Eksakta : Berkala Ilmiah Bidang MIPA
VOLUME 22 NO 03 2021, pp 190-199
ISSN : Print 1411-3724 — Online 2549-7464
DOI : https://doi.org/10.24036//eksakta/vol22-iss2/282

Eksakta
Berkala Ilmiah Bidang MIPA
http://www.eksakta.ppj.unp.ac.id/index.php/eksakta

Article

Precipitation and Land Cover Change in Komodo National Park During El Nino and La Nina

Article Info

Article history :

Received July 30, 2021
Revised August 18, 2021
Accepted August 25, 2021
Published September 30, 2021

Keywords :

Climate, Komodo National Park, land cover, El Nino, La Nina

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Abstract. Komodo National Park is located in East Nusa Tenggara province which has a dry tropical climate. Air temperature in this area is relatively high with a lower rainfall compared to most of other Indonesian regions. This condition causes ecosystem in Komodo National Park to be unique with a wide area of savannah and dryland forest. This study aims to identify the change of rainfall and land cover in Komodo National Park in 2018-2020. The analysis was conducted using secondary data from observations and satellite products. The result shows that West Manggarai is classified in Aw climate type. The value of rainfall follows the pattern of ENSO events with a correlation between tree-month data of rainfall and the Ocean Nino Index (ONI) is 42% in average of June-December. The land cover of vegetation in March/April has decreased by 2,240 Ha (2018-2019) and 2,517 Ha (2019-2020) or around 4% and 5% of total area. La Nina has occurred during wet season 2017/2018 followed by El Nino in the coming years. There was decreasing of rainfall during November-February period in 2019 and 2020, which was 17% and 37% lower compared to 2018.

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1. Introduction

Indonesia has a tropical climate with high solar radiation throughout the year. The air temperature in this country ranges from 21.3 °C to 28.4 °C [1]. In general, rainfall patterns in Indonesia are divided into three types, affected by Australian monsoon, south-eastern Passat monsoon and

Indonesian seaborne current (*Arlindo*) [2]. Due to global warming, global climatic conditions including in Indonesia are starting to change, increasing average air temperatures and sea surface temperatures were confirmed [1, 3-4]. Climatic conditions in Indonesia are also dynamics due to climate variability. Climate variability in Indonesia is caused by several factors, including climate phenomena in the oceans such as the Indian Ocean Dipole (IOD) and the El Niño–Southern Oscillation (ENSO) [5]. Independently, IOD and ENSO influence the rainfall in Indonesia differently by location and time [6]. ENSO phenomena is divided into three events, which are normal, El Nino and La Nina. Rainfall tends to decrease during El Nino events and to increase during La Nina events in several parts of Indonesia regions [7].

The geographical location and tropical climate make the regions in this archipelagic country, Indonesia, have ecosystems that are rich in biodiversity. Komodo National Park is one of the unique ecosystem areas as a habitat for Komodo dragon (*Varanus komodoensis*). This area is also a world heritage site by UNESCO since 1991. With total area of 0.17 million hectares, the Komodo National Park is also a habitat for hundreds of species of plants and animal [8]. This national park, which is located in West Manggarai Regency, is attracting tourists not only from local but also from abroad. In 2017, out of a total of 134,181 tourists who visited this district, 43% of them are foreigners. The number of visitors increased significantly by 219% from 80,626 in 2014 to 176,935 in 2018 [9]. The dynamics of tourism in West Manggarai Regency follows the seasonal pattern, where the highest visitors recorded during the dry season, in July and August in particular. A study from Susanto et al. (2020) reported that climate condition in Indonesia, temperature and humidity in particular, has contribution to the number of tourists [10].

Komodo National Park is located in East Nusa Tenggara Province, southern part of Indonesia. This region has a dry tropical climate type with annual rainfall of less than 2000 mm [11-12]. Some areas of Komodo National Park are covered by savannah, such as Huek (*Eucalyptus alba*) savannah, *lontar* savannah (*Borassus flabellifer*) and *gewang* savannah (*Corypha utan*) with potential carbon storage in the range of 53-537 tons/ha [13]. Fires on savannah not only contributes to emission production but also lead to further impact including soil property [14]. Savannah conditions are influenced by climatic factors, especially the availability of water. The variability of rainfall affects the distribution of savannah ecosystem [15]. This study aims to identify the character of climate in West Manggarai Regency, as well as to estimate the changes of precipitation and land cover in Komodo National Park during climate phenomena, El Nino and La Nina events.

2. Methods

2.1. Study Area

This study focuses on the mainland area of Komodo National Park particularly in three islands; Padar Island, Rinca Island and Komodo Island) (Figure 1), located in Komodo District, West Manggarai Regency. Geographically this area is located between 119°22' - 119°49' east longitude and 08°23' –08°50' south latitude. The area is the habitat of the Komodo dragon and other biodiversity, including 277 animal species (Komodo National Park, 2021). The vegetated area in the study area consists of savannah and secondary dryland forest. The secondary dryland forest area in Komodo National Park includes deciduous forest and quasi-cloud forest [16].

2.2. Climate of the study area

Rainfall and daily air temperature are the parameters used in this study to describe the climate characteristic of study area. The data used is the information from observations at the Komodo Meteorological Station which is located at 8.48673° south latitude and 119.88683° east longitude at an elevation of 67 metre. Data were collected from the BMKG website (https://www.

https://dataonline.bmkg.go.id/home). The analysis was carried out to picture the climate character which was described from the average of climatic factors of 10 years (2010-2020).

To identify the impact of ENSO phenomena in study area, the analysis is also complemented by calculating the correlation (R^2) between quarterly average rainfall and the parameters of ENSO phenomena based on Ocean Nino Index (ONI) and (sea surface temperature) SST in Nino 3.4 area in Pacific Ocean using data available from NOAA [17].

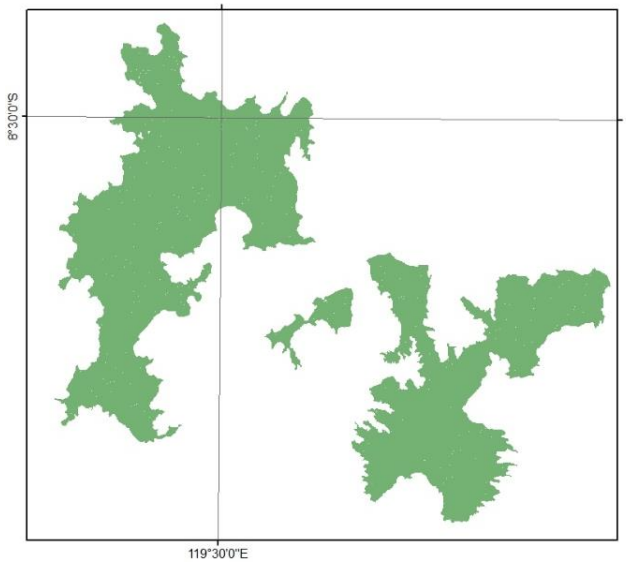

Figure 1. Study area of Padar Island, Komodo Island and Rinca Island in Komodo National Park

2.3. Land cover

Land cover in the study area was classified using supervised classification method. The data used are Landsat 8 path/row 114/66 satellite imagery with the acquisition of the end of wet season (9th April 2018, 11th March 2019, and 29th March 2020), and Google Earth imagery of the Komodo National Park area with the acquisition of the same period with Landsat which are in 9th April 2018, 11th March 2019, and 29th March 2020. This step was processed using ArcMap 10.3, Google Earth Pro, and Microsoft Office 2010.

Data processing started from cutting the image, which is necessary to detail the image coverage focussing in the research area. Furthermore, land cover classification is carried out based on training sample data from land cover classes referring to the similarity of pixel values using the Maximum Likelihood method. To identify the results accuracy, a kappa accuracy test was conducted with Google Earth data. Accuracy is calculated using an error matrix by comparing reference data and the classification results using the following formula:

$$Kappa\ coefficient = \frac{(TS\ x\ TCS) - \sum(total\ column\ x\ total\ row\ )}{TS^2 - \sum(\ total\ column\ x\ total\ row)}\ x\ 100\%$$

where TS = number of samples, and TCS = number of contingency samples. The results are confirmed when the accuracy level is 85% or more.

2.4. Rainfall distribution

Observations at the Komodo Meteorological Station at one location have not been able to cover the spatial distribution of rainfall in study area. For this reason, an analysis of the average total rainfall on the three islands of Komodo National Park was carried out using data of CHIRPS satellite products from The Climate Hazards Center, with accuracy reach 86% compared to observation data [18]. This data was downloaded from the website (https://www.chc.ucsb.edu). Data processing was done using ArcMAP 10.6.

3. Results and Discussion

3.1. Climate in West Manggarai Regency

West Manggarai Regency is located in the tropics. The average daily air temperature for the period 2010-2020 in this region ranges from 26.4 ºC to 28.5 ºC (Figure 2). The monthly average of maximum daily air temperature reaches 32.39 ºC while the lowest monthly average of minimum daily air temperature is 23.4 ºC. The total monthly rainfall in the study area are lower than most of regions in Indonesia. Annual rainfall for the 2010-2020 period varied from 697 mm to 1792 mm with an average of 1217 mm/year. The wet season with rainfall exceeding 100 mm/month is found in the period of November-March, while the dry season is during the period of April-October. September is the drier month with average of rainfall around 21 mm/month. There is possibility that during dry season, the study area has no rainfall for a whole month (0 mm/month), around July-September in particular. Based on koppen climate classification, the West Manggarai region belongs to the Aw climate type. This condition is drier than most of Indonesia which has an Af climate type [19].

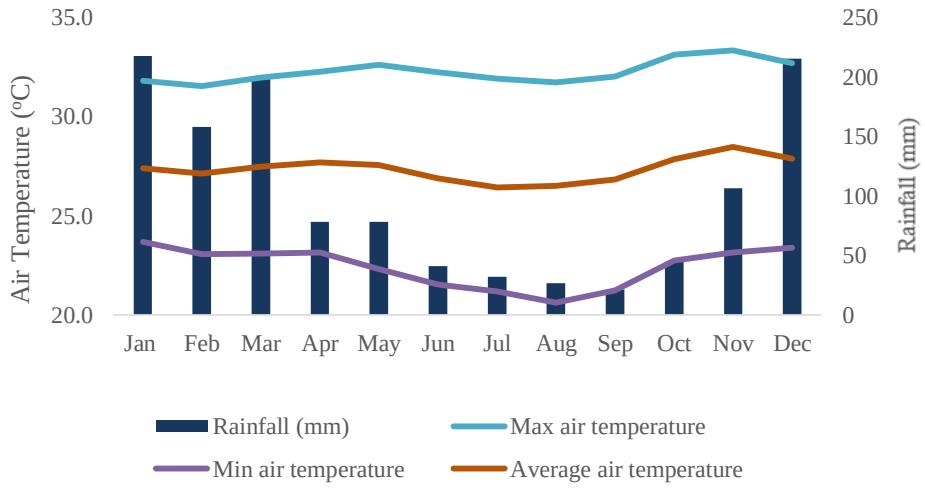

Figure 2. Average climatic conditions (2010-2020) in Komodo Meteorological Station.

The total rainfall varies in every year as shown in Figure 3. Focussing on ENSO phenomena, the trend of rainfall data is quite similar with the trend of ONI. From the figure below, it shows that El Nino events with ONI ≥0.5 occurred in 2009/2010, 2015/2016, 2018/2019, while La Nina events (ONI ≤ -0.5) occurred in 2010/2011, 2017, and 2020/2021. La Nina causes an increase in rainfall compared to normal conditions. For instance, with a strong La Nina in 2010, rainfall during the dry season increased significantly reaching 192 mm/month. On the other hand, rainfall tends to decrease during El Nino events. The strong El Nino at the end of 2015 caused a decrease in rainfall

which lead to drought condition and contribute to fires in several regions of Indonesia [18, 20]. The decrease in rainfall in the 2015 due to El Nino were approximately 50-300mm/month [21]. Strong El Nino caused some areas in West Nusa Tenggara Province to experience drought [22].

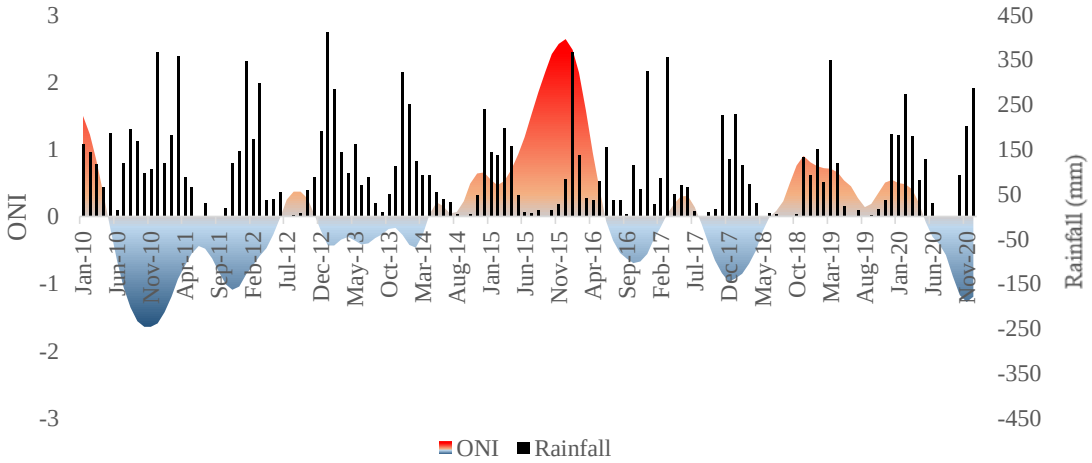

Figure 3. Variations in Oceanic Nino Index and rainfall (mm) in the Komodo Meteorological Station for 2010-2020 (Source: BMKG; NCAR)

The level of impact of ENSO on rainfall in Indonesia varies by location and time [23]. Table 1 shows that rainfall in West Manggarai is associated with Pacific Ocean conditions. The correlation of three-month data between average-rainfall, ONI and SST in the Nino 3.4 region varies. The highest correlation was found during last half of the year, June-December, with average R^2 is 42% (rainfall and ONI) and 43% (rainfall and SST) in average. This makes the study area has a higher potential to face a severe drought in dry season during El Nino. Meanwhile La Nina lead to a wetter condition in the beginning of wet season.

Table 1. Correlation of rainfall in Komodo Meteorology Station with the sea surface temperature (SST) of the Nino 3.4 region and the Oceanic Niño Index (ONI) 2010-2020.

Correlation (R^2)	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
Rainfall and SST in Nino 3.4	0.10	0.09	0.08	0.00	0.00	0.37	0.43	0.30	0.37	0.59	0.66	0.31
Rainfall and ONI	0.10	0.08	0.10	0.00	0.00	0.36	0.36	0.30	0.38	0.58	0.67	0.30

3.2. Changes in Land Cover of the Study Area

The result displayed in Figure 4 shows changes in land covers in the Komodo National Park area at the end of wet season in 2018, 2019 and 2020. During this period, vegetated area showed a decreasing trend while non-vegetated area increased. At the end of the wet season, early April, 2018, Komodo National Park had a vegetated area covering of 84% of total area. The remain 16% was the non-vegetated land scattered around the coastal area, in the form of open and build lands. The closer to inland, the land cover of savannah and secondary dryland forest increasingly dominated. The percentage of non-vegetated area increased from 16% of the total area in 2018 to 20% and 24% in 2019 and 2020 respectively. In contrast, the secondary dry land decreased from 39% in 2018 to 35%

(2019) and 32% (2020). Meanwhile the savannah areas remained the same at 45% of total area in 2018 and 2019, which then reduced slightly to 43% in 2020.

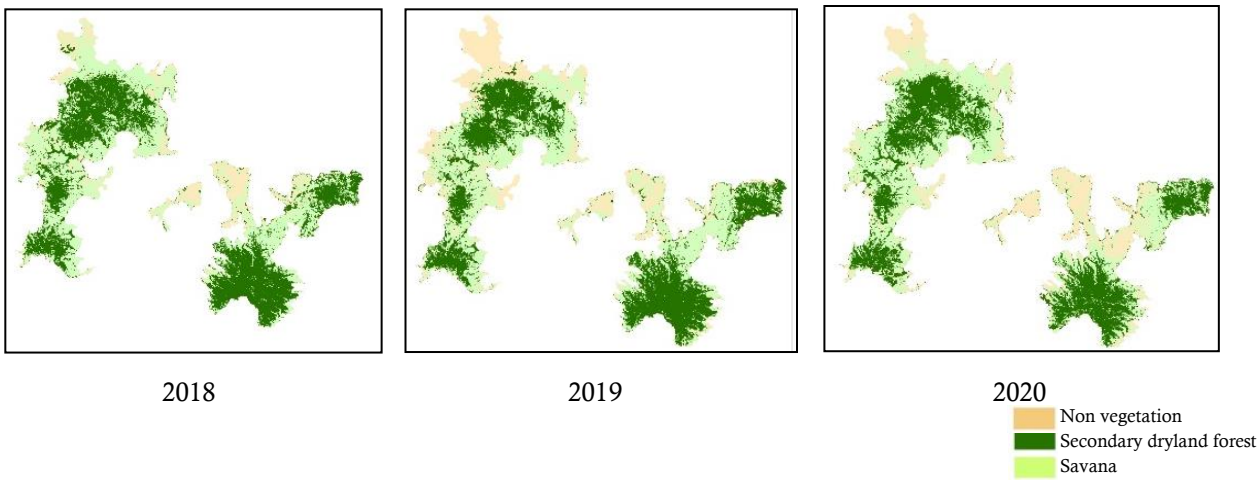

Figure 4. Map of land cover in Komodo National Park (Rinca Island, Padar Island and Komodo Island) in March/April 2018, 2019, and 2020.

Variations in land cover is associated with the climatic factors. Figure 5 shows that land cover changes (in March/April) were followed by a downward trend in total rainfall during the previous months, wet season specifically during November-February. Compared to 2018, total rainfall of November-February in Komodo National Park in 2019 and 2020 went down by 134 mm and 295 mm respectively. Lower rainfall slows the growth of grass that have been burnt in dry season. This resulted a decrease in the vegetation area by 2,240 Ha in 2018-2019 and 2,517 Ha in 2019-2020 with assumption that the impact of human activities is not taking into account. The decrease in rainfall was also followed by the dynamics of conditions in the Pacific Ocean. Negative value of ONI, which indicates La Nina event, was detected during wet season of November 2017-February 2018. Meanwhile, in the next two-year, there was an increase in SST in the Pacific region and caused El Nino.

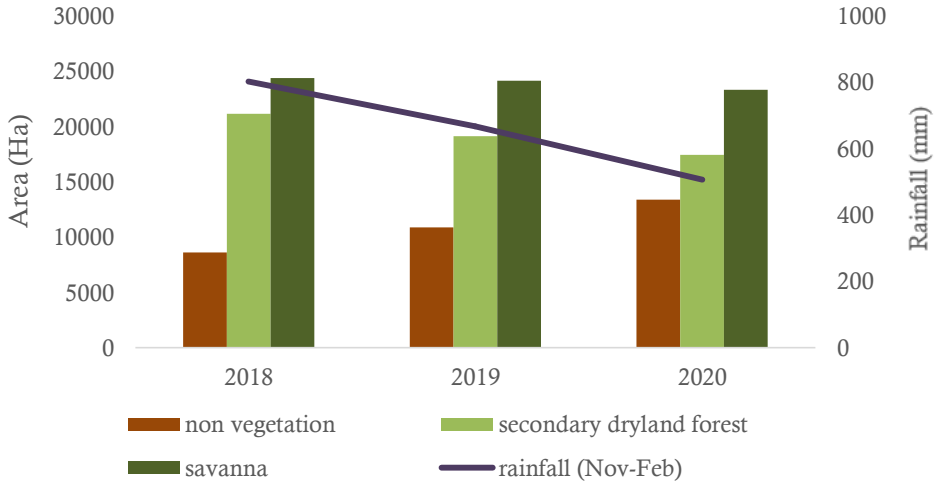

Figure 5. Total area in the period of March-April and total rainfall (mm) of November-February period in Komodo National Park (Rinca Island, Padar Island and Komodo Island) 2018-2020

Tropical savannah experiences fire more frequent than in subtropics [24]. This is shown by the dynamical change of land cover spatially as seen in Table 2 and 3. This study found that in one-year period, 17-32% of total area in each land cover type has been changed spatially. The savannah and the non-vegetated land are the most dynamic land cover type to change. The largest change is shown especially in region near the coast. During one-year period, there were around 16% (2018-2019) and 29% (2019-2020) of non-vegetated land has converted to be savannah. Meanwhile 24% and 19% of savannah has changed to be non-vegetated area. At the same time 6% and 8% of savannah area turned into forest. On the other hand, forest is the type of land cover that is hardly shifting to be non-vegetated area. It was only 1-3% of forest has been converted to be bare land, and vice versa. The change of forest area mostly became savannah, 14% and 18% of forest land was replaced by savannah in 2018-2019 and 2019-2020 respectively.

Table 2. Matrix of percentage in land cover change Komodo National Park (Rinca Island, Padar Island and Komodo Island) for the period 2018-2019.

Land cover change (%)			
2018	**2019**		
	Non-vegetated	**Savannah**	**Forest**
Non-vegetated	83	16	1
Savannah	24	70	6
Forest	3	14	83

Table 3. Matrix of percentage in land cover change Komodo National Park (Rinca Island, Padar Island and Komodo Island) for the period 2019-2020.

Land cover change (%)			
2019	**2020**		
	Non-vegetated	**Savannah**	**Forest**
Non-vegetated	68	29	3
Savannah	19	73	8
Forest	1	18	81

Climate variability in Komodo National Park has an essential role to the ecosystem conditions. The high dynamics of the distribution of the savannah ecosystem is caused by the high vulnerability to environmental changes including the climatic factors such as ENSO and rainfall [25]. Drier condition makes the savannah vulnerable to fire. The sensitivity level varies according to species that determines the adaptation capability [26]. The distribution of vegetation also affects the microclimate conditions which are closely related to the ability to adapt and survive by hundreds of flora and fauna species in the study area. The coverage of vegetation canopy is correlated to surface temperature [27]. Vegetation cover also has other important functions, including as the habitats and providing foods for the animals. In addition, climate change that affects the climate characteristic also become a thread to Komodo National Park. It is predicted that the Komodo dragon habitat would be decreased in 2050 [28]. Furthermore, beside climate factors, other driver factors such as human activities and vegetation composition might also has impacts on the ecosystem quality [29-30].

4. Conclusion

The climate in West Manggarai is categorised as Aw type based on Koppen climate classification. The rainfall in West Manggarai Regency is correlated to ONI particularly from June to December. La Nina was occurred during wet season in 2017/2018, while El Nino is detected in 2019 and the beginning of 2020. The increase in bare land between 2018 and 2020 in three islands of Komodo National Park was followed by a decrease in rainfall. In addition to the influence of climate, a further analysis of the global warming impacts also needs to be carried out. Conditions with higher temperatures would have implications to the ecosystem and the local climate.

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