

## Abstract

Drought is a natural phenomenon caused by prolonged periods of insufficient rainfall. The Standardized Precipitation Index (SPI) is one of the key tools for analyzing and monitoring drought conditions across various timescales. This study aims to examine drought conditions at 15 meteorological stations in northern Thailand using SPI over 3, 6, 9, and 12-month timescales. Precipitation data, derived from the Non-Hydrostatic Regional Climate Model (NHRM) under the high greenhouse gas emission scenario Representative Concentration Pathway 8.5 (RCP8.5), was applied to estimate SPI. A comparative analysis of drought characteristics, including intensity and frequency, was conducted between a baseline period (1980–2000) and a future period (2079–2099). The preliminary results indicated severe and prolonged drought conditions (SPI12 < -2) were found at 9 stations during the baseline period, persisting for 12 consecutive years with SPI12 values ranging from -2.002 to -2.474. Severe drought (SPI12 ranging from -2.001 to -3.561) would affect 12 stations for 19 consecutive years in the future period. This study suggests a future increase in both the frequency and duration of drought in northern Thailand relative to the baseline period.

## Introduction

The Standardized Precipitation Index (SPI) is a tool developed by McKee et al. (1993) to analyze drought conditions based on precipitation levels. It can be applied over various time scales from 1 to 48 months. Generally, precipitation usually follows a Gamma distribution function:

$$G(x) = \int_0^x g(x)dx = \frac{1}{\beta^\alpha \Gamma(\alpha)} \int_0^x t^{\alpha-1} e^{-\frac{t}{\beta}} dt \quad (1)$$

However, since the gamma distribution is not defined for x=0 and precipitation data often include zero values (representing no rainfall), it is necessary to adjust the cumulative distribution function (CDF):

$$H(x) = q + (1 - q)G(x) \quad (2)$$

Where q is calculated as the proportion of non-rainy days (m) relative to the total number of days in the study period (n).

The SPI can be determined using Equations as follows:

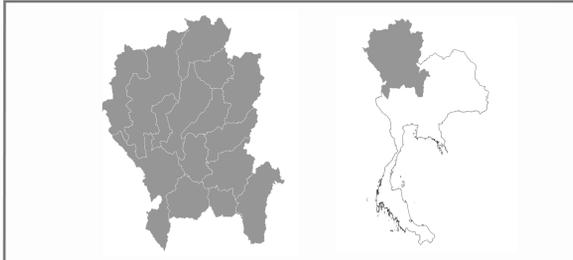
$$SPI = \pm \left( t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \right) \quad (3)$$

where  $t = \sqrt{\ln\left(\frac{1}{H(x)}\right)}$ ;  $0 \leq H(x) \leq 0.5$  and  $t = \sqrt{\ln\left(\frac{1}{1-H(x)}\right)}$ ;  $0.5 \leq H(x) \leq 1$

Table 1. Drought category according to SPI

Extreme drought	< -2
Severe drought	-1.50 to -1.99
Moderate drought	-1.00 to -1.49
Near normal	-0.99 to 0.99
Moderate wet	1.00 to 1.49
Severe wet	1.50 to 1.99
Extreme wet	> 2

Figure 1. Geographical location of the northern Thailand.



## Methodology

The NHRM precipitation data were extracted for 15 meteorological stations in Northern Thailand using the nearest grid point method, both for the baseline and the future period. Figure 1 shows the locations of the 15 selected stations: Chiang Rai, Mae Hong Son, Chiang Mai, Lamphun, Lamphang, Phayao, Phrae, Nan, Uttaradit, Sukhothai, Tak, Kamphaeng Phet, Phitsanulok, Phichit, and Phetchabun. In this study, the Standardized Precipitation Index (SPI) was used to analyze the drought conditions at each station over a period of 3, 6, 9, and 12 months to show the evolutions from agricultural to hydrological drought. The drought frequency at each weather station (i) is defined as the percentage of months within the study period that are characterized by drought conditions, calculated as the ratio of months affected by drought to the total number of months.

$$P_i = \frac{n}{N} \times 100\% \quad (4)$$

Where n is the number of months in which SPI < -1 or SPI < -2 was observed and N is total number of months.

## Results and discussion

### Temporal Analysis

Figure 2 shows the analysis of SPI values over different time periods, including SPI3, SPI6, SPI9, and SPI12 for the Sukhothai meteorological station. From the analysis of SPI12 results, red bars indicate drought conditions and blue bars indicate wet conditions. During the baseline period, the red and blue bars are balanced, indicating no significant extreme drought events (SPI12 < -2). However, in the future period, SPI12 values continuously decrease from 2086 to 2090, with red bars becoming longer and more frequent, indicating more severe droughts and prolonged droughts. While blue bars have decreased in length and frequency. Analysis of 15 stations revealed increased extreme drought conditions, with Sukhothai demonstrating a significant decline in moisture index values and a notable increase in drought frequency percentages.

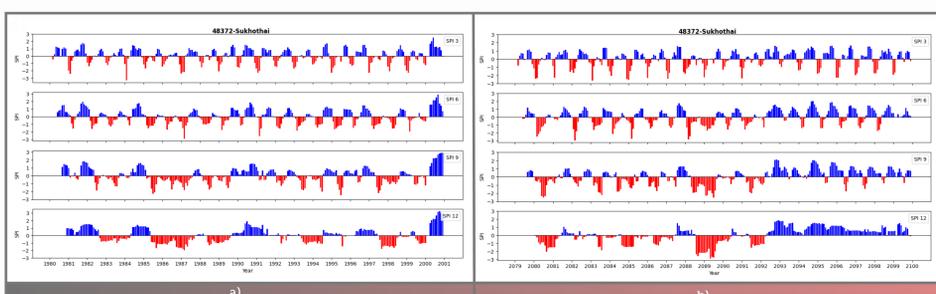


Figure 2. SPI3, SPI6, SPI9 and SPI12 at Sukhothai during baseline period (1980–2000) and future projection (2079–2099), a) Baseline period b) Future period.

## Results and discussion

### Temporal Analysis

Figure 3 shows the percentage of drought frequency based on SPI12 < -2 across all stations, both in the baseline period and future period. The analysis highlights a significant increase in extreme drought probability at the Sukhothai meteorological station. Analysis of the baseline period revealed no occurrences of SPI12 values below -2, indicating no extreme drought conditions. The station's lowest SPI12 value during the future period was -2.8729, with a 5.42% frequency.

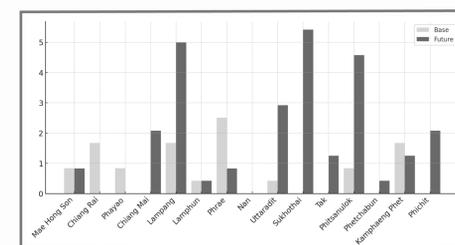


Figure 3. Comparison of Drought Frequency (%) based on SPI12 < -2 during baseline period (1980–2000) and future projection (2079–2099).

### Spatial Analysis

Figure 4 presents a comparison of drought frequency percentages between baseline periods and future periods, analyzed on both annual (SPI12 < -1) and seasonal (SPI3 < -1) scales. Drought probabilities, calculated using Equation (4), were interpolated by the Inverse Distance Weighted (IDW) method. Increase in drought probability, rising from 11.30% to 22.50% at Mae Hong Son. The double rise suggests a heightened vulnerability to severe drought conditions in the future at this station (Figure 4a). Additionally, Phayao, Uttaradit, and Phetchabun also showed increased drought frequency, indicating a wider regional shift towards drier conditions. Twelve meteorological stations showed an increase in drought frequency during winter (Figure 4b). Uttaradit displayed the largest increase, rising from 30.65% to 40.32%. Analysis of the summer season revealed an increasing drought trend at four meteorological stations (Figure 4c). Notably, Sukhothai station showed a near doubling of drought percentage, rising from 6.45% to 12.90%. During the rainy season, an increase in drought frequency was detected at the Tak, rising from 0% to 1.19% (Figure 4d). While this increase is relatively small, it may indicate potential climate shifts, at the station since the rainy season is traditionally associated with the highest precipitation levels.



Figure 4. Spatial distributions of drought frequency on an annual scale (SPI12) and a seasonal scale (SPI3) in Northern Thailand during baseline period (1980–2000) and future projection (2079–2099) a) annual cycle, b) winter, c) summer and d) rainy.

## Conclusion

The analysis of SPI values across different timescales indicates a significant increase in drought frequency and severity in Northern Thailand under future climate projections. While the baseline period exhibits a balance between wet and dry conditions, the future period (2086–2090) shows a continuous decline in SPI12 values, with more frequent and prolonged drought events. Annually, several meteorological stations in Northern Thailand show a significant increase in drought frequency. Seasonally, winter exhibits the highest number of stations with increased drought frequency, with some stations projecting notable changes. Similarly, summer also shows an increased drought frequency, with some locations experiencing nearly double the baseline drought frequency. Rainy season presents only a slight increase in drought frequency at selected stations. This may suggest potential climatic changes that could impact overall rainfall distribution in the future.

## References

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