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The influences of sea surface temperatures on the rainfall onset in the west-south region of Aceh

Anggun Arwulan Dani, Yopi Ilhamsyah*, Syahrul Purnawan

Department Marine Sciences, Faculty of Fisheries and Marine Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia 23111

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ABSTRACT

Rainfall variability is influenced by several annual global and regional phenomena including the influence of monsoons, *El Nino Southern Oscillation* (ENSO), *Indian Ocean Dipole* (IOD), La Nina, and local climates. Sea surface temperature is one of the elements that affect weather patterns in Indonesia. This is because sea surface temperature plays an important role in the evaporation process, thus affecting cloud formation and subsequently affecting rainfall. The purpose of this study was to obtain information about the effect of sea surface temperatures on the onset in the Southwest Aceh region. The method used in this study is the correlation method between sea surface temperature anomalies (SST) and rainfall. The results of this study show that rainfall in the West-South region of Aceh varies greatly and has an equatorial pattern. The equatorial pattern is characterized by a rainfall type with a bimodal shape or there are two rain peaks during the year, namely around March and October. A positive anomaly in the West-South region of Aceh indicated that the rainfall at that time was higher than normal. Meanwhile, negative anomalies indicate that rainfall in the region is lower than normal conditions. The beginning of the average rainy season that occurs in the Southwest Aceh region starts on the 25th which occurs in September and ends until February. The beginning average rainy season that occurs in the West-South region of Aceh, starts on the 25th basis which occurs in September, and ends until February. The highest onset occurred in the Southwest Aceh area, which was 0,2059, and the beginning of the lowest rainy season or regression occurred in the West Aceh area, which was 0,0122.

Introduction

Indonesia is a country in Southeast Asia that is crossed by the equator and is located between the continents of Asia and Australia, as well as between the Pacific and Indian Ocean. Indonesia is the largest archipelagic country in the world and is one of the tropical countries that have two seasons, i.e., rainy and dry seasons.

As surrounded by the oceans, it then affects the variability of rainfall in Indonesia. Rainfall variability in Indonesia is influenced by various phenomena such as: monsoon, El Niño, La Niña, Indian Ocean Dipole (IOD), and local climate influences (Qian, 2008; Qian *et al.*, 2013; Supari *et al.*, 2018). In general, the rainy season in Indonesia occurs from October to March, while the dry season occurs from April to September even though it may differ over certain regions.

Surrounded by vast oceans, the climate in the tropics is affected by changes in sea surface temperature (SST). Ocean temperature is one of the factors that affect climate variability in Indonesia (Affandi *et al.*, 2012; Aldrian & Susanto, 2003). This is because SST plays an important role in the evaporation process so it affects cloud formation and further drop the rainfall (Habibie & Nuraini, 2014; Irkhos & Sutarno, 2008). Many sectors are influenced by SST, e.g., the productivity of waters and in the field of fisheries (As-syakur & Prasetia, 2010; Juneng & Tangang, 2005; Sukresno, 2008).

Global warming increases the occurrence of global droughts, heat waves, and the frequency of tropical storms. Rising global temperatures will lead

* Corresponding author.
Email address: yopi.ilhamsyah@usk.ac.id

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to the melting of north and south polar ices, resulting in the expansion of seawater masses, and sea level rise. Global warming will also cause seasonal shifts as a result of changes in rainfall patterns (Khodijah, 2015; Yana *et al.*, 2014).

The determination of seasons in Indonesia by the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) is carried out by analyzing rainfall data at ground station for *dekad* period (i.e., ten-day cumulative rainfall). The rainfall based on BMKG is classified into three categories, i.e., normal, below normal, and above normal.

Based on the provisions made by the BMKG the rainfall onset is characterized by a *dekad* rainfall of more than 50 mm and followed by a minimum of two subsequent *dekad*. Meanwhile, the beginning of the dry season is characterized by a *dekad* rainfall of less than 50 mm and followed by a minimum of two consecutive *dekad*. The onset and dry condition are not always the same. Consequently, the seasons could shift that may lead to longer dry season or the retreat of the rainy season.

One of the factors that cause seasonal shifts in Indonesia is the IOD. The latter event has a strong effect on rainfall fluctuations during the dry season (As-syakur, 2012). The IOD could cause a decrease or increase in SST accompanied by a decrease or increase in rainfall over Indonesian archipelago.

Aceh Province consists of 23 districts that have different climate characteristics among regions. One of the differences between those regions is the difference on the onset of each region. The West-South region of Aceh is an area directly facing the Indian Ocean so that it has high rainfall due to evaporation from the sea. Geographically, the location of West-South Aceh is located starting from, Aceh Jaya, Aceh Barat, Nagan Raya, Aceh Barat Daya, and Aceh Singkil.

Research on the relationship of SST to the onset has been widely investigated. However, in the West-South region of Aceh, there is still no more detailed study. Therefore, this study aims to determine the effect of SST on the onset in the West-South region of Aceh. The purpose of this study is to investigate the effect of SST on the onset in the West-South region of Aceh

Materials and Methods

The research location is the West-South region of Aceh in five different districts. They are Aceh Jaya (04°22'-05°16' N and 95°10'-96°03' E), Aceh Barat (2°00'-5°16' N and 95°10' E), Aceh Barat Daya (96°34'57"–97° 09 '19" E and 3°34'24"-4° 05'37" N), Nagan Raya (4.17°N 96.5°E), and Aceh Singkil (2°0'20"–2°36'40" N and 97°04'54"–98°11'47" E). The map of the study site is shown in Figure 1.

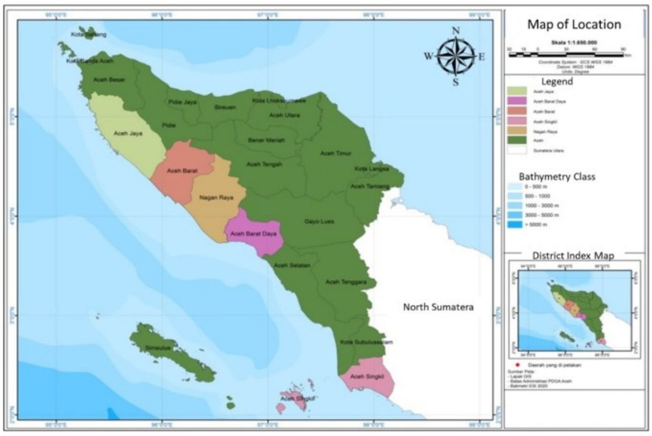

Figure 1. Research Map.

Rainfall data is originated from CMORPH which cover a spatial resolution of 0.25° latitude x 0.25° longitude. It is a monthly rainfall data from 1998-2021. The data is summed up for ten days to calculate *dekad*. Thus, there are three *dekad* every month, i.e., DI, DII, and DIII. DI is from the 1st to the 10th day, DII is from the 11th to the 20th day, DIII is from the 21st to the end of the month. The rainfall onset is calculated from the average onset of the rainy season each year in every district. If the rain is above 50 mm and occurs consecutively for two *dekad* then it is said that the rainy season has arrived. The length of the rainy season is calculated from the average length of the rainy season each year in every district. SST is originated from 1998-2021. It is a monthly average data with 0,25° spatial resolution.

Rainfall data in every district is divided into three *dekad* (i.e., DI, DII, and DIII). One *dekad* is for 10 days. If the rain height exceeds 50 mm and occurs consecutively for two *dekad*, it is concluded that the rainy season has arrived. The end of the rainy season is indicated when the rain height in the final months of the rainy season is less than 50 mm which occurs consecutively for two *dekad*. And to investigate the relationship between SST and the onset in the West-South region of Aceh, a correlation analysis was carried out between the rainfall and the SST anomaly.

Data Analysis

The following formula is used to find the correlation between two variables:

$$r_{xy} = \frac{n\,\Sigma xiyi - (\Sigma xi)(\Sigma yi)}{\sqrt{\{\Sigma xi^2 - (\Sigma xi)^2\}}\sqrt{n\{\Sigma yi^2 - (\Sigma yi)^2\}}}$$

Information:
r = correlation
n = amount of data
x = SST anomaly
y = rainfall

Results

The Correlation between Rainfall and SST in Aceh Jaya

The rainfall pattern in the West-South region of Aceh is an equatorial-type climate which is characterized by a bimodal shape or two peaks of rainfall. Figure 2 is the average monthly rainfall in Aceh Jaya district from 1998 to 2021. In Aceh Jaya, two peaks of rainfall are found on April and October. The highest rainfall occurred on April with 278 mm, while the lowest occurred on February with 139 mm of rainfall.

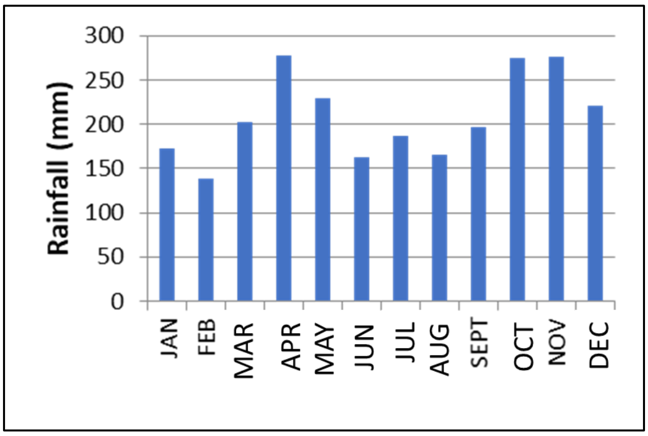

Figure 2. Average rainfall in Aceh Jaya.

The results of the correlation between rainfall and SST in Aceh Jaya are shown in Figures 3 and Figures 4.

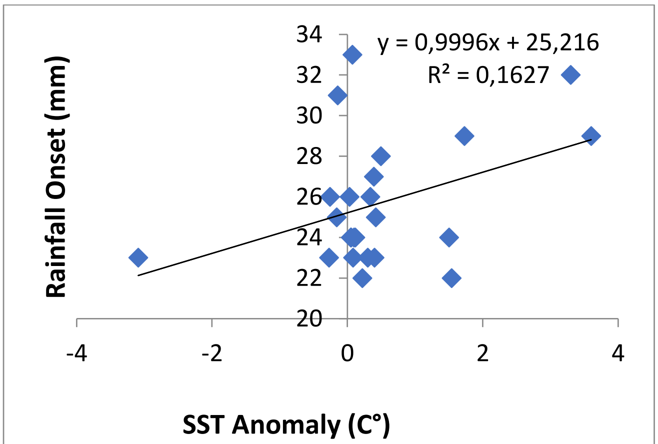

Figure 3. Correlation between the onset and the SST anomaly in the Aceh Jaya district.

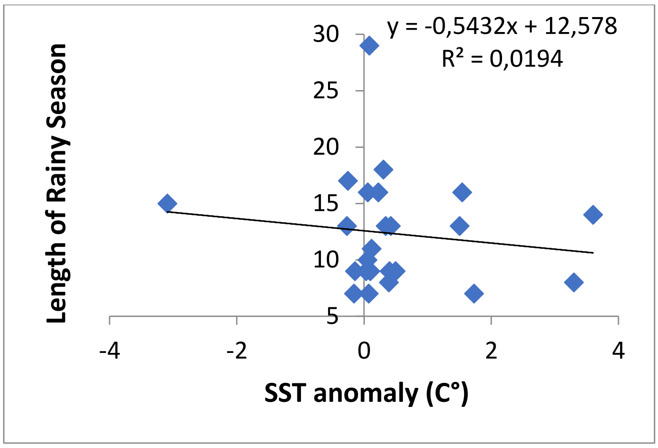

Figure 4. Correlation between the length of the rainy season and the SST anomaly of Aceh Jaya.

Figure 3 and Figure 4 shows the correlation between the rainfall and SST anomaly in Aceh Jaya. The average onset in Aceh Jaya district fell in the 25th *dekad* of September (Appendix 1). The onset of the rainy season in Aceh Jaya is 1 *dekad* advance and the average length of the rainy season last for 12 dekad starting from September to December.

The Correlation between Rainfall and SST in Aceh Barat

Figure 5 shows the average monthly rainfall in the Aceh Barat for 23 years from 1998 to 2021. Aceh Barat district has two peaks of rainfall that occurred on April and November. The highest is 406 mm which occurs on November, while the lowest on July with 140 mm in height.

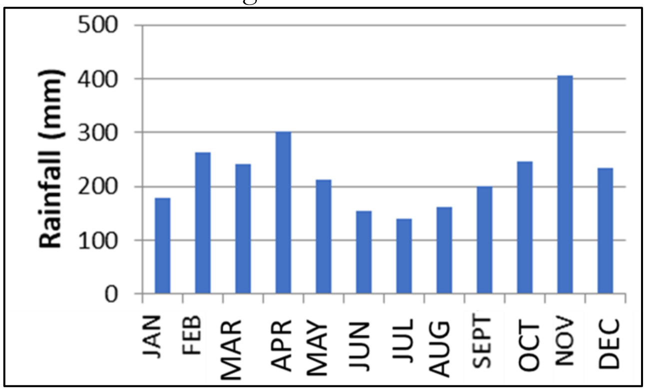

Figure 5. Average monthly rainfall in Aceh Barat.

The correlation between rainfall and SST in Aceh Barat for 23 years, i.e., 1998-2021 are shown in Figures 6 and Figures 7.

Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
Volume 13, Number 1, Page 1-12

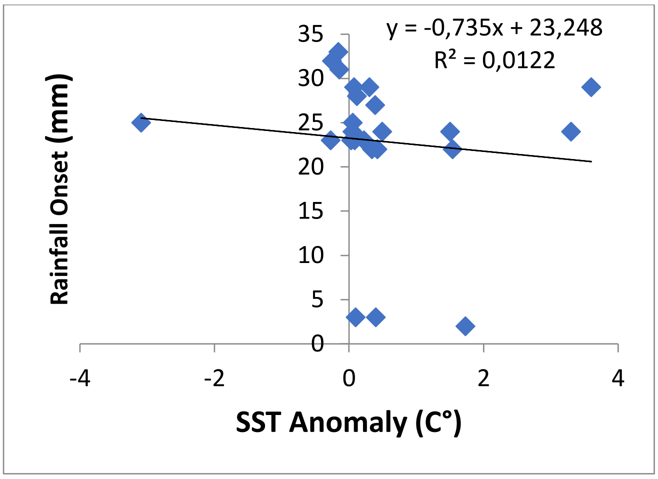

Figure 6. Correlations between the onset and the Aceh Barat SST anomaly.

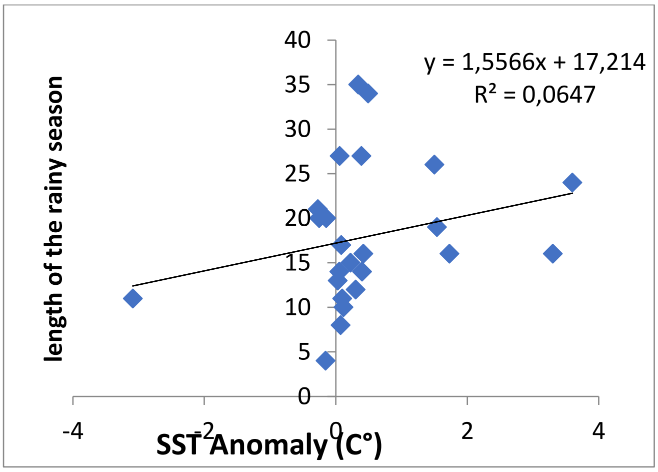

Figure 7. Correlation between the length of the rainy season and the SST anomaly of Aceh Barat.

The average onset in Aceh Barat district fell in the 25th *dekad* which occurred at the beginning of September (Appendix 2). Figure 7 shows that in this district the onset of the rainy season is about 1 *dekad* advance and the average length of the rainy season is about 17 *dekad* lasting from September to February.

The correlation between rainfall and SST in Aceh Barat Daya

Figure 8 shows the average monthly rainfall in Aceh Barat Daya from 1998-2021. Aceh Barat Daya has two main peaks of rainfall. The first on April while the second on October. The highest monthly rainfall average is 285 mm which occurs on November while the lowest occurs in December which is 136 mm in height.

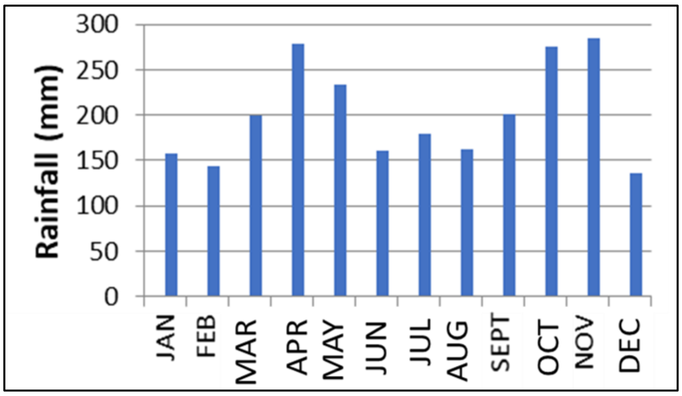

Figure 8. Monthly average rainfall in Aceh Barat Daya.

The correlation between rainfall and SST in the Aceh Barat Daya for 23 years from 1998-2021 are shown in Figures 9 and Figures 10.

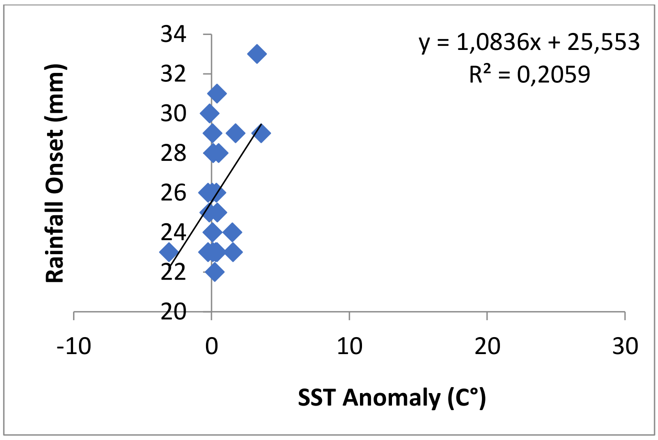

Figure 9. Correlations between the onset and SST anomaly in Aceh Barat Daya.

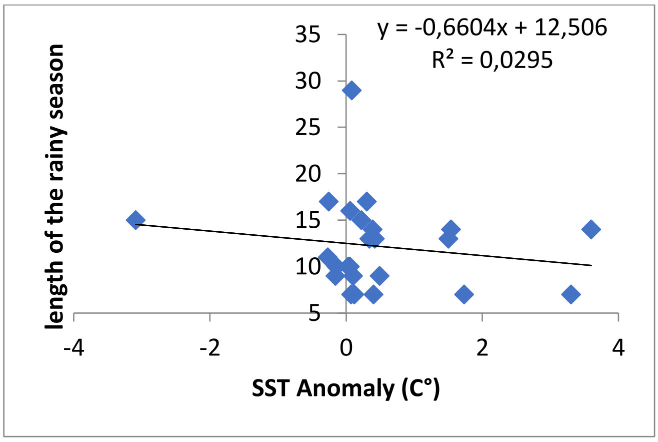

Figure 10. Correlations between the length of the rainy season and SST anomaly in Aceh Barat Daya.

Figure 9 shows that the onset is about 1 dekad advance from the average (normal). The average onset in Aceh Barat Daya district occurred in 26th *dekad* on September (Appendix 3). The average

Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
Volume 13, Number 1, Page 1-12

length of the rainy season lasts for 12 *dekad* that occur from September to January.

The correlation between rainfall and SST in Nagan Raya

Two peaks of rainfall were found from monthly rainfall averages of Nagan Raya district. The first occurs on April while the second on November. The highest rainfall with 262 mm in height occurs on November, while the lowest occurs in June, which is 97 mm.

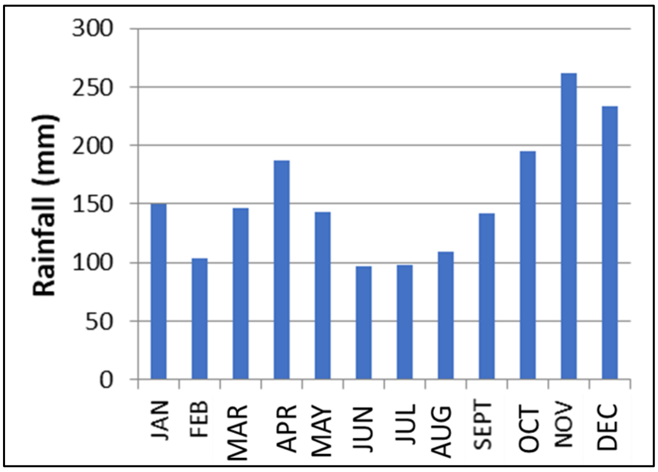

Figure 11. Average monthly rainfall in Nagan Raya.

The correlation between rainfall and SST in Nagan Raya for 23 years from 1998-2021 are shown in Figures 12 and Figures 13.

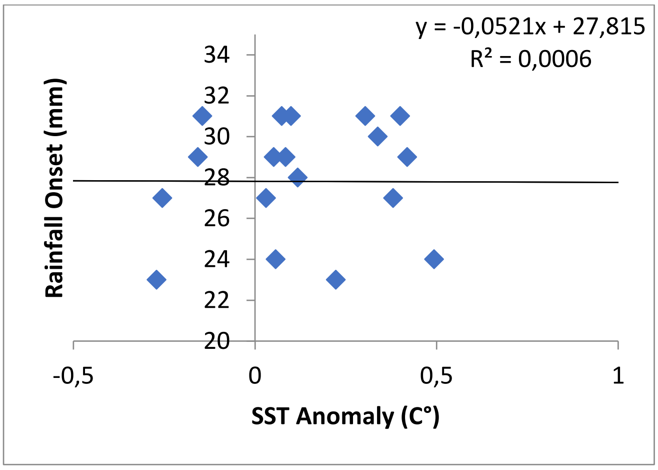

Figure 12. Correlations between the onset and the SST anomaly in Nagan Raya.

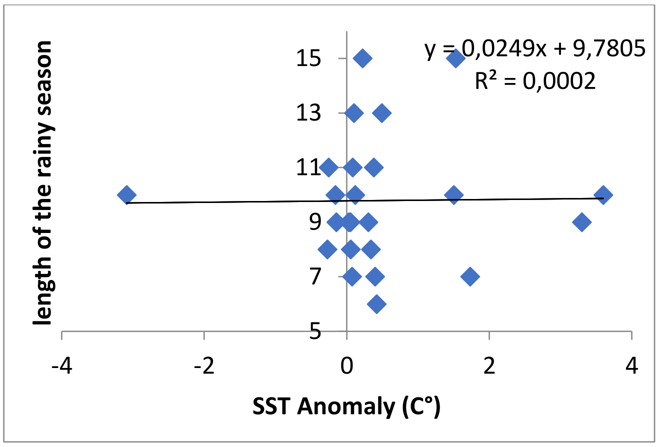

Figure 13. Correlation between the length of the rainy season and the SST anomaly in Nagan Raya.

Figure 12 show that the onset is about 1 *dekad* advance and the average onset fell in the 28th *dekad* that occurs on early October (Appendix 4). In Figure 13, the average length of the rainy season is about 10 *dekad* which occur from October until January.

The correlation between rainfall and SST in Aceh Singkil

Two peaks of rainfall were found based on the calculation of average monthly rainfall in Aceh Singkil district for 23 years. The first occurs on April while the second occurs on November. Figure 14 shows that the highest monthly rainfall in Aceh Singkil is 344 mm which occurs on April, and the lowest occurs on November which is 113 mm.

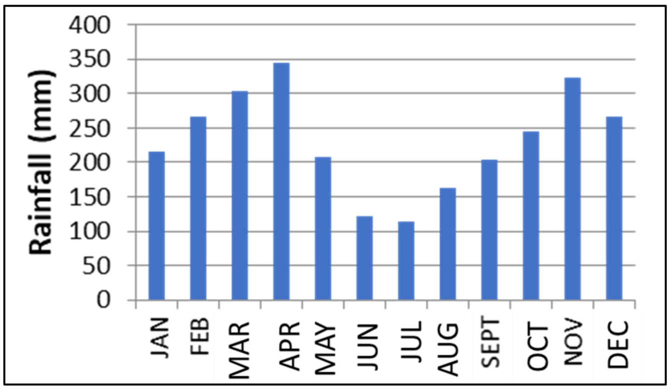

Figure 14. Monthly average rainfall in Aceh Singkil.

The correlation between rainfall and SST in Aceh Singkil district for 23 years 1998-2021 are shown in Figures 15 and Figures 16.

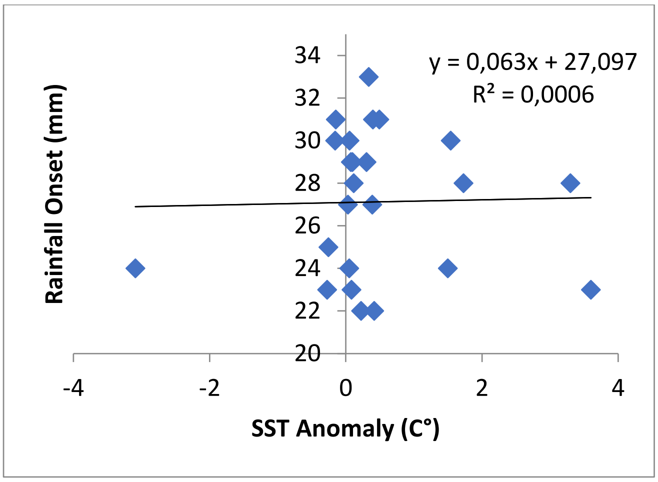

Figure 15. Correlations between the onset and the SST anomaly in Aceh Singkil.

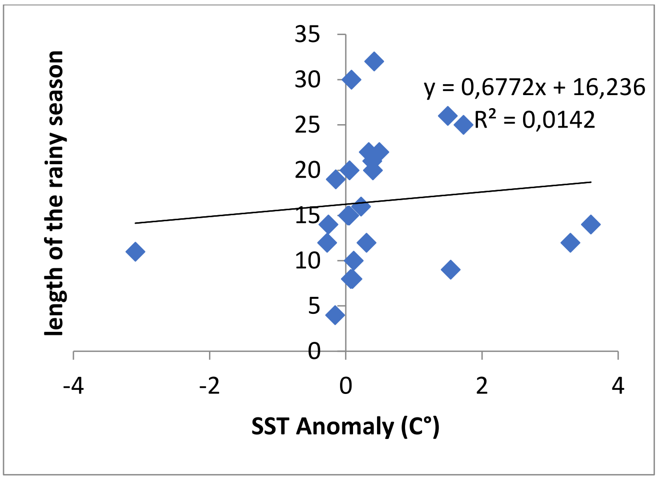

Figure 16. Correlations between the length of the rainy season and the SST anomaly in the Aceh Singkil.

Figure 15 showed that the onset advanced of about 1 *dekad* from the average. The onset fell in the 27th dekad that occurred at the end of September (Appendix 5). Figure 16 shows that the length of the rainy season starts from the end of September to February.

Discussion

Rainfall in the West-South Region of Aceh

Wang *et al.* (2004) stated that in determining the onset there are several different criteria and it is still a controversy among experts. In this case, there are five methods used to determine the onset, i.e., wind data, *outgoing longwave radiation* (OLR) data, a combination of wind and OLR data, daily rainfall data, and a combination of rainfall and wind data. In this case, Moron *et al.* (2009) states that the onset is characterized by the beginning of the monsoon. Daily rainfall is the amount of rainfall recorded in a single day, while *dekad* rainfall is the amount of rainfall for 10 days. It is said that the onset is when the rain height is more than 50 mm and occurs successively on as many as two *dekad*. Meanwhile, it is said that the end of the rainy season when the rain height is less than 50 mm it occurs successively for two *dekad*.

The West-South part of Aceh is generally a plateau with mountains. This condition causes the air to become rapidly saturated due to the urgency of rising on the slopes of the mountains. Saturated air will condense and form rain clouds resulting in rain falling around the mountains. Rainfall in the West-South region of Aceh is higher than in the eastern region of Aceh because this region is located in the windward.

Hermawan (2010) stated that Indonesia in general can be divided into 3 main climate patterns, i.e., monsoonal, equatorial, and local patterns, by looking at these rainfall patterns for a year. Rainfall patterns in each region vary greatly due to several factors such as geographical location, topography, and others. Vitri and Marzuki (2014) revealed that rainfall variability are caused by several factors, both local and global. Setiawan (2012) stated that the potential impacts of climate change are changes in rainfall patterns, increases in air temperature, and sea surface temperature rise.

Based on *dekad* average rainfall data from 1998-2021 in the West-South region of Aceh, the rainfall pattern in this region is equatorial. Rainfall patterns in this region with the lowest rainfall occurred from March to July. Rainfall can be interpreted as the level of rainwater collected in a flat, non-pervasive, and non-flowing place. This is reinforced by Tjasyono *et al.* (2008) stating that rainfall is 1 mm that is if the area is 1 square m in a flat place accommodated by water as high as 1 mm assuming it does not evaporate, does not permeate, and does not flow.

Sea Surface Temperature (SST) in the West-South region of Aceh

SST in the tropics usually follows seasonal patterns as it is heavily influenced by meteorological factors such as rainfall, evaporation, air humidity, air temperature, and wind speed. Gustari (2009) states that in the Indian Ocean generally a lower-than-usual SST is found on the west coast of Sumatra. The spread of SST in the Western season in January shows warm SST looks dominant on the West and South sides. The existence of high cloud closures in the West season is related to the blowing of Western monsoon winds that carry a lot of water vapor which causes the clouds to become thick and covering the atmosphere.

Boer and Faqih (2004) stated that there are five factors that affect climate variability in Indonesia, i.e., the meridional cycle, zonal cycle, monsoon wind activity, local influences, and tropical cyclones. The phenomenon of climate anomalies that occurs is an implication of the dominance of one of several factors among the five factors.

According to As-syakur (2012) IOD activities affect rainfall fluctuations during the dry season. Climate anomalous phenomena in the tropics that are common and most dominant include ENSO and IOD. In this case, Hendon (2003) stated that La Nina causes quite high rainfall even during the dry season. In accordance with the statement of Ashok *et al.* (2004) that there is a clear influence on rainfall in Indonesia will be significant if there is an El Nino and positive IOD and negative IOD simultaneously.

Boer and Subbiah (2005) state that the onset which usually occurs around mid-September can retreat to 4-6 days during an El Niño year or advance to mid-August in a La Nina year. This incident is known as a wet drought. Reinforced by Aldrian *et al.* (2004) that the start date is defined as the first wet day of the first 5-day sequence to receive 40 mm which is not followed by a sequence of 10 dry days receiving less than 5 mm in the next 30 days from the start date. Onset is calculated from August 1 because August to September is the driest month in Indonesia.

Martono and Wardoyo (2017) stated that the ENSO phenomenon greatly affects rainfall conditions, especially in the Indonesian region which is located in the southern part of the equator. SST is also concerned with the phenomenon of upwelling and *downwelling*. When the upwelling phenomenon occurs, the mass of seawater on the surface will be replaced by a colder mass of seawater in the deeper water column. Reinforced by Kaufman (2010) that the identification of *upwelling* areas can be known with a colder SST compared to the surroundings.

The relationship of SST anomalies to the onset in the West-South region of Aceh

Rainfall affects thermocline fluctuations. The condition of the atmospheric environment that occurs at a time when rainfall increases is that the level of cloud cover is high. This causes the sun's thermal energy to be blocked from entering the sea so that the thermocline becomes shallow or its thickness decreases. Meanwhile, when rainfall decreases, the level of cloud cover also decreases so that the solar thermal energy that enters the water column increases. Kunarso *et al.* (2012) states that this can make a lot of sun enter the seawater column so that the thermocline layer drops and its thickness increases. Solar activity affects the rainfall conditions of an area. In accordance with the statement from Sinambela *et al.* (2008) that the position of the sun around the equator causes a high sea surface temperature so that the area around the equator gets the intake of wet air masses.

Naylor *et al.* (2007) state that rainfall in Indonesia is regulated by austral-Asian monsoons whose beginnings take place from the sea to the Southeast during the austral spring. SST affects high and low rainfall. It is reinforced by Hamada *et al.* (2002) that this is the season when ENSO exerts the strongest influence on rainfall in Indonesia. A high SST will cause high evaporation to occur, resulting in a high chance of the formation of convective clouds that cause rain. In accordance with the statement of Aldrian (2008) that an increase in SST can result in an increase in the availability of water vapor which encourages high rainfall.

The results of the correlation analysis between rainfall in the West-South region of Aceh and the SST anomaly each year show that the coefficient values vary greatly and have an equatorial pattern. The equatorial pattern is characterized by a type of rainfall with a bimodal shape or there are two peaks of rain during the year, i.e., around March and October. Based on the correlation data between rainfall data and SST anomalies, it can be seen that there is a relationship between rainfall and SST.

Based on the correlation results that have been made, there are several districts that show positive correlation results and negative correlation results. A positive correlation suggests that the increase in SST in the zone is related to increased rainfall in the region. Meanwhile, negative correlation results show that the increase in SST in the zone is related to decreased rainfall in the region. In accordance with Rahayu *et al.* (2018) that a decrease in sea surface temperature when IOD is positive will have an effect on reducing rainfall intensity.

Rainfall anomalies are used to analyze excess or lack of rainfall that occurs at one time. Every 1 °C increase or decrease in SST anomaly than the onset will advance or retreat from the average. In the West-South region of Aceh, the onset in each region varies. Some areas have progress or setbacks at the beginning of the rainy season. To see the closeness of the relationship between SST and the beginning of the rainy season, namely by correlating the two data. According to Hasan (2003) correlation analysis is a method used to determine whether there is a relationship between variables. If there is a change between variables, the change that occurs in one of the variables can be in the form of a positive correlation, negative correlation, no correlation, or perfect correlation. The highest correlation of the onset occurred in Aceh Barat Daya district (Figure 9), i.e., 0.2059 that occurred in the 26th *dekad*, and the length of the rainy season last for 12th *dekad*. Meanwhile, the lowest correlation occurred in Aceh Barat district (Figure 6) which was 0.0122 that occurred in the 25^{th} *dekad* in average, and the length of the rainy season last 17^{th} *dekad*. This is due to the variability of the climate in the West-South region of Aceh.

Conclusion

Rainfall in the West-South region of Aceh varies widely and has an equatorial pattern. The equatorial pattern is characterized by a type of rainfall with a bimodal shape or there are two peaks of rain during the year, namely around March and October. The average onset that occurs in the region begins on the 25th day which occurs in September and ends until February. The West-South region of Aceh has high rainfall because the area is facing directly toward the Indian Ocean. Positive anomalies in the West-South region of Aceh indicate that rainfall at that time was higher than normal. Meanwhile, negative anomalies indicate that rainfall is lower than in normal conditions. At the beginning of the rainy season the highest occurred in the Southwest Aceh area, namely 0.2059, and the beginning of the lowest rainy season, which occurred in the West Aceh area, was 0.0122. It is hoped that future research can be studied more fully on other factors that affect rainfall such as Indian Ocean Dipole (IOD), Madden Julian Oscillation (MJO), and others so that it can be used as information and literature for future research.

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Appendix 1. *Decade* rainfall of Aceh Jaya

	AGUSTUS			SEPT			OKT			NOV			DES			JAN			FEB			MARET			APRIL			MEI			JUN			JUL		
	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII
DASARIAN	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14	15	17	18	19	20	21
1998	60	122	96	75	65	85	52	44	88	100	190	27	69	130	140	52	19	6	8	12	3	0	7	20	40	18	23	129	107	146	28	108	32	18	58	63
1999	31	63	182	90	53	113	113	116	101	21	72	130	49	44	14	23	110	86	32	128	13	45	101	58	118	129	12	60	98	90	13	17	54	115	47	88
2000	34	48	50	49	97	122	61	84	63	32	67	103	3	88	38	64	53	11	102	30	84	24	42	101	149	64	231	52	15	102	101	39	83	123	17	52
2001	20	12	33	80	73	50	93	35	273	51	30	49	23	20	33	33	35	95	13	89	1	103	16	115	109	92	140	66	14	67	27	9	109	42	31	148
2002	76	2	58	62	31	86	79	98	70	113	166	40	66	57	60	1	30	114	3	19	51	23	54	122	38	71	143	231	6	6	63	18	20	50	40	53
2003	24	121	30	37	55	77	124	68	77	136	136	115	134	24	3	5	84	42	80	35	1	35	74	107	99	75	81	196	30	9	20	43	65	47	28	25
2004	2	13	142	88	54	211	43	97	116	101	57	41	59	61	14	50	40	104	31	25	49	102	145	72	129	21	122	117	7	82	117	4	64	70	27	49
2005	11	33	63	75	47	23	185	62	120	49	80	73	100	41	23	68	9	12	77	15	20	16	31	101	51	48	73	115	67	20	23	88	2	33	86	15
2006	10	21	59	90	58	93	32	75	110	74	138	99	27	43	44	87	27	4	43	72	23	15	64	144	10	113	144	35	37	26	27	117	56	59	69	25
2007	5	47	28	31	46	22	39	109	66	174	32	3	98	128	5	11	34	164	1	28	53	17	97	24	120	136	86	142	16	49	66	104	28	19	56	34
2008	8	12	107	41	7	101	46	116	18	39	66	113	143	65	108	50	21	114	23	32	11	117	151	107	105	123	150	44	46	55	158	12	21	34	76	2
2009	25	54	29	43	102	77	23	134	43	44	33	55	111	96	68	143	65	108	39	12	17	15	2	58	123	44	25	112	15	10	71	135	40	12	5	81
2010	18	108	60	21	87	12	85	39	113	110	60	21	117	103	83	111	74	89	124	13	34	40	47	43	25	54	89	102	19	92	68	105	36	161	34	70
2011	19	63	61	60	54	83	95	60	180	59	115	54	53	78	123	67	1	68	12	78	87	85	14	141	32	74	85	85	31	63	11	17	56	39	65	38
2012	3	82	40	21	27	87	10	215	83	180	103	69	72	123	88	36	146	18	83	99	138	29	17	131	82	124	100	26	34	189	108	2	8	78	24	78
2013	70	40	59	118	5	8	99	64	29	116	109	126	211	40	106	28	46	97	113	114	33	20	34	149	145	192	53	251	52	8	101	115	13	68	40	24
2014	77	96	79	44	121	114	126	105	108	175	100	166	118	174	154	73	3	8	3	123	8	3	107	49	50	126	110	134	107	92	63	74	12	119	18	40
2015	86	30	34	82	75	98	44	81	206	67	120	133	104	77	34	80	22	33	115	14	46	54	6	123	135	190	104	17	67	32	102	109	3	78	134	28
2016	41	55	216	86	61	27	62	227	59	116	159	120	88	70	60	8	64	121	46	32	23	60	57	127	44	97	81	84	216	152	24	129	51	45	101	32
2017	85	56	33	114	45	25	64	16	72	116	174	129	167	27	94	195	146	77	3	23	127	91	19	66	75	36	58	74	133	50	42	8	29	54	22	57
2018	28	58	85	46	49	72	132	149	89	107	72	101	89	84	8	54	37	28	26	21	226	107	36	79	98	151	140	64	124	68	3	76	41	76	32	135
2019	35	42	75	34	9	139	152	159	177	49	93	83	81	38	22	167	49	33	18	34	58	12	46	46	21	152	97	32	27	26	65	34	97	9	239	6
2020	27	17	96	75	38	48	75	66	116	73	81	58	83	83	76	28	4	15	4	127	8	73	39	107	45	127	187	175	57	97	16	49	85	36	54	138
2021	148	98	36	43	64	121	18	51	98	159	118	111	31	98	13	60	65	33	38	12	6	63	112	333	90	48	102	80	113	140	31	54	77	350	98	75

Appendix 2. *Decade* rainfall of West Aceh

	AGUSTUS			SEPT			OKT			NOV			DES			JAN			FEB			MARET			APRIL			MEI			JUN			JUL		
	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII
DASARIAN	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1998	73	204	107	95	69	57	143	43	100	85	138	34	71	89	139	41	50	22	154	45	22	50	99	107	70	47	106	87	102	68	88	77	31	27	109	96
1999	31	76	101	86	59	139	132	114	71	19	75	105	117	74	59	42	117	53	81	38	57	81	41	41	109	58	31	73	155	27	17	60	81	73	49	59
2000	63	49	13	80	100	99	76	63	17	31	174	127	2	117	75	93	113	31	68	69	86	58	72	120	112	126	170	77	66	119	34	50	34	34	13	78
2001	12	19	43	77	76	49	40	46	115	40	46	115	85	59	65	31	45	63	45	61	32	118	14	31	126	73	120	33	6	27	58	23	49	14	62	122
2002	37	4	81	66	62	109	113	130	122	130	164	50	62	131	92	19	84	119	19	86	108	50	59	129	74	104	204	130	24	21	59	22	37	32	20	48
2003	32	71	69	69	42	69	97	30	89	103	116	98	129	65	21	46	64	43	67	143	24	15	159	109	84	96	118	106	25	5	66	54	69	37	42	30
2004	7	28	42	57	158	83	25	93	77	91	66	91	62	88	49	74	102	74	71	78	60	116	119	101	143	65	167	92	15	80	31	6	51	44	56	28
2005	9	29	75	44	24	45	105	101	76	55	114	91	93	54	22	98	47	25	54	30	48	77	78	102	67	47	101	71	17	23	26	35	23	33	28	16
2006	14	28	109	136	46	78	46	115	138	112	100	125	93	86	139	51	45	6	46	103	55	41	87	79	38	100	25	33	41	22	35	40	29	28	25	19
2007	6	56	50	68	24	44	49	115	51	129	60	12	113	109	34	12	60	71	21	85	86	21	129	24	135	121	93	96	50	100	103	62	40	10	45	79
2008	21	44	95	62	21	95	79	95	19	76	75	133	76	46	61	27	30	118	24	27	31	82	122	96	111	101	13	9	13	9	75	38	82	39	93	28
2009	17	57	84	17	58	30	30	69	74	149	89	51	63	50	53	27	25	79	9	3	92	`123	99	66	143	31	24	40	58	52	12	25	60	54	34	28
2010	10	66	20	47	56	125	112	13	40	79	93	94	55	38	45	98	33	82	74	91	105	68	87	133	114	99	158	93	116	28	88	43	37	29	37	37
2011	31	110	68	56	68	35	56	55	103	119	70	69	59	102	59	75	16	116	36	32	69	77	70	140	31	106	112	16	50	58	13	6	62	11	46	16
2012	32	102	43	63	33	29	29	138	122	167	75	117	70	119	102	48	80	15	108	1616	99	59	20	63	89	121	93	60	34	54	51	2	13	35	38	42
2013	43	49	40	88	8	15	24	59	27	90	104	71	111	29	87	32	28	90	112	164	74	14	51	147	146	80	129	251	36	34	55	31	22	8	29	8
2014	49	101	61	45	62	74	61	139	112	131	150	97	78	136	106	98	13	8	2	35	31	34	76	77	109	104	117	150	95	83	35	29	10	83	11	20
2015	73	55	50	95	125	98	61	125	106	103	116	146	86	84	57	91	25	34	111	66	43	79	32	107	93	194	127	102	91	63	97	80	5	41	64	70
2016	21	33	118	58	23	10	29	82	64	86	94	129	61	47	66	75	78	104	107	23	30	76	55	207	99	61	107	131	99	43	26	113	16	13	89	14
2017	44	72	51	124	81	31	68	21	44	138	93	113	129	36	111	113	66	115	21	166	104	109	23	54	100	100	129	83	71	26	16	39	39	68	30	25
2018	20	12	45	89	53	153	183	113	118	135	76	95	93	63	41	42	20	25	45	39	193	146	84	79	107	151	83	85	208	92	5	26	88	59	35	54
2019	8	87	49	44	26	123	140	230	151	66	184	116	117	142	60	106	100	83	78	78	83	48	59	147	65	98	69	39	97	105	64	50	30	30	91	18
2020	12	35	108	73	34	59	80	31	54	103	126	2691	74	82	110	29	76	48	72	120	23	59	58	93	141	128	145	104	101	80	34	94	51	57	117	164
2021	58	135	94	41	80	93	12	64	127	160	99	75	44	172	16	85	51	24	53	28	65	110	97	174	130	74	102	141	140	57	54	63	512	151	38	59

Appendix 3. *Decade* rainfall of Southwest Aceh

	AGUSTUS			SEPT			OKT			NOV			DES			JAN			FEB			MARET			APRIL			MEI			JUN			JUL		
	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII
DASARIAN	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1998	59	122	89	76	65	86	52	44	52	99	189	27	69	129	137	43	18	5	8	12	3	1	7	20	40	17	23	129	94	145	27	109	35	19	60	49
1999	37	64	180	80	54	112	113	116	102	21	73	130	49	45	14	24	114	85	32	128	12	46	101	40	118	128	9	59	99	89	13	18	53	115	46	71
2000	38	46	15	49	96	123	150	67	94	32	67	100	2	88	28	67	53	7	102	30	93	23	42	88	150	62	231	52	14	99	101	38	80	125	16	53
2001	19	12	31	80	72	51	92	36	272	51	32	50	23	21	33	33	35	84	13	58	1	103	13	113	109	99	140	66	14	57	27	8	116	42	31	137
2002	76	2	58	60	31	86	62	98	57	113	166	41	79	60	61	1	29	114	3	19	63	23	86	67	38	71	183	234	6	7	63	18	20	32	40	23
2003	25	121	26	37	55	77	126	68	365	116	136	115	134	61	3	23	85	27	79	66	3	35	74	97	99	75	80	200	30	3	21	43	76	47	29	26
2004	2	13	132	88	54	210	43	97	108	113	58	41	59	55	14	50	60	52	31	25	57	102	162	47	130	38	122	117	7	80	117	4	64	73	27	47
2005	11	33	49	77	47	23	185	62	116	49	80	73	95	41	13	68	9	12	77	20	23	16	31	91	52	48	73	102	68	20	23	88	2	33	86	13
2006	10	21	59	91	58	93	32	76	109	74	137	99	27	43	44	87	24	2	43	72	23	15	63	144	10	114	145	36	37	26	27	128	56	59	64	25
2007	7	47	28	30	46	22	44	109	74	174	32	3	98	129	5	11	47	164	1	28	53	17	97	24	120	135	87	142	20	49	65	84	28	19	53	33
2008	8	12	107	41	7	101	46	117	18	39	48	113	143	65	108	50	21	114	23	32	11	117	151	106	105	123	150	44	46	56	158	12	21	34	76	22
2009	43	101	76	23	133	43	44	33	56	111	96	68	111	74	89	39	12	18	14	2	58	123	44	25	113	15	11	71	135	40	15	5	81	25	73	29
2010	21	87	12	86	39	151	151	6	21	117	113	83	104	73	55	124	13	34	40	47	43	25	55	89	102	19	92	69	105	36	140	34	70	18	108	60
2011	19	63	61	60	54	83	95	60	178	58	115	54	53	78	111	68	1	67	20	79	88	85	14	138	32	74	86	84	31	52	30	18	76	39	65	37
2012	3	82	39	21	27	86	8	136	81	180	103	69	94	123	82	36	146	17	80	99	138	30	17	89	82	123	100	84	34	182	108	2	8	77	33	78
2013	70	40	37	118	5	8	100	64	15	116	113	87	211	40	104	28	46	96	113	114	53	20	33	128	145	190	54	261	51	7	101	115	13	68	40	14
2014	77	96	79	45	121	114	126	106	94	175	100	166	118	171	142	73	3	8	3	123	10	3	107	45	50	126	110	134	120	91	63	74	12	119	18	39
2015	81	30	33	83	76	98	44	81	157	66	120	133	103	78	34	80	22	30	115	14	46	54	6	96	135	190	104	18	67	25	102	109	3	78	134	28
2016	41	55	215	87	61	27	62	227	59	116	159	119	86	70	60	8	64	121	46	32	23	61	57	127	53	97	81	83	216	153	24	129	51	45	101	32
2017	85	56	18	114	45	24	64	16	64	115	172	129	167	27	76	195	146	77	3	23	152	91	20	66	74	36	36	74	133	50	42	7	29	54	22	41
2018	23	58	84	46	49	72	133	149	75	107	71	101	89	84	8	54	37	28	25	22	233	107	36	71	97	151	140	64	124	67	3	76	41	76	33	135
2019	35	42	56	19	9	139	152	159	176	49	93	82	81	38	21	167	49	28	18	34	60	13	46	42	21	152	97	32	27	19	68	34	97	9	240	5
2020	27	17	90	75	38	49	73	65	110	72	81	59	82	84	75	29	4	17	4	126	9	73	39	107	46	127	180	175	57	86	17	49	85	36	54	137
2021	148	98	33	43	64	121	18	51	87	159	118	112	31	97	5	59	65	32	38	12	18	63	113	280	89	47	103	80	113	124	31	55	77	350	98	36

Appendix 4. *Decade* rainfall of Nagan Raya

	AGUSTUS			SEPT			OKT			NOV			DES			JAN			FEB			MARET			APRIL			MEI			JUN			JUL		
	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII
DASARIAN	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1998	67	128	92	67	62	56	82	43	64	90	120	23	58	128	114	40	32	6	10	18	7	2	17	13	56	18	49	42	59	67	38	69	27	13	40	60
1999	24	77	127	57	32	108	74	76	73	19	47	80	88	40	40	18	78	116	45	119	16	48	52	33	93	47	14	26	84	38	12	27	21	46	38	31
2000	49	35	13	27	73	91	61	38	41	35	104	231	7	96	32	86	40	14	48	47	88	29	39	125	78	50	82	35	20	63	61	31	58	39	4	41
2001	22	8	17	54	54	37	34	64	210	74	72	94	17	82	116	32	101	45	15	33	3	60	37	49	69	62	65	45	5	25	30	6	41	27	27	69
2002	35	0	49	28	32	55	90	77	52	115	139	37	49	73	58	8	21	81	2	14	62	14	19	58	44	41	126	143	1	3	44	19	27	35	20	12
2003	17	91	14	18	22	56	71	56	71	113	55	76	131	57	6	43	49	33	60	98	4	19	59	120	38	52	52	116	25	1	17	29	60	34	28	18
2004	0	9	54	55	52	119	42	62	87	144	34	48	83	80	14	38	40	53	32	14	42	72	76	41	60	42	82	69	69	39	53	0	39	24	28	22
2005	4	14	53	34	21	33	119	69	69	24	95	110	97	117	30	53	36	11	39	18	29	27	31	67	48	40	54	47	72	14	20	34	5	13	48	4
2006	5	15	44	86	47	45	23	76	77	83	111	67	36	54	54	57	34	2	33	72	17	27	38	91	31	82	58	29	32	27	24	73	31	12	28	11
2007	2	25	53	41	23	18	32	101	73	114	50	23	97	128	2	10	32	96	0	20	45	13	48	14	63	117	87	82	19	44	55	52	12	9	36	63
2008	9	16	88	38	4	41	64	70	30	37	69	230	162	48	87	32	12	64	17	14	25	75	66	115	84	65	74	9	7	45	65	15	12	36	65	10
2009	17	36	88	14	69	20	14	28	54	111	116	49	114	63	39	110	9	18	9	2	44	69	81	39	150	7	9	63	42	36	3	3	31	14	31	16
2010	13	61	12	35	35	80	75	10	43	125	105	66	87	66	47	119	12	42	41	26	41	40	45	87	73	32	85	63	66	22	79	46	48	46	53	39
2011	14	55	61	55	56	25	35	55	107	54	55	111	33	125	89	84	2	120	18	33	47	80	29	121	19	61	58	29	39	24	4	6	31	8	25	15
2012	1	53	40	40	30	44	12	104	64	117	60	83	84	150	109	46	110	10	51	65	80	59	13	42	68	104	29	27	9	65	38	1	3	54	13	20
2013	40	19	21	116	7	6	41	34	32	61	60	95	168	52	87	63	47	62	66	70	88	66	30	45	97	87	37	145	16	8	44	72	3	26	10	5
2014	28	51	68	28	71	62	75	93	68	123	109	90	70	150	233	84	13	3	0	55	3	5	43	30	1	1	2	6	12	72	30	31	4	31	8	19
2015	52	29	26	64	57	49	27	70	107	77	107	130	83	47	22	66	30	18	48	21	19	29	2	72	76	191	72	31	34	31	68	79	4	47	76	28
2016	16	24	104	47	29	11	21	94	46	90	76	85	139	40	73	14	54	70	33	32	11	22	25	77	37	54	59	54	69	59	20	46	17	18	56	25
2017	25	48	31	65	60	36	42	8	46	90	54	174	269	25	51	194	140	103	4	36	109	68	33	72	65	39	53	70	79	27	15	15	32	34	13	17
2018	10	28	30	34	34	65	119	104	93	98	90	78	102	78	17	91	20	25	16	12	108	50	25	38	70	87	66	60	97	67	8	47	28	38	18	46
2019	21	47	39	26	25	97	103	133	128	26	75	91	96	82	17	142	35	28	17	14	33	12	38	39	60	86	57	38	34	27	67	14	28	6	76	5
2020	27	15	62	87	57	26	62	48	51	50	85	121	87	92	53	12	12	18	20	80	6	32	43	59	58	147	108	146	73	50	26	43	27	36	48	96
2021	54	62	59	34	60	74	19	46	104	106	91	142	57	114	14	95	49	18	23	5	9	39	57	167	74	51	44	101	89	52	51	38	70	188	35	27

Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
Volume 13, Number 1, Page 1-12

Appendix 5. *Decade* rainfall of Aceh Singkil

	AGUSTUS			SEPT			OKT			NOV			DES			JAN		
	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII
DASARIAN	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	1	2	3
1998	84	243	112	44	59	70	25	31	105	50	84	15	103	123	176	82	156	15
1999	9	87	93	74	39	103	91	80	65	7	80	104	134	43	37	92	123	41
2000	41	42	32	61	94	105	49	105	49	15	158	54	1	122	70	119	135	10
2001	13	31	64	35	113	44	57	28	87	53	47	53	11	14	90	22	27	74
2002	20	4	65	54	53	96	80	137	64	94	88	58	54	144	184	13	123	100
2003	17	36	77	45	49	52	64	29	51	121	129	106	93	84	16	73	83	27
2004	1	48	29	49	96	92	20	39	111	91	92	160	50	222	50	94	92	64
2005	6	35	82	21	32	44	110	128	127	76	118	58	100	36	60	116	37	35
2006	18	13	90	128	48	56	23	172	171	103	106	210	143	85	196	33	253	10
2007	7	36	52	83	41	49	104	166	53	145	37	210	127	92	50	28	140	63
2008	27	53	102	83	27	42	117	96	14	99	114	100	63	59	64	33	58	112
2009	24	89	95	18	28	45	19	61	76	148	106	32	78	59	58	35	40	107
2010	5	59	10	25	73	115	116	5	32	56	100	54	15	55	37	94	56	72
2011	35	106	75	79	65	37	83	51	159	255	121	117	53	103	43	63	26	146
2012	23	73	53	64	34	78	10	146	182	255	54	78	37	102	333	43	45	20
2013	33	42	34	115	11	7	45	61	55	205	94	78	206	17	123	16	40	155
2014	54	75	60	38	53	56	84	101	100	105	155	118	49	171	74	99	32	6
2015	60	50	84	102	132	119	59	125	133	119	177	159	118	57	78	119	20	107
2016	7	7	83	66	26	5	14	82	51	116	164	236	53	45	35	72	92	116
2017	22	87	50	130	101	19	50	9	28	132	143	94	152	29	126	119	48	134
2018	21	27	67	50	69	200	168	97	257	191	54	101	69	34	33	32	24	30
2019	27	122	59	25	28	153	146	161	124	45	197	143	193	141	73	121	92	67
2020	26	53	198	282	34	62	58	21	22	77	121	101	36	55	134	43	75	94
2021	24	153	67	50	93	101	18	42	154	18	42	154	240	108	64	74	29	66

	FEB			MARET			APRIL			MEI			JUN			JUL		
	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII
DASARIAN	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1998	36	55	36	93	107	173	72	103	64	178	162	35	41	69	36	19	105	43
1999	29	67	49	88	112	25	85	56	17	85	163	40	21	65	84	80	25	121
2000	49	55	65	33	47	111	107	50	67	22	3	118	23	58	11	14	16	82
2001	79	87	50	96	4	43	157	78	84	17	9	55	40	8	61	5	30	82
2002	24	150	134	84	107	155	55	94	235	231	8	20	94	20	19	16	13	58
2003	68	144	36	6	158	111	129	137	169	29	4	1	25	42	64	26	39	12
2004	80	124	26	57	166	81	93	128	195	65	2	52	64	4	27	24	46	17
2005	63	52	90	65	140	80	26	52	89	107	17	19	29	44	13	24	49	14
2006	49	104	44	32	100	87	33	126	23	24	39	22	16	48	17	18	9	14
2007	81	131	146	13	239	12	78	163	56	99	36	58	62	31	26	14	31	80
2008	41	31	44	111	134	113	105	120	98	21	6	57	98	15	66	64	51	41
2009	10	2	141	137	67	587	170	23	56	34	52	24	10	32	69	75	25	10
2010	95	135	109	109	101	122	94	173	259	150	122	23	87	18	28	52	27	36
2011	86	31	72	61	78	76	24	80	92	11	62	51	38	5	26	6	72	4
2012	109	210	117	48	27	79	82	47	103	56	55	46	47	4	21	45	51	46
2013	94	694	90	22	52	142	100	70	160	108	12	21	25	31	27	23	4	35
2014	1	11	35	64	134	112	86	151	137	83	42	25	8	53	7	6	7	6
2015	199	54	78	96	84	88	137	281	199	93	75	64	64	54	5	25	47	38
2016	95	36	43	127	135	291	158	99	127	212	110	46	6	64	4	13	95	13
2017	6	173	185	118	67	119	102	145	171	122	40	24	4	69	45	44	14	8
2018	55	46	270	119	67	97	226	228	93	112	201	103	0	25	65	34	35	24
2019	152	60	176	121	72	100	97	114	36	44	66	155	72	92	25	52	87	29
2020	100	77	18	71	108	82	164	368	183	36	120	72	78	44	26	30	126	100
2021	55	39	106	158	119	197	90	107	103	200	213	72	52	136	131	29	44	24