

## METEOROLOGICAL DROUGHT HAZARD ASSESSMENT FOR AGRICULTURE AREA IN EASTERN REGION OF THAILAND

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### Abstract

Drought disasters in the eastern region of Thailand occur more frequently now than in the past. The trend of observed rainfall or precipitation is reducing as a consequence of climate change and global warming. This study investigates the assessment of meteorological drought on rice, field crops and orchard fruits using Standard Precipitation Index (SPI) and observed daily rainfall data (1951-2017) from 16 meteorological stations. The analysis considers the observed daily rainfall delineating into four time steps: 1960s (1951-1970), 1980s (1971-1990), 2000s (1991-2010) and 2020s (2011-2017). The Theory of Runs (ToR) was used to define the drought characteristics such as drought duration (DD), drought event (DE), drought severity (DS) and drought intensity (DI) based on the result from SPI values. The result of drought hazard in May 2015 was categorized into five levels; very low (0.05%); low (12.80%); medium (49.11%); high (29.31%) and very high (8.70%). In a long-term period from 1960s to 2000s, all drought characteristics tend to slightly increase from 1.90 to 2.06 months for drought duration; 54 to 59 events for drought event; -1.31 to -1.50 for drought severity; -0.66 to -0.72 for drought intensity, respectively.

**Keywords:** *Standardized Precipitation Index SPI, Drought Characteristics, Drought Hazard Assessment, Agricultural Crops, Eastern Thailand*

### 1. INTRODUCTION

Drought is a natural disaster event that results in shortage of water supply and tends to increase intensity and frequency in future due to climate change and global warming. The IPCC report [5] shows that the future temperature will be increasing from 1.5°C to 2°C until the twenty-first century creating critical damage on hydrological cycle and ecosystem. The changing of water cycle and meteorological phenomenon has effects on both precipitation and temperature. This has large impact on future flood and drought situations [6]. It affects crop growth and yield [1,2,13]. About 26 billion baht of on-season and off-season agricultural product was lost because of severe drought in 2020 [12]. Thailand is the biggest rice exporter as reported by OAE [11]. Paddy field in 2017 covered about 18% of Thailand area or approximate 9.38 million hectares that yields rice products to 25.24 million tons [2,11]. Field crops and fruits (cassava, maize, sugar cane, pineapple and durian) are also main agricultural products of Thailand. All of crops require a lot of water resources for cultivation. Thus, sustainable water resource management is very important

to organize water supply at local, region and country levels with optimal allocation under the conditions of climate change, urbanization and water availability.

Droughts are slowly occurring and result in longer term damage unlike floods. Previous studies were analyzed on the basis of drought indicators from rainfall, evaporation, soil moisture and water surface volume. Droughts can be classified in sequence of occurrence as meteorological droughts, agricultural droughts and hydrological droughts respectively. The first evidence of droughts can be judged by meteorological conditions. Although there are many meteorological drought indicators, the Standardized Precipitation Index or SPI which is widely used is highly recommended [9]. SPI requires only rainfall data and it provides a reasonable estimate of meteorological drought conditions. The studies suggested to apply SPI to evaluate drought hazard and risk in Asian region [3,8,14]. Tingsanchal and Piriya Wong [14] simulated drought hazard maps in a sub-basin of Thailand using SPI, ground water and available water resources. The result shows that upper and lower Munbon-Lamsae sub-basin has highest hazard level in

2015.

The main objective of this study is to simulate meteorological drought hazard based on past precipitation data. As reported by IPCC in 2018 [5], the impact of climate change and global warming leads to changing on trend of precipitation. Standard Precipitation Index (SPI1, SPI3 and SPI6) is for the analysis in this study. In the eastern region, three main basins (i.e. Bangpakong, Prachin Buri and East Coast) of Thailand, are selected to analyze and simulate meteorological drought situation as its agricultural area is under very high risk and vulnerability due to limited irrigation water supply.

## 2. STUDY AREA AND DATA COLLECTION

### 2.1. STUDY AREA

The eastern region (ER) of Thailand with a total area of 36,502 km<sup>2</sup> is bounded by the Middle and Northeast region of Thailand and the Banthat Mountain Range along the boundary between Thailand and Cambodia. The Bangpakong, Chanthaburi and Welu rivers located in north to south directions discharge into the Gulf of Thailand. This eastern region covers 8 provinces including Chachoengsao, Chanthaburi, Chon Buri, Rayong, Prachin Buri, Sa Kaeo, Trat and Nakhon Nayok. The upper part is dominated by large flat area called Thai Corridor; it is suitable to cultivate rice and field crops (i.e., cassava, corn, sugar cane and pineapple). The middle part is covered by national forest that originates streams and rivers to support fresh water to irrigation area and water supply. The lower part is coastal land with a coastline length of about 574.5 km. The major economic developments in the eastern regions are industries and fruits agriculture (e.g., durian, rambutan and mangosteen). Recently, Eastern Economic Corridor project (EEC) plans to develop three provinces namely Chachoengsao, Chon Buri and Rayong to be the main economic region of Thailand. The majority of land use types of ER are agricultural area about 68%, forest 17%, build-up 10% and water body 5%. ER has a tropical climate with three different seasons including: summer (Feb.-Apr.), rainy (May-Sep.) and winter (Oct.-Jan.). The average annual rainfall is 2,085.7 mm. High temperature during in May to October can exceed 40° C. The average annual evaporation rate is 1,512.5 mm.

### 2.2. DATA COLLECTION

Data used in this study is observed daily precipitation gathered from Thailand Meteorological Department of 16 weather stations. The observed precipitation data were

classified into four time steps: 1960s (1951-1970), 1980s (1971-1990), 2000s (1991-2010) and 2020s (2011-2017).

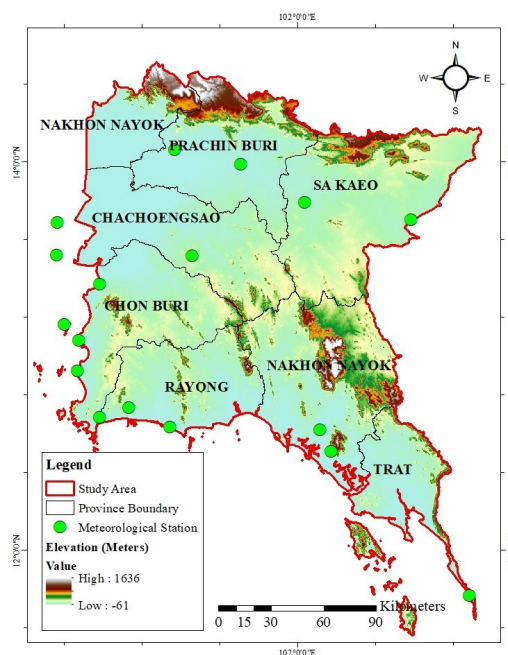


Figure 1 The Study Area in Eastern Region of Thailand

## 3. METHODOLOGY

The methodology of this study can be separated into two steps which are: 1) calculation of the Standardized Precipitation Index (SPI) [9] and 2) the application of the Theory of Runs method [4]. The first step is to evaluate standardized precipitation index (SPI) from historical daily precipitation data for the four time steps namely: 1960s (1951-1970), 1980s (1971-1990), 2000s (1991-2010) and 2020s (2011-2017). Sixteen weather stations located in 8 provinces in the ER were chosen to analyze to compute monthly SPI values for the one- and three-months drought intervals (SPI1 and SPI3) which are very suitable for hazard assessment on paddy field and for field crops (cassava, maize, potato, pineapple and corn) respectively. SPI6 is an index for assessing high damage and vulnerability of orchard fruits (durian, mangosteen, rambutan, salacca, etc.). Next, the Theory of Runs is applied to evaluate drought parameters which are duration (DD), drought event (DE), drought intensity (DI) and drought severity (DS) based on the SPI values. All of these parameters were analyzed on monthly basis.

### 3.1. STANDARD PRECIPITATION INDEX (SPI)

The Standard Precipitation Index (SPI) was suggested by McKee [9] to calculate the drought level at different time scales from long term of historical precipitation (normally over than 30 years). The detail in calculating SPI can be referred to [13,14].

The study used monthly precipitation to compute SPI1, SPI3 and SPI6 for 1-, 3- and 6-months drought intervals for drought hazard on rice, field crops, and fruits, respectively. The past precipitation data from 1951 until 2017 was grouped into four time steps which are 1960s (1951-1970), 1980s (1971-1990), 2000s (1991-2010) and 2020s (2011-2017).

The observed daily precipitation data were used to converted to monthly precipitation for 12 months. The distribution of monthly precipitation has a distribution pattern of gamma distribution function [6] and hence for SPI analysis, it is transformed to standard normal distribution function [15]. The SPI values generally ranging from -3 to 3 for monthly precipitation [9] are calculated by using SPI generator software V.1.7.5 developed by National Drought Mitigation Center [10].

### 3.2. DROUGHT HAZARD CLASSIFICATION

Drought hazard level was analyzed from SPI values that included SPI1, 3 and 6. The SPI values were categorized into five hazard levels as very low (above 0), low (-0.01 to -0.99), medium (-1 to -1.49), high (-1.50 to -1.99), and very high (less than -2) which followed the suggestion of Tingsanchali and Piriya Wong [14] as shown in table 1.

Table 1 Drought Hazard Classification [9, 14]

Drought Hazard Ranges	Category [9]	Drought Hazard Level [14]
SPI < -2	Extremely Dry	Very High
-1.50 to -1.99	Severely Dry	High
-1.00 to -1.49	Moderately Dry	Medium
-0.01 to -0.99	Near Normal	Low
SPI > 0	Wet	Very Low

### 3.3. THEORY OF RUNS

Drought characteristic includes several drought

conditions such as drought event (DE), duration (DD), severity (DS) and intensity (DI) by using Theory of Runs (ToR) to define and analyze [4,7]. The ToR is a statistical property of drought situation. DE is a period in which the SPI value is lower than zero with lowest SPI less than -1. DD is the number of months in a DE. The DS is the absolute value of summation of SPI values per DE. DI is the ratio of DS and DD as presented in equation 1 and 2. The inverse distance weighted interpolation method (IDW) was selected to develop drought characteristic and drought hazard maps based on SPI for the eastern region of Thailand.

Table 2 Drought Classification based on Drought Event, Drought Duration, Drought Severity and Drought Intensity (DE, DD, DS and DI), respectively

Drought Hazard Ranges	Drought Conditions	Drought Hazard Level
Drought Event, DE (Event)		
	Less than 20	Very Low
	21 to 40	Low
	41 to 60	Medium
	61 to 80	High
	Over than 81	Very High
Drought Duration, DD (Month)		
	Less than 1	Very Low
	1 to 2	Low
	2 to 3	Medium
	3 to 4	High
	Over than 4	Very High
Drought Severity, DS		
More than 0	Wet	Very Low
0 to -1	Near Normal	Low
-1 to -1.5	Lightly Dry	Medium
-1.5 to -2	Moderate Dry	High
Less than -2	Extremely Dry	Very High
Drought Intensity, DI		
More than 0	Wet	Very Low
0 to -0.25	Near Normal	Low
-0.26 to -0.5	Lightly Dry	Medium
-0.51 to -0.75	Moderate Dry	High
Less than -0.76	Extremely Dry	Very High

$$DS = \left| \sum_{i=1}^{DD} x_i \right| \quad (1)$$

$$DI = \frac{DS}{DD} \quad (2)$$

Where,  $x_i$  is SPI value which is lower than zero.

All drought characteristics are categorized into five hazard levels such as very low, low, high and very high for 1960s, 1980s, 2000s and 2020s as shown in Table 2.

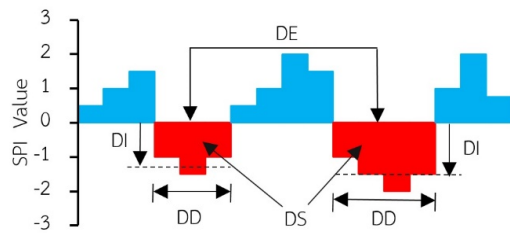


Figure 2 Drought Conditions using Theory of Runs

## 4. RESULTS

### 4.1. STANDARD PRECIPITATION INDEX

The observed monthly precipitation was used to generate SPI values for 1, 3 and 6 months. The SPI1 is equivalent to standardized monthly rainfall for rice crop which can stand shortage of rainfall for one month. The SPI3 is for standardized 3-month rainfall for field crops (e.g. cassava, maize, pineapple and corn) which can stand shortage of rainfall for 3 months. The SPI6 is for standardized 6-month rainfall for orchard fruits such as durian, mangosteen, rambutan, salacca, etc., which can stand shortage of rainfall for 6 months. Thus, SPI-1, 3 and 6 are considered in this study.

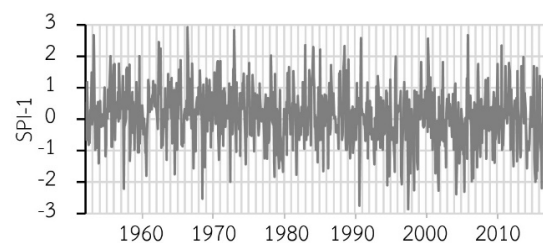
Table 3 The average SPI Value in 1960s, 1980s, 2000s and 2020s at Prachin Buri Meteorological Station.

Season		1960s	1980s	2000s	2020s
Rainy	SPI-1	0.21	0.04	-0.25	0.04
	SPI-3	0.32	0.10	-0.31	-0.19
	SPI-6	0.41	0.11	-0.32	-0.46
Summer	SPI-1	0.35	0.04	0.00	-0.43
	SPI-3	0.46	-0.03	-0.17	-0.50
	SPI-6	0.38	0.01	-0.29	-0.23
Winter	SPI-1	0.30	0.39	0.04	0.35
	SPI-3	0.13	0.16	-0.37	0.21
	SPI-6	0.34	0.09	-0.54	0.35

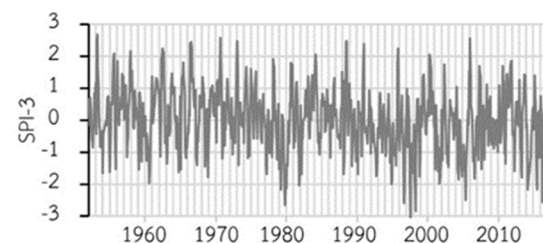
Data from 16 meteorological stations were used to analyze and compute SPI values during 1950 until 2017. The SPI value normally showed on a range -3 to 3 as recommended of Mc Kee [9]. Table 3 shows SPI-1, 3 and 6 values at Prachin Buri meteorological station in three

seasons (rainy, summer and winter) for four different time steps (1960s, 1980s, 2000s and 2020s).

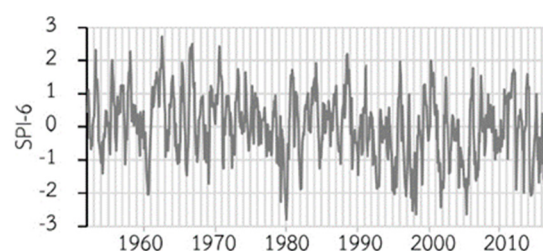
The SPI values tend to change from positive in the past to negative at the present time for all drought durations. The critical decade is in 2000s because the SPI values are negative in rainy and summer seasons. This indicates the existence of drought problem in both seasons. The historical trends of SPI-1, 3 and 6 are highly fluctuating from -3 to 3 for monthly rainfalls during 1950 to 2017. The fluctuation of SPI is decreased with the increase in the duration of SPI. The SPI1 has more fluctuation than SPI3 and SPI6. The fluctuations of SPI, SPI3 and SPI6 of the Prachin Buri Station are shown in figure 3.



(a) SPI-1



(b) SPI-3



(c) SPI-6

Figure 3 SPI-1, -3 and -6 of the Prachin Buri Meteorological Station.

### 4.2. DROUGHT HAZARD MAPS

The monthly drought hazard maps are categorized

into five hazard levels (very low, low, medium, high and very high) as shown figure 4. For example, in the summer month of May 2015, the very high and high hazard levels exist in Sa Kaeo, Chachoengsao and Chon Buri Provinces. While Rayong, Chanthaburi and Trat provinces exhibit very low, low and medium hazard levels, respectively. The percentage area of each hazard level are 0.05% for very low, 12.80% for low, 49.11% for medium, 29.31% for high and 8.70% for very high. However, the change in drought hazard map depends on specific locations and time.

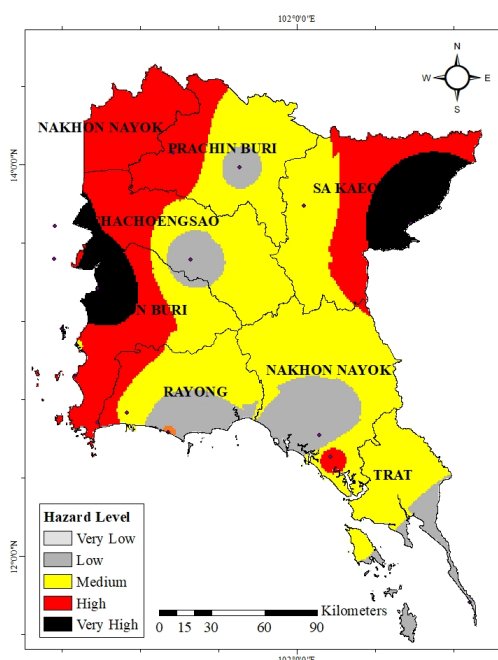


Figure 3 Meteorological Drought Hazard Map for SPI-1 in May 2015

#### 4.3. DROUGHT CHARACTERISTICS

The multiple drought characteristics namely DD, DE, DS and DI and hazard levels of previous drought situations are evaluated by using the Theory of Runs. The results of all drought characteristics for SPI-1 are separated into different time scales. The DE of 20-year intervals shows to have 54 (1960s), 59 (1980s), 59 (2000s) and 19 (2020s) events. Drought duration (DD) during 1950-2017 varies from 1.90, to 1.94, 2.06 and 1.99 months for the periods of 1960s, 1980s, 2000s and 2020s, respectively. Moreover,

the averages of DS and DI are in the range of -1.31 (1960s) to -1.50 (2000s) and -0.66 (1960s) to -0.72 (2000s) respectively. This shows a slight change from medium to high hazard levels. All drought characteristic represented by SPI shows an increasing trend for past (1960s) to present (2020s) time as shown in figure 5.

#### 5. CONCLUSION

The results of this study yield drought hazard maps by analyzing drought indicator (Standard Precipitation Index; SPI). The SPI-1, 3 and 6 values refer to standardized rainfalls of 1 month, 3 months and 6 months which serve as an indicator in judging the effects on shortage of rainfall on rice paddy, field crops and orchard fruits. The drought hazard in May 2015 has very high level at Sa Kaeo, Chachoengsao and Chon Buri provinces and low hazard level in some parts of Rayong, Chanthaburi and Trat provinces. The hazard levels were classified into five levels and the percentages area which are very low (0.05%), low (12.80%), medium (49.11%), high (29.31%), and very high (8.70%). All drought characteristic shows a slightly increased trend. The hazard values of DD is 1.90 to 2.06 months, DE is 54 to 59 events, DS is -1.31 to -1.50, DI is -0.66 to -0.72. This study will be useful for agricultural planners and farmers to learn the adaptation practices such as changing type of crops and cultivation time in the past and at present for future improvement.

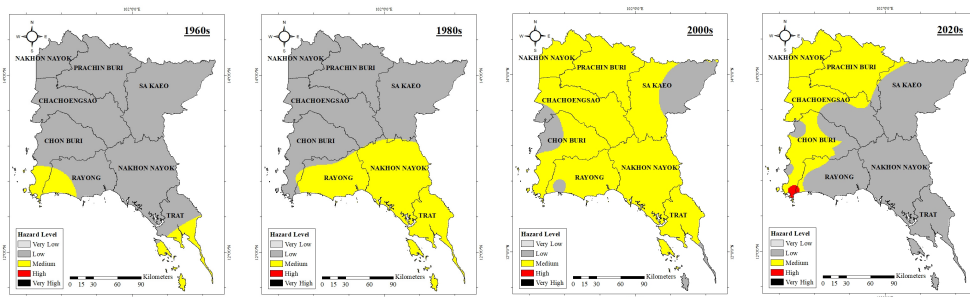
#### 6. ACKNOWLEDGMENTS

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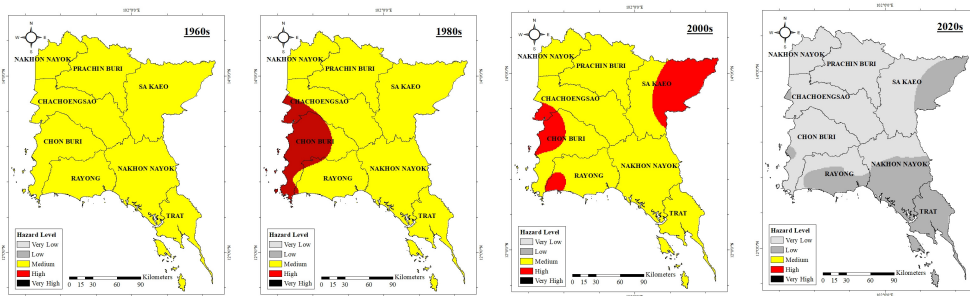
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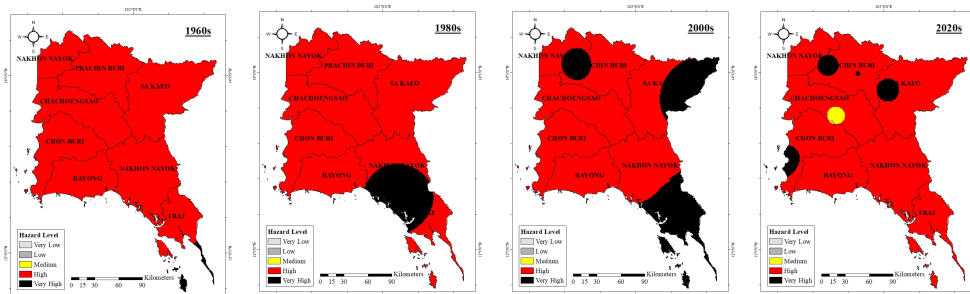




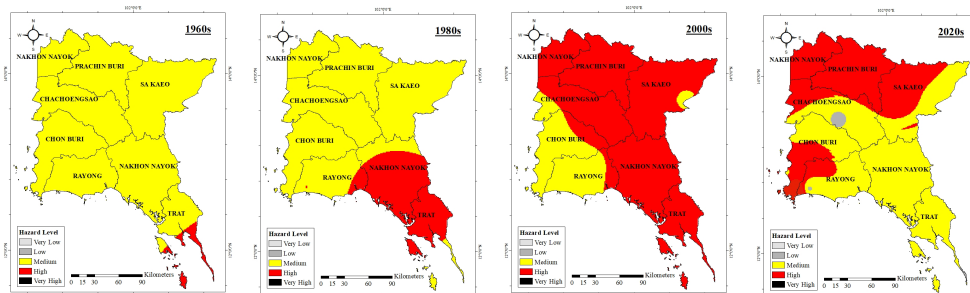
(a) Drought Duration (DD)



(b) Drought Event (DE)



(c) Drought Severity (DS)



(d) Drought Intensity (DI)

Figure 5 Meteorological Drought Hazard Characteristics of Eastern Region in 1960s, 1980s, 2000s and 2020s, respectively

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