1	1,824.2	10,784.2	2.08	Banyuwangi, Lumajang, Probolinggo, Trenggalek, T.Agung
4	C2	30,132.3	27,477.6	-0.61	Blitar, Kediri, Lumajang, Malang, Ngawi, Pacitan, Trenggalek, T. Agung
5	C3	179,048.7	228,575.3	11.47	Blitar, Bojonegoro, Kediri, Madiun, Malang, Nganjuk,Ngawi, Pacitan, Pasuruan, Ponorogo, Trenggalek, Tuban, T.Agung
6	C4	-	314.5	0.07	Probolinggo
7	D1	6.9	-	0.00	Banyuwangi
8	D2	2,191.5	89.8	-0.49	Banyuwangi, Bojonegoro, Lamongan, Pamekasan, Sampang, Trenggalek, Tuban, T.Agung
9	D3	200,645.9	142,950.9	-13.37	Banyuwangi, Blitar, Bojonegoro, Gresik, Kediri, Lamongan, Lumajang, Madiun, Nganjuk, Pasuruan, Probolinggo, Sampang, Situbondo, Sumenep, Trenggalek, Tuban, T.Agung
10	D4	7,151.3	25,956.1	4.36	Gresik, Lamongan, Pamekasan, Sampang, Situbondo, Sumenep, Tuban
11	E	1,484.9	-	-0.34	Situbondo

Changes of climate type occurred in the largest climate type C3 and D3. In the period 1990-2007, the type of climate C3 increased by 11:47% and D3 type decreased by 13:37%. This indicates that some of the districts in East Java that includes Blitar, Bojonegoro, Kediri, Madiun, Malang, Nganjuk, Ngawi, Pacitan,Pasuruan, Ponorogo, Trenggalek, Tuban, Tulungagung regencies become more wet while the District of Banyuwangi, Blitar, Bojonegoro, Gresik, Kediri,Lamongan, Lumajang, Madiun, Nganjuk, Pasuruan, Probolinggo, Sampang,Situbondo, Sumenep, Trenggalek, Tuban, Tulungagung become more dry (Table 3).

Table 4. Changes in Planting Pattern of Rice-Secondary crops Due to Oldeman Type of Climate Changes

No.	Climate Type Period 1971-1989	Climate Type Period 1990-2007	Planting Pattern Rice-Secodary crops (Period 1971-1989)	Planting Pattern Rice-Secodary crops (Period 1990-2007)	Informatin
1.	B1	C2	rice 2 x and *) secondary crops 1 x	rice 1 x and secondary crops 1-2 x	*More dry*
2.	B2	C3	rice 2 x and secondary crops 1x	rice 1 x, secondary crops 1-2 x	
3.	C1	C2	rice 1 x and secondary crops 2 x	rice 1 x and secondary crops 1 or 2 x	
4.	C2	C3	rice 1 x and secondary crops 1 or 2 x	rice 1 x and secondary crops 1-2 x	
5.	C3	D3	rice 1 x and secondary crops 1 or 2 x	rice 1 x or secondary crops 1 x	
6.	D3	D4	rice 1 x or secondary crops 1 x	rice 1 x or secondary crops 1 x	
7.	C3	C1	rice 1 x and secondary crops 1 or 2 x	rice 1 x and secondary crops 2 x	*More wet*
8.	C3	C2	rice 1 x and secondary crops 1 or 2 x	rice 1 x and secondary crops 1 or 2 x	
9.	D3	C3	rice 1 x or secondary crops 1 x	rice 1 x and secondary crops 1 or 2 x	
10.	D4	D3	rice 1 x or secondary crops 1 x	rice 1 x or secondary crops 1 x	
11	E	D4	secondary crops 1 x	rice 1 x or secondary crops 1 x	

*Notes : more dry, when the number of wet months reduced or increased the number of dry months; not changed, when the number of wet months and the number of dry months still; more wet, when the wet months increased or the dry months decreased month; *) according to the planting pattern modified by Oldeman (1975)*

Oldeman type of climate changes will affect the planting pattern. When it is become more dry or wet will result in the farmers in dry land can not plant paddy or rice planting that they used to be (Table 4). Pacitan districts in the period 1971-1989 has 8302.35 ha area that can be planted with rice 2x and secondary crops1x,while in the period 1990-2007, the farmers are only able to plant rice 1x, and secondary crops 1 or 2 times. On the other hand, in period 1971-1989, the farmers in Situbondo District (4531.18 ha) cannot planted rice, but in period 1990-2007 they can plant rice 1x or secondary crops 1x.

The Changes in Amount of Rainfall in Dry and Rainy season within the period of 1971-1989 and 1990-2007

Within the period of 1971-1989, the amount of dry season rainfall is within the range of 1001-1200 mm and 2001-2200 mm occurred in approximately 35 % of the area of East Java. The range peak of the amount of dry season rainfall is 1201-1400 mm. In the period of 1990 until 2007, the range of amount of the rainfall is smaller (801-1000 mm to 1601-1800 mm) and the peak of 1001-1200 mm. This rainfall decrease occurred in about 40% area of East Java except in part of Malang, Ngawi, Madiun, Ponorogo, Tulungagung, Trenggalek, Kediri,
Pasuruan, and Banyuwangi. This result indicates that during the period of 1990 to 2007 there has been a declining amount of rainfall by about 200-400 mm in dry season which covers approximately 50-60% area of East Java.

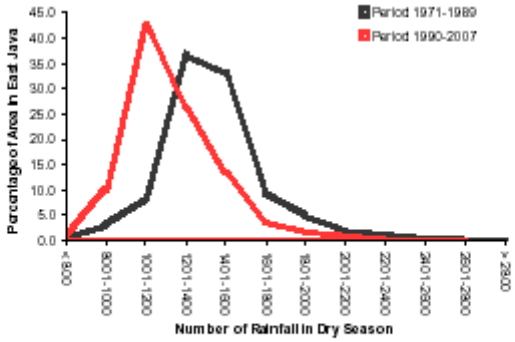


Figure 6. Area Change Number of Rainfall in Dry season Period 1971-1989 and 1990-2007

In rainy season, the change in amount of rainfall is not similar that in the dry season. The range value of rainy season rainfall in the two (2) periods of 1971- 1989 and 1990-2007 does not change. In addition, the range peak of the amount of rainy season rainfall (1401-1600) mm also does not change. The only change in the two (2) periods of observation is in the percentage of the area of each rainfall value range in rainy season. In the period of 1990-2007, some areas with the amount of rainfall of 1201-1400 and 1401-1600 mm became smaller, about 5% less than that in the period of 1971-1989 such as that occurred in part of Sumenep,Pamekasan, Sampang, Bangkalan, Lamongan, and Situbondo. In some areas such as Malang, Pasuruan, Probolinggo, Lumajang, and Jember experienced an increase in area within the range of 1601-1800 mm rainfall (Figure 7 and 8).

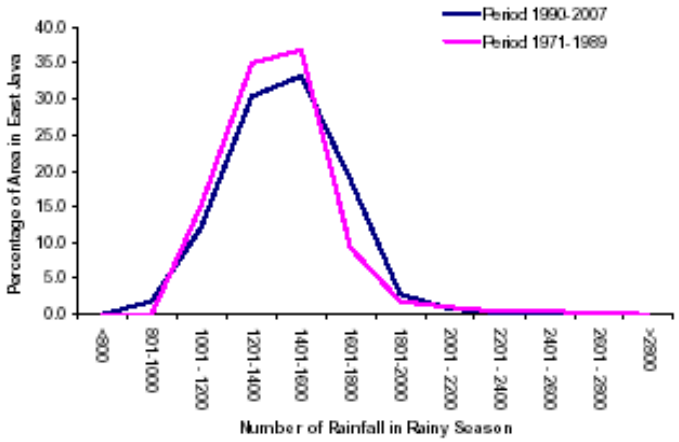


Figure 7. Area Change Number of Rainfall in Rainy Season Period 1971-1989 and 1990-2007

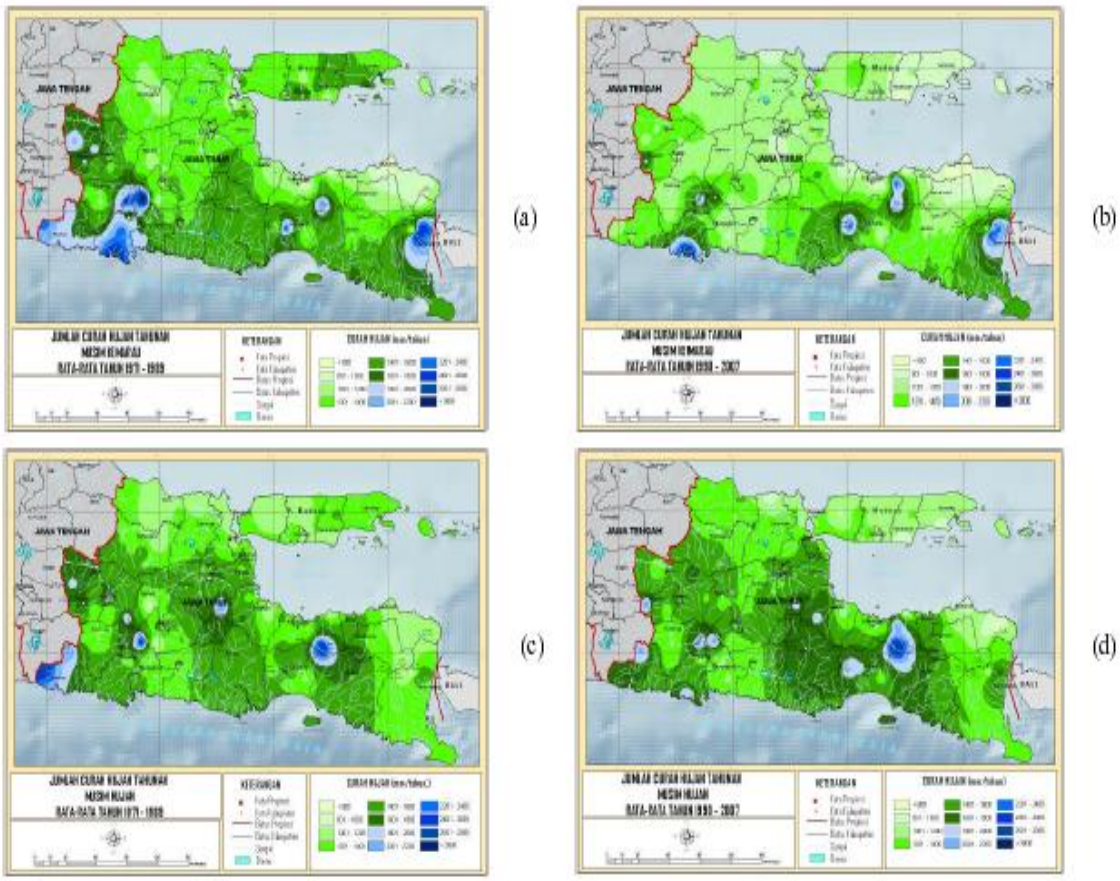


Figure 8. Number of Rainfall in Dry Season : (a) Period 1971-1989, (b) Period 1990-2007, Number of Rainfall in Rainy Season : (c) Period 1971-1989, (d) Period 1990-2007

Changes in the beginning of Dry and Rainy season

In the period of 1990-2007, the beginning of dry season with rainfall <100 mm occurred 1 month earlier (May) than usual (June) (Figure 9).

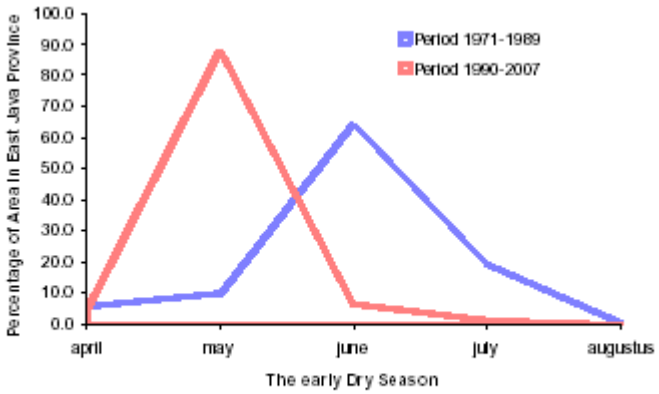


Figure 9. Area Changes in The Early Dry Season Period 1971-1989 and 1990-2007

In the period 1971-1989 about 20% of East Java area that includes some regencies such as Sumenep, Pamekasan, Sampang, Tuban, Lamongan, Ngawi,Magetan, Ponorogo, Pacitan, Tulungagung, Trenggalek, Blitar, Malang, Lumajang have a month with rainfall <100 mm which occurred in July, but after the period of 1990 to 2007 it occurred earlier (Figure 9 and 11). The early dry season from June into May and from July into June give a serious problem for the availability of water for plants, especially in dry season-I (February-May) and dry season-II (June-September). In the period 1971-1989, the secondary crops in dry land in dry season-I is still relatively "safe" in term of water availability, because rainfall in May is still more than 100 mm or in a term usually used by farmers in East Java,there is still "remaining rain". However, in the period of 1990-2007, the average rainfall in May is less than 100 mm and covering approximately 90% of East Java Province agricultural area (Figure 9 and 11).

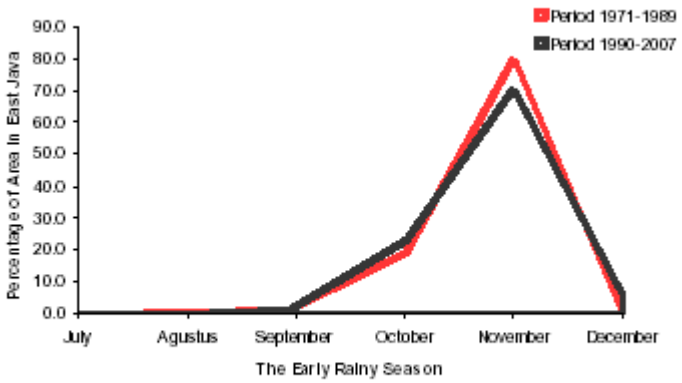


Figure 10. Area Changes in the Early Rainy Season Period 1971-1989 and 1990-2007

The early of rainy season (rainfall = 100 - 200 mm) during the period 1971- 2007 relatively does not change much. It occurs in October-November. There are areas in Trenggalek and Banyuwangi District in the period 1971-1989, having rainfall more than 200 mm in July or August. However, in the period 1990-2007,in the same regency area no rainfall 100 - 200 mm occurred July or August,instead, it decline 1-2 months (September) (Figure 10 and 11). In addition, some parts of the region such as in the District of Sumenep,Lamongan, Probolinggo, Situbondo and Bondowoso the rainfall (100-200 mm) was setback to December in the period 1990-2007 (Figure 11). The decline of the early rainy season has caused the setback of early planting in the rainy season which originally occurred in November to December. No significant change in the early rainy season indicates that the early planting rice/secondary crops at the season will not experience many problems except in the case of extreme climate conditions, such as the occurrence of El-Nino.

The El-Nino often causes more long dry season and early rainy season retreat. Regarding the problem of rainfall and the planting management, the attention should be paid to: 1) changes in the early dry season which is one month earlier in average, 2) the increases in the number of dry month, and 3) the decrease in amount of rainfall in dry season. Those three aspects will greatly determine the success of cropping in the dry land, especially in the dry season-1 (February-March) and dry season-2 (June-July) especially when considering the availability of water problem at the beginning of the planting and harvesting. Changes in rainfall characteristics (Oldeman climate type, the amount of rainfall, early dry and rainy season) between the periods of 1971-1989 and 1990-2007 shows a change of rainfall in the area of East Java Province. East Java is influenced by the global climate, because the rainfall patterns in East Java is monsoon type. Based on the strength of the El-Nino impact, Tjasyono (1997) concluded that the strong influence of El-Nino occurred in the region with the rainfall monsoon type (including Southern Sumatra, Java, Bali, and most of the Eastern Indonesia region) and weak influence in the area with the Equatorial type (Central Sumatra, Central Kalimantan and the regions that accross the equator), unclear for the local type (Maluku). Studies conducted by Ratag *et al*., 1998 shows that in the condition of doubling of current CO2 concentration due to global climate change, the frequency of ENSO *(El-Nino Southern Oscillation*) occurrence will increase from once in 3-7 years to once in 2-5 years.

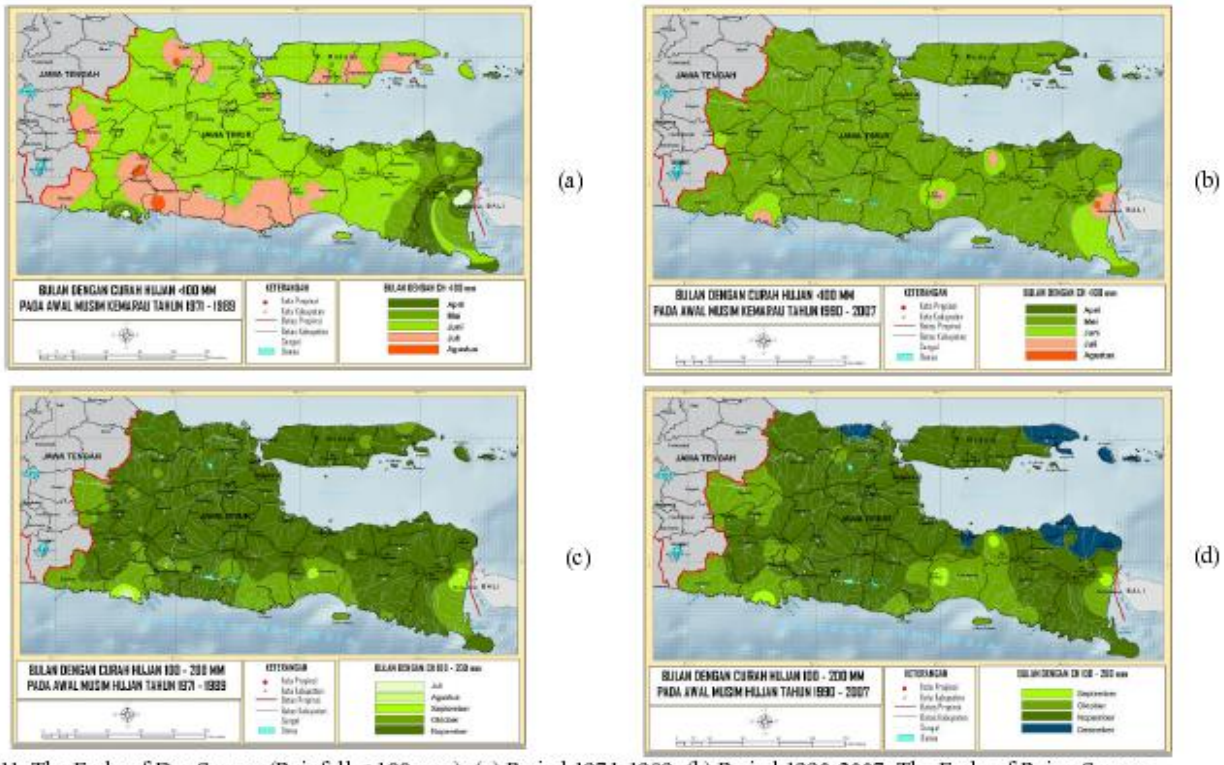
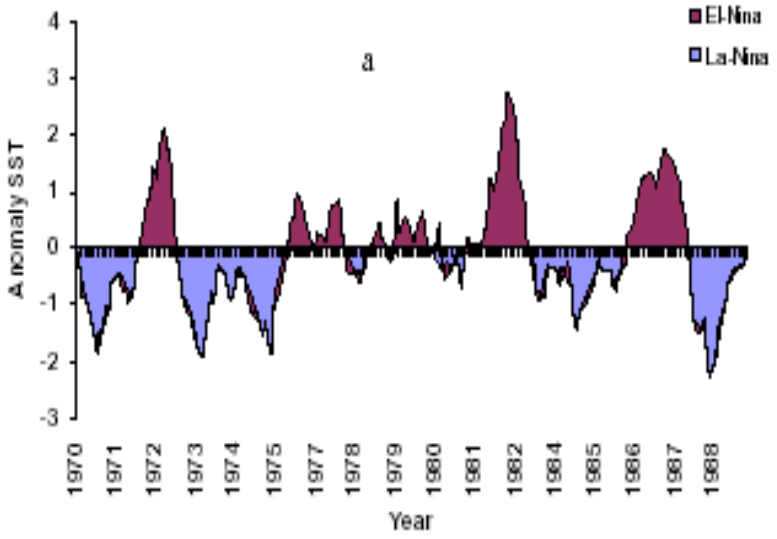


Figure 11. The Early of Dry Season (Rainfall < 100 mm): (a) Period 1971-1989, (b) Period 1990-2007, The Early of Rainy Season (Rainfall = 100-200 mm) : (c) Period 1971-1989, (d) Period 1990-2007

ENSO phenomenon has a strong influence on the diversity of rainfall in East Java, especially in the early rainy season. The change in characteristics of rainfall in East Java within the period of 1971-1989 and 1990-2007 that include climate change in the Oldeman type, the amount of rainfall in dry and rainy season, early dry and rainy season can be explained by the ENSO.



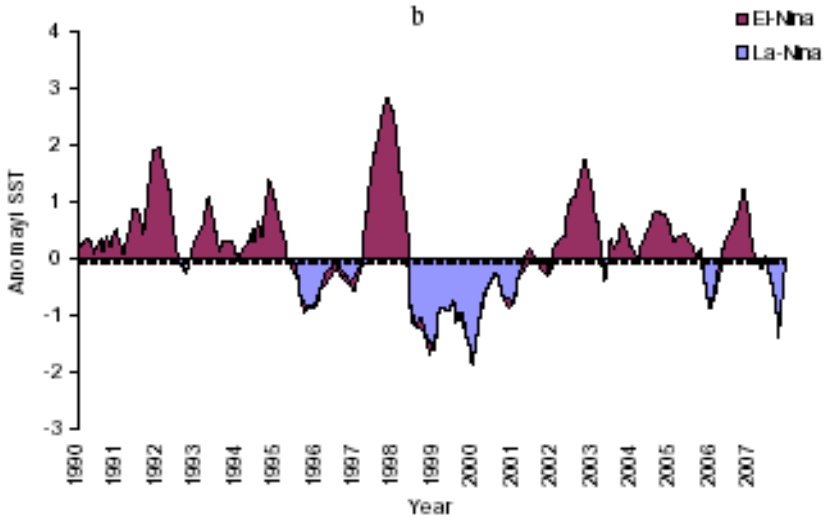


Figure 12. Sea Surface Temperature Anomalies The Pacific Equator Waterworks Nino 3.4 period 1970-1989 (a) and 1990-200 (b) *(http://www.cpc.ncep.noaa.gov/data)*

Figure 12 shows that in the period 1990-2007, the temperature anomaly in the Nino 3.4 have more a positive value compared to 1971-1989 period. This indicates that the El-Nino occur more frequent in the period 1990-2007 compared to 1970-1989 period. For every 10C increase in sea surface temperature anomalies in the Nino 3.4, the average rainfall in Indonesia in dry season will decrease by about 60 mm (Boer and Subbiah, 2005). Therefore, the changes in rainfall characteristics in East Java within the period of 1971-1989 and 1990-2007 were, among others, caused by the ENSO phenomenon.

Conclusion

Within the 1971-1989 period, the change in type of climate Oldeman in East Java vary from B1 to E, but after the 1990s, type of climate Oldeman change variations only from C1 to D4 meaning that a part of East Java area (16.7%) become more dry and 17.8% area of East Java become more wet. From a number of rainfall stations (106 stations), the analysis of rainfall showed that some of rainfall stations (58.49%) have experienced of decrease in the number of dry season rainfall by about 3 – 500 mm/season. 56 stations (52.8%) have experienced of increase in the number of rainy season rainfall in the range of 1-600 mm/rainy season, while the 49 rainfall stations (46.22%) have experienced of decrease in the number of rainfall within the range of 1-500 mm/season. Changes in the characteristics of rainfall in East Java, which occurred between the periods of 1971-1989 and 1990-2007 was, among others,caused by the ENSO phenomenon.

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