Chapter 32
Analysis of Rainfall Characteristics of East Kalimantan Province

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Abstract This research was conducted in the region of East Kalimantan province. It aims to identify conditions of precipitation each period of 10 years as long as 40 years. The analysis is done using a linear Equation using auto correlation. Test the trend of precipitation data is done using Cox-test- Stuart t. Based on the Binomial Distribution Table at 5% unreal levels indicate precipitation data during 40 years used in this research was not significant, which means it does not have a trend, the pattern of the relationship between precipitation and the time of forming the open curves upwards, with the equation Y = 2,645.44 + 31.26 X. Changes in forest cover are synchronize with changes in average monthly rainfall.

Keywords Climate · Rainfall · Forest · Plantation

32.1 Introduction

The most important climatic element in Indonesia is rainfall, which is highly variable both in time and place. Hence, climate studies are more directed towards rainfall. The Indonesia region is located in the tropics which affects the amount of rainfall received. The Indonesian average rainfall is high at > 2,000 mm/year. The amount of rainfall received causes the atmosphere of the Indonesian region to contain a lot of water vapour. Because of this, Indonesia's climate is ealizingd as a humid tropical climate. Rainfall variability in Indonesia is very complex and is a chaotic part of the seasonal variability associated with annual and semi-annual rainfall variations in Indonesia (Elias 2012; Aldrian and Susanto 2013).

There have been many studies conducted to analysis the trend of rainfall phenomena. The changes in annual average rainfall have occurred in many countries especially in the tropics (Aragao et al. 2008; Avissar et al. 2012; Batool et al.

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2015). For the most part, Indonesia's average rainfall has decreased significantly in all seasons, with an average rate of 7.8 mm per month (3.6%) per decade since 1975. By the year 2000 the decline in rainfall varied between 7.5–8.9 mm or 3.3–3.6% per month per decade. Nevertheless, using various climate model simulations in the twenty-first century, it is estimated that Indonesia as a whole will experience changes in rainfall that vary between (–28) and (+53) mm or –12% to + 20% per month (Elias 2012).

In the tropics, large-scale loss of forest cover is generally associated with less rain and weakening monsoons, although the full impact of a dryer climate is not yet fully understood by scientists (Aragao et al. 2008; Kumagai et al. 2013; Muluneh et al. 2014). This requires critical thinking and a reorientation of the vision of development by considering more environmental factors and the sustainability of development, so that preventive steps can be taken to withstand the rate of climate change (Lawrence 2014), including to ealizing the government's motto "one man five trees" (Sujalu 2015). Based on the description above, it is necessary to conduct research of observational data to pinpoint impact of land cover change on local rainfall is difficult due to multiple environmental factors that cannot be strictly controlled. In this study we use a statistical approach to identify the relationship between removal of tree cover and rainfall with data for > 40 years (1977–2020) from best available sources for large areas in Kalimantan.

32.2 Methods

The used data is historical (long-term) rainfall data, derived from 76 climate observation station in East Kalimantan. This research uses a descriptive quantitative method with comparative analysis techniques from the exploration of regional data and characteristics of climatic elements, especially rainfall. The analysis is generally carried out using the Free Linear Method, as follows: $Y = a + bX$. Furthermore, the Cox-Stuart test was carried out at the 5% level on the Binomial probability distribution to determine the existence of an upward trend or a downward trend in a group of data (Spiegel et al. 2014; Sujalu 2015)

32.3 Results and Discussion

32.3.1 Result

The Province of East Kalimantan with the capital city of Samarinda before the division of the region has an area of 20,865,774 hectares with a land area of 19,844,117 hectares (95.1%), the Inland waters reached 2,184,523 hectares and marine waters as far as 12 nautical miles from the coastline of the outermost region of 1,021,657

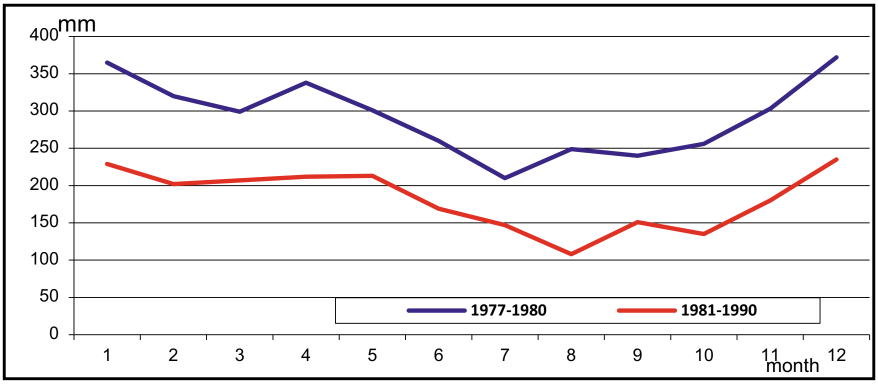

Fig. 32.1 Rainfall periode 1975–1980 and 1981–1990

hectares (4.9%) located between 113º44'- 119º00 'East and between 4º24 'LU and 2º25 'LS. The land area of East Kalimantan Province has an undulating topography with a slope that is from steep to highest, with land elevations ranging from 0–1,000 m above sea level.

The long-term rainfall conditions in East Kalimantan Province as a tropical region as a whole generally have 3 patterns with high and low trends influenced by the movement of monsoon winds (Sujalu 2015), while cumulative annual rainfall in the long term does not experience uptrend or downtrend. Although, based on observations of 40 years of rainfall can be grouped into 4 trends, namely:

a. During the first decade, there was a trend of high rainfall decreasing sharply between 1981–1990. The highest rainfall occurred in 1980 at 3,521 mm per year and the lowest rainfall occurred in 1990 at 1,972 mm per year.
b. During the second decade, The occurrence of high rainfall tends to be low and tends to decrease, because between the period 1991–2000 there was a period of strengthening El-Nino. The highest rainfall occurred in 1999 at 2,328 mm per year and the lowest rainfall occurred in 1992 at 1,889 mm per year.
c. In the third decade, the occurrence of high rainfall tends to increase, which is between the period 2001–2010. The highest rainfall was in 2009 at 3,237 mm per year and the lowest rainfall was in 2002 at 1,889 mm per year.
d. The decade IV. high rainfall tends to increase, namely between the period 2011–2020 The highest rainfall occurred in 2019 at 3,335 mm per year and the lowest rainfall occurred in 2012 at 2,163 mm per year (Figs. 32.1, 32.2).

32.3.2 *Discussion*

Converting forests (deforestation) to become agricultural fields, logging, and clearing forest land for various purposes causes the release of CO_2 into the atmosphere, FAO

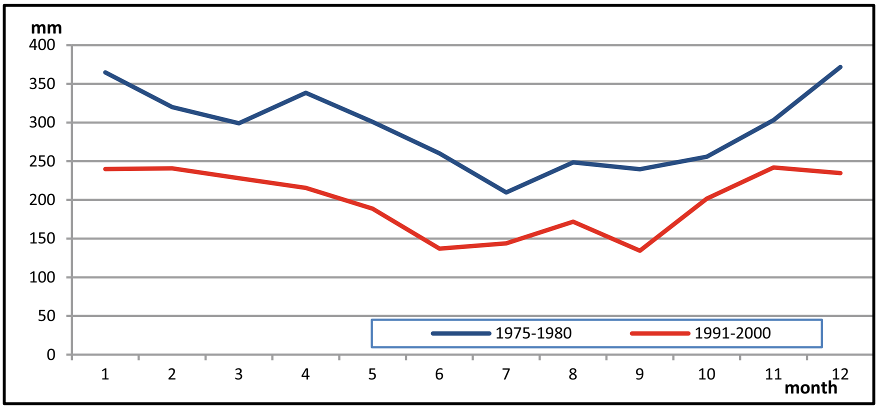

Fig. 32.2 Rainfall periode 1975–1980 and 1991–2000

experts estimate in 2008 that tropical deforestation worldwide ranges from 3.3–20 million hectares each year (Gaveau 2015). The Province of East Kalimantan is among the highest contributors to deforestation and forest degradation. The rate of movement of deforestation and forest degradation is increasing very significantly (Seizarwati 2011). The rate of decline in forest cover on the island of Kalimantan from 2001 to 2020 was 1.12% (± 0.36 million hectares) per year.

The models of current climate research do not seem to take into account the impact of forest vegetation on rainfall patterns, as they are more focused on potential land cover change and increasing global temperatures. As Sheil and Murdiyarso (2009); Dias et al. (2012) and Spracklen et al. (2018) have argued, forest cover change is also a factor in the eastward shift of rainfall zones in Southeast Asia, with both regional and global impacts. For the tropics, large-scale forest cover loss is commonly associated with reduced rainfall and a weakened monsoon season.

However, based on the assumption of an average annual rate of forest loss, each province has a different rate of forest cover loss. From 89 000 hectares per year in 2001 to 157 000 hectares per year in 2020, almost double the increase or an average of 95,878.17 hectares per year (GFW 2021). Such a process directly has been a seasonal shift as well as changes in rainfall patterns, including increasingly frequent occurrences of high rainfall intensity albeit with shorter periods, while the summer season occurs in a longer period (Lawrence 2014),

Large-scale changes in forest cover and land use can alter rainfall patterns hundreds to thousands of kilometres away from the deforested area (Spracklen et al. 2018). It also affects local thermodynamic circulation, resulting in reduced potential for cooling effects to the atmosphere (Avissar et al. 2012). Forests absorb more moisture from the soil than other types of vegetation. These moisture transfers through the trees and evaporation from the leaves into the atmosphere cool the air through latent heat transfer. These mechanisms cause moisture to rise above the forest, which in turn promotes cloud formation and rainfall. Forests also form aerodynamic roughness surfaces which will increase turbulence and reduce wind speed and can further increase convection, cloud formation and rainfall (Meier et al. 2021; Muluneh et al. 2014; Sheil and Murdiyarso 2009).

The forest cover change in various studies has been found to contribute positively to the decreasing rainfall in various regions (including the Sahel, West Africa, Cameroon, Central Amazonia, and India), as well as the weakening of monsoon winds (Avissar et al. 2012). It has also been observed that extensive deforestation often reduces cloud formation and rainfall, and accentuates seasonality (Kumagai et al. 2013). Clear-cutting of forests can lead to a different convection-driven mechanism, the "vegetation wind" in which moist air is drawn out of the forest (Lawrence 2014). There are many correlations that have yet to be unravelled with specifics, especially about the influence of evaporation, convection, cloud development, and aerosols and land cover, and how changes in cloud cover get translated into changes in rainfall (Aragao et al. 2008).

BMKG (Meteorological, Climatological and Geophysics Agency) recorded 6 El-Nino events which occurred with strong intensity, which are in 1957/1958, 1965/1966, 1972/1973, 1982/1983, 1987/1988 and 1997/1998. The 1982/1983 and 1997/1998 el-Ninos have been the two greatest el-Nino events that have occurred in the modern era with impacts felt globally. Borneo's native forest cover decreased by 37.1% between 1980 and 2015 with large areas being replaced by oil palm and a mosaic of plantations and regrowth vegetation. Boosted by the 1997/98 ENSO phenomena, uncontrolled fires have destroyed huge areas of rainforest and bush land in the province of East Kalimantan. The total burned area of the site is estimated to be 1.3 million hectares out of 1.85 million hectares (71%) (Siegert and Hoffman 2000; Gaveau 2015; Sujalu 2015).

The devastating forest fires in many parts of Sumatra and Kalimantan were not directly caused by the El-Nino phenomenon (Hermawan 2010). Nevertheless, the dry air conditions and the lack of rainfall have made the fires easy to ignite and spread and also difficult to control. The relationship between forest loss and rainfall presented here is correlational, this relationship is significantly greater than a potentially reverse causal effect. This has been illustrated in the results of the comparative analysis of rainfall between the 1975- 1980 period and the 1991–2000, 2001–2010 and 2011–2020 periods which show lower and significantly different at the 5% level.

The researchers have proven that smoke from forest fires inhibits rain. An extensive analysis of Tropical Rainfall Measurement Mission (TRMM) data showed that the "warm rain" process that often makes it rain in tropical forests practically "dies" when clouds are polluted by thick smoke from forest fires (Wahdianty et al. 2016); Sheil and Murdiyarso (2009) showed that aerosols—small polluting air particles found in smoke from wildfires—have a "semi- direct" effect on climate, causing a reduction in cloud cover and warming of the land surface. During forest fires these aerosol particles have a higher latent heat than normal, so they require more water vapour molecules to reach saturation point. The same is true for aerosol particles of bare forest or bare soil, as degradation and deforestation of primary tropical forests causes the cooling effect of the forest atmosphere to be reduced or even lost.

For the tropics, the extensive loss of forest cover is generally associated with erratic rainfall, rainfall tends to decrease and monsoon atmospheric circulation weakens.

Indeed, Webb et al. (2015) and Avissar et al. (2012) predict that deforestation activity across Southeast Asia causes rainfall to decrease by 1 mm/day in the following year. Tropical rainforest reduction in Sulawesi by 15% represents a 2% decrease in monthly evapotranspiration and a 21% increase in soil evaporation, as well as a 1 °C increase in temperature in areas of total deforestation. Within a 100 km radius, forest areas have experienced severe deforestation and change, suggesting that minor forest change has resulted in annual rainfall reductions of between 2–8%. Nevertheless, the maximum daily rainfall at the beginning of the rainy season has increased, causing flooding to occur more frequently. The observations of Avissar et al. (2012) on a forest area of about 250 km × 250 km showed that deforestation of > 30% of the study area resulted in a high decrease in rainfall by 30–40%. During the wet season, more clouds formed in deforested areas.

A study in Sabah-Malaysia covering an area of 10,000 km^2 also showed similar results, with a decrease in evapo-transpiration and rainfall receipts mostly occurring (85%) in the area of forest logging. Boochabun et al.'s (2008) study was conducted in the Chi River Basin-Thailand covering an area of 49,500 km2 for 30 years (1973–2003). Most forested areas in the area were converted into agricultural and plantation areas. Research results show that rainfall tends to decrease in the range of 10–20%, evapotranspiration also shows a decrease in the range of 15–25%. There was a weak and insignificant correlation between changes in forest cover and changes in rainfall and evapotranspiration.

The Climate Policy Initiative/Pontifical Catholic University of Rio de Janeiro (CPI/PUC-Rio) shows that Amazon deforestation affects rainfall in the state of Mato Grosso. As a case study, CPI/PUC-Rio found that deforestation in the Xingu River region can cause 7% decrease in the annual historical average rainfall in the state of Mato Grosso. This impact varies greatly across the state and across seasons. Estimated declines in the wet season due to deforestation could be as high as 8% of the average seasonal rainfall. Over the course of the dry season, the estimated impact of deforestation can result in a 15% decrease from this seasonal. Tropical deforestation leads to reduced evapotranspiration, increasing surface temperatures by 1–3 K and causing boundary layer circulations, which in turn increase rainfall over some regions and reduce it elsewhere. On larger scales, deforestation leads to reductions in moisture recycling, reducing regional rainfall by up to 40% (Spracklen 2018).

There has been an increase in the area of oil palm plantations in East Kalimantan from 1,115,415 hectares in 2013 and in 2020 it increased to an area of 2,889,435 hectares, oil palm plantations that have been in production reached 1,287,449 hectares or 7.86 per cent of the total area of national oil palm plantations. Other than Palm oil plantations, East Kalimantan also experienced an increase in rubber plantations from 101,156 hectares in 2013 to 123,460 hectares in 2020. The change in forest cover seems to correlate with the increase in rainfall, as can be seen in Figs. 32.3, 32.4.

Planting more trees brings rain because plants transpire. Transpiration is a process by which aerial parts of the plants lose water as water vapor during photosynthesis. This water is added to the normal moisture of the air thus making the air saturated

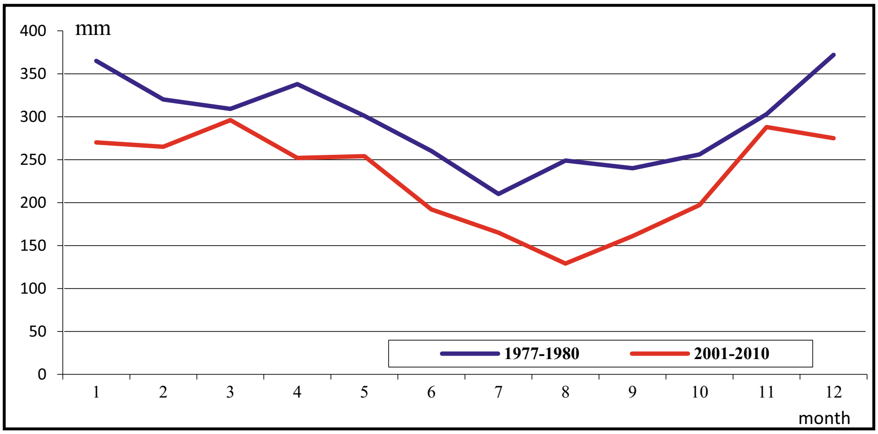

Fig. 32.3 Rainfall Periode 1975–1980 and 2001–2010

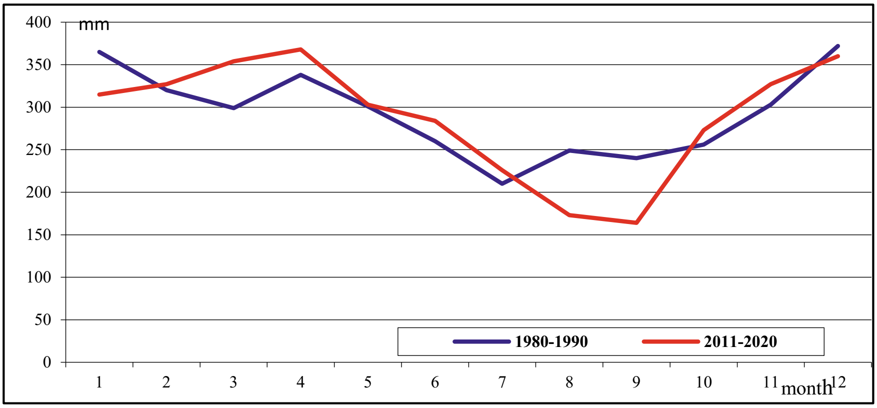

Fig. 32.4 Rainfall Periode 1975–1980 and 2011–2020

faster and bringing rain (Kumagai et al. 2013; Spracklen et al. 2018; Wulfmeyer et al. 2017). A new study suggests that planting 20% more trees in Europe could also increase rainfall (Meier et al 2021). It would boost local rainfall, especially in winter and with greater impacts in coastal regions. Planting trees would also cause impacts down wind of the reforested areas, as the rainfall in these locations was increased especially in the summer months. The research found that converting agricultural land into forests can have a "substantial" impact on dry conditions associated with climate change and could boost rainfall by 7.6% in the summer (Meier et al. 2021).

Trees and forests increase rainfall intensity through the fungal spores, pollen, bacterial cells and other particles they release into the atmosphere. Atmospheric moisture condenses when the air becomes sufficiently saturated with water and does so much more readily when these particles are present (Ellison et al. 2017; Sheil and Murdiyarso 2009; Webb et al. 2015). Over the plantations, the mean temperature decreased as a result of non-linear changes of the diurnal cycle caused by less warming during the day than cooling during the night (Wulandari et al. 2018). Moreover, the plantations caused an increase in vertical instability and a modification of the horizontal flow leading to the development of convergence zones (Sheil and Murdiyarso 2009). During several isolated cases in summer, this process led to convection initiation and precipitation with an enhancement of about 30 mm in both areas, respectively. These convection-permitting simulations lend confidence that an increase in precipitation could be induced at the meso-scale by the introduction of vegetation (Wulfmeyer et al. 2017).

A simulation with 4 different forest cover conditions in East Kalimantan Province shows changes in surface climate parameters. The resulting deforestation will affect an increase in surface temperature, a decrease in surface evaporation, and changes in rainfall patterns and intensity. Change that occurs in convective rainfall parameters is spatially not homogeneous in all regions, there are areas that experience an increase and some that experience a decrease in rainfall intensity (Seizarwati 2011). Researched by Iswati et al. (2013) in Kubu Raya Regency, West Kalimantan, changes in land cover patterns also had an impact on increasing rainfall in the third decade of this study. During the third decade there was an increase in rainfall patterns that tended to increase linearly. An increase at the end of the third decade almost matched the rainfall pattern before the first decade or the 1970s era. Rainfall peaks have shifted to earlier. Rainfall intensity tends to increase, especially in the third decade period of the study.

32.4 Conclusion

Changes in natural forest cover conditions in East Kalimantan show changes in surface climate parameters. Mainly affecting the increase in surface temperature, changes in rainfall patterns and intensity. The characteristics of rainfall during the 1975–2020 period fluctuate, namely in the 1981–1990 period annual rainfall tends to decrease, the 1991–2020 period annual rainfall tends to increase. Changes in forest cover indicate that they are in line with changes in average monthly rainfall.

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