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The analysis of the El Niño phenomenon in the East Nusa Tenggara Province, Indonesia

Mahawan Karuniasa ✉, Priyaji Agung Pambudi

University of Indonesia, School of Environmental Science, Salemba Raya Street No. 4, Central Jakarta, DKI Jakarta, 10430, Indonesia

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Abstract: Climate change causes various events, such as El Niño , and we experience their larger frequency. This study based on a quantitative approach uses observation data from the Umbu Mehang Kunda Meteorological Station and the Ocean Niño Index (*ONI*). As a result, East Sumba, which has an arid climate, has more challenges in dealing with drought and water deficits during El Niño. This study identifies rainfall when the El Niño phenomenon takes place in East Sumba through data contributing to the *ONI* value and dry day series from 1982 to 2019. The analysis was carried out by reviewing these data descriptively and supported by previous literature studies. The research found that there was a decrease in the accumulative total rainfall in El Niño years. The annual rainfall in the last six El Niño events is lower than the annual rainfall in the first six El Niño events. The dry day series is dominated by an extreme drought (>60 days) which generally occurs from July to October. This drought clearly has a major impact on livelihoods and causes difficulties in agriculture as well as access to freshwater. This results in crop failure, food shortages, and decreased income. The phenomenon triggers price inflation in the market and potential increase in poverty, hunger, and pushes the country further away from the first and second Sustainable Development Goals. This phenomenon and problems related to it need to be dealt with by multistakeholders.

Keywords: climate, communities, drought, El Niño, freshwater, rainfall

INTRODUCTION

Access to clean water is a universal right, and the obligation to maintain water availability is the responsibility of the community. Water is a basic human need that supports life of individuals and societies [Hamidi 2020], and our daily life activities cannot be separated from water needs. Therefore, the availability of water must be the concern of all parties involved to ensure optimal survival [Al-Ansari 2013]. Over time, the increasing number of populations is directly proportional to the growing need for water, whereas according to the hydrological cycle, the amount of water is constant [Shiklomanov 2009]. This case, of course, will cause problems in the future, namely the water crisis. Based on the 2015 Central Statistics Agency (Ind. Badan Pusat Statistik), the per capita water availability of Indonesians was 220,465 m^3 [BPS 2015]. However, the World Water Forum held in the Hague in 2000 predicted that Indonesia would become one of the countries that would experience a water crisis in 2025 [WWC 2000].

The primary source of surface water recharge is atmospheric precipitation which is mostly determined by climatic conditions in the catchment. Changes in temperature conditions and an increase in the frequency and length of drought periods are factors that cause changes in surface water reserves [Venitsianov, Adgienko 2018]. Besides, groundwater balance is also influenced by water availability, precipitation, and precipitation and evapotranspiration. Therefore, rainfall data are needed as a supporting factor. The hydrological cycle is expected to intensify with more evaporation and more rainfall. However, additional rain will be distributed unevenly around the world due to climate change. Some parts of the world may experience significant decreases in rainfall or large changes during the wet and dry seasons [Kumar 2012].

As an archipelago located between the Indian Ocean and the Pacific Ocean, Indonesia is greatly influenced by changes in sea surface temperature around it. When there is an increase in sea surface temperature in the Central and Eastern Pacific Ocean

around the equator, known as El Niño, this is related to a decrease in rainfall in Indonesia. El Niño causes changes in regional and global climate variability, leading to catastrophic droughts. Meteorological drought is related to rainfall levels below average in a season where meteorological drought is the first indication of water shortages [Nuarsa *et al.* 2015].

The National Disaster Management Agency (Ind. Badan Nasional Penanggulangan Bencana – BNPB) estimates that 4.87 mln people were affected by drought due to the dry season in 2018. Based on data from the National Disaster Management Agency (BNPB) processed by Lokadata Beitagar.id, there were 606 events of drought in Indonesia from 2010 to July 2017. During that period, the number of victims affected was 2.2 mln people in 2013. In East Nusa Tenggara (NTT), drought-affected around 866 thous. people spread across 22 districts/cities, 254 sub-districts and 896 villages in 2018. East Nusa Tenggara already had water deficit in 1995 and it is an area hit by drought almost every year. Drought has reduced water supply, decreased river discharge, reduced water levels in lakes and reservoirs, and dry wells. Some people are forced to buy clean water to meet their daily needs for clean water. Farmers also pay an additional IDR800,000 (USD57.14) to rent a water pump and buy diesel to water their fields. Even though the economy of East Nusa Tenggara Province is sectorally dominated by agriculture [Adrianto 2019], actually, if the impact of El Niño is not immediately minimised, it will gradually affect productivity and food availability which will affect the price of basic foodstuffs in NTT. Besides, it will have an impact on reducing the availability of water for the daily needs of the community, and it will cause various other social problems. The fundamental problem of the community's unmet need for clean water is inseparable from the difficulty of finding water sources or groundwater due to low annual rainfall; in 2018 the precipitation was only 911.1 m^3, with the most precipitation occurring in three to four months of the year [Central Statistics Agency 2019; Scarsoglio *et al.* 2013].

According to the MoE [2007], various disasters in Indonesia indicate that most disasters are related to the El Niño Southern Oscillation (ENSO) phenomenon. The ENSO is a recurring pattern of climate variability in the eastern Pacific Ocean characterised by sea surface temperature anomalies (sea level warming represents an El Niño event while sea level cooling describes a La Niña event) and Sea level pressure (Southern Oscillation) anomalies [Naylor *et al.* 2002]. ENSO values can be indicated by the Oceanic Niño Index (*ONI*) and changes in sea surface temperature, which have an impact on rainfall intensity so that the El Niño and La Niña events cause a decrease or increase in rainfall in Indonesia.

In this study, the observation of the ENSO in the form of El Niño, which is related to rainfall in the East Sumba Region, can be based on the *ONI*. The *ONI* is one of parameters that is often used to assess El Niño and La Niña. The Niño Ocean Index provides the monthly average value of the *SST* (Sea Surface Temperature) in the month after and the month before from regular, which is then compared with the average *SST* in a given month. If it is less than –0.5, then it experiences Strong La Niña, –0.5 to 0.5 neutral conditions and more than 0.5 leads to Strong El Niño.

The El Niño phenomenon has a significant influence on the climate in the East Sumba Region. Reduced rainfall and drought are direct impacts that can trigger other problems in the agricultural sector, such as crop failure and reduced food security. Therefore, it is necessary to study the rainfall during the El Niño phenomenon that occurred in a period of 38 years in East Nusa Tenggara and the impact in the form of drought as the effect of the El Niño phenomenon.

STUDY METHODS

This study was conducted in East Sumba, East Nusa Tenggara (NTT), which was selected as one of the Indonesian ecoregions that experiences vast differences in arid climate and savanna due to the tropical rainforests in general. Data used in this study originate from rainfall observation at the Umbu Mehang Kunda Meteorological Station and *ONI* in 1981–2019. The rainfall data from the Umbu Mehang Kunda Meteorological Station used in this study is from 1982 to 2019. The determination of the El Niño period is based on *ONI* data from the National Oceanic and Atmospheric Administration (NOAA). Provided the *ONI* value is more than +0.5, it indicates an El Niño period, whereas if it is less than –0.5, it indicates a La Niña period. El Niño generally occurs in the middle of a month and ends in the middle of the following year, so that the annual rainfall calculated when El Niño occurs starts in July in the first year and lasts to June of the following year.

The dry day series is calculated based on the number of days without rain. The East Sumba region is included in three dry day series categories according to the Indonesian Meteorological, Climatological, and Geophysical Agency (Ind. Badan Meteorologi, Klimatologi, dan Geofisika – BMKG). These categories include a long day without rain (21–30 days), a critical long day without rain (30–60 days), and an extreme drought (>60 days). This study used a qualitative approach based on secondary data collected through literature review from various sources, namely journals, articles, government reports, and documents from related agencies regarding the physical, social and economic conditions of East Nusa Tenggara. The impact study of El Niño and drought in East Sumba was carried out by means of a desk-study analysis and then reviewed and extracted descriptive data.

RESULTS AND DISCUSSION

EL NIÑO EVENTS AND THE DRY DAY SERIES

In general, the East Sumba area is classified as hot, with an average temperature between 27 and 28°C [Central Bureau of Statistics Agency East Sumba, 2019]. East Sumba has a monsoonal rainfall pattern type which shows a clear difference between the rainy and dry season periods in a year, and there is only one maximum monthly rainfall per year [Tukidin 2010]. The monsoonal pattern of rainfall is characterised by a unimodal pattern (one peak of rainy season). The rise of the dry season occurs in the period of June–August, and the height of the rainy season occurs in the period December–February. In contrast, the other six months between these periods are transitions between the two seasons [Salmayenti *et al.* 2017]. Sea breezes influence the monsoon pattern on an extensive scale. Monsoon winds are winds that move periodically or seasonally due to differences in heat between continents and oceans that occur twice a year and cause a monsoonal pattern. The arid climatic conditions of this region force it to accept the challenge of more frequent droughts

and water deficits. The current climate change has the potential to increase the frequency of water shortages in the East Sumba region. One of the markers of climate change is that the return period of climate variability is getting shorter. One of the effects is the El Niño event.

Based on data from the National Oceanic and Atmospheric Administration (NOAA), during the last 38 years or nearly four decades, El Niño climate variability events have occurred 13 times with an average of 4 times a decade. The years with El Niño are shown in Table 1. El Niño occurs when for three consecutive months, the value of the Ocean Niño Index (*ONI*) is more than 0.5. Generally, every year, El Niño starts in the middle of that year. *ONI* values of more than 0.5 begin typically in the middle three months, namely June, July, and August, and they end in the middle of the following year. It is because the dry season in this area is in the middle of the year, considering that the type of rainfall pattern in this region is the monsoonal rainfall pattern [Sipayung *et al.* 2019]. In the rainy season, the monthly rainfall in East Sumba ranges from 219 mm to 785 mm. In the dry season, monthly rainfall ranges from 0 mm to 105 mm. The El Niño effect tends to exacerbate the drought in East Sumba (Photo 1).

Table 1. Rainfall based on El Niño years

Year	Rainfall (mm)
1982/1983	840.7
1986/1987	586.5
1987/1988	741.5
1991/1992	769.5
1994/1995	822.6
1997/1998	700.5
2002/2003	104.1
2004/2005	346.9
2006/2007	764.7
2009/2010	621.2
2014/2015	731.2
2015/2016	773.9
2018/2019	883.5

Source: own study.

In the first 19 years of El Niño, the phenomenon occurred six times, while in the following 19 years seven times. One of these El Niño years still has a high rainfall value and it is classified as a weak El Niño. The results of this research show that the annual rainfall in the first six El Niño events is higher than the last six times. The research found that there was an accumulative decrease in total rainfall in the count of El Niño events, especially in the East Sumba region. The years 2002–2003 showed a higher rainfall value than other El Niño years. This could happen because El Niño these years was classified as weak with no *ONI* value greater than 1.5. Besides, El Niño began in mid-2002 and ended in early 2003, namely February, March, and April, whereas, other El Niño years generally occurred until the middle of the month or even the end of the month. Therefore, the rainfall in 2002–2003 reached more than 1000 mm.

Photo 1. Extreme drought in East Sumba, East Nusa Tenggara Province (phot. *P.A. Pambudi*)

When viewed from the series of dry days that occur in this region, the results of the analysis show that each year this region has predominantly experienced a series of dry days with extreme drought (Fig. 1). In nearly four decades, 27 years of dry days were categorised as severe drought, namely more than 61 days without rain. Similar to the El Niño years, the dry day series is also dominated by extreme drought. Generally, the severe drought occurs between July and October. The only dry day series year in the long rain day category is 2016. This could be due to the fact that the *ONI* value was calculated in the middle of the year, which is usually indicated as El Niño, but that year it showed

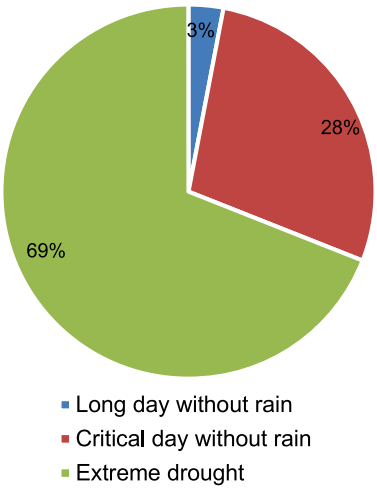

Fig. 1. Series of day without rain in the East Sumba Regency (1982–2019); source: own study

the opposite. In July to December, there is an indication that La Niña phenomenon is weak, as shown by an increased number of days without rain. The *ONI* value is less than negative 0.5, which indicates that La Niña occurred in these months. Therefore, the series of dry days in that year was in the long rain-free day category and its impact is shown in Photo 2.

Photo 2. The impact of dry days in that year is in the long rain-free day in East Nusa Tenggara (phot. *P.A. Pambudi*)

Interestingly, in nearly four decades, the dry day series has never occurred in December, January, February, and March. These months are included in the rainy season category in the East Sumba region. This indicates that during a rainy season, there is no day without rain for 20 days or more. These months also witness the highest accumulation of rainfall. Therefore, the maximum precipitation in this area should be utilised optimally to reduce the impact of drought, especially during El Niño climate variability.

THE IMPACT OF THE EL NIÑO PHENOMENON

Future reductions in annual rainfall are an aspect of climate change that will have very strong effects on people and ecosystems [Polade *et al.* 2014]. The increase in the frequency of dry days in parts of Indonesia is likely due to changes in ENSO teleconnections in warmer climates [Bulic *et al.* 2011]. Climate change which causes changes in rainfall patterns, the length of the rainy season, a shift in the beginning of the rainy season, and an increase in extreme climate events have a serious impact on the agricultural sector, especially food crops [Surmaini 2016]. The El Niño climate phenomenon has an impact on the occurrence of drought in several areas of East Nusa Tenggara which is caused by low intensity and frequency of rainfall and the short span of the rainy season. The El Niño delays the beginning of the rainy season, shortens the rainy season, and causes the rainfall to remain below normal in most of the seasonal zones in the East Nusa Tenggara region. This is because during the El Niño phenomenon, the sea surface temperature in Indonesian waters, especially East Nusa Tenggara is cooler than the sea surface temperature in the East Pacific, in particular on the Peruvian coast so that the pressure in waters around the East Nusa Tenggara region was higher than the pressure in Peru. Thus, winds heading for East Nusa Tenggara only carry a little water vapour, making cloud formation difficult and creating potential for minor rain in the East Nusa Tenggara region [Kain *et al.* 2018].

When the El Niño phenomenon occurs, and the sea surface temperature in the central and eastern Pacific equator warms, waters around Indonesia generally experience a decrease in temperature (deviating from usual temperature). As a result, there is a change in the circulation of the air mass which results in reduced formation of rain clouds in Indonesia. The super El Niño phenomenon can cause drought. Increased incidence of drought as a result of climate anomalies often lead to crop failure and poor harvest. The most recent incident in 2014 that occurred in several villages of the East Sumba Regency forced local populations to consume intoxicating yam (*Dioscorea hispida*), often referred to as "forest sweet potato", which is poisonous as a result of prolonged drought. It is one clear evidence of the negative impact of drought on traditional farmers [Riwu Kaho 2014]. The reduced rainfall has depleted soil moisture content in many areas. There is tremendous confusion among traditional farming communities about the increasingly volatile weather which changes climate dynamics. Thus, local wisdom that has been used for estimating planting times based on the knowledge of climate can hardly be used due to unpredictable climate changes [Riwu Kaho 2014].

Severe drought disasters adversely affect socio-economic and environmental sectors and can cause massive hunger and migration, and degradation of natural resources and weak economic performance. Drought can also exacerbate social tensions and trigger civil unrest. The Meteorology, Climatology and Geophysics Agency (BMKG) noted that the 2019 dry season was drier than the 2018 one and the climatological normal reference for 1981–2010. Even so, it is no drier than the dry season conditions in 2015, when the El Niño phenomenon was strong. The disaster was caused by the El Niño phenomenon present from September 2018 to July 2019 in the central equatorial Pacific Ocean [Kuswanto *et al.* 2019]. Then it was exacerbated by the positive phase dipole mode phenomenon of the Indian Ocean (IOD +) which strengthened from April to December 2019. The 2019 drought became quite severe partially due to lower sea surface temperatures in Indonesia, especially in the southern part (>0.5°C) normally in the period June–November 2019. Lower sea surface temperatures prevent the formation of rainy clouds due to a lack of moisture in the atmosphere and low evaporation from oceans. The Rumbangaru area, East Sumba, recorded the longest period of days without rain in 2019 (259 days). Kuswanto *et al.* [2018] has found that the magnitude and duration of drought in East Nusa Tenggara, Indonesia tends to increase over time.

Strong El Niño events, e.g. in 1997 and 2015, not only caused crop failure and delayed planting, but also led to the increase in food prices and contributed to food insecurity involving millions of people. The World Food Program [WFP 2016] estimates that food production must increase by 50% until 2030 in order to meet the demands of an increasing population. At the same time, the impact of climate change is projected to see a 1–7% reduction in world food production by 2060. If the impacts of climate change are not anticipated, it is estimated that around 20% of the world's population is at risk of starvation. In addition, according to the Indonesia Food Security 2 Monitoring Bulletin [2015], ten districts in the East Nusa Tenggara Province

are the first priority regarding the impact of drought in Indonesia. The first priority district is the one that has no rain for more than 60 days and the poverty rate is above 20%. In East Nusa Tenggara, the majority of families are poor with low educational background [Kuswanto 2019].

The drought in East Nusa Tenggara is strongly influenced by the global El Niño phenomenon, which makes people even more vulnerable. This situation is getting worse because people find it difficult to get water due to inappropriate basic services, such as water and electricity supply [Kuswanto 2019]. The majority of NTT's population works as farmers, so water shortages due to drought have a significant impact on livelihoods and cause difficulties in agriculture as well as access to clean water. This results in crop failure, food shortages, and decreased income [WFP 2016].

CONCLUSIONS

The accumulative decrease in rainfall occurs in El Niño years. The annual rainfall for the last six El Niño events has been lower than the annual rainfall for the first six El Niño events. In the East Sumba region, series of dry days categorized as extreme drought prevail. The El Niño phenomenon greatly affected the drought in East Nusa Tenggara and had a significant impact on livelihoods and caused difficulties in agriculture and access to clean water. This resulted in crop failure, food shortages, and decreased income. The El Niño phenomenon affects the availability of food which triggers price inflation in the market. In the long-run, this results in increased rates of poverty, hunger, and brings us further away from meeting Sustainable Development Goals. Technology and ecological engineering are needed to overcome this problem, for example the integrated multistakeholder partnership.

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