AGRICULTURAL DROUGHT INVESTIGATION OF NORTHERN THAILAND USING GENERALIZED MONSOON INDEX

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Abstract: This research aims to study a change of rainfall and indicate levels of agricultural drought in the Southwest monsoon period of the northern region of Thailand by using the GMI. The rainfall data from June to September of the year 1987 to 2019 were collected from 21 meteorological stations over the northern region of Thailand. The data were used to create the maps of agricultural drought levels and to analyze the distribution of agricultural drought on the study period. Then, the distribution of total rainfall maps of each month and the trend of rainfall over the past 33 years were examined. The results showed that agricultural drought in Northern Thailand had no exact pattern. However, there was a drought impact on crops level in the lower part of Northern Thailand at the end of the Southwest monsoon period in 2019 with the GMI percentile score average (GMIpct$_{sw}$) of 22.82 %. Furthermore, the severe drought impact and possible crop failure level were observed in the upper part of Northern Thailand in the same period. Moreover, the total rainfall sharply increased from June to August then decreased in September. The trend of total rainfall of the Southwest monsoon period (June to September) fluctuates along the study period with average value of 796.67 millimeter.

Keywords: Agricultural drought; Drought in Thailand; Generalized Monsoon Index; Rainfall change

Introduction

Drought is a natural hazard which Thailand have to face with many years. The drought situation impacts on any activities of people, community, agriculture and forest situation in many areas of Thailand. (Luedi, 2016) However, northern Thailand is located at 98.99 N – 99.95 N and 97.33 E - 101.79 E (decimal degrees) covered 15 provinces (Thai meteorological department, 2019) and this region has a variety of topography types such as plain, floodplain, mountains, and valley. Moreover, the Koppen climate type of this region is tropical wet and dry climate (Aw) which has 3 seasons (summer in February to May, rainy in June to September and winter in October to January). The dry season can become severe, and often drought conditions prevail during the course of the year. (CTN News, 2019) Furthermore, main occupation of people in northern areas is agriculturist and there are agricultural areas about 21.8% of the total of agricultural area in Thailand (Office of national economic and social development council, 2020). These reasons bring northern Thailand has many types of agriculture such as Paddy field, Field crops, Flower farm, etc. (Office of Agricultural Economics, , 2019; CARE/HRIP, 1994). Moreover, the most of agricultural season usually under Southwest monsoon period thus, water situation for agriculture is necessary to monitor in this region. Therefore, the drought situation can impact on agriculture and affect to main income of the people in this region.

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From all problems mentioned above bring authors to the objectives of this study which are; (1) to study a change of rainfall and its trend in northern Thailand and (2) to monitor agricultural drought situation and indicate levels of agricultural drought in the Southwest monsoon period of the northern region by using the Generalized Monsoon Index or GMI over 33 years past. The results of this study can be an evidence that Thailand is facing with climate change and global warming problems.

Objectives

1. To study a change of rainfall and its trend in Northern Thailand.
2. To monitor agricultural drought situation and indicate levels of agricultural drought in the Southwest monsoon period of the northern region by using the Generalized Monsoon Index or GMI

Materials and Methods

Study area

The study area which using in this study included 21 meteorological stations covered **15** provinces around Northern Thailand as shown in the table1 and figure 1. (Thai meteorological department, 2019)

Table 1: Meteorological stations in Northern Thailand. (Thai meteorological department, 2012)

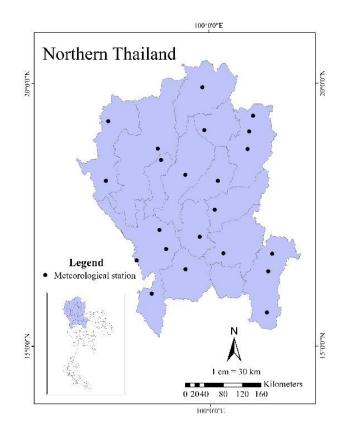| No.	Station No.	Station name	Province	Latitude	Longitude
1	48300	Mae Hong Son	Mae Hong Son	19º 18'	97º 50'
2	48303	Chiang Rai	Chiang Rai	19º 58'	99º 53'
3	48307	Thung Chang	Nan	19°24'	100°52'
4	48310	Phayao	Phayao	19º 08'	99º 54'
5	48315	Tha Wang Pha	Nan	19º 07'	100º 48'
6	48325	Mae Sariang	Mae Hong Son	18º 10'	97º 56'
7	48327	Chiang Mai	Chiang Mai	18º 47'	98º 59'
8	48328	Lampang	Lampang	18º 17'	99º 31'
9	48329	Lamphun	Lamphun	18º 34'	99º 02'
10	48330	Phrae	Phrae	18º 10'	100º 10'
11	48331	Nan	Nan	18º 47'	100º 47'
12	48351	Uttaradit	Uttaradit	17º 37'	100º 06'
13	48374	Lom Sak	Phetchabun	16º 46'	101º 15'
14	48375	Mae Sot	Tak	16º 40'	98º 33'
15	48376	Tak	Tak	16º 53'	99º 07'
16	48377	Bhumibol Dam	Tak	17º 14'	99º 03'
17	48378	Phitsanulok	Phitsanulok	16º 47'	100º 16'
18	48379	Phetchabun	Phetchabun	16º 26'	101º 09'
19	48380	Kamphaeng Phet	Kamphaeng Phet	16º 29'	99º 32'
20	48385	Umphang	Tak	16º 01'	98º 52'
21	48413	Wichian Buri	Phetchabun	15º 39'	101º 07'

Figure 1: Study area

Adequacy investigation of meteorological stations

The objective of adequacy investigation of meteorological stations is for checking the number of meteorological stations which can represent of rainfall data collection in northern Thailand. Therefore, C_v method (Wichitarapongsakun, 2016). is the suitable method to use in this study to check the adequacy investigation of meteorological station. The equations of this method are shown below

$$N = (C_v/\varepsilon)^2 \qquad (1)$$

$$C_v = (100\sigma_{m-1})/\overline{P} \qquad (2)$$

$$\sigma_{m-1} = \{[\Sigma^m_1(P_i- \overline{P})^2]/(m-1)\}^{\frac{1}{2}} \qquad (3)$$

Whereas N is the suitable number of meteorological stations. C_v is rainfall coefficient coefficient of m stations. ε is the percentage of allowable errors in the estimation. The estimation of average of rainfall data determine ε = 10% by the suggestion of world meteorological organization: WMO (Subramanya, 2008). σ is standard deviation of the data of rainfall from m stations. $\overline{P}$ is the average of rainfall data from m stations. and P_i is the rainfall data which was collected from any stations (i = 1, 2, 3, …, m)

Rainfall change and its trends monitoring

The total rainfall data from 21 meteorological stations which covered Northern Thailand, of June to September of 1987 – 2019 were used in this study to create the total rainfall distribution maps under

SW monsoon period by using raster interpolation method (Kriging) to monitor how the rainfall in Northern Thailand changes. The data were collected by Thai meteorological department. Line graph of trend of total rainfall in SW period of Northern Thailand by months and trend of total rainfall in SW monsoon period of Northern Thailand were created by excel program to monitor the trend of rainfall change in the study area

Generalized Monsoon Index (GMI) analysis

Agricultural Drought can be investigated by Generalized Monsoon Index or GMI which is developed by Yield Monsoon Index (YMI) in 1982 (Achutuni, Steyaert and Sakimoto, 1982) to illustrate and monitor the drought affect plants in every growing step in monsoon period. The most of planting season in Thailand is under Southwest Monsoon or SW period which affect to Thailand around June to September. Therefore, GMI can be analysed to understand health of plants in SW period by gathering monthly rainfall data of each station in the study area. (Thai meteorological department, 2012)

$$GMI6 = \mathbf{0.125}\,P6 \tag{4}$$

$$GMI7 = \mathbf{0.125}\,P6 + \mathbf{0.125}\,P7 \tag{5}$$

$$GMI8 = \mathbf{0.125}\,P6 + \mathbf{0.125}\,P7 + \mathbf{0.5}\,P8 \tag{6}$$

$$GMI9 = 0.125\,P6 + 0.125\,P7 + 0.5\,P8 + 0.25\,P9 \tag{7}$$

Whereas; GMI6 refer to P6 is total monthly rainfall of June, P7 is total monthly rainfall of July, P8 is total monthly rainfall of August and P9 is total monthly rainfall of September.

Therefore, the agricultural drought in the end of southwest monsoon period (June to September) can investigate by the equation below,

$$GMI_{sw} = \mathbf{0.125}\,P6 + \mathbf{0.125}\,P7 + \mathbf{0.5}\,P8 + \mathbf{0.25}\,P9 \tag{8}$$

GMI_{sw} of each meteorological station which was calculated from the equation (5), is shown in millimeter. However; it is so hard to identify the drought impact and determine criteria of plants health. Therefore, GMI_{sw} can be transfer to percentile rank of each meteorological station by the equation (9) and the criteria which was used to consider plants health is illustrated in the table 2.

$$GMI_{pct} = (r \times 100)/(n + 1) \tag{9}$$

Whereas; GMI_{pct} refer to percentile rank of GMI of each meteorological station in the end of southwest monsoon period, r is rank of GMI in each year of each meteorological station, n is number of years which the data was gathered in each meteorological station.

Table 2: The criteria which was used to consider plants health (Wichitarapongsakun, 2016)

GMI$_{pct}$	Level of drought	Plants health	
0-20	6	severe drought impact and possible crop failure	
21-30	5	drought impact on crops	
31-40	4	moderate drought impact on crops	
41-60	3	normal crops condition	
61-90	2	possible above normal crops	
91-100	1	possible excessive moisture	

Results

1. Adequacy investigation of meteorological stations

The suitable number of meteorological stations which checked by C_v method is 9 stations, which calculated by equation (1). Thus, 21 meteorological stations which using in this study is suitable for represent the rainfall data in northern Thailand.

2. Rainfall change and its trends

Southwest Monsoon period of Thailand starts from June to September of every years. Therefore, the total of rainfall in SW period are presented in figure 2. The maps are illustrated that there is no certain pattern which how total rainfall changed. The total rainfall in SW period is significantly lower in 1987, 1990, 1993, 1998, 2015 and 2019 especially, the central of Northern Thailand. In contrast, the total of rainfall is remarkably higher in 1994, 1995, 2005, 2010, 2011 and 2013 especially, the upper and round of Northern Thailand. From the figure 3(A), the trend of total rainfall in June, July, August and September of Northern Thailand from 1987 to 2019 were analysed by excel program. The trend of rainfall gradually increased from June and hit the peak at August then, its gradually decreased in September in every year. However, the trend of total rainfall in SW period of Northern Thailand was fluctuated with the total rainfall averaging at 796.67 millimeters and standard deviation at 110.36. Moreover, the total rainfall decreased by 0.1527 millimeter per year as shown in the figure 3(B).

3. Agricultural Drought analysis by Generalized Monsoon Index

Agricultural Drought in Northern Thailand in SW period was analysed by Generalized Monsoon Index (GMI$_{sw}$). From the figure 4, the maps were presented GMI Percentile rank after finishing Southwest Monsoon period over 33 years past. The level of agricultural drought is presented in table 2. The agricultural drought characteristics in the most area of Northern Thailand was in drought impact on crops level and severe drought impact and possible crop failure level in 1989, 1990, 1993, 1997, 1998, 1999, 2007, 2015, 2018 and 2019. Moreover, the most years which Northern Thailand faced to extreme agricultural drought such as 1989, 1990, 1993, 2015 and 2019, was agreeable with the total rainfall data which illustrated in the maps figure 2.
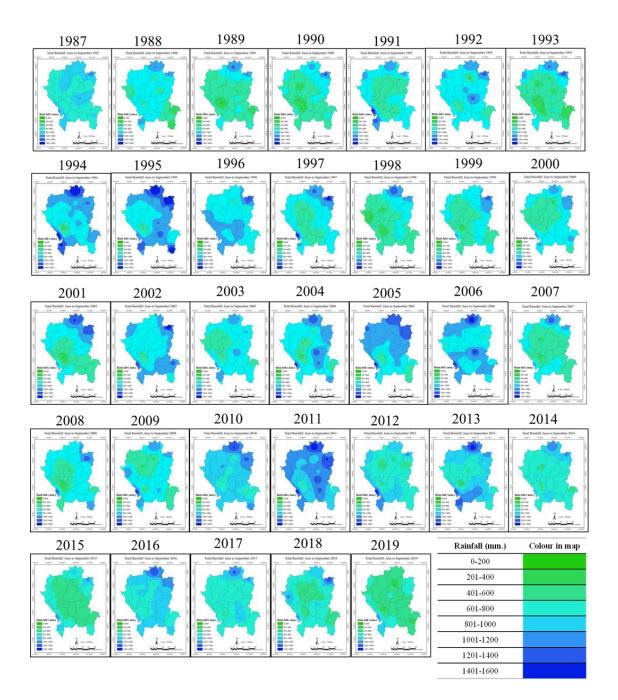
Figure 2: Distribution of total rainfall in Northern, Thailand during Southwest Monsoon period of 1987 to 2019
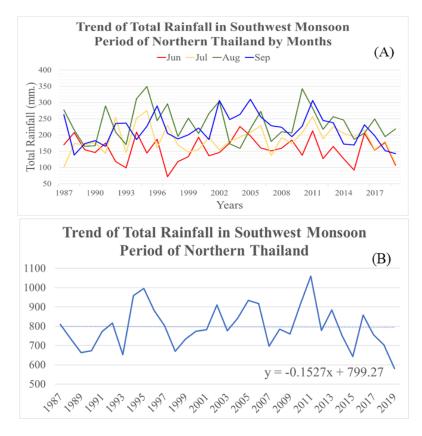
Figure 3 (A) Trend of total rainfall in SW period of Northern Thailand by months (B) Trend of total rainfall in SW monsoon period of Northern Thailand

Discussion and Conclusion

There was no pattern for total of rainfall distribution and agricultural drought characteristics distribution. The total rainfall trend was illustrated that the rainfall trend fluctuated, and when focused on by months, the trend hit the peak at August then, gradually decreased. The agricultural drought was presented by total rainfall maps and GMI_{sw} in 1989, 1990, 1993, 1997, 1998, 1999, 2007, 2015, 2018 and 2019. Moreover, Thailand had to face with El Nino effect in 1987, 1991, 1992, 1993, 1997, 2002, 2014, 2015, 2018 and 2019 which caused Thailand to have high temperature than normal and the rainfall was lower than usual (Australian Government Bureau of Meteorology, 2020). The agricultural drought analysis by GMIsw can be a prove that Northern Thailand faced with abnormal situation, which all authorities and people have to be awareness and plan to solve this situation. For the weakness of this study is that the author focused on just the total of rainfall in Northern Thailand and analyzing of agricultural drought by just Generalized Monsoon Index (GMI_{sw}) method. This drawback might represent that it might be not enough to analyse the drought in Northern Thailand. However, there are many methods to analyse drought impact such as the standardized Precipitation Index or SPI method and the meteorological Drought Index or D method. Moreover, there are several different data which can be used to analyse the drought impact such as topography pattern, Slope pattern, human activities, relative humidity, Land use pattern, etc.
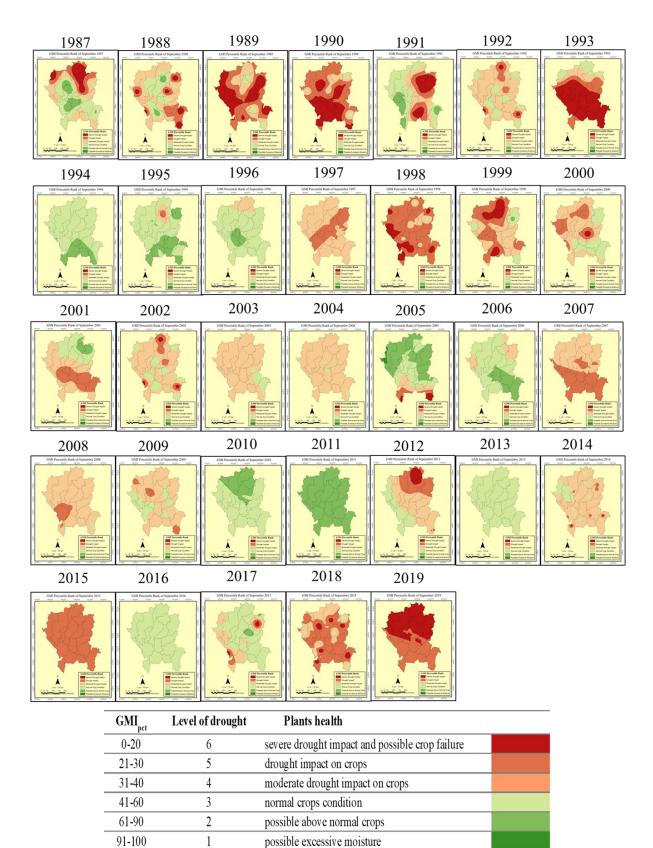
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61-90	2	possible above normal crops	
91-100	1	possible excessive moisture	

*Figure 4: Distribution of GMI Percentile rank after Southwest Monsoon period of 1987 to 2019
in Northern, Thailand*

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