Assessment of Drought Change in Northeastern Thailand Using the Standardized Precipitation Index (SPI)

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Abstract

Climate change is altering precipitation patterns, resulting in decreased rainfall and, consequently, more prolonged and intense droughts. One technique used to estimate drought conditions is the Standardized Precipitation Index (SPI). This study examines changes in drought conditions in northeastern Thailand using rainfall data from a high-resolution climate model, the Non-Hydrostatic Regional Climate Model (NHRCM), under the high greenhouse gas emissions Representative Concentration Pathway 8.5 (RCP8.5) scenario. In this study, SPI was estimated for the baseline period (1980–2000) and the projected period (2079–2099) across four time intervals: 3, 6, 9, and 12 months, to assess drought conditions. The results from the SPI12 values indicated that the likelihood of drought conditions falling within the normal range (SPI12 values between -0.99 and 0.99) at the 16 meteorological stations in the northeastern region, both during the baseline period and future projections, was between 60% and 70%. The number of stations experiencing drought conditions, ranging from slight to severe (SPI12 values lower than -0.99), is projected to increase from 8 to 10 in future years. This suggests an increased occurrence of drought in the northeastern region in the future.

Introduction

Northeastern Thailand faces increasingly severe droughts each year [1] due to droughts and intermittent rainfall, which affects the economy, especially the agricultural sector. Therefore, the scientific analysis of drought characteristics and changes is essential for minimizing economic and environmental damages. In this study, the analysis was performed using the Standardized Precipitation Index (SPI) with the objective of analyzing the spatial and temporal variations in drought conditions in the region.

The SPI, calculated by fitting rainfall data to a Gamma distribution as defined in Equation (1), quantifies precipitation anomalies to assess drought or heavy rainfall.

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

The Gamma distribution, fundamental to SPI calculation, is undefined for zero precipitation values. Following the Meteorological Department's standard that considers rainfall below 0.1 mm [2] as effectively zero, rainfall amounts below this threshold were substituted with a minimal positive value. This enables the application of the Gamma distribution for SPI determination.

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

Where q is the probability of no rain, which is equal to the number of months with no rain (m) divided by the number of months studied (n), then H(X) is converted to a standard normal value with mean of zero and a variance of 1., and the SPI can be calculated as Equations (3) and (4), and t can be calculated from Equations (5) and (6) depending on the value of H(x):

$$SPI = -\left(t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right);\ 0 \le H(x) \le 0.5 \quad (3)$$

$$SPI = +\left(t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right);\ 0.5 \le H(x) \le 1 \quad (4)$$

$$t = \sqrt{\ln\left(\frac{1}{H(x)^2}\right)};\ 0 \le H(x) \le 0.5 \quad (5)$$

$$t = \sqrt{\ln\left(\frac{1}{1-H(x)^2}\right)};\ 0.5 \le H(x) \le 1 \quad (6)$$

The SPI index can be used to classify drought severity levels as follows:

Level of drought severity	Moderate drought	Near normal	Moderate wet
SPI score	≤ -1.00	-0.99 ถึง 0.99	≥ 1.00

Methodology

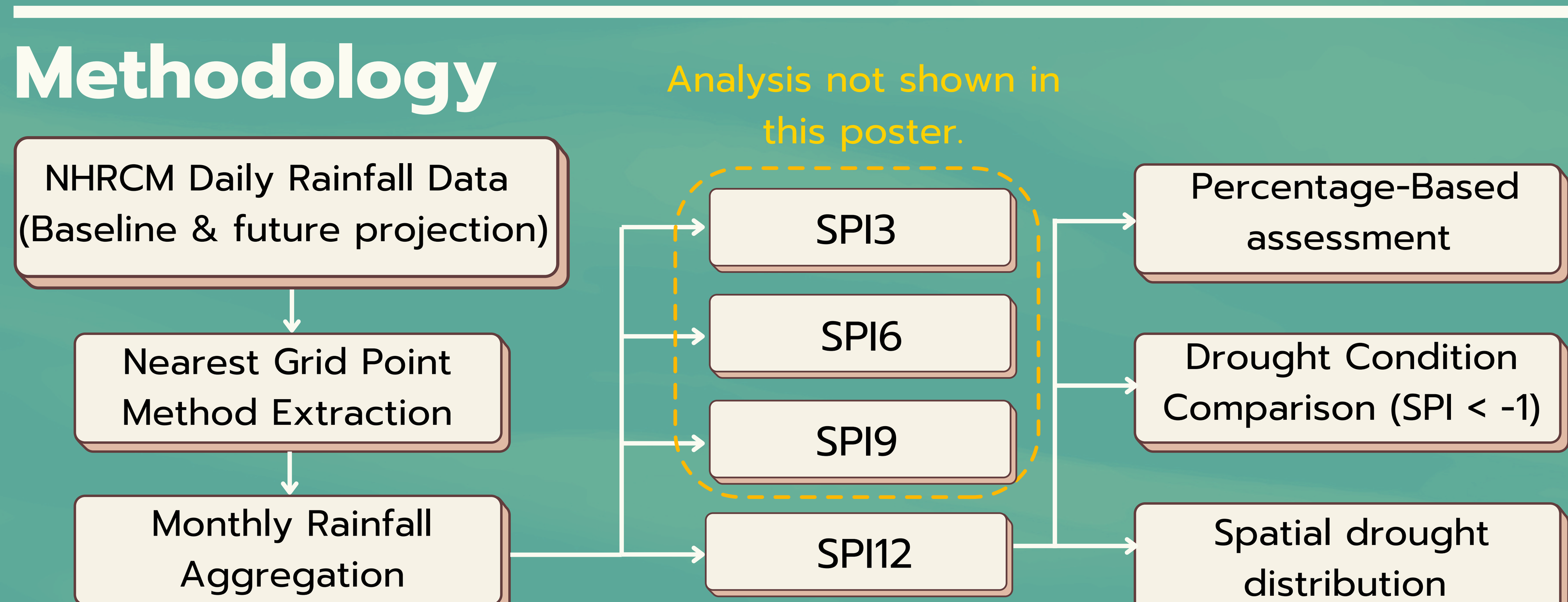

Figure 1. Diagram of the Research Methodology.

Methodology

This study used gridded daily rainfall data from the high-resolution climate model NHRCM for baseline and future projection (1980–2000 and 2079–2099). Data were extracted for 12 meteorological and 4 hydrological stations across 14 northeastern provinces of Thailand (Nong Khai, Loei, Udon Thani, Sakon Nakhon, Nakhon Phanom, Khon Kaen, Mukdahan, Maha Sarakham, Chaiyaphum, Roi Et, Ubon Ratchathani, Nakhon Ratchasima, Surin, and Buriram) using the nearest grid point method. Subsequently, daily rainfall values were aggregated to monthly averages.

The Standardized Precipitation Index (SPI) was then calculated for 3, 6, 9, and 12-month periods to analyze drought conditions at each station. Specifically, the 12-month SPI (SPI12) was further analyzed through: (1) percentage-based assessment of SPI categories, (2) comparative analysis of drought occurrences where SPI values fell below -1, and (3) spatial mapping of drought distribution, ranging from dry to humid conditions. This approach enables a spatial visualization of projected future drought patterns across the study region, as shown in Figure 1.

Results and discussion

The results of the SPI analysis, categorizing drought conditions as near normal (-0.99 ≤ SPI ≤ 0.99), dry (SPI ≤ -1), and wet (SPI ≥ 1) for baseline and future climate projections, are presented in Table 1 for all meteorological and hydrological stations in northeastern Thailand.

Table 1. Percentage of near normal, dry, and wet conditions over baseline and future projections at the stations in northeastern Thailand.

Stations	Pecentage (%)					
	Base			RCP8.5		
	≤-1	-0.99 *to* 0.99	≥1	≤-1	-0.99 *to* 0.99	≥1
	Drought	Near normal	Wet	Drought	Near normal	Wet
Nong Khai	15.06	74.06	10.46	18.33	60.00	21.25
Loei	10.88	73.64	13.39	17.08	64.58	17.92
Udon Thani	16.32	68.20	13.81	16.67	67.50	15.00
Sakon Nakhon	16.32	63.18	18.83	16.67	67.08	15.83
Nakhon Phanom	13.81	72.38	13.39	16.67	68.75	13.75
Khon Kaen	10.46	80.33	8.37	15.83	71.67	12.08
Mukdahan	18.41	64.44	17.15	18.33	64.17	15.83
Kosum Phisai	13.39	74.90	10.88	18.75	65.00	15.83
Chaiyaphum	17.99	64.44	16.74	16.25	67.08	15.83
Roi Et	10.46	76.99	11.30	19.58	65.42	14.58
Ubon Ratchathani	16.32	64.02	19.67	12.50	71.25	16.25
Nakhon Ratchasima	9.62	76.57	12.97	16.25	69.17	14.17
Chok Chai	14.23	69.04	14.64	13.75	69.17	16.67
Surin	14.23	69.87	15.48	17.92	69.58	11.25
Tha Tum	11.72	70.71	17.57	17.50	62.50	18.75
Nang Rong	12.97	72.38	12.55	14.17	67.08	17.92
count	8	-	8	10	-	6

As shown in Table 1, while near-normal precipitation conditions constituted the majority of occurrences, a notable shift was observed in the balance between drought and wet events. Specifically, the number of stations where drought events exceeded wet events increased from 8 during the baseline period to 10 in the future (RCP 8.5) projection.

Analysis of the 16 stations revealed that 12 showed an increase in the percentage of drought conditions under the future projection, suggesting a likelihood of more frequent and widespread droughts compared to the baseline period (Figure 2). For the remaining four stations, an increase in the frequency of near normal precipitation was observed during the projected period. No stations showed an increase in the probability of wetter conditions.

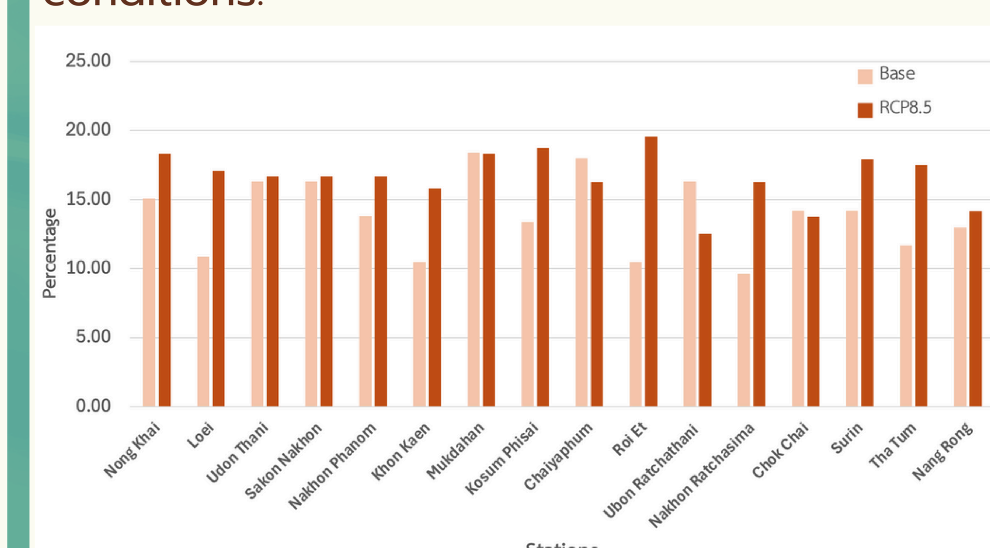

Figure 2. Comparison of the percentage of drought conditions (SPI ≤ -1) between the baseline and future projection (RCP 8.5) at each station.

Analysis of Figure 3 revealed an increase in stations exhibiting a higher frequency of drought events compared to wet events, rising from 8 in the baseline period to 10 in the future projection. The spatial distribution of drought, represented by red areas, showed increased intensity and expansion, particularly in the central and eastern regions. Meanwhile, a reduction in the spatial coverage of blue areas, indicative of wet conditions, was detected, suggesting a potential increase in drought susceptibility across the study area.

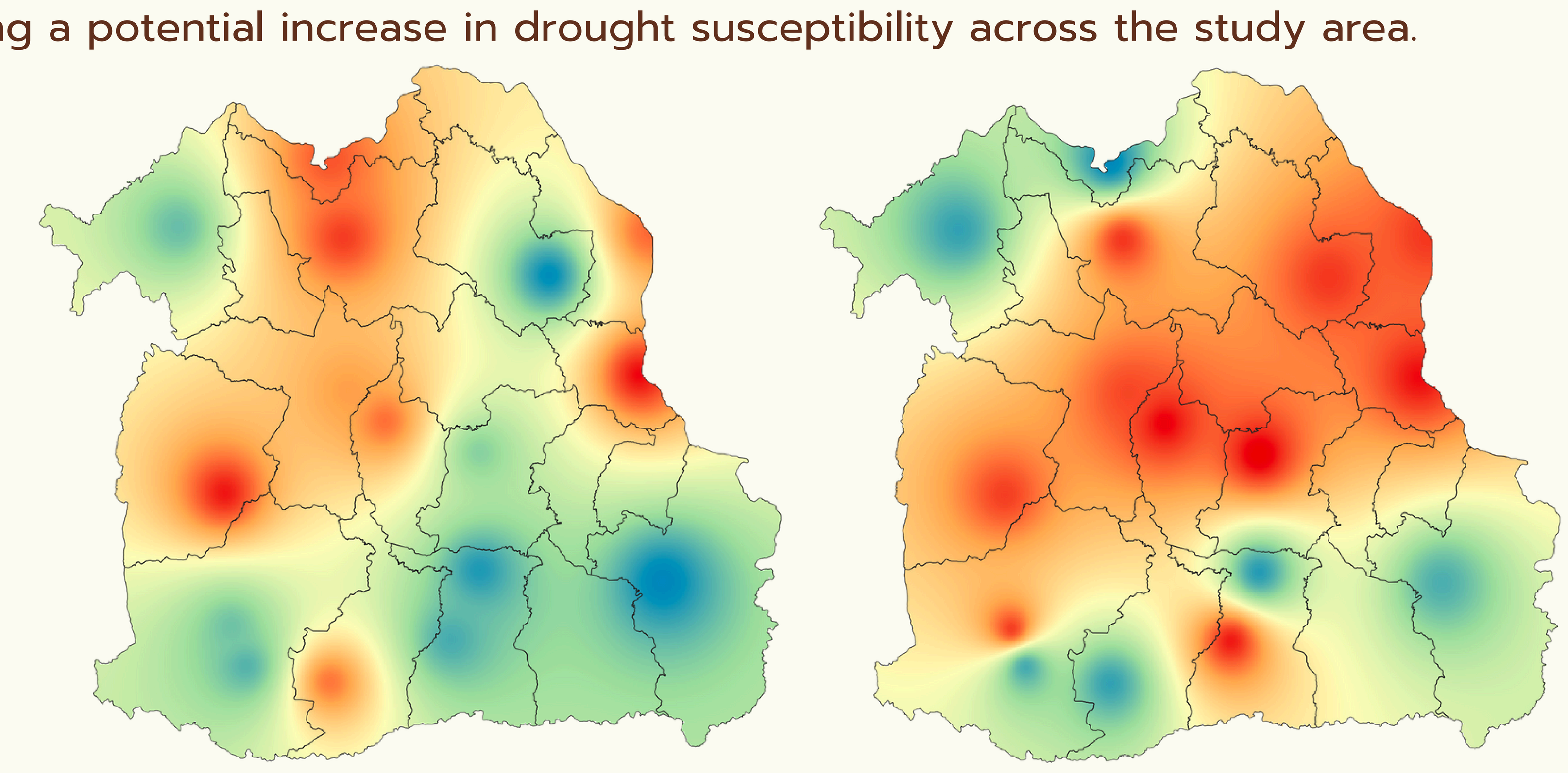

Figure 3. Spatial distribution of drought conditions (ranging from drought to wet) for baseline (left) and projection (right). (Red: drought; blue: wet; darker shades indicate a higher probability of occurrence.)

Conclusion

A comparative analysis between the baseline and future (RCP 8.5) periods indicates an increase in drought conditions. The number of stations exhibited a higher incidence of drought events compared to wet events increased. Moreover, the spatial expansion and intensification of the affected drought region, coupled with a reduction in wet season occurrences, suggest a heightened drought severity in the future.

References

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[2] Thai Meteorological Department, *Meteorological Standards.* Thai Meteorological Department, 2006.
[3] C.C., *Impact of Wind Characteristics and Climate Change on Drought*, The 25th National Convention on Civil Engineering, 2020.