International Journal of Education, Vocational and Social Science
https://e-journal.citakonsulfindo.or.id/index.php/IJEVSS
E-ISSN : 2963 4954
IJEVSS

Drought Characterization Using The Standardized Precipitation Index (SPI) Method In The Ogan Ilir Region, South Sumatra

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Abstract

Ogan Ilir Regency, South Sumatra, is vulnerable to meteorological drought and land fires due to extreme rainfall variability and the influence of El Niño. This study aims to characterize drought using the Standardized Precipitation Index (SPI) at 1, 3, and 6-month scales for the period 1995-2024, along with spatial mapping and correlation with forest and land fire hotspots. A quantitative approach was applied to monthly rainfall data from the BMKG SMB II Palembang station (360 observations) as a purposive sample. Analysis techniques include SPI calculations based on gamma distribution, WMO classification, GIS interpolation, and statistical correlation. The results show recurrent droughts of moderate to extreme intensity (SPI ≤ -3.0), peaks in July-September, strong correlations with El Niño in 1997, 2015, and 2023, and the highest hotspot in Pemulutan District. SPI is effective as an early indicator for disaster mitigation.

Keywords: Drought Characterization, El Niño, Ogan Ilir, SPI, South Sumatra

INTRODUCTION

Global climate change has increased the frequency and intensity of hydrometeorological disasters in Indonesia, including systemic and prolonged droughts. These droughts not only reduce water availability and agricultural productivity but also trigger forest and land fires (karhutla), particularly in areas with dry vegetation or flammable peatlands (Surmaini, 2016; Pratama et al.,

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2022; Fajri et al., 2023). In South Sumatra, this phenomenon is increasingly felt due to extreme rainfall variability (Hidayat et al., 2021).

Ogan Ilir Regency stands out as a vulnerable area because it is dominated by lowlands with shrubs, peat swamps, and shallow mineral soils that dry out quickly during the dry season. The El Niño phenomenon exacerbates these conditions by extending the dry period, significantly increasing hotspots each year (BNPB, 2020; KLHK, 2022; Syafitri et al., 2024; Nugroho et al., 2023).

The main problem arises from the combination of rainfall deficits with climatological factors such as high temperatures, low humidity, and strong winds, which accelerate land drying. Data from the National Disaster Management Agency (BNPB) and the Ministry of Environment and Forestry (KLHK) consistently ranks Ogan Ilir as the top hotspot in South Sumatra, causing ecosystem damage, transboundary haze pollution, and public health and economic disruptions (Surmaini, 2016; Pratama et al., 2022). The region's dependence on vulnerable peat ecosystems further exacerbates the impact, as the high organic content facilitates the spread of fire (KLHK, 2022; Fajri et al., 2023).

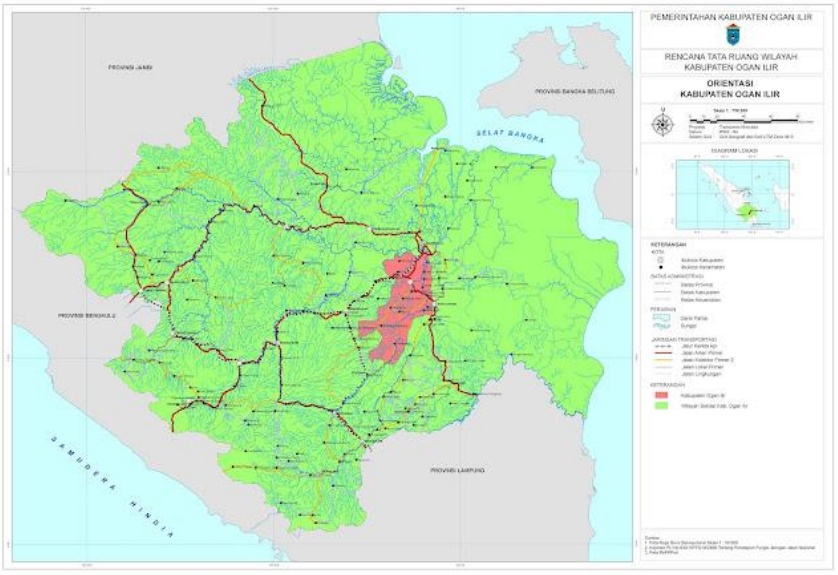
The lack of spatial and temporal analysis of drought hampers effective mitigation planning, despite the availability of rainfall data from the Meteorology, Climatology, and Geophysics Agency (BMKG). Global climate variability, such as ENSO, has not been adequately integrated with local monitoring, resulting in limited early warning systems (Hidayat et al., 2021; Syafitri et al., 2024). Consequently, forest and land fires recur without timely response, placing a burden on regional resources (Nugroho et al., 2023; Sari et al., 2025).

This study aims to characterize meteorological drought in Ogan Ilir using the Standardized Precipitation Index (SPI) at 1-, 3-, and 6-month scales, along with spatial mapping via GIS and correlation with ENSO and forest and land fires. The urgency lies in the need for early indicators for disaster mitigation, sustainable water management, and reduction of socio-economic impacts in vulnerable areas. The novelty of this study is the integration of long-term SPI analysis (1995-2024) with the latest hotspot data, which has not been comprehensively conducted in Ogan Ilir, thus supporting climate-based policies (Syafitri et al., 2024; Nugroho et al., 2023).

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The research location map can be seen in Figure 1 below.



Picture1. Map of Ogan Ilir

(Source :https://bappeda.oganilirkab.go.id/page/peta-kabupaten-ogan-ilir)

METHODOLOGY

Types and Methods of Research

This study uses a quantitative approach using drought index analysis, specifically the Standardized Precipitation Index (SPI), to characterize meteorological drought in Ogan Ilir Regency. This quantitative approach was chosen because it allows objective measurement of rainfall variability through statistical calculations and spatial mapping, in accordance with the principles of numerical data analysis in climate research (Sugiyono, 2021; Creswell & Creswell, 2023; McKee et al., 1993). The SPI is applied at 1-, 3-, and 6-month time scales to represent short- to medium-term drought, with integration of Geographic Information Systems (GIS) for visualization of spatial distribution (KLHK, 2019; BNPB, 2020; Emzir, 2022). This method has proven effective in detecting rainfall anomalies and correlations with phenomena such as ENSO and land fires, as recommended by the World Meteorological Organization (WMO, 2012; Sudaryono, 2024).

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Data Analysis Instruments and Techniques

The main research instrument is secondary monthly rainfall data from the BMKG SMB II Palembang station and Kenten Station for the period 1995–2024, which meets the 30-year climatology standard for long-term analysis accuracy. The analysis technique includes fitting the data with a gamma distribution for transformation to a standard normal distribution, using the formula SPI = $(X - \bar{X})/\sigma$, where X is the rainfall for a given period, $\bar{X}$ the long-term average, and σ the standard deviation (McKee et al., 1993; Sugiyono, 2021; Creswell & Creswell, 2023). Drought classification follows WMO standards with categories such as very dry (SPI ≤ -2.00) to very wet (SPI ≥ 2.00), equipped with GIS spatial interpolation and correlation with ENSO hotspot data (WMO, 2012; Emzir, 2022; Sudaryono, 2024; KLHK, 2022).

Population and Sample

The study population comprised all monthly rainfall data in Ogan Ilir Regency, South Sumatra Province, which is prone to drought and forest and land fires due to the dominance of peatlands. The sample was taken from secondary data from the BMKG SMB II Palembang station for the period 1995–2024 (360 monthly observations), selected for its geographic representativeness and data quality according to purposive sampling criteria for climatological analysis (BNPB, 2020; Sugiyono, 2021; Creswell & Creswell, 2023). This 30-year period ensures the representation of long-term patterns, including the influence of El Niño, with spatial coverage of sub-districts such as Pemulutan and Indralaya, which show variations in vulnerability (KLHK, 2019; Emzir, 2022; Sudaryono, 2024).

Research Procedures

The procedure begins with the collection of rainfall data from the Meteorology, Climatology, and Geophysics Agency (BMKG), followed by data cleaning and normalization to calculate gamma distribution parameters. Next, SPI calculations are performed at 1-, 3-, and 6-month scales using statistical software, followed by drought classification and spatial mapping via GIS to identify vulnerable areas. The final analysis includes correlation of SPI with ENSO data and forest and land fire hotspots, validated through statistical tests to ensure reliability (McKee et al., 1993; WMO, 2012; Sugiyono, 2021; Creswell & Creswell, 2023). This process follows a systematic flow from data description to interpretation, with cross-validation against BNPB and KLHK reports to support disaster mitigation (BNPB, 2020; KLHK, 2022; Emzir, 2022; Sudaryono, 2024).

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RESULTS AND DISCUSSION

General Description of the Area and Research Data

This research was conducted in Ogan Ilir Regency, South Sumatra Province, with an area of approximately 2,666 km². Topographically, Ogan Ilir has a relatively flat landscape and is dominated by peat, swamp, and shallow mineral soils that are highly susceptible to drying out during the long dry season (KLHK, 2019). This condition makes this region one of the areas with the highest land fire rates in South Sumatra Province (BNPB, 2020). According to the BNPB report (2020), the Ogan Ilir region experiences significant land fires almost every year, especially during extreme climate phenomena such as El Niño. This demonstrates the importance of drought analysis to support fire risk mitigation efforts in the region.

Rainfall Data Analysis

This research usesmonthly rainfall data for the period 1995–2024obtained from BMKG Kenten Station and SMB II Palembang. The 30-year period was chosen following the climatological analysis standards recommended by the World Meteorological Organization (WMO, 2012), because long duration is important for understanding climate variations and long-term trends (WMO, 2012). Based on the results of data compilation, the average annual rainfall in Ogan Ilir Regency ranges from 1,800–3,500 mm per year. Research and data calculations have been carried out, obtaining the average rainfall for 30 years starting from 1995-2024, the results are obtained in the following graph:

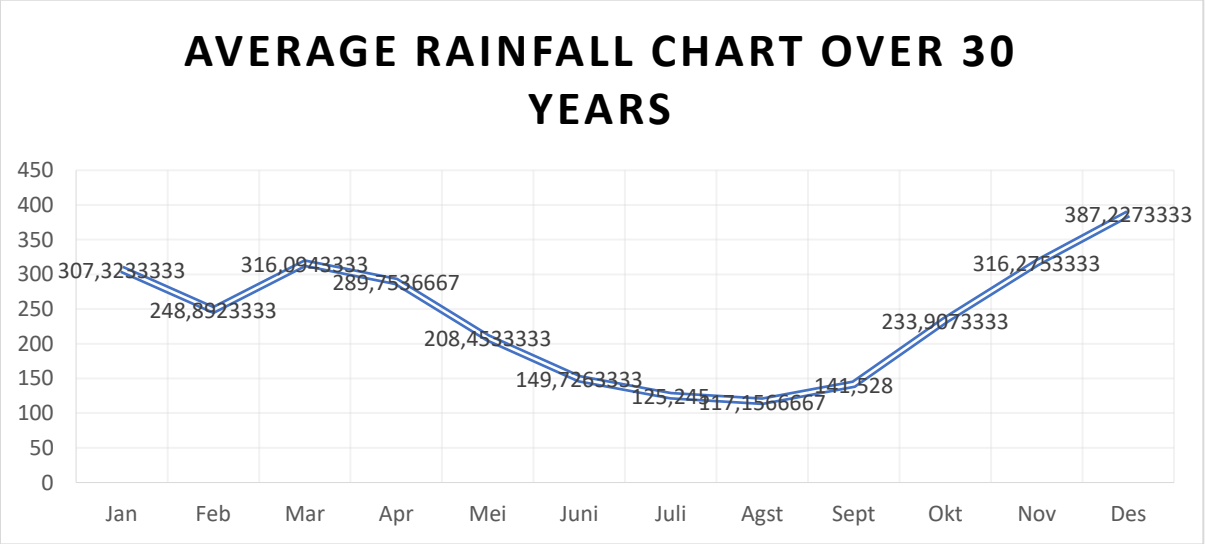


Figure 2. Average rainfall

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Based on Figure 2, significant fluctuations are seen, suspected to be closely related to the global El Niño–Southern Oscillation (ENSO) phenomenon over the past 30 years. Strong El Niño years such as 1997, 2015, and 2019 recorded decreased rainfall compared to the normal average (Aldrian & Susanto, 2003; McPhaden et al., 2006). Conversely, La Niña years such as 2010 and 2016 recorded a significant increase in rainfall, which is in accordance with the general pattern of ENSO impacts in Indonesia (NOAA, 2023). To provide a quantitative overview of the distribution of rainfall data, Figure 4.1 presents descriptive statistics, including the average value, as well as the minimum and maximum values. From this analysis, it can be seen that the standard deviation is relatively high (around 140–380 mm), reflecting significant variability between years (BMKG, 2023).

This is important to note because high levels of variability can increase the uncertainty of climate predictions, which needs to be considered in drought risk analysis (Wilhite & Pulwarty, 2005). Furthermore, seasonal patterns are also analyzed using monthly data. The rainy season generally occurs in December–March with a monthly average of more than 250 mm, while the dry season predominantly occurs in July–September with a monthly average below 150 mm (BMKG, 2023). Figure 4.1 can be displayed to visualize this seasonal pattern. This pattern reflects the characteristics of the monsoon climate in southern Indonesia, where the shifting west and east monsoon winds affect rainfall distribution (Aldrian & Susanto, 2003).

The analysis also shows that there isinhomogeneity of spatial distribution of rainfall between sub-districts in Ogan Ilir Regency. For example, Pemulutan Sub-district has a lower average annual rainfall than Indralaya Sub-district. This is thought to be due to variations in topography, proximity to large rivers, and peatland cover, which influence local humidity (Susilowati et al., 2018). These local factors are important because they can make some sub-districts more susceptible to drought than others (Vicente-Serrano et al., 2010). The findings from this rainfall data analysis provide an important basis for interpreting the SPI in the following sub-section. The SPI, as a meteorological drought index, is highly dependent on the stability of monthly rainfall distribution; therefore, understanding seasonal patterns, annual variability, and spatial distribution is crucial to ensuring accurate and relevant SPI results as an early drought detection tool (McKee et al., 1993; WMO, 2012).

This study uses monthly rainfall data for the period 1995–2024 obtained from the BMKG Kenten Station and SMB II Palembang. The data cover a 30-year observation period, in accordance with climatological analysis standards (WMO, 2012). Figure 4.1 displays a graph of annual rainfall variations, indicating year-to-year fluctuation trends. In addition to the graph, Table 4.1 contains

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descriptive statistics (mean, median, standard deviation, minimum, and maximum) of rainfall per station, to provide a quantitative overview of data distribution. Variations in the rainy and dry seasons are also analyzed, with the rainy season dominant in December–March and the dry season in July–September (BMKG, 2023). These findings are important as a basis for interpreting the SPI.

SPI Calculation Results and Trends (1995–2024)

Calculations of the Standardized Precipitation Index (SPI) for the period 1995–2024 show that Ogan Ilir Regency has experienced significant drought fluctuations over the past three decades. The results for SPI-1, SPI-2, and SPI-3 over the past 30 years were then graphed as follows.

Based on the results of the 1-month SPI calculation (SPI-1), the following results were obtained:

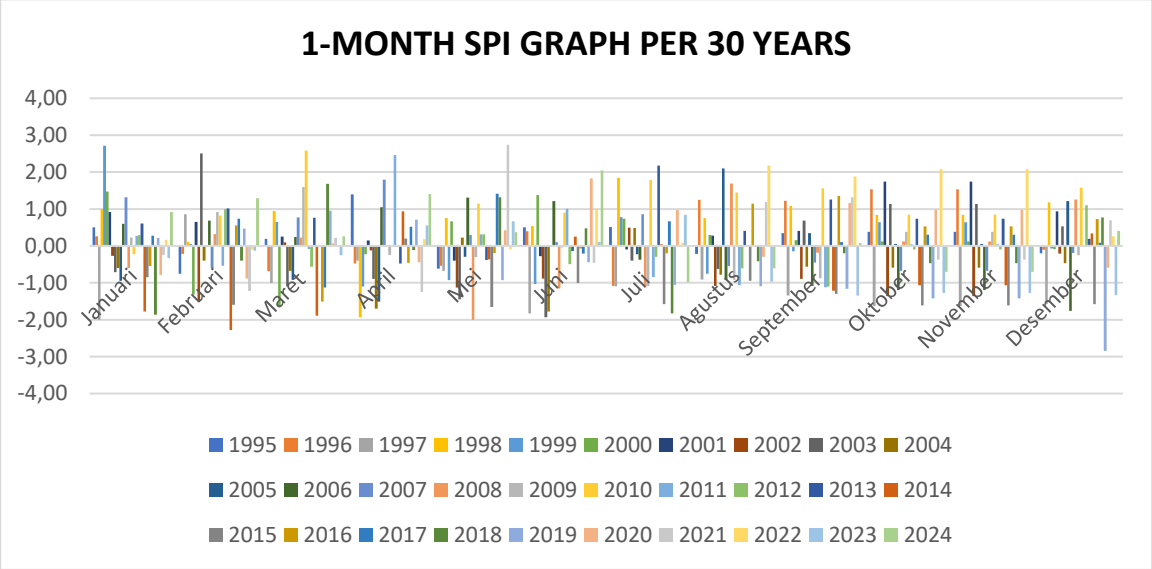


Figure 3. 1-month graph of the 30-year SPI

Based on Figure 3, the 1-month SPI graph over a 30-year period illustrates the dynamics of rainfall anomalies that occur very quickly and fluctuate sharply between months. The 1-month SPI index is used to detect short-term hydrometeorological conditions, so extreme changes in values on the graph reflect a direct response to monthly rainfall variations. SPI values below zero indicate dry conditions, while values above zero indicate wet conditions, with the intensity of events increasing as the absolute value of the SPI increases.

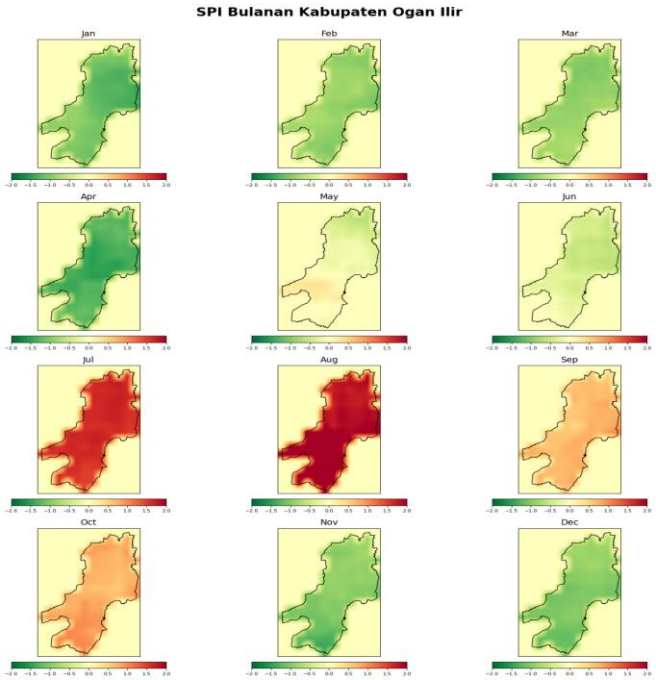
From the graphical observations, the most extreme drought event is indicated by the

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lowest SPI value, reaching around -3.0. This value appears to be dominant in 2023, especially in several months in the latter half of the year. This SPI value falls into the extreme dry category, indicating a significant monthly rainfall deficit. Meanwhile, the highest wetness condition is indicated by the maximum SPI value reaching around +3.0, which was seen in 2015. During this period, several months experienced rainfall far exceeding the climatological normal value, thus categorizing it as an extreme wet condition. This event has the potential to cause hydrological impacts in the form of waterlogging, high surface runoff, and the risk of flooding, especially in areas with limited soil infiltration capacity.

Spatial Map of Drought Based on SPI

The results of spatial analysis using the interpolation method indicate that the distribution of drought in Ogan Ilir Regency is uneven and tends to form a consistent spatial map from year to year. This approach allows the study to visualize areas with the highest drought risk based on the SPI calculations at specific time scales. As shown in the figure.Figure 1 and Figure 2 from January to December show the results of the SPI map for the last 30 years. As follows:



DISCUSSION

Meteorological drought analysis based on the Standardized Precipitation Index (SPI) on a

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1-month scale (SPI-1) for the period 1995–2024 shows that Ogan Ilir Regency has very high rainfall variability on a monthly time scale. Rainfall data over 30 years shows an average annual rainfall ranging from 1,800–3,500 mm with a relatively large standard deviation value of around 140–380 mm. This high variation reflects sharp rainfall fluctuations between months and between years, making SPI-1 a highly relevant indicator in detecting short-term rainfall anomalies that have the potential to quickly trigger meteorological drought.

The monthly SPI-1 calculations show a very extreme range of values, ranging from approximately −3.0 to +3.0 during the observation period. Negative SPI-1 values indicate dry conditions, while positive values reflect wet conditions. The most extreme drought was identified in 2023, when SPI-1 values reached approximately −3.0 in several months in the latter half of the year. This value falls into the extreme dry category, indicating a significant monthly rainfall deficit compared to normal climatological conditions. This condition has the potential to cause serious environmental impacts, particularly peatland drying and an increased risk of land fires in the Ogan Ilir region.

In contrast, extreme wet conditions are indicated by a maximum SPI-1 value of approximately +3.0, identified in 2015. This value indicates a significant excess of monthly rainfall, far exceeding the climatological average. This condition has the potential to increase surface runoff and inundation, especially in areas with relatively flat topography and limited soil infiltration capacity. This clear contrast between extreme dry and extreme wet conditions underscores the high level of monthly climate dynamics in Ogan Ilir Regency.

Based on the January–December seasonal cycle, the SPI-1 pattern shows a relatively consistent trend. Early in the year, particularly from January to March, SPI-1 values generally hover in the positive range, reflecting normal to wet conditions and corresponding to the peak of the rainy season. During this phase, rainfall is relatively high, making water deficits rare. Entering the April–June period, SPI-1 values begin to fluctuate toward zero, signaling the transition from the rainy season to the dry season.

The most critical conditions consistently occur between July and September. During these months, SPI-1 values often range from -1.0 to -2.0, even dropping to near -3.0 in some years. This value falls into the dry to very dry category, indicating a significant and rapid monthly rainfall deficit. This monthly drought is particularly dangerous for the Ogan Ilir region because it coincides with the peak of the dry season, when air temperatures are relatively high and peatlands experience intensive drying.

From October to December, SPI-1 values generally show a trend of recovery toward

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normal or slightly wetter conditions as rainfall begins to increase. However, in some extreme years, SPI-1 values remain negative until the end of the year, indicating a delayed onset of the rainy season. This pattern is particularly evident in years with strong El Niño influences, such as 1997–1998, 2015, and 2019, when dry conditions persisted from mid- to late-year periods. Temporally, the 30-year monthly SPI-1 time series shows very rapid changes in conditions from month to month. These sharp fluctuations confirm the rapid onset of meteorological drought in Ogan Ilir Regency, necessitating climate monitoring with monthly resolution. In this context, SPI-1 has proven effective in detecting short-term extreme events that often trigger further drought and land fires, especially when dry conditions occur repeatedly over several consecutive months.

Thus, monthly SPI-1 analysis is a crucial approach for understanding meteorological drought dynamics in Ogan Ilir Regency. SPI-1 information based on rainfall data can be used as an early indicator to support drought mitigation and land fire control efforts, particularly during the critical period of July–September, which consistently exhibits extreme negative SPI values over 30 years of observation.

CONCLUSION

Analysis of the Standardized Precipitation Index (SPI) at 1, 3, and 6-month scales over the period 1995-2024 revealed the main finding that Ogan Ilir Regency experienced recurring meteorological droughts with moderate to extreme intensity, marked by SPI values of up to -3.0, especially in July-September which coincided with the dry season and the influence of El Niño in 1997, 2015, and 2023. Annual rainfall variability of 1,800-3,500 mm with a standard deviation of 140-380 mm strengthens the vulnerability of peatland areas, where spatial distribution shows that districts such as Pemulutan are more vulnerable than Indralaya, as well as a strong correlation between negative SPI periods and an increase in forest and land fire hotspots. SPI has proven effective as an early indicator for rapid detection of drought onset and disaster risk mitigation, supporting sustainable water management in South Sumatra (WMO, 2012; McKee et al., 1993).

However, limitations of this study lie in its reliance on secondary rainfall data from two BMKG stations, which may not fully capture microspatial variations, and the lack of integration of non-climate variables such as human land use. For further research, it is recommended to develop the SPI with the SPEI model that incorporates evapotranspiration data, machine learning-based predictive analysis for ENSO forecasting, and field validation on specific peatlands. Practically, these results are recommended for local governments and BMKG to develop an SPI-based early warning system, optimize irrigation, and proactively prevent forest and land fires to mitigate the

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socio-economic impacts in vulnerable areas.

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