Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

October 2023. Vol. 11, No. 4
p-ISSN: 2338-4530
e-ISSN: 2540-7899
_pp. 1084-1101_

Characterization of Meteorological Drought Using Standardized Precipitation Index and Standardized Precipitation Evapotranspiration Index Methods in North Sumatera

[1,2] Fanly Parhimpunan Manullang, [1*]Kerista Tarigan, [1]Marhaposan Situmorang, [1]Syahrul Humaidi, [1,2]Deassy Eirene Diana Doloksaribu, [3]Yahya Darmawan

1 Department of Physics, Faculty of Mathematics and Natural Sciences – Universitas Sumatera Utara, Jl. Dr. T. Mansur No.9, Padang Bulan, Medan 20222, Indonesia.

2 BMKG – Indonesia Meteorology, Climatology and Geophysics Agency Regional I, Jl. Ngumban Surbakti No. 15, Medan 20131, Indonesia.

3 School of Meteorology, Climatology and Geophysics (STMKG), Jl. Perhubungan I No.5, Pd. Betung, Tangerang Selatan 15221, Indonesia.

*Corresponding Author e-mail: kerista@usu.ac.id

Received: August 2023; Revised: September 2023; Published: October 2023

Abstract

Climate variability in Indonesia is influenced by several global factors including El Niño Southern Oscillation and Indian Ocean Dipole, one consequence of climate variability is drought. The drought index is used to identify and describe the level of drought in an area, the methods used in this study are the Standardized Precipitation Index and the Standardized Precipitation Evapotranspiration Index which are calculated based on climate data with a span of 24 years as many as 67 rain observation posts in North Sumatra using R Studio software. The purpose of this study is to determine the factors of global climate phenomena that affect drought in North Sumatra and its impact on rice crop productivity and analyze drought characteristics spatially and temporarily. The resulting index values are then analyzed using correlation methods to see their relationship with ENSO and IOD. The results showed that the incidence of the ENSO phenomenon had a very strong relationship with meteorological drought in North Sumatra with a correlation value range of -0.85 to -0.97, and as many as 62.5% of 32 districts experienced a decrease in rice crop productivity during El Niño with strong intensity in 2015.

Keywords: SPI, SPEI, ENSO, IOD, Drought, North Sumatera

How to Cite: Manullang, F., Tarigan, K., Situmorang, M., Humaidi, S., Doloksaribu, D., & Darmawan, Y. (2023). Characterization of Meteorological Drought Using Standardized Precipitation Index and Standardized Precipitation Evapotranspiration Index Methods in North Sumatera. *Prisma Sains : Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram, 11*(4), 1084-1101. doi:https://doi.org/10.33394/j-ps.v11i4.9961

https://doi.org/10.33394/j-ps.v11i4.9961

INTRODUCTION

The Indonesian region has climate variability based on geographical and topographic conditions (Hermawan et al., 2016), besides that climate variability is also influenced by several global factors, such as El Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) (Putra et al., 2020), this global factor causes the impact of drought on the Indonesian region which cannot be avoided because it will have an impact on the community. Drought can occur and develop anywhere in a short time or several months, even longer than several seasons (drought for many years) (Wong et al., 2013).

Drought is one of the climate disasters due to the impact of the most serious climate phenomena that can affect society (Li et al., 2019), agriculture, water quality and also water supply for the community (Blauhut et al., 2015) and is the result of interactions between meteorological anomalies, processes on the ground surface, human activities in water use, and reduced water storage availability media (Van Loon et al., 2016). The incidence of drought in an area is described through the level of drought expressed in several indices used to calculate and compare the severity of the drought objectively, as well as the duration and extent of the drought in various regions (Stagge et al., 2015).

One of the widely used drought indices is the Standardized Precipitation Index and was first proposed by McKee et al (1993) hereinafter referred to as SPI. SPI is a very powerful index and is flexible and easy to calculate (Svoboda et al., 2012). SPI is an index that can be used on short and long time scales temporally or spatially. This index only considers rainfall without taking into account other weather elements, besides rainfall, the element that affects drought is temperature, because it can accelerate the evaporation of water from the soil surface and plants (Serrano et al., 2010) modifying the SPI by considering the temperature element can calculate potential evapotranspiration called the Standardized Prepicipitation Evapotranpiration Index (SPEI).

In each region has different climate variability and cannot be avoided, this climate variability is influenced by global factors such as El-Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) so that it has impacts such as meteorological drought (Narulita et al., 2019). Lia et al., (2022) conducted a study by looking at the relationship between drought events and the El-Nino phenomenon in the North Lombok region, with meteorological drought indices used, namely SPI and SOI (Southern Oscillation Index) as indicators of ENSO events. The results of the study show a close relationship between drought events and the El-Nino phenomenon in North Lombok.

In addition to the ENSO phenomenon, research by Xu et al., (2019) on the IOD phenomenon also has an impact on increasing the incidence of drought when IOD events are positive. According to Jun-Ichi et al., (2012) Drought during the dry season usually appears together when positive IOD and El-Nino occur. Meanwhile, when the IOD is negative, it results in more rainfall in the northwestern part of Java.

Spatial and temporal variability are the basic conditions related to drought in measuring drought hazards and vulnerabilities of different regions, with the ultimate goal being to improve adaptation and mitigation to drought phenomena. SPI is an indicator value that describes meteorological drought with the use of a time scale of 3,6,12 months, Based on Muharsyah's research, (2016) obtained SPI 12 is more suitable in testing drought in Medan, while in Ambon and Denpasar it is more suitable SPI 6 and SPI 3. In addition to SPI indicators, another meteorological drought index used in looking at drought is SPEI, based on research (Musei et al., 2021) SPEI12 was successfully used to identify and characterize drought events. A comparative study of these two meteorological drought indicators has also been conducted by Faisol and Budiyono (2022) who looked for SPI and SPEI values to see the correlation between the two indicators, with the result that SPI and SPEI are quite accurate in identifying drought in West Papua Province.

One of the most densely populated provinces in Indonesia is North Sumatra with a population of 15 million people (BPS, 2020) which can cause a reduction in green open land, which can lead to natural disasters such as drought. North Sumatra is also included in the priority area for drought disaster management which has a threat area of 24,206 ha (Sutarjo et al., 2013), therefore in minimizing the incidence of this drought disaster, appropriate steps are needed in anticipating it, so the author conducted a study related to global climate control factors that affect meteorological drought in North Sumatra and its effect on food crop productivity.

METHOD

The location in this study is North Sumatra Province, the length of data used in this study starts from 1998 to 2022, the data used include monthly rainfall from 67 BMKG rain posts in the North Sumatra region (Figure 1), maximum and minimum temperature data of the North

Sumatra Climatology station which is used to estimate the maximum temperature and minimum temperature of the rain post, rain post latitude and elevation data, solar irradiation time data, wind speed model data obtained from the NASA (National Aeronautics and Space Administration) website, monthly global phenomenon index data ENSO and IOD, rice production data from 2010-2022 obtained from the Central Statistics Agency (BPS) of North Sumatra Province. In this calculation, to get the SPI and SPEI values, rainfall data processing is used using the R Studio application.

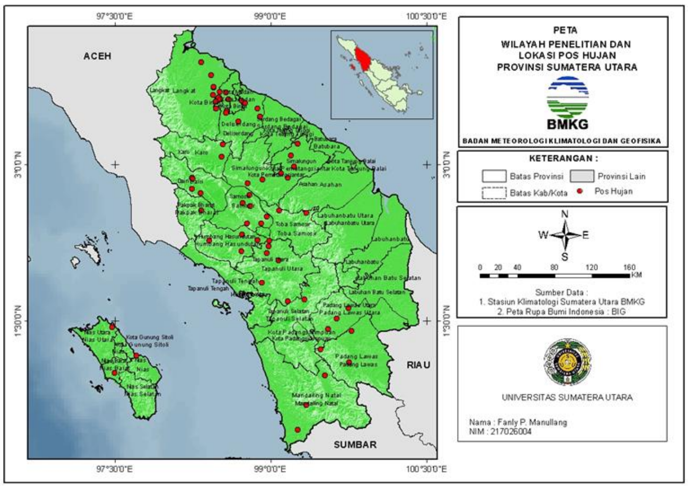

Figure 1. Research area

In this study, maximum and minimum temperature estimation needs to be carried out at 67 rain post points used, to estimate the temperature, maximum and minimum temperature data from the North Sumatra Climatology Station are used as reference stations. The calculation of temperature estimation uses the formula in equation 1 (Braak, 1929)

$$T_x = T_0 - \left(\frac{0.6}{100}\, h\right) \tag{1}$$

T_x = Maximum temperature/minimum rain post
T_0 = Maximum/minimum temperature of the reference station
h = Difference in height of rain post with reference station

Then the calculation of the SPI value is based on the amount of gamma distribution which is defined as a function of frequency, the gamma distribution is used to estimate the probability of rainfall events per rain post (McKee et al., 1993), the calculation of the SPI value is obtained by the formula of equation 2 as follows :

$$G(x) = \int_0^1 g(x)\,dx = \frac{1}{\beta^{\alpha}\Gamma_{(a)}} \int_0^x t^{a-1} e^{-\frac{x}{\beta}} dx \tag{2}$$

With the gamma function:

$$\Gamma_{(a)} = \int_0^{\infty} y^{a-1}\, e^{\frac{-x}{\beta}}\, dx \tag{3}$$

Description:
$G(x)$ = Gamma distribution
$\alpha > 0$ = Shape parameters
$\beta > 0$ = Scale parameter
$x > 0$ = Parameter amount of precipitation

The gamma function is not defined at x = 0, while the distribution of precipitation is likely to be zero, so the calculation for the cumulative probability of precipitation valued at 0 to be:$G(x)$

$$H(x) = q + (1 - q)G(x) \tag{4}$$

Where the value of q = m / n with m is the number of events with values of 0 and n for the period of rainfall. The SPI value is the result of the transformation of cumulative probability to normal standard with variable Z. The calculation of the SPI value for is:$0 < H < (x) \leq 0{,}5$

$$Z = SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \quad (5)$$

with $t = \sqrt{In\left(\frac{1}{(H(x))^2}\right)}$ (6)

Meanwhile, the calculation of SPI value for:$0{,}5 < H < (x) \leq 1$

$$Z = SPI = +\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_a t^a}\right) \quad (7)$$

with $t = \sqrt{In\left(\frac{1}{(1 - H(x))^2}\right)}$ (8)

Information:

c_0	= 2.515517	d_1	= 1.432788
c_1	= 0.802853	d_2	= 0.189269
c_2	= 0.010328	d_3	= 0.001308

For SPEI calculations using rainfall (P) and PET input data, it can be calculated by the following equation:

$$Di = Pi - PETi \quad (9)$$

Description:

D_i : Difference from precipitation with potential evapotranspiration,
P_i : Monthly rainfall
PET_i : Monthly potential evapotranspiration.

The values D_i are accumulated based on the time scale with the following equation:

$$D_n^k = \sum_{i=0}^{k-1} P_{n-1} - PET_{n-1} \quad (10)$$

Description:
k = time scale (months)
n = month to -n

The PET value is obtained by calculating the Penman–Monteith potential evapotranspiration (Monteith, 1965) using the following formula

$$ET_0 = \frac{0.408\,\Delta(R_n - G) + \gamma \frac{900}{(T+273)} U_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,U_2)} \quad (11)$$

SPEI is a calculation for the drought index obtained from the normalization results using three log-logistic variables based on *the probability density function* and shown by the following equation.

$$F\,(x) = \frac{\beta}{\alpha}\,\left(\frac{x-\gamma}{\alpha}\right)^{\beta-1}\,\left(1 + \left(\frac{x-\gamma}{\alpha}\right)\beta\right)^{-2} \quad (12)$$

The α, β, γ values are respectively scales, shapes, and initial values that describe the values of D in the range (γ> D < ∞), with the equation α, β, γ as follows.

$$\beta = \frac{2w_1 - w_0}{6w_1 - w_0 - 6w_2} \tag{13}$$

$$\alpha = \frac{(w_0 - 2w_1)}{\Gamma\left(1+\frac{1}{\beta}\right)\Gamma\left(1-\frac{1}{\beta}\right)} \tag{14}$$

$$\gamma = w_0 - \alpha\Gamma\left(1+\frac{1}{\beta}\right)\Gamma\left(1-\frac{1}{\beta}\right) \tag{15}$$

The value of $\gamma\left(1+\frac{1}{\beta}\right)$ is the gamma function of $(1+\frac{1}{\beta})$, with $\Gamma(\beta)$ is gamma function of β. The calculation of the value of w is probability *weighted moments*

$$w = \frac{1}{n}\sum_{i=1}^{n}\left(1 - \frac{j-0{,}35}{n}\right) D_i \tag{16}$$

where is the number of data points and is the range of observations made. The function of the series D probabilistic distribution based on the *njlog-logistic distribution* is shown in the following formula,

$$F(x) = \left[1 + \left(\frac{\alpha}{x-y}\right)^{\beta}\right]^{-1} \tag{17}$$

The SPEI value or standard normal variable Z for P ≤ 0.5 is calculated using the following formula.

$$Z = SPEI = W - \frac{c_0 + c_1W + c_2W^2}{1 + d_1W + d_2W^2 + d_3W^3} \tag{18}$$

Where W = $\sqrt{-2\ln(P)}$

While the value of SPEI or standard variable Z for P > 0.5 is calculated using the formula,

$$Z = SPEI = W + \frac{c_0 + c_1W + c_2W^2}{1 + d_1W + d_2W^2 + d_3W^3} \tag{19}$$

Where W = $\sqrt{-2\ln(1 - P)}$

Information:

c_0	= 2.515517	d_1	= 1.432788
c_1	= 0.802853	d_2	= 0.189269
c_2	= 0.010328	d_3	= 0.001308

In this study, the calculation of SPI and SPEI was carried out using RStudio software with SPI package.

The Pearson correlation method is used to determine the degree of relationship between variables but does not describe causal relationships. Positive correlation describes the relationship between variables directly proportional, while negative correlation describes the relationship between variables inversely proportional and uncorrelated describes the absence of relationship between variables. Pearson correlation equation is expressed by the following formula.

$$r_{xy} = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{\{n\sum X^2 - (\sum X)^2\}\{n\sum Y^2 (\sum Y)^2\}}} \tag{20}$$

Description:

r_{xy} = X and Y variable correlation value
n = Lots of data
X = Variable X (SPI, SPEI)
Y = Variabel Y (ENSO, IOD)

The range of correlation values is interpreted in the following table 1:

Tabel 1. Range of correlation values

Correlation Coefficient	Description
0	No correlation
0.01 - 0.20	Very low correlation
0.21 - 0.40	Low correlation
0.41 - 0.60	Moderate Correlation
0.61 - 0.80	Strong correlation
0.81 - 0.99	Very Strong correlation
1	Perfect Corelation

RESULTS AND DISCUSSION

The pattern of sea level temperature anomalies in the Pacific Ocean region (Nino region 3.4) has a fairly variable variation in anomalies during the period 1998 – 2022 seen in Figure 2.

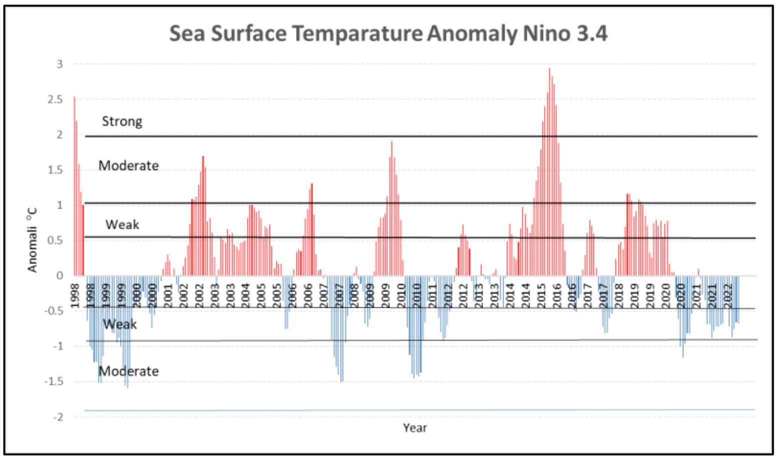

Figure 2. Sea Surface Temperature Anomaly 1998 – 2022

The El Niño phenomenon occurs when the sea level temperature anomaly is greater than or equal to +0.5, and the La Niña phenomenon occurs when the sea level temperature anomaly is less than or equal to -0.5. ENSO based on its intensity is grouped into weak ENSO with sea level temperature anomaly of 0.5 to 0.9, medium ENSO with sea level temperature anomaly of 1.0 to 2.0, strong ENSO with sea level temperature anomaly of more than 2.0. Based on Figure 2 above, the criteria for the year of El Niño and La Niña events that occurred from 1998 to 2022 are presented in Table 2.

Table 2. El Niño and La Niña events of 1998 - 2022

El-nino			La-Nina		
Weak	Moderate	Strong	Weak	Moderate	Strong
2004	2002	1998	2011	1998	-
2005	2009	2015	2022	1999	

While the Sea Level Temperature anomaly in the Indian Ocean also has quite varied temperature variations. IOD is calculated based on the difference in sea surface temperature between the western tropical Indian Ocean and the eastern tropical Indian Ocean during the period 1998 – 2022 as seen in figure 3.

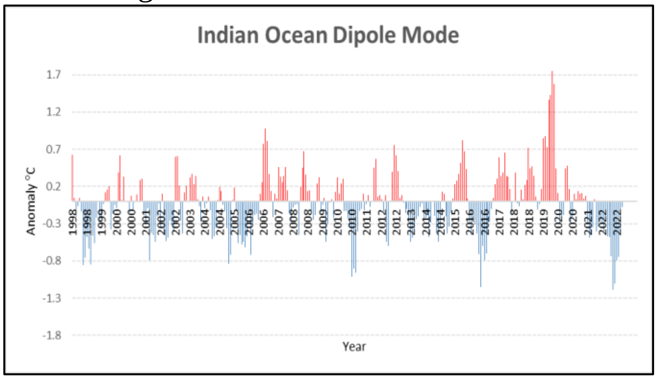

Figure 3. Indian Ocean Dipole Mode 1998 – 2022

Based on the graph above, the criteria for the year of incidence of positive IOD (+) and negative IOD (-) during the period 1998 to 2022 are shown in Table 3 below.

Table 3. Positive IOD (+) and negative IOD (-) events 1998 - 2022

IOD Positif (+)	IOD Negatif (-)
2015	2016
2019	2022

The relationship of the drought index with ENSO.

The correlation value between the SPI and SPEI indices with the Nino 3.4 sea level temperature anomaly in 2005 is generally negative / inversely proportional, which means that when the SPI / SPEI value is negative (-) then the value of the sea level temperature anomaly is positive (+). The SPI correlation value shows that 73.1% of rain posts in the North Sumatra region are negative. Meanwhile, the correlation value between the SPEI index shows that 76.1% of rain posts in the North Sumatra region are negative. The correlation value between the SPI and SPEI indices with the Nino 3.4 sea level temperature anomaly in 2005 can be seen in figure 4 below.

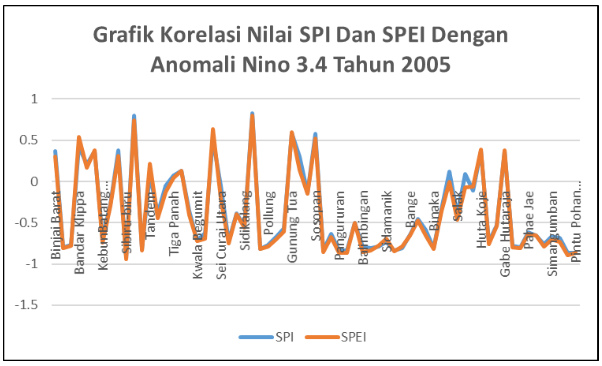

Figure 4. Correlation of SPI and SPEI with Nino 3.4 during a weak El Niño in 2005

Based on figure 4 on the SPI value, there are several areas that have a strong negative relationship, namely Sibiru-biru, Lumban Julu, Pintu Pohan Meranti, Pangururan, Simarjarunjung, Simanindo, Nainggolan, North Sumatra Staklim, Lintong Nihuta, Bandar Betsy, Marihat, Binaka, Muara and there is one area that has a strong positive correlation, namely Sipoltong. In the SPEI value, there are several regions that have a strong negative relationship, namely Sibiru-biru, Lumban Julu, Simanindo, Pintu Pohan Meranti, Pangururan, Nainggolan, Balimbingan, Simarjarunjung, Bandar Betsy, Staklim North Sumatra, Lintong

Nihuta, Binaka, Muara, Binjai Selatan, Garoga, the correlation value can be seen in Table 4 below.

Table 4. Correlation value of SPI and SPEI with Nino 3.4 in 2005

SPI			SPEI		
Nama Pos	**r**	**Keterangan**	**Nama Pos**	**r**	**Keterangan**
Sibiru-biru	-0.92	Kuat Negatif	Sibiru-biru	-0.94	Kuat Negatif
Lumban Julu	-0.87	Kuat Negatif	Lumban Julu	-0.89	Kuat Negatif
Pintu Pohan Meranti	-0.86	Kuat Negatif	Simanindo	-0.86	Kuat Negatif
Pangururan	-0.84	Kuat Negatif	Pintu Pohan Meranti	-0.86	Kuat Negatif
Simarjarunjung	-0.84	Kuat Negatif	Pangururan	-0.86	Kuat Negatif
Simanindo	-0.84	Kuat Negatif	Nainggolan	-0.86	Kuat Negatif
Nainggolan	-0.83	Kuat Negatif	Balimbingan	-0.86	Kuat Negatif
Staklim Sumut	-0.82	Kuat Negatif	Simarjarunjung	-0.8466	Kuat Negatif
Lintong Nihuta	-0.82	Kuat Negatif	Bandar Betsy	-0.8391	Kuat Negatif
Bandar Betsy	-0.81	Kuat Negatif	Staklim Sumut	-0.8348	Kuat Negatif
Marihat	-0.81	Kuat Negatif	Lintong Nihuta	-0.8195	Kuat Negatif
Binaka	-0.80	Kuat Negatif	Binaka	-0.8134	Kuat Negatif
Muara	-0.80	Kuat Negatif	Muara	-0.8077	Kuat Negatif
Sipoltong	0.82	Kuat Positif	Binjai Selatan	-0.8047	Kuat Negatif
			Garoga	-0.8023	Kuat Negatif

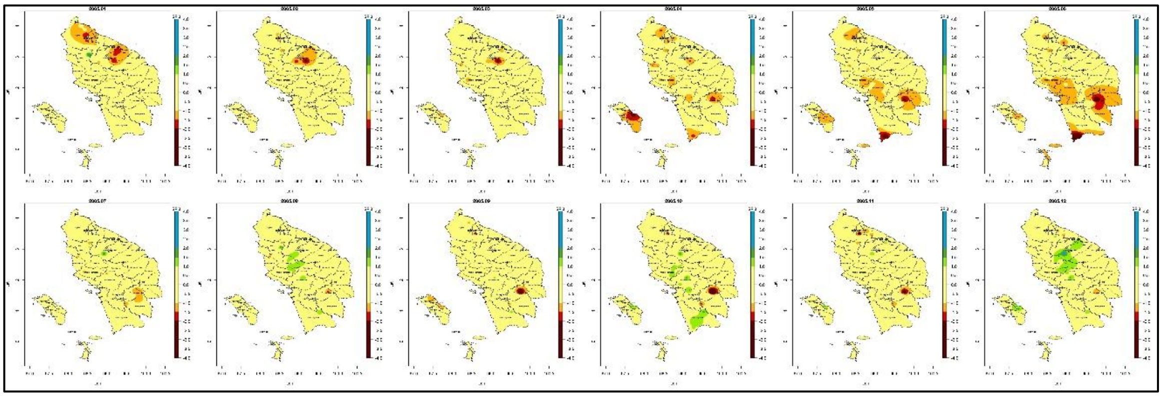

Figure 5. Map of SPI in 2005 North Sumatra region

Spatial pattern of SPI index in general are shows the North Sumatra region in 2005 was in the normal category (Figure 5.), the SPI drought characteristic at the time of the *El Niño* event with weak intensity in 2005 which began in January to May, as much as 20.9% experienced drought levels with moderately dry category, severely dry category as much as 8.06% and extremely dry category as much as 3.28%, However, there are some areas that experience moderately wet drought rate of 1.79%, the very wet category as much as 0.9% and the extremely wet category as much as 0.3%.

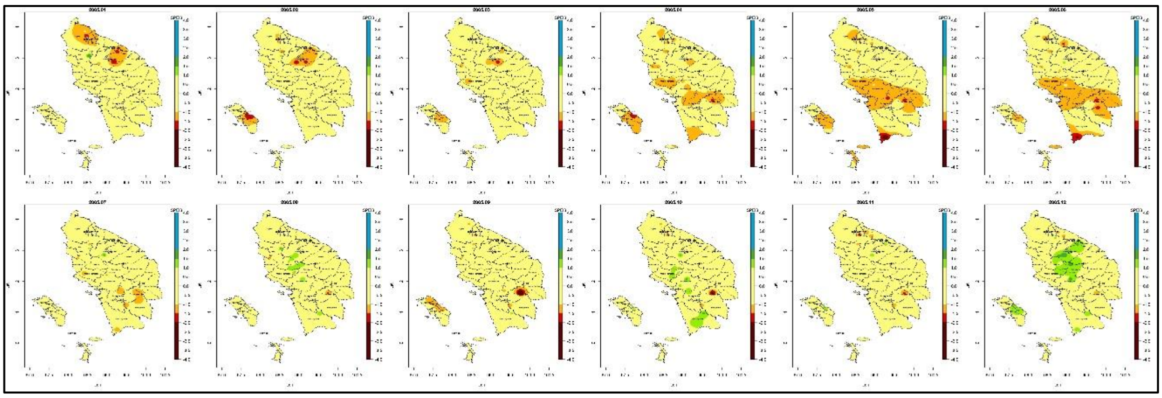

Figure 6. Map of SPEI in 2005 North Sumatra region

Spatial pattern of SPEI index in general are shows the North Sumatra region in 2005 was in the normal category (Figure 6), as many as 29.3% experienced drought levels with a moderately dry category, severely dry category of 8.7% and extremely dry category of 0.9%, but there were several regions that experienced a moderately wet drought level of 1.8%, very wet category of 0.9% and extremely wet category of 0.3%.

The correlation value between the SPI and SPEI indices with the Nino 3.4 sea level temperature anomaly in 2009 is generally negative / inversely proportional, which means that when the SPI / SPEI value is negative (-) then the value of the sea level temperature anomaly is positive (+). The SPI correlation value in 2009 showed that 76.1% of rain posts in the North Sumatra region were negative, while the SPEI correlation value of 76.1% of rain posts in the North Sumatra region was positive. The correlation value between the SPI and SPEI indices with the Nino 3.4 sea level temperature anomaly at the time of the *moderate El Niño* event in 2009 can be seen in Figure 7 below.

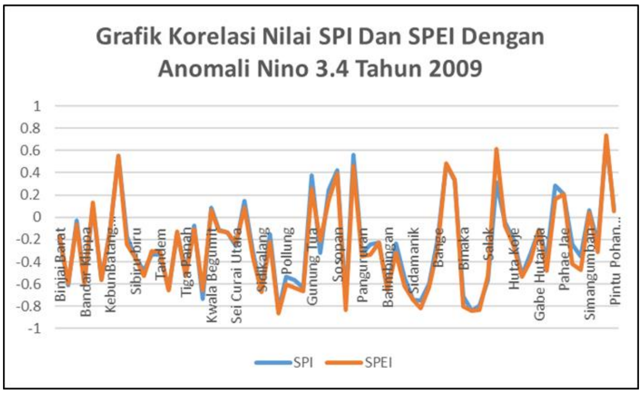

Figure 7. Correlation of SPI and SPEI values with Nino 3.4 during El Niño in 2009

Based on Figure 7 on the SPI value there are two regions that have a strong negative relationship, namely Lintong Nihuta and West Nias, while on the SPEI value there are several regions that have a strong negative relationship, namely Lintong Nihuta, West Nias, Nainggolan, Sogawu, Simarjarunjung and Binaka, the correlation value can be seen in Table 5.

Table 5. Correlation value of SPI and SPEI with Nino 3.4 in 2009

SPI			SPEI		
Nama Pos	**r**	**Keterangan**	**Nama Pos**	**r**	**Keterangan**
Lintong Nihuta	-0.84	Kuat Negatif	Lintong Nihuta	-0.86	Kuat Negatif
Nias Barat	-0.84	Kuat Negatif	Nias Barat	-0.84	Kuat Negatif
Sogawu	-0.79	Cukup Kuat Negatif	Nainggolan	-0.83	Kuat Negatif
Nainggolan	-0.77	Cukup Kuat Negatif	Sogawu	-0.83	Kuat Negatif
Simarjarunjung	-0.75	Cukup Kuat Negatif	Simarjarunjung	-0.81	Kuat Negatif
Sidamanik	-0.74	Cukup Kuat Negatif	Binaka	-0.80	Kuat Negatif
Cempa	-0.73	Cukup Kuat Negatif	Sidamanik	-0.74	Cukup Kuat Negatif
Binaka	-0.71	Cukup Kuat Negatif	Sidikalang	-0.67	Cukup Kuat Negatif
Sidikalang	-0.67	Cukup Kuat Negatif	Tarabintang	-0.67	Cukup Kuat Negatif
Balimbingan	-0.65	Cukup Kuat Negatif	Cempa	-0.66	Cukup Kuat Negatif
Tandem Hilir	-0.65	Cukup Kuat Negatif	Tandem Hilir	-0.66	Cukup Kuat Negatif
Tarabintang	-0.63	Cukup Kuat Negatif	Balimbingan	-0.66	Cukup Kuat Negatif
Binjai Selatan	-0.61	Cukup Kuat Negatif	Sijamapolang	-0.63	Cukup Kuat Negatif
Lumban Julu	0.69	Cukup Kuat Positif	Marihat	-0.62	Cukup Kuat Negatif
			Laras Emplasmen	-0.61	Cukup Kuat Negatif
			Pollung	-0.60	Cukup Kuat Negatif
			Lumban Julu	0.73	Cukup Kuat Positif
			Arse	0.61	Cukup Kuat Positif

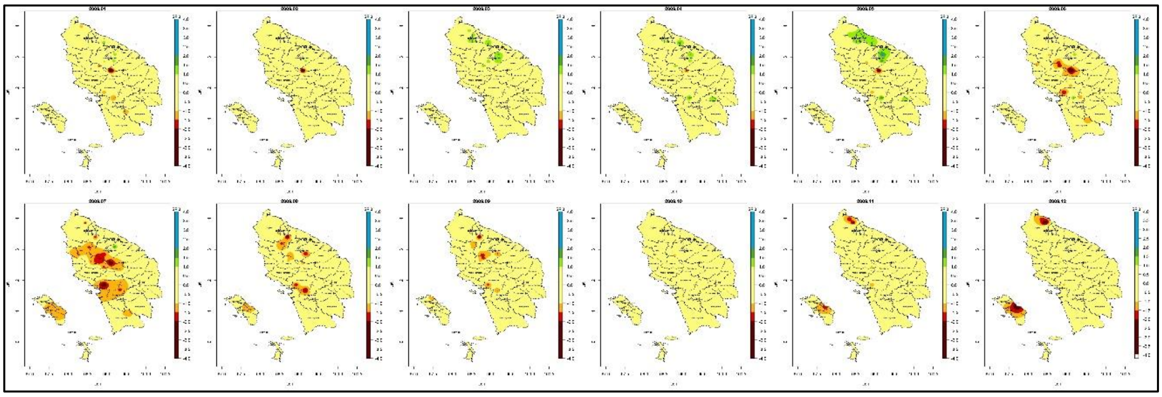

Figure 8. Map of SPI in 2009 North Sumatra region

Spatial pattern of SPI index in general are shows the North Sumatra in 2009 was in the normal category (Figure 8), characteristic of SPI drought at the time of *El Niño* events with moderate intensity starting from June to December, showing as many as 12.4% experiencing drought levels with moderately dry category, severely dry category as much as 6.2% and extremely dry category as much as 4.7%, However, there are some areas that experience moderately wet drought rate of 1.9%, very wet category as much as 1.3%.

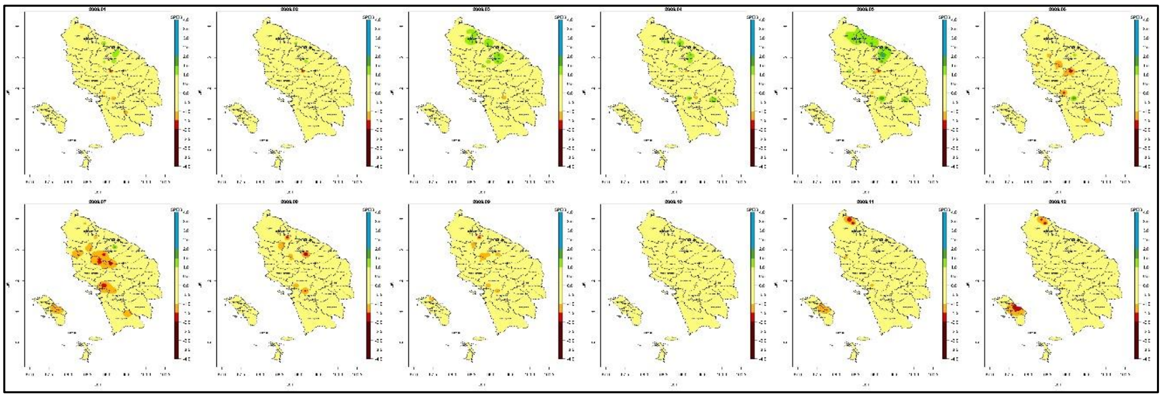

Figure 9. Map of SPEI in 2009 North Sumatra region

Spatial pattern of SPEI index in general are shows the North Sumatra region in 2009 was in the normal category (Figure 9), the SPEI drought characteristic at the time of *the El Niño* event with moderate intensity starting from June to December, as much as 16.2% experienced drought levels with moderately dry category, severely dry category of 6% and a extremely dry category of 1.7%, However, there are some areas that experience moderately wet drought level of 2.6% and very wet category of 1.5%.

The correlation value between the SPI and SPEI indices with the Nino 3.4 sea level temperature anomaly in 2015 is generally negative / inversely proportional, which means that when the SPI / SPEI value is negative (-), the value of the sea level temperature anomaly is positive (+). The correlation value of SPI in 2015 was 71.6% of rain posts in the North Sumatra region was negative, while the correlation between the SPEI index and the Nino 3.4 sea level temperature anomaly showed that 71.6% of rain posts in the North Sumatra region were negative. The correlation value between the SPI and SPEI indices with the Nino 3.4 sea level temperature anomaly in 2015 can be seen in Figure 10 below.

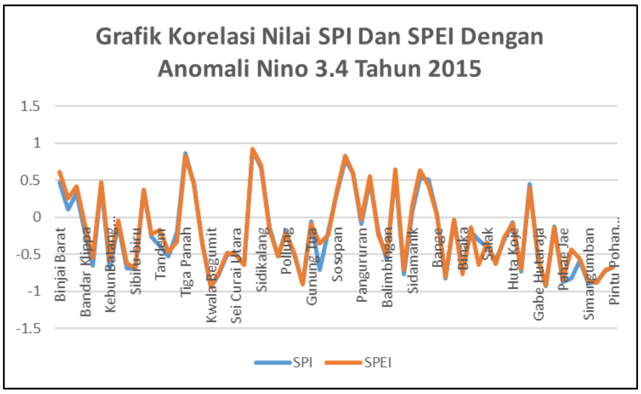

Figure 10. Correlation of SPI and SPEI values with Nino 3.4 during a strong El Niño in 2015

Based on Figure 10 on the SPI value, there are several areas that have a strong negative relationship, namely Kwala Begumit, Garoga, Tarabintang, Simangumban, Pahae Jae, Sipahutar, Muarasoma, Parmonangan dan there are areas that have a strong positive correlation, namely Mount Sayang and Three Arrows. In the SPEI value, there are several regions that have a strong negative relationship, namely Kwala Begumit, Garoga, Tarabintang, Sipahutar, Simangumban, Pahae Jae and there are areas that have a strong positive relationship, namely Gunung Sayang, Tiga Arrow and Nainggolan, the correlation value can be seen in Table 6 below.

Table 6. Correlation value of SPI and SPEI with Nino 3.4 in 2015

SPI			SPEI		
Nama Pos	**r**	**Keterangan**	**Nama Pos**	**r**	**Keterangan**
Kwala Begumit	-0.93	Kuat Negatif	Kwala Begumit	-0.93	Kuat Negatif
Garoga	-0.93	Kuat Negatif	Garoga	-0.92	Kuat Negatif
Tarabintang	-0.90	Kuat Negatif	Tarabintang	-0.91	Kuat Negatif
Simangumban	-0.89	Kuat Negatif	Sipahutar	-0.88	Kuat Negatif
Pahae Jae	-0.87	Kuat Negatif	Simangumban	-0.86	Kuat Negatif
Sipahutar	-0.87	Kuat Negatif	Pahae Jae	-0.85	Kuat Negatif
Muarasoma	-0.83	Kuat Negatif	Gunung Sayang	0.92	Kuat Positif
Parmonangan	-0.83	Kuat Negatif	Tiga Panah	0.83	Kuat Positif
Gunung Sayang	0.91	Kuat Positif	Nainggolan	0.83	Kuat Positif
Tiga Panah	0.87	Kuat Positif			

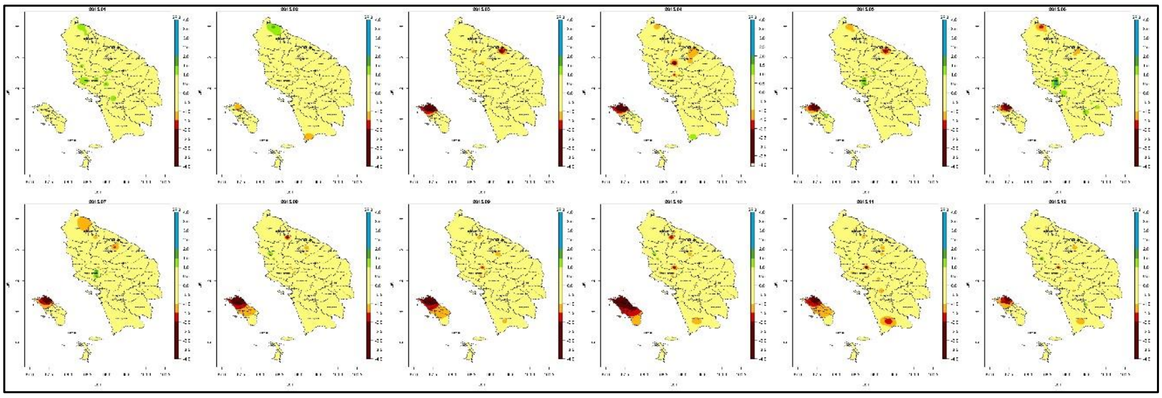
Figure 11. Map of SPI in 2015 North Sumatra region

Spatial pattern of SPI index in general are shows the North Sumatra region in 2015 was in the normal category (Figure 11), characteristic of SPI drought at the time of *El Niño* events with strong intensity starting from April to December, showing as many as 12.8% experiencing drought levels with moderately dry category, severely dry category of 3.6% and a extremely dry category of 3.8%. However, there are some areas that experience a moderately wet drought rate of 5.8%, very wet category of 1.7% and extremely wet 1.3%.

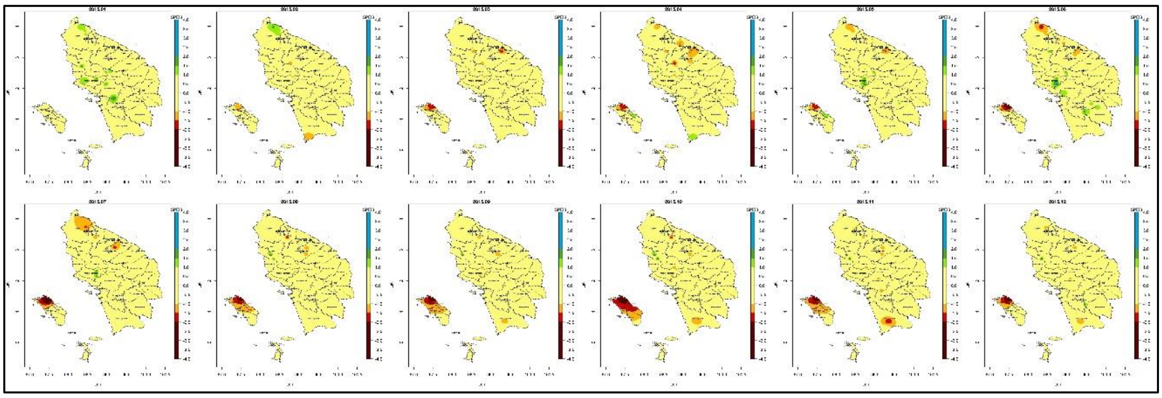

Figure 12. Map of SPEI in 2015 North Sumatra region

The SPEI Index shows that in general the North Sumatra region in 1998 was in the normal category (Figure 12), as many as 31.3% experienced drought levels with moderately dry category, severely dry category of 33.8% and extremely dry category of 6.5%. However, there are some areas that experience moderately wet drought rate of 6.3%, very wet category as much as 2% and extremely wet 1.5%.

The relationship of drought index with IOD.

The correlation value between the SPI and SPEI indices with sea level temperature anomalies in the Indian Ocean at the time of the IOD+ event in 2019 is generally negative / inversely proportional, which means that when the SPI / SPEI value is negative (-), the value of sea level temperature anomalies is positive (+). The correlation value of SPI in 2019 was 74.6% of rain posts in the North Sumatra region were negative, while the correlation value of SPEI was also 74.6% of rain posts in the North Sumatra region were negative. The correlation value between the SPI and SPEI indices with sea level temperature anomalies in the Indian Ocean region at the time of the IOD+ event in 2019 can be seen in Figure 13 below.

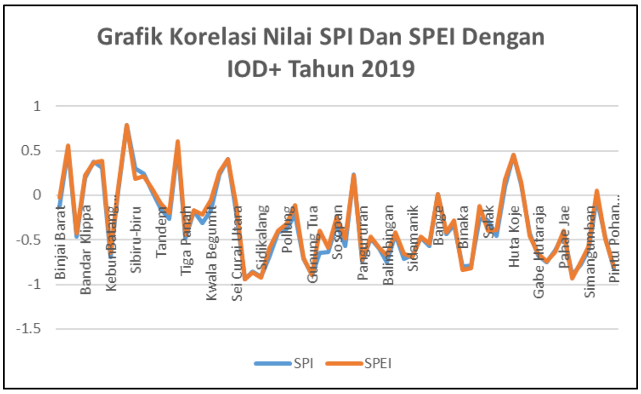

Figure 13. Correlation of SPI and SPEI values with IOD+ in 2019

Based on Figure 13 on the SPI value, there are areas that have a strong negative relationship, namely Bantun Kerbo, Sidikalang, Gunung Tua, Parmonangan, Gunung Sayang, Pintu Pohan Meranti, Binaka and there are areas that have a strong negative relationship, namely West Nias, Siborong-borong, Garoga, Balimbingan, Pangururan, Laras Emplasmen, Tarabintang, Batangkuis Garden, Sipoltong, Gabe Hutaraja, Sidamanik, Balangka Sitongkon, Binanga, Muara, Simangumban, Pancur Batu. While in the SPEI value, there are areas that have a strong negative relationship, namely Bantun Kerbo, Parmonangan, Sidikalang, Gunung Tua, Gunung Sayang, Binaka, West Nias and there are areas that have a strong negative relationship, namely Pintu Pohan Meranti, Siborong-borong, Garoga, Pangururan, Tarabintang, Sidamanik, Balimbingan, Gabe Hutaraja, Laras Emplasmen, Batangkuis Garden, Muara, Pancur Batu, Tanjung Gorbus, the correlation value can be seen in Table 7 below.

Table 7. The correlation value of SPI and SPEI with IOD+ in 2019

SPI			SPEI		
Nama Pos	r	Keterangan	Nama Pos	r	Keterangan
Bantun Kerbo	-0.94	Kuat Negatif	Bantun Kerbo	-0.94	Kuat Negatif
Sidikalang	-0.91	Kuat Negatif	Parmonangan	-0.94	Kuat Negatif
Gunung Tua	-0.90	Kuat Negatif	Sidikalang	-0.92	Kuat Negatif
Parmonangan	-0.89	Kuat Negatif	Gunung Tua	-0.90	Kuat Negatif
Gunung Sayang	-0.86	Kuat Negatif	Gunung Sayang	-0.87	Kuat Negatif
Pintu Pohan Meranti	-0.82	Kuat Negatif	Binaka	-0.84	Kuat Negatif
Binaka	-0.80	Kuat Negatif	Nias Barat	-0.82	Kuat Negatif
Nias Barat	-0.79	Cukup Kuat Negatif	Pintu Pohan Meranti	-0.80	Cukup Kuat Negatif
Siborong-borong	-0.78	Cukup Kuat Negatif	Siborong-borong	-0.76	Cukup Kuat Negatif
Garoga	-0.75	Cukup Kuat Negatif	Garoga	-0.75	Cukup Kuat Negatif
Balimbingan	-0.75	Cukup Kuat Negatif	Pangururan	-0.72	Cukup Kuat Negatif
Pangururan	-0.75	Cukup Kuat Negatif	Tarabintang	-0.70	Cukup Kuat Negatif
Laras Emplasmen	-0.71	Cukup Kuat Negatif	Sidamanik	-0.69	Cukup Kuat Negatif
Tarabintang	-0.71	Cukup Kuat Negatif	Balimbingan	-0.68	Cukup Kuat Negatif
Kebun Batangkuis	-0.69	Cukup Kuat Negatif	Gabe Hutaraja	-0.66	Cukup Kuat Negatif
Sipoltong	-0.69	Cukup Kuat Negatif	Laras Emplasmen	-0.65	Cukup Kuat Negatif
Gabe Hutaraja	-0.68	Cukup Kuat Negatif	Kebun Batangkuis	-0.65	Cukup Kuat Negatif
Sidamanik	-0.68	Cukup Kuat Negatif	Muara	-0.64	Cukup Kuat Negatif
Balangka Sitongkon	-0.65	Cukup Kuat Negatif	Pancur Batu	0.79	Cukup Kuat Positif
Binanga	-0.64	Cukup Kuat Negatif	Tanjung Gorbus	0.61	Cukup Kuat Positif
Muara	-0.62	Cukup Kuat Negatif			
Simangumban	-0.62	Cukup Kuat Negatif			
Pancur Batu	0.79	Cukup Kuat Positif			

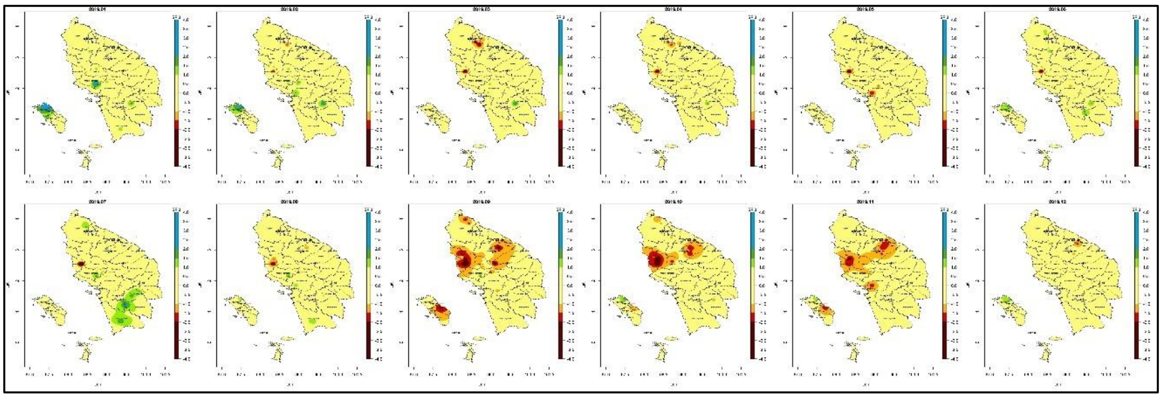

Figure 14. Map of SPI in 2019 North Sumatra region

Spatial pattern of SPI index in general are shows the North Sumatra region in 2019 was in the normal category (Figure 14), the characteristics of SPI drought at the time of the IOD + event which began in Mei to December, as many as 10.3% experienced drought levels with moderately dry category, severely dry categories as much as 6.9% and extremely dry categories as much as 4.3%, there were several areas that experienced moderately wet drought level of 7.6%, very wet category is 2.6% and extremely wet category 0.6%.

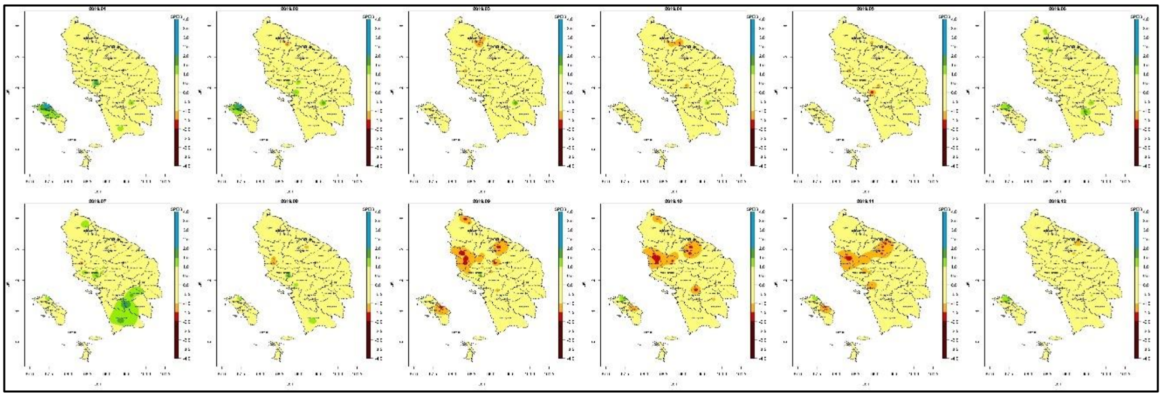

Figure 15. Map of SPEI in 2019 North Sumatera region

SPEI index in general the North Sumatra region in 2015 was in the normal category (Figure 15), the SPEI drought characteristics showed that 13.8% experienced drought levels with moderately dry category, severely dry category of 8.8% and a extremely dry category of 0.9%, there were several areas that experienced moderately wet drought level of 8.8%, very wet category of 2.6% and extremely wet category 0.6%.

SPI and SPEI Temporal Index Analysis

In general, the SPI and SPEI drought indices show a similar pattern, in 2015 when *El Niño* with a strong category occurred in April to December, showing some areas experiencing moderately dry to extremely dry categories.

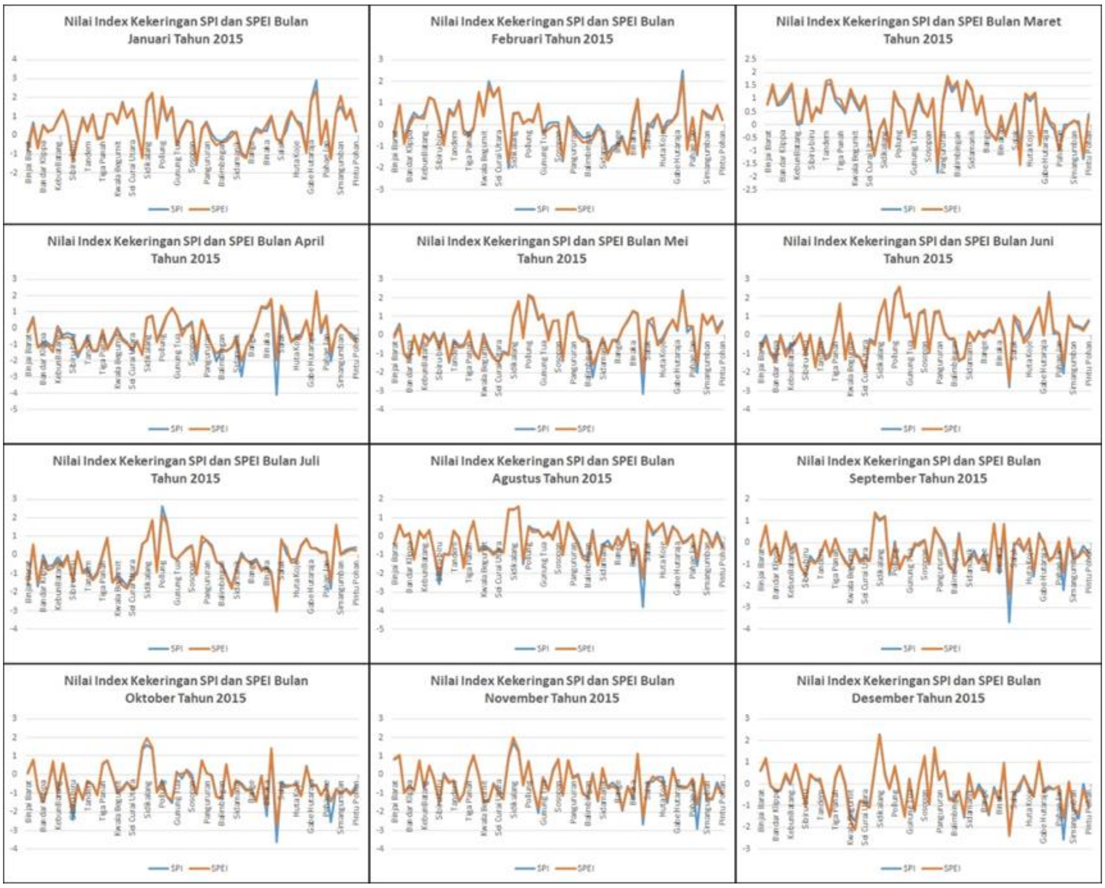

Figure 16. Monthly SPI and SPEI drought index values in 2015

Based on Figure 16 at the time of the drought, the SPI index shows a higher value than the SPEI index, meaning that the SPI shows a more extreme drought than the SPEI. However, in posts that experience wetness, the SPEI index tends to show a higher value than SPI. The rain posts Parmonangan and Sogawu showed the longest drought during *the El Niño* event of 2015. The index values of both headings can be seen in Figure 17 below.

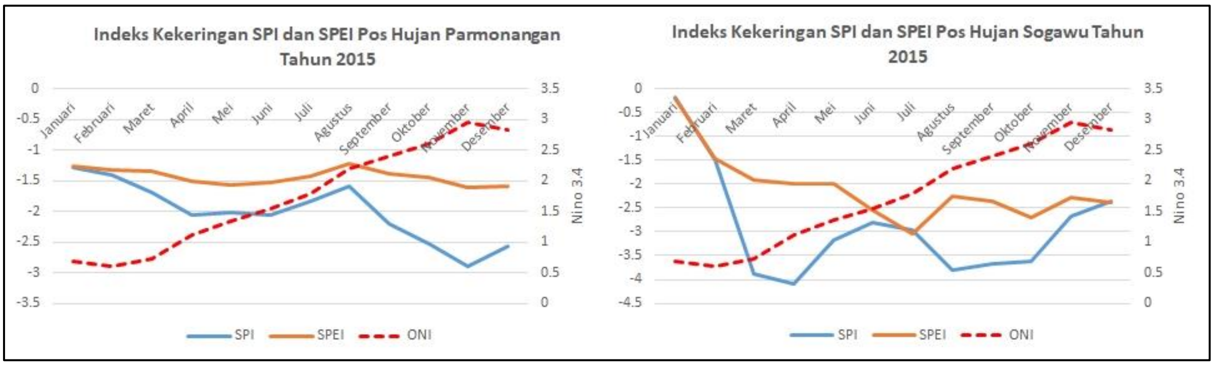

Figure 17. SPI and SPEI Sogawu and Parmonangan Value in 2015

Based on Figure 17, the SPI and SPEI index values in the Parmonangan rain post experienced drought from January to December, this is in line with the Nino index 3.4 which shows an increase in anomalous values up to 2.95°C. El Niño that occurs from April to December shows that the SPI index represents a more extreme level of drought with extremely dry category for most of the El Niño than the SPEI index which is in the moderately dry to severely dry category. The SPI and SPEI values in 2015 can be seen in Table 4.17 below.

Table 8. SPI and SPEI values of Parmonangan rain post in 2015

Bulan	SPI	Keterangan	SPEI	Keterangan
Januari	-1.28	Agak Kering	-1.27	Agak Kering
Februari	-1.41	Agak Kering	-1.31	Agak Kering
Maret	-1.69	Kering	-1.34	Agak Kering
April	-2.05	Sangat Kering	-1.52	Kering
Mei	-2.01	Sangat Kering	-1.57	Kering
Juni	-2.05	Sangat Kering	-1.54	Kering
Juli	-1.83	Kering	-1.41	Agak Kering
Agustus	-1.59	Kering	-1.21	Agak Kering
September	-2.20	Sangat Kering	-1.39	Agak Kering
Oktober	-2.54	Sangat Kering	-1.45	Agak Kering
November	-2.90	Sangat Kering	-1.60	Agak Kering
Desember	-2.57	Sangat Kering	-1.59	Agak Kering

Analysis of the influence of climate phenomena on rice productivity.

Sea level temperature anomalies result in fluctuations in climatic elements such as rainfall. The occurrence *of El Niño, La Niña*, positive IOD (+), and negative IOD (-) is an interaction between the atmosphere and sea level temperature that has an impact on rainfall intensity, rain nature and season length and indirectly impacts the productivity of food crops. El Niño *and IOD+* events have an impact on reducing rainfall, rice crop productivity during the El Niño event in 2015 in each district in North Sumatra Province shows varying values. The decrease in rice crop productivity dominates more than the increase. As many as 62.5% of 32 districts experienced a decrease in productivity against the average value.

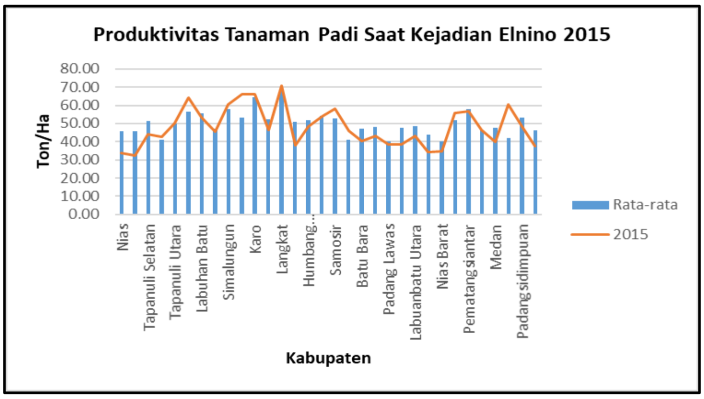

Figure 16. Productivity of rice crops against average in 2015

In figure 16, it can be seen that the El Niño event can affect the decline in rice crop productivity, as in 2015, the largest decrease in rice crop productivity occurred in Mandailing Natal district with a decrease value of 13.15 tons / ha. In addition, there are also areas that have increased production, namely Central Tapanuli, North Tapanuli, Toba Samosir, Simalungun, Dairi, Karo, Langkat, Samosir, Serdang Bedagai, Tanjung Balai, Tebing Tinggi, Binjai. The largest increase in productivity occurred in Binjai district with an increase value of 18.47 tons / ha. Meanwhile, during the IOD + event which had an impact on reducing rainfall, it also affected the decline in rice crop productivity in 2019 but in contrast to the El Niño event, the increase in rice crop productivity when IOD + dominated more than the decrease.

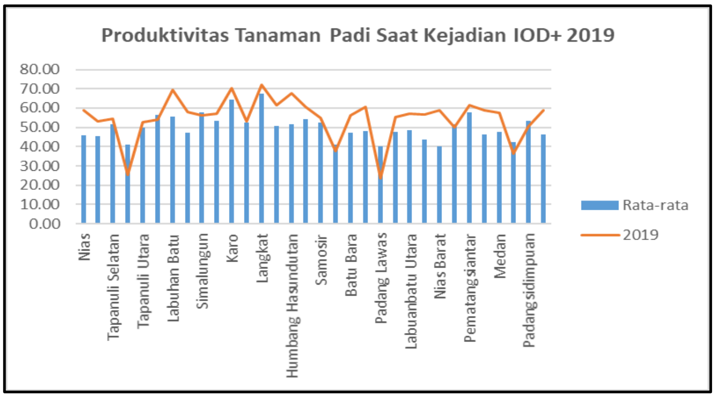

Figure 17. Productivity of rice crops against average in 2019

In figure 17, it can be seen that the decline in rice crop productivity at the time of the IOD + event in 2019 was greatest in Padang Lawas district with a decrease value of 16.5 tons / ha.

CONCLUSION

Based on the results and discussions that have been carried out, it is concluded that in general the climate phenomenon that affects drought in the North Sumatra region is at the time of the ENSO event, which is seen from the calculation of the correlation between the SPI and SPEI indices which shows a strong negative relationship with a correlation value of -0.85 to -0.97. Spatial pattern of the drought characteristics of SPI and SPEI show similar results, which are dominant in the normal category. Temporally the SPI index shows more extreme results during drought compared to SPEI. At the time of the strong El Niño incident in 2015, as many as 62.5% of 32 districts in North Sumatra experienced a decrease in rice crop productivity from the average value and the largest decrease in rice crop productivity occurred in Mandailing Natal district with a decrease value of 13.15 tons / ha.

RECOMMENDATION

There is a need to increase the distribution of meteorological observation stations as well as increase the quality and quantity of data to create the SPI and SPEI indices. It is necessary to conduct a field verification study on the distribution of drought impacts produced by the two indices so that they can reflect actual drought conditions. Further studies need to be carried out regarding other phenomena that influence drought in North Sumatra

REFERENCES

Blauhut, V., Gudmundsson, L., & Stahl, K. (2015). Towards pan-European drought risk maps: Quantifying the link between drought indices and reported drought impacts. Environmental Research Letters, 10(1). https://doi.org/10.1088/1748-9326/10/1/014008

Faisol, A., &; Budiyono. (2022). Comparison between Standardized Precipitation Index (SPI) Method and Standardized Precipitation Evapotranspiration Index (SPEI) for Meteorological Drought Identification in West Papua Province Comparison between Standardized Precipitation Index (SPI. Agritechnology, 5(2).

Hermawan, E., Satyawardhana, H., Witono, A., Berliana, S., & Rustiana, S. (2016). Status Terkini Prediksi Curah Hujan MK 2016 dan MH 2016/2017 (Studi Kasus: DI Yogyakarta). Prosiding Seminar Nasional Geografi UMS 2016, Imc, 9–24. https://publikasiilmiah.ums.ac.id/xmlui/handle/11617/8202

Jun-Ichi, H., Mori, S., Kubota, H., Yamanaka, M. D., Haryoko, U., Lestari, S., Sulistyowati, R., & Syamsudin, F. (2012). Interannual rainfall variability over northwestern Jawa and its relation to the Indian Ocean Dipole and El Niño-Southern Oscillation events. Scientific Online Letters on the Atmosphere, 8(1), 69–72. https://doi.org/10.2151/sola.2012-018

Li, S., Wang, X., Gao, C., & Ye, X. (2019). Meteorological Drought Warning Research in Fujian Province, China during 1971-2016. Journal of Geoscience and Environment Protection, 07(11), 220–228. https://doi.org/10.4236/gep.2019.711016

Lia, R. Y., I Nyoman, S., &; Ismail, Y. (2022). The relationship of drought events with the El-Nino phenomenon in the North Lombok Regency area. Scientific Journal of Agrocomplex Students, 1(3), 285–293. https://doi.org/10.29303/jima.v1i3.2147

McKee, T. B., Doesken, N. J., & Kleist, J. (1993). THE RELATIONSHIP OF DROUGHT FREQUENCY AND DURATION TO TIME SCALES. Eighth Conference on Applied Climatology, 17-22 January 1993, Anaheim, California.

Monteith J. (1965). Evaporation and Environment. Symposia of the Society for Experimental Biology, 19(2393175), 205–234.

Muharsyah, R. (2016). THE DROUGHT STUDY USED THE STANDARD PRECIPITATION INDEX IN INDONESIA AND ITS RELATIONSHIP WITH THE INCIDENCE OF EL NINO 1997-1998. MegaScience Bulletin on Meteorology, Climatology, Air Quality, Geophysics and the Environment, 6(August), 129–140.

Musei, S. K., Nyaga, J. M., & Dubow, A. Z. (2021). SPEI-based spatial and temporal evaluation of drought in Somalia. Journal of Arid Environments, 184(March 2020), 104296. https://doi.org/10.1016/j.jaridenv.2020.104296

Narulita, I., Rahayu, R., Kusratmoko, E., &; Muhamad, Rd. (2019). Threat of Meteorological Drought on Tropical Small Islands caused by El-Nino and Positive Indian Ocean Dipole (IOD), case study: Bintan Island Threat of Meteorological Drought on Tropical Small Islands caused by El-Nino and Positive Indian Ocean Dipole (I. Journal of Environment and Geological Hazards, 10(3), 127–138. http://jlbg.geologi.esdm.go.id/index.php/jlbg

Son, R. M., Alfiandy, S., &; Haq, B. E. A. (2020). El Nino Southern Oscillation (Enso), Indian Ocean Dipole (IOD), and Madden Julian Oscillation (Mjo) on monthly rainfall intensity in Indonesia. Ngurah Rai Bulletin, September, 1.

Stagge, J. H., Tallaksen, L. M., Gudmundsson, L., Van Loon, A. F., & Stahl, K. (2015). Candidate Distributions for Climatological Drought Indices (SPI and SPEI). International Journal of Climatology, 35(13), 4027–4040. https://doi.org/10.1002/joc.4267

Sutarja, I. N., Norken, I. N., Dibia, I. N., &; Pratama, I. K. (2013). Academic Review of Drought Risk Master Plan. Proceedings of the National Seminar on Disaster Research, 2015–2019.

Svoboda, M., Michael, H., & Wood, D. A. (2012). Standardized Precipitation Index User Guide (WMO-No.1090). In World Meteorological Organization.

an Loon, A. F., Stahl, K., Di Baldassarre, G., Clark, J., Rangecroft, S., Wanders, N., Gleeson, T., Van Dijk, A. I. J. M., Tallaksen, L. M., Hannaford, J., Uijlenhoet, R., Teuling, A. J., Hannah, D. M., Sheffield, J., Svoboda, M., Verbeiren, B., Wagener, T., & Van Lanen, H. A. J. (2016). Drought in a human-modified world: Reframing drought definitions, understanding, and analysis approaches. Hydrology and Earth System Sciences, 20(9), 3631–3650. https://doi.org/10.5194/hess-20-3631-2016

Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010). A multiscalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index. Journal of Climate, 23(7), 1696–1718. https://doi.org/10.1175/2009JCLI2909.1

Wong, G., van Lanen, H. A. J., & Torfs, P. J. J. F. (2013). Probabilistic analysis of hydrological drought characteristics using meteorological drought. Hydrological Sciences Journal, 58(2), 253–270. https://doi.org/10.1080/02626667.2012.753147

Xu, C., An, W., Wang, S. Y. S., Yi, L., Ge, J., Nakatsuka, T., Sano, M., & Guo, Z. (2019). Increased drought events in southwest China revealed by tree ring oxygen isotopes and potential role of Indian Ocean Dipole. Science of the Total Environment, 661, 645–653. https://doi.org/10.1016/j.scitotenv.2019.01.186