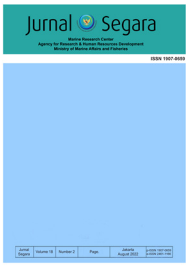

JURNAL SEGARA
http://ejournal-balitbang.kkp.go.id/index.php/segara

ISSN : 1907-0659
e-ISSN : 2461-1166
Acreditation Number : 158/E/KPT/2021

THE EFFECT OF ENSO AND IOD CLIMATE VARIABILITY ON SALT PRODUCTION IN NUSA TENGGARA ISLANDS

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Received: 26 Juli 2022; Revised: 3 November 2022; Accepted: 4 November 2022

ABSTRACT

The Nusa Tenggara Islands have an ideal environment for salt production, such as low rainfall and humidity, high evaporation and wind speed, and relatively good seawater quality. However, global climate variability, such as ENSO and IOD, affects the salt harvest volume of the region. This paper aims to discuss the effect of ENSO and IOD climate variability on salt production in the Nusa Tenggara Islands and their comparison with salt production on the islands of Java and Madura. The result shows that salt production in Nusa Tenggara Islands increased when El Nino and positive DMI simultaneously occurred, as in 2012, 2014, and 2015. Conversely, salt production decreased when La Nina and negative DMI simultaneously occurred, as in 2016. When ENSO and DMI are in normal or opposite conditions, salt production is moderate, as in 2013 and 2017. The La Niña event and IOD negative in 2016 triggered high rainfall and salt production decrease in Nusa Tenggara, about 5.8% of the annual average salt production. Meanwhile, this condition also affected salt crop failure on the islands of Java and Madura. Thus, the effect of ENSO and IOD climate variability on salt production in Nusa Tenggara is less significant than in Java and Madura.

Keywords: Dipole Mode, El Niño , evaporation, La Niña, precipitation.

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INTRODUCTION

Salt is one of the potential marine resources that is strongly affected by weather and climate factors. When the weather and climate are favorable for producing salt, the salt harvest will grow significantly (Bramawanto & Abida, 2017). Rainfall, rainy days, wind speed, air temperature, humidity, solar radiation, and evaporation play an important role in making solar evaporation salts (Bramawanto *et al*., 2019). In addition, seasonal climate variability (Monsoons) also affects salt production, especially related to sooner or later the dry and rainy seasons come.

Nusa Tenggara Islands have ideal environmental parameters for producing salt. The areas generally have good water quality, low rainfall and humidity, high evaporation and wind speed. Rainfall in The Nusa Tenggara Islands belongs to the Monsoon type (Figure 1). Therefore, salt production with the solar evaporation system can only be done during the dry season, from June-November (JJASON).

Average rainfall data of the Bima district (West Nusa Tenggara) and Kupang districts (East Nusa Tenggara) show rainfall patterns in Nusa Tenggara Islands. The peak rainfall in this area occurred in December, January, and February. The minimum rainfall occurred in June, July, August, and September (Figure 2). The dynamics of the Australian and Asian Monsoons influence the rainfall in Nusa Tenggara Islands. The Australian Monsoons blow from the southeast, and the Asian Monsoons blow from the Pacific (Kirono *et al*, 2014; Nurlatifah & Wulandari, 2019).

El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) climate variability also influence rainfall variations in Indonesia. (Sitompul & Nurjani, 2013; Hidayat & Ando, 2014; Nur'utami & Hidayat, 2016). Saji *et al*. (1999) showed that IOD has independent properties of ENSO. There are certain years when the phenomena of IOD (Positive or Negative) and ENSO (El Niño or La Niña) occur almost simultaneously. For example, IOD and ENSO were simultaneously found in 1997 and 2015 (Meyers et al., 2007; Bramawanto *et al*., 2019). In 2015 there was a positive IOD phenomenon and El Niño that resulted in a decrease in the accumulation of monthly rainfall and the duration of the dry season longer than usual (Nur'utami & Hidayat, 2016). The effect of a single event and a combination of ENSO and IOD on the Indian Summer Monsoon found that IOD significantly affects rainfall and can reduce the impact of ENSO when it simultaneously occurs (Ashok *et al*., 2004; Liu *et al*., 2009).

Salt production in West Nusa Tenggara and East Nusa Tenggara, like other salt producers in Indonesia, is also affected by global climate variabilities such as the El Nino Southern Oscillation and the Indian Ocean Dipole. We arrive at the scientific question: How do ENSO and IOD affect salt production in Nusa Tenggara islands? Is the condition different from salt production in Java and Madura? This paper will look at the impact of ENSO and IOD climate variability on salt production in the Nusa Tenggara Islands and their comparison with salt production on the islands of Java and Madura.

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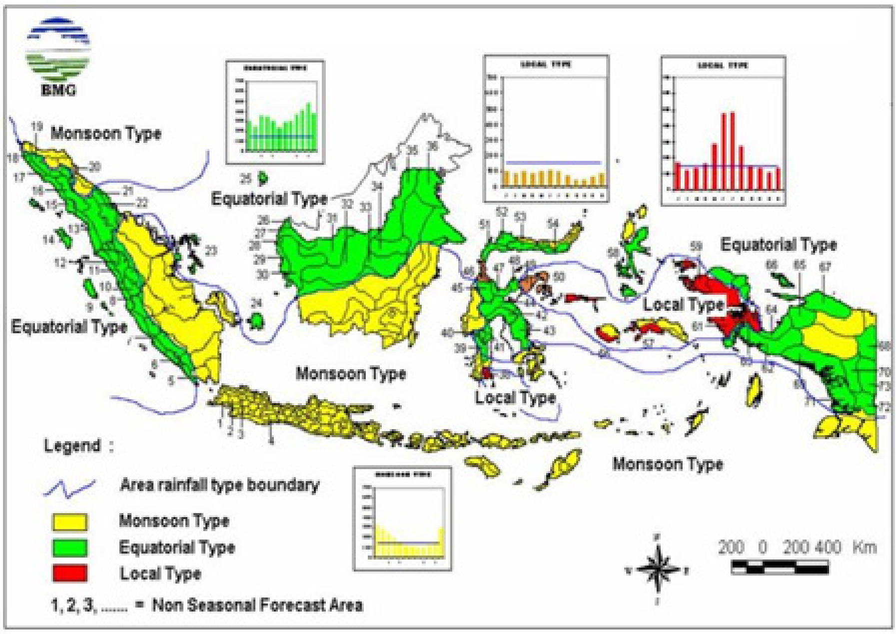

Figure 1. Rainfall patterns in Indonesia. (sources: Meteorology Agency (BMG), Indonesia) in Yulihastin *et al*, 2009).

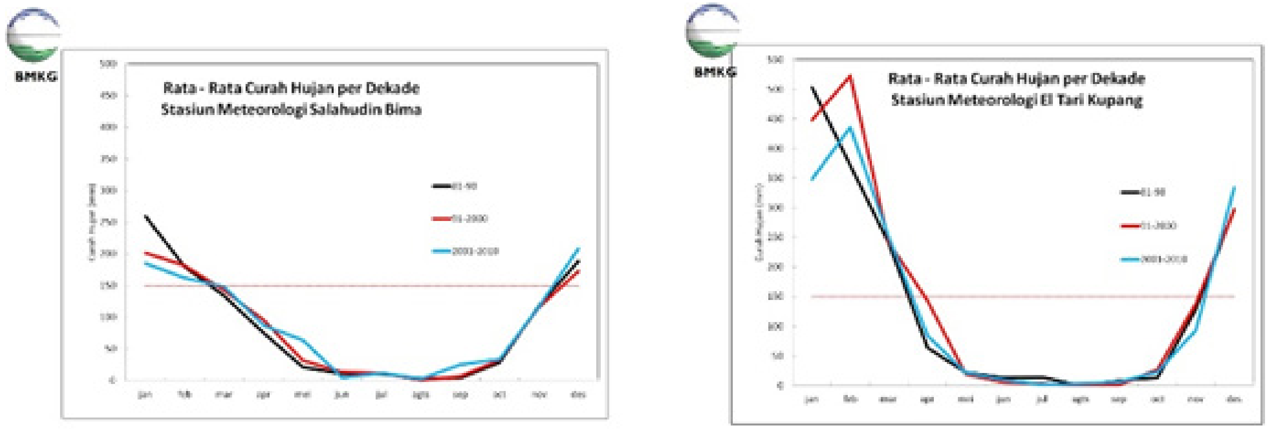

Figure 2. Average rainfall in major cities in West Nusa Tenggara & East Nusa Tenggara Provinces. (sources: Meteorology, Climatology, and Geophysical Agency BMKG)

METHODOLOGY

Study Location

The study area is the Provinces of West Nusa Tenggara and East Nusa Tenggara (Figure 3) as salt producers in the Nusa Tenggara Islands. It is in the southern hemisphere of the equator, eastern Indonesia. Data Collection

The data used in this study include precipitation, salt production, sea surface anomaly, and rainfall. Precipitation data were obtained from the website http://apps.ecmwf.int/datasets/data/interim-full-daily. Salt production data from Ditjen PRL 2011 to 2018. Sea surface temperature (SST) anomaly data (NINO 3.4 index and the dipole mode index) from 2011 to 2018 was taken from the website www.cpc.ncep.noaa.gov. Rainfall and rainy days data from Central Bureau of Statistics/BPS (2016-2018) Bima and Nagekeo District in Figures 2015 to 2017.

Analysis

This study was carried out using a literature study approach, followed by an analysis of the relationship between ENSO and IOD Climate Variability on salt production. The data is then processed and visualized with Ocean Data View software (ODV 4.5) and ms. Excel 2016.

RESULTS AND DISCUSSION

Salt production activities generally occur when the Monsoon wind blows from East to West in April-October. During this period, Indonesia entered a dry season due to the dry nature of the wind because it passes through the desert in northern Australia and only through narrow seas (Wheeler & McBride, 2005). Salt farmers use this condition to optimize salt production. However, the impact of this Monsoon is different in certain areas of Indonesia. Therefore, salt farmers need Monsoon information related to rainfall in the rainy and dry seasons, such as forecasts for the

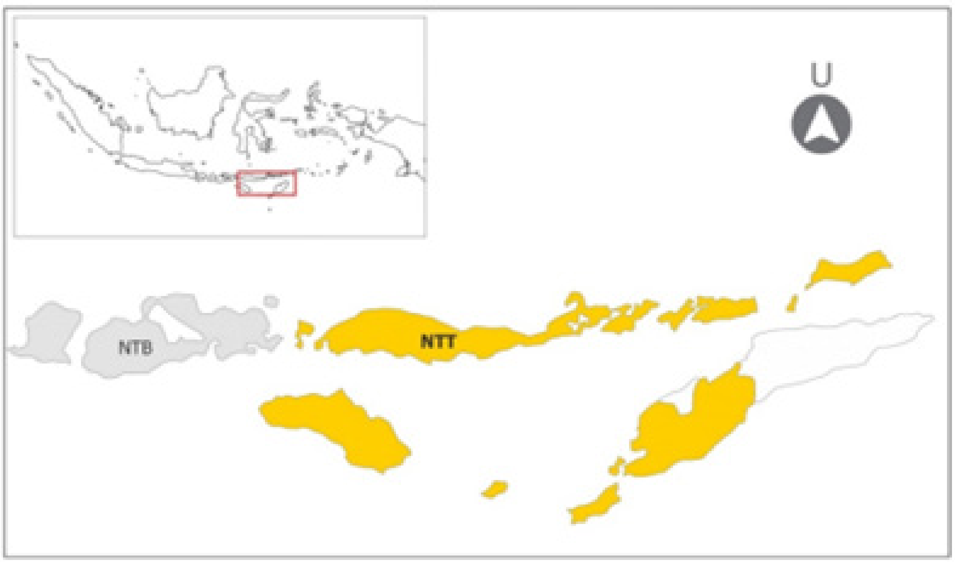

Figure 3. Provinces of West Nusa Tenggara (NTB)& East Nusa Tenggara (NTT) as study locations.

beginning of the rainy and dry seasons, the nature of the rain, and the peak of the rainy and dry seasons, to exploit the potential for salt production.

Stakeholders should consider the inter-annual climate variability of ENSO and IOD in optimizing salt production. When an El Nino occurs, sea surface temperatures in the equatorial Pacific grow warmer from east to center, increasing the temperature and humidity of the air above. This event causes cloud formation that also increases rainfall in the area. As a result, air pressure increases in the western Pacific Ocean. It has hampered the growth of clouds in the eastern part of Indonesia's sea, so rainfall has decreased abnormally in several areas in Indonesia. Otherwise, La Niña caused by higher sea surface temperatures in the Western and Eastern Pacific. This incident caused the air pressure in the equatorial Western Pacific to decrease, encouraging excessive cloud formation and causing high rainfall in the affected area, namely Indonesia. La Niña makes the weather tends to be warmer and more humid. The La Niña phenomenon that increases rainfall makes the weather in Indonesia's dry season wetter. The eastern equatorial Pacific is dominated by El Niño Southern Oscillation (ENSO) scale variability with periods ranging from 2 to 7 years, while The northeastern Pacific is dominated by decadal-scale variability with periods ranging from 10 to 30 years. (Wang & Fiedler, 2006; Meyers *et al.*, 2007).

The impact of La Niña and negative IOD significantly reduce salt production. During La Niña, rainfall and rainy days are increasing, which can interfere salt production process. When rainfall and the number of rainy days increase, saltwater quality and evaporation in the salt pond will decrease. Meanwhile, the positive impact of El Niño and positive IOD on salt farmers is being able to increase salt productivity. It is due to the decrease in the number of rainy days and rainfall that occurs in salt farmers' areas to improve the quality of saltwater and the evaporation process (Bramawanto & Abida, 2017).

Salt pan areas in the Provinces of West Nusa Tenggara and East Nusa Tenggara each have different characteristics of salt production even though they are in the same area that tends to be dry. Although East Nusa Tenggara has more salt pans and more favorable conditions than West Nusa Tenggara, the salt production in West Nusa Tenggara is higher than in East Nusa Tenggara (Table 1). Seeing the potential of the salt farm environment in East Nusa Tenggara, PT Garam (Persero) and the government have encouraged efforts to expand salt land in East Nusa Tenggara in recent years (Nababan, 2018).

The average salt production in West Nusa Tenggara and East Nusa Tenggara from 2011 to 2018 is around 158,771 tons and 7,798 tons, respectively. However, suppose the average is calculated only during the normal salt production season (excluding 2016). Because it has known that 2016 was the year of La Nina and negative Dipole Mode simultaneously, causing a wet-dry season in most of Indonesia and significantly decreasing salt production (Bramawanto & Abida, 2017). In that case, the average salt production in West Nusa Tenggara is around 179,948 tons, and East Nusa Tenggara is around 7,635 tons.

Salt production in West Nusa Tenggara is an example because the production is higher and tends to be more stable than in East Nusa Tenggara. Figure 4 below shows that ENSO, represented by the Nino 3.4 index, and IOD, represented by the Dipole Mode Index, and the combined activity of the two affects the amount

Table 1. Average Salt Production in West Nusa Tenggara and East Nusa Tenggara from 2011 to 2018

Province	District	Salt Production (Ton)								
		2011	2012	2013	2014	2015	2016	2017	2018	Average
West Nusa Tenggara	Sumbawa	2,719.1	6,118.0	665.9	4,559.0	3,306.4	513.4	2,029.5	5,601.4	
	Kota Bima	1,972.5	5,356.7	1,472.5	3,016.4	1,688.1	2.2	671.4	276.9	
	Bima	120,719.5	199,500.2	96,492.5	156,339.0	152,439.2	7,216.3	80,470.4	263,238.3	
	Lombok Barat	2,224.8	5,127.5	5,754.4	9,313.2	4,355.0	1,402.1	257.8	1,129.1	
	Lombok Tengah		2,308.3	971.4	2,101.4	2,788.2	400.6	3,480.4	25,179.5	
	Lombok Timur	8,153.6	11,685.3	13,105.8	22,881.1	12,228.7	997.9	4,183.8	13,759.7	
	Amount	**135,789.5**	**230,096.0**	**118,462.4**	**198,210.2**	**176,805.6**	**10,532.5**	**91,093.4**	**309,184.9**	**158,771.8**
East Nusa Tenggara	Kupang	1,831.4	5,939.8	740.5	3,146.5	2,350.7	1,705.1	868.7	291.1	
	Ende	455.0	920.9	510.4	720.4	351.0	32.1	411.8	401.0	
	Timur Tengah Utara (rebus)	320.0	863.8	553.3	260.5	1,100.7	792.3	224.5	336.1	
	Alor	225.0	132.3	206.1	261.1	315.1	-	6.7	8.3	
	Sumba Timur	404.2	937.0	1,285.1	622.4	846.1	318.1	259.7	672.1	
	Manggarai	223.5	761.0	215.6	329.2	441.0	108.0	643.4	1,832.8	
	Nagekeo	1,880.0	2,303.0	215.4	1,865.7	2,478.9	63.1	1,373.0	6,382.6	
	Lembata						174.6	2,334.3	960.5	
	Flores Timur						474.2	172.4	166.7	
	Sabu Raijua						5,270.7		90.4	
	Amount	**5,339.1**	**11,857.9**	**3,726.4**	**7,205.7**	**7,883.5**	**8,938.2**	**6,294.5**	**11,141.7**	**7,798.4**

of salt production in West Nusa Tenggara. When El Nino and a positive DMI occurred during the salt season, which runs from June to November (JJASON), as they did in 2012, 2014, and 2015, salt output surged. On the other side, when La Nina and negative DMI both happened simultaneously, like in 2016, salt production declined. In contrast, salt production is moderate when ENSO and DMI are neutral, normal, or in the opposite direction, particularly when La Nina and positive DMI are present, as in 2013 and 2017.

Differences in rainfall can explain the difference in salt production each year during the salt processes. Several studies have shown that ENSO and IOD affect rainfall, which is the dominant limiting factor in the salt production. As an illustration, the precipitation data shows the rainfall condition during the peak of the salt yield processes (September) in 2015-2017. When there was a strong El Niño and a positive IOD in 2015, the rainfall in Nusa Tenggara was very small (below 0.5 mm), as was the case in most salt pans in Java, Madura, and Southern Sulawesi (Figure 5).

In 2016, when La Niña and negative IOD occurred, the rainfall in Nusa Tenggara was still quite low, although almost all salt pans in Java experienced rain (Figure 6). It explains why salt production in West Nusa Tenggara and East Nusa Tenggara can still happen when salt harvest failure occurs on the islands of Java and Madura. However, the salt production in Nusa Tenggara was only found in the first week of August to the second week of October 2016 and was

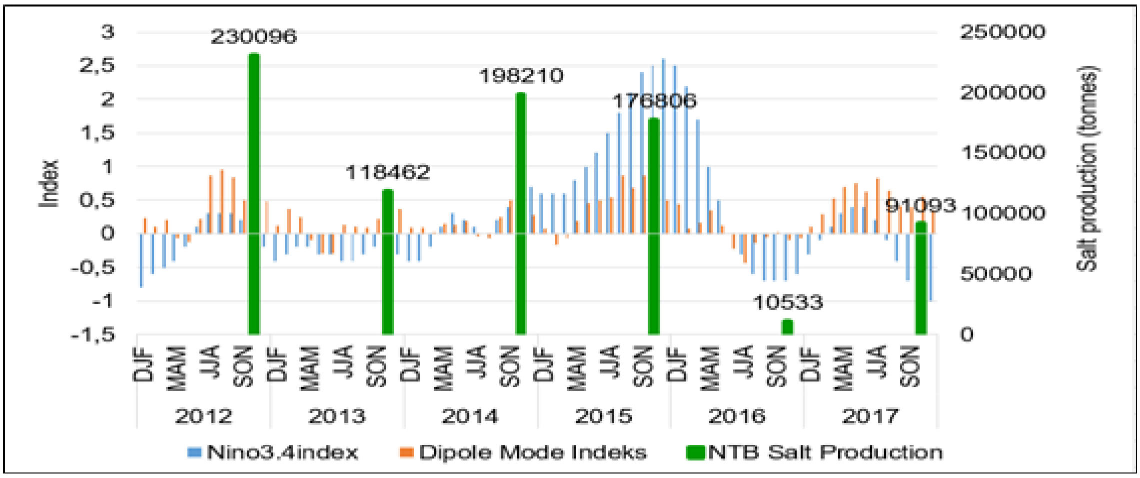

Figure 4. The relationship between ENSO and IOD with salt production in West Nusa Tenggara as represented by the Nino 3.4 index and DMI (Dipole Mode Index).

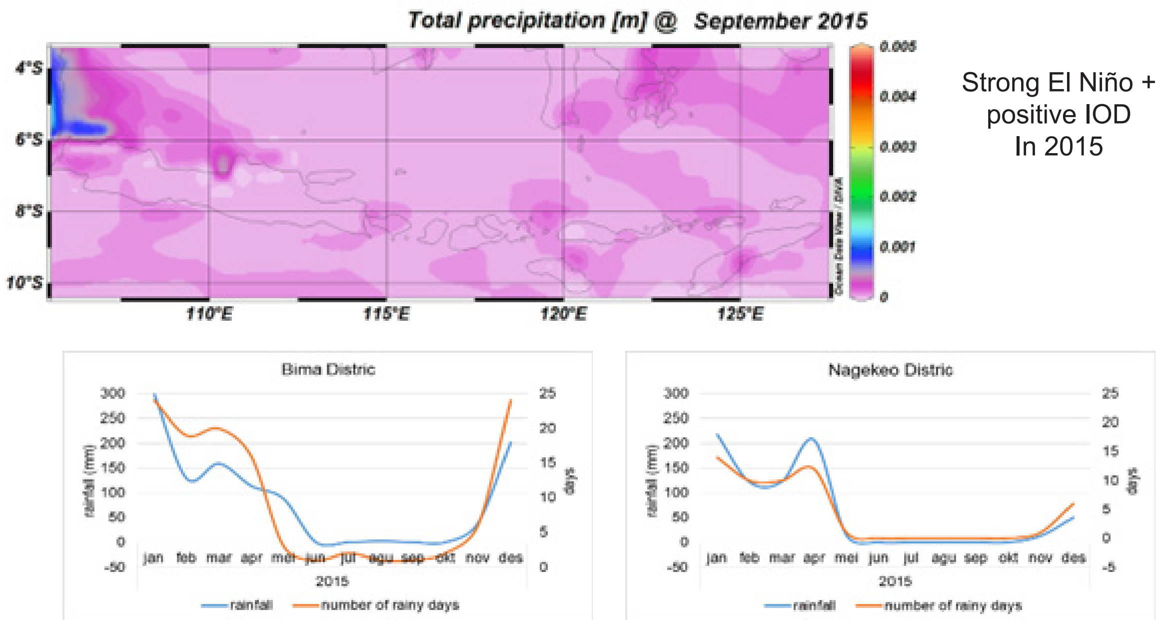

Figure 5. Spatial distribution of precipitation (rainfall) and rain pattern in West Nusa Tenggara and East Nusa Tenggara in September 2015. (source: ECMWF, processed data).

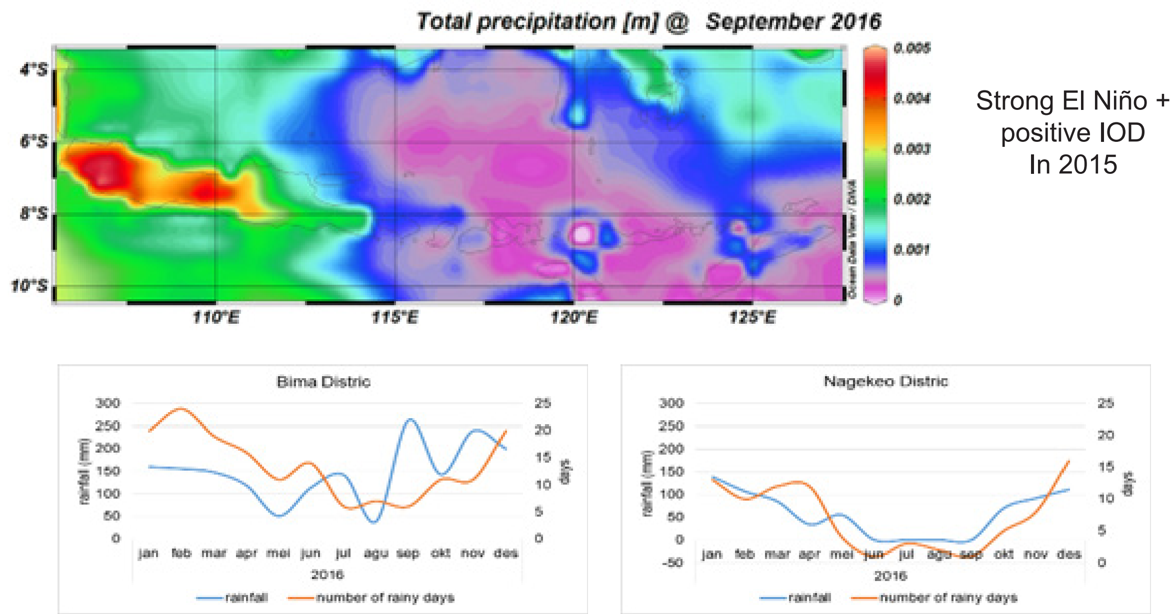

Figure 6. Spatial distribution of precipitation (rainfall) and rain pattern in West Nusa Tenggara and East Nusa Tenggara in September 2016. (source: ECMWF, processed data).

interspersed with some rain, so salt production was still not optimal.

When there was a weak La Nina and a positive IOD in 2017, the rainfall in Nusa Tenggara was still quite low, as in East Java and Madura, so most salt centers could still produce salt (Figure 7). The condition differs from the salt centers in Central Java and West Java, where the salt production was not optimal in September 2017 because rain intensity disturbed it.

The variations of salt yield from different locations and years (2015-2017) are explained based on the evaporation condition. The optimum evaporation that supports salt production is between 0.25 to 1.25 mm, represented by yellow and green (Figure 8). In 2015, the optimum evaporation still occurred in August-October in all salt pans. In 2017, the optimum evaporation in Nusa Tenggara continued until October, although at the same time, the evaporation in Java Island began to decrease. When La Nina and IOD even happened simultaneously in 2016, optimum evaporation still occurred in parts of West Nusa Tenggara and almost all areas of East Nusa Tenggara. Meanwhile, in Java Island, evaporation that is too high to reach more than 2 mm (purple color) triggers the formation of high rainfall

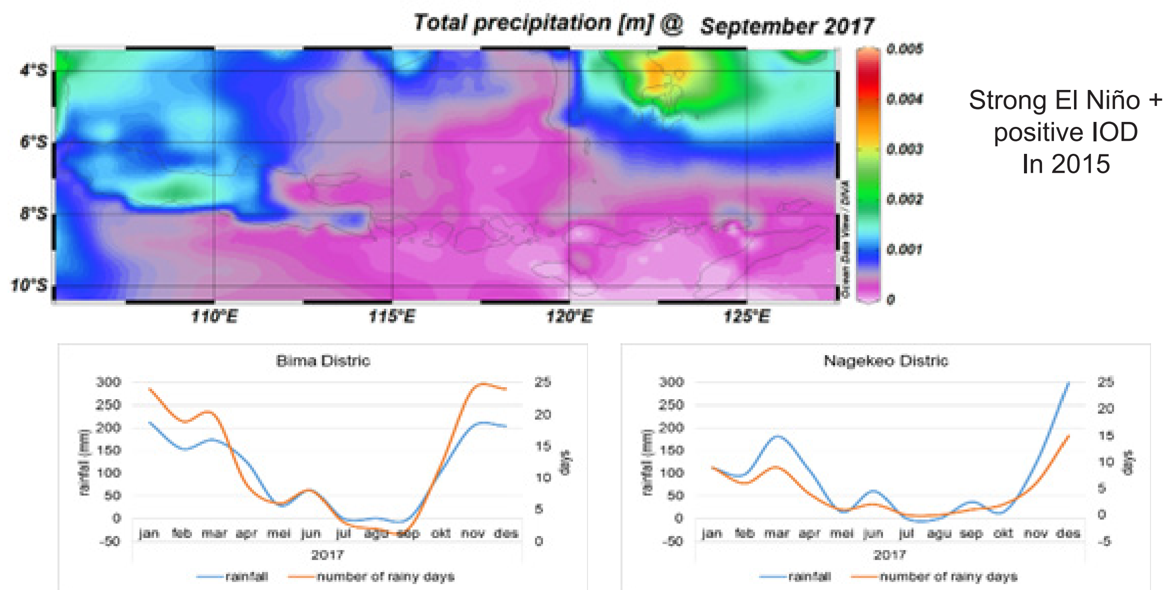

Figure 7. Spatial distribution of precipitation (rainfall) and rain pattern in West Nusa Tenggara and East Nusa Tenggara in September 2017. (source: ECMWF, processed data).

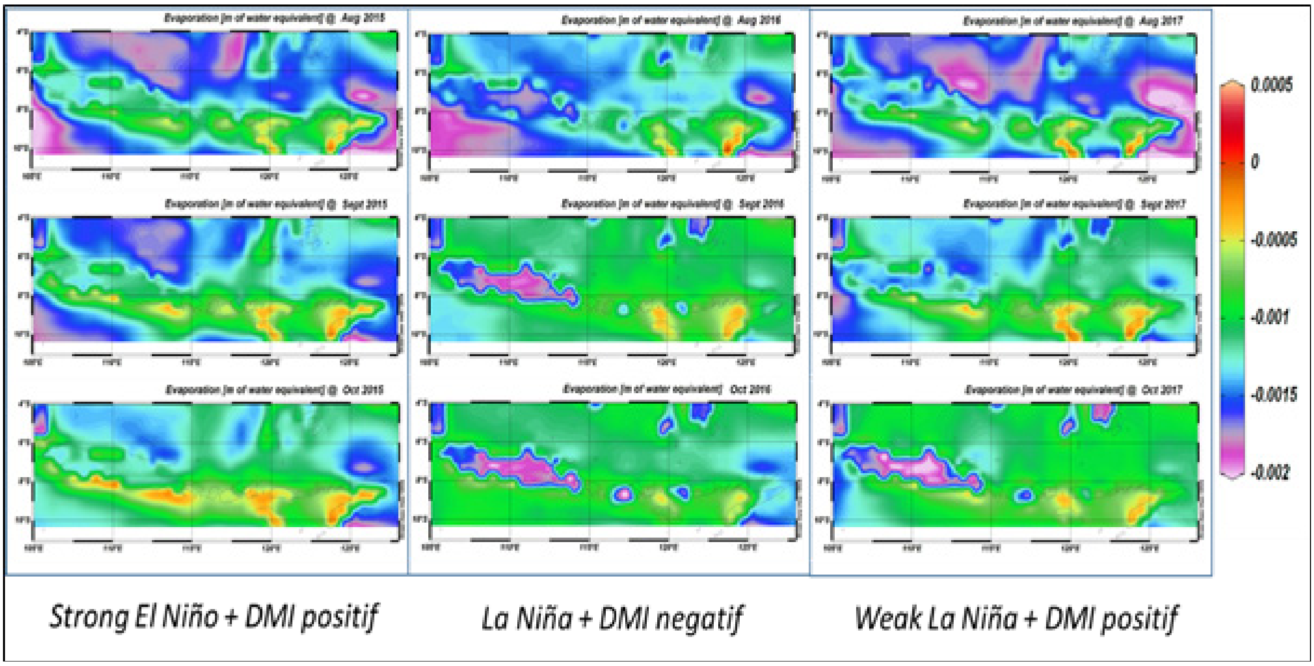

Figure 8. Spatial distribution of evaporation in Nusa Tenggara Barat and Nusa Tenggara Timur in September, 2015, 2016, and 2017. (source: ECMWF (2018), processed data).

so that salt production in Java Island suffers from crop failure.

CONCLUSION

The difference in salt production (2015-2017) shows the effect of ENSO and IOD Climate Variability in the Nusa Tenggara Islands. When El Nino and positive IOD occurred in 2015, the dry season in West and East Nusa Tenggara was about 4.5 and 5.5 months, increasing salt production. In 2016, when there was a wet-dry season due to La Nina and negative IOD, the salt production period in West and East Nusa Tenggara was only about 1-2 months. As a result, salt production was only 5.8% of the average annual production. West and East Nusa Tenggara salt production in 2017 was moderate when there was a weak La Nina and a positive IOD because the dry season went to its normal condition, around 4-5 months.

The effect of ENSO and IOD on salt production in the Nusa Tenggara Islands is less significant than in Java and Madura. The proof was that in 2016 when Java and Madura failed to produce salt, Nusa Tenggara could still produce salt, even in small quantities. The eastern part of Nusa Tenggara is potential for salt land extensification because it is supported by low annual and seasonal rainfall. In addition, dry air gusts from Australia during the dry season increase the region's evaporation rate.

ACKOWLEDGEMENTS

All authors having equal contributions. This research is funded by DIPA APBN for Marine Research Center of KKP in 2019.

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