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LONG-TERM TRENDS OF AIR TEMPERATURE AND THE POSSIBLE IMPACTS ON AGRICULTURE IN THAILAND

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ABSTRACT

In order to study the influences of global warming in Thailand, we conducted an analysis of long-term air temperature trends in Thailand over the period from 1951 to 2015, with the daily data acquired from the Meteorological Department in Thailand. In most regions in Thailand, both the air temperature anomalies compared to the 30 years period normal and the 5 years moving average did not show clear tendencies of warming. However, conspicuous warming trends were observed in 5 big cities, indicating that the urban heat island phenomenon may have a huge impact on long-term air temperature trends in Thailand. Our results indicated that the global warming may have little impacts on air temperatures in Thailand during these 5 decades, and rainfall distribution is considered to be more crucial in the influence of global warming on agricultural activities.

Key words: Agricultural activities; global warming; temperature anomaly; warming trend

INTRODUCTION

Climatic information is indispensable for the analysis of agricultural ecosystems. In terms of air temperatures, it was reported that the period from 1983 to 2012 was likely the warmest 30-year period in the Northern Hemisphere (IPCC 2014). As a result of rapid global warming, its negative impacts on crop yield have been more common than positive impacts (IPCC 2014). A simulated result based on crop models indicated that the crops grown in the tropics, rice and corn for example, with a 2℃ warmer condition, rice exhibited 10% yield decline, whereas corn exhibited 15% yield decline (Easterling et al. 2005). Many countries will face the problem of food security as they meet the challenges of climate changes. A lot of research works concerning the impact of global warming on crop yields have been conducted in temperate areas, and a direct rice field study from 1979 to 2003 showed that each 1℃ increase in minimum air temperature during growing-season could cause a grain yield decrease by at least 10% (Peng et al. 2004). A crop model based research in the US mentioned that the threshold mean temperature for corn was 29℃, and for soybean was 30℃, and if the temperature raised higher than the threshold, severe damages could be caused to the crop yields (Schlenker and Roberts 2009). But in the tropics limited works have been conducted, for the reason that it is difficult to obtain sufficient climatic data due to the lack of meteorological stations. In Thailand, climatological measurements started from 1951 at few stations controlled by the Meteorological Department (Nawata et al. 2005). By utilizing the climatic data obtained from the Meteorological Department in Thailand, this research aims to construct a general climatic database of Thailand in order to analyze long-term air temperature changes, and thus enable us to figure out possible impacts of climate changes on agricultural activities in the tropics.

MATERIALS AND METHODS

Daily mean air temperature data recorded from 1951 to 2015 in 34 stations were collected from the Meteorological Department in Thailand. According to the officer in the Department, the database experienced several times of upgrade, and due to the upgrade process in most stations the data in 2005 were missing. All the 34 stations are distributed in Central, Eastern, Northern and Northeast Thailand area. Although there are over 100 stations taking climatological measurement records now in Thailand, only those which started measurements from 1950s for the long-term trend analysis were selected. For the reason that limited areas were developed for agricultural purposes and the areas are generally considered as a part of Insular Southeast Asia, the Southeast and Southwest areas were not taken into consideration in this research. Table 1 shows the codes and names of all the meteorological stations and Figure 1 demonstrates the locations of all the stations.

Table 1. Codes and names of meteorological stations used in this research.

Central Thailand		Eastern Thailand		Northern Thailand		Northeast Thailand	
Station Code	**Station Name**	**Station Code**	**Station Name**	**Station Code**	**Station Name**	**Station Code**	**Station Name**
400201	Nakhon Sawan	430201	Prachin Buri	300201	Mae Hong Son	353201	Loei
425201	Suphan Buri	440201	Aranyaprathet	300202	Mae Sariang	354201	Udon Thani
426201	Lop Buri	459201	Chon Buri	327501	Chiang Mai	356201	Sakon Nakhon
450201	Kanchanaburi	459202	Ko Sichang	328201	Lampang	357201	Nakhon Phanom
455201	Bangkok Metroplois	501201	Khlong Yai	330201	Phrae	381201	Khon Kaen
455601	Don Muang (Airport)			331201	Nan	383201	Mukdahan
				351201	Uttaradit	403201	Chaiyaphum
				376201	Tak	405201	Roi Et
				376202	Mae Sot	407501	Ubon Ratchathani
				378201	Phitsanulok	431201	Nakhon Rachasima
				379201	Phetchabun	431401	Chok Chai
						432201	Surin

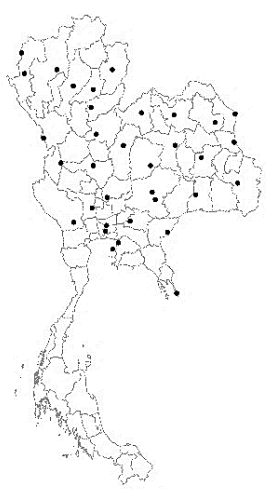

Fig. 1. Locations of meteorological stations in Thailand used in this research.

For each station, temperature anomalies compared to the 30 years normal (from 1951 to 1980) and 5 years moving averages were calculated. In addition, the earliest 10-year average temperature (from 1951 to 1960) and the latest 10-year average temperature (from 2006 to 2015) in each region were calculated. The anomaly indicates the departure from a calculated normal mean temperature, and in this research the normal mean temperature is the 30 years average of annual mean temperatures (from 1951 to 1980). For each individual station, the anomaly is the annual mean temperature minus the normal mean temperature. For all the 4 areas, the area level temperature anomalies and 5 years moving averages were calculated from the station data in each area.

RESULTS AND DISCUSSION

In Central Thailand, the earliest 10-year average temperature was 28.5℃, whereas the latest 10-year average temperature was 28.4℃; in Eastern Thailand, the earliest 10-year temperature was 28.0℃, and the latest 10-year average temperature was 28.3℃; in Northeast Thailand, both the earliest and latest 10-year average temperatures were 27.0℃; in Northern Thailand, the earliest 10-year average temperature was 26.9℃, and the latest 10-year average temperature was 26.8℃.

Figure 2 shows the annual mean temperature anomalies in different regions in Thailand over the period from 1951 to 2015, with a 5-year moving average.

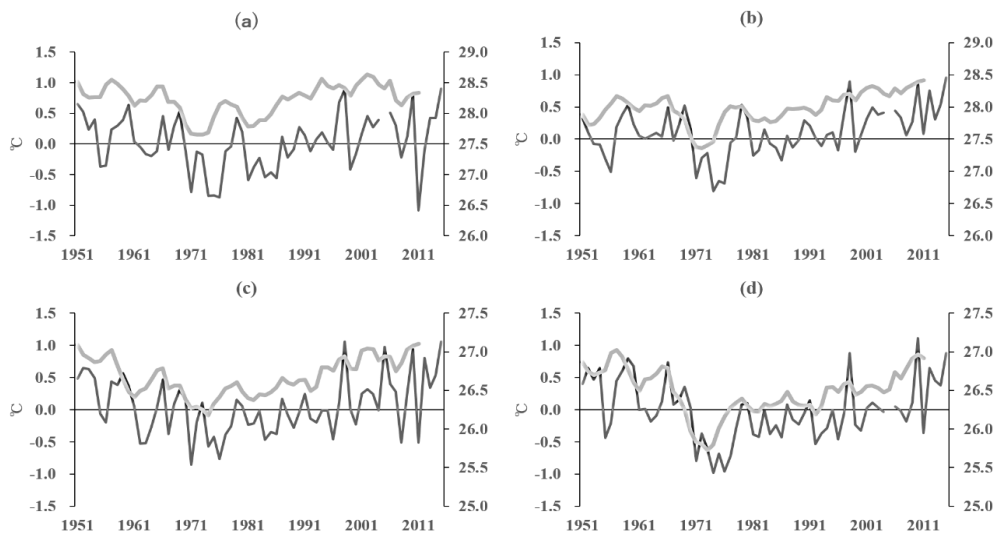

Fig. 2. Annual mean temperature anomalies in Central (a), Eastern (b), Northeast (c) and Northern (d) Thailand (black lines), with 5-year moving averages (grey thicker lines).

The 5-year moving average trend almost matches the anomaly trend (Fig. 2). From 1950s to early 1970s, all the 4 regions showed a cooling trend, and from early 1980s, a warming trend was observed. Although a warming trend from 1980s was observed, the overall temperature did not rise so much compared to the 1950s, when all the meteorological stations started data collection. It is important to note that the air temperatures in Northeast and Northern Thailand did not increase conspicuously, where agricultural activities are dominant in this country (Fig. 2 c and d). Global warming seems to have limited impacts on raising air temperatures in Thailand.

Although a warming trend was hardly observed at regional levels, noticeable conspicuous warming trends were observed in 6 stations. These stations are 455201-Bangkok Metropolis, 459201-

Chon Buri, 354201-Udon Thani, 431201-Nakhon Ratchasima, 327501-Chiang Mai and 378201-Phitsanulok (Fig. 3). The population and city area of these 6 regions are shown in Table 2 (data quoted from Thailand Yearbook (National Statistical Office 2015). Bangkok is the capital city of Thailand, located in the Central Area; Chon Buri is a city in Eastern Area; Nakhon Ratchasima and Udon Thani are 2 major cities in Northeast Area; Chiang Mai is a major city in Northern Area, and Phitsanulok is a city developing rapidly in Northern Area.

Table 2. Population and city area of 6 cities in Thailand.

City Name	Population	City Area (km^2)
Bangkok	5,696,409	1,568.7
Chon Buri	29,048	4.5
Udon Thani	153,329	47.0
Nakhon Ratchasima	166,217	37.5
Chiang Mai	148,447	40.2
Phitsanulok	84,311	10.8

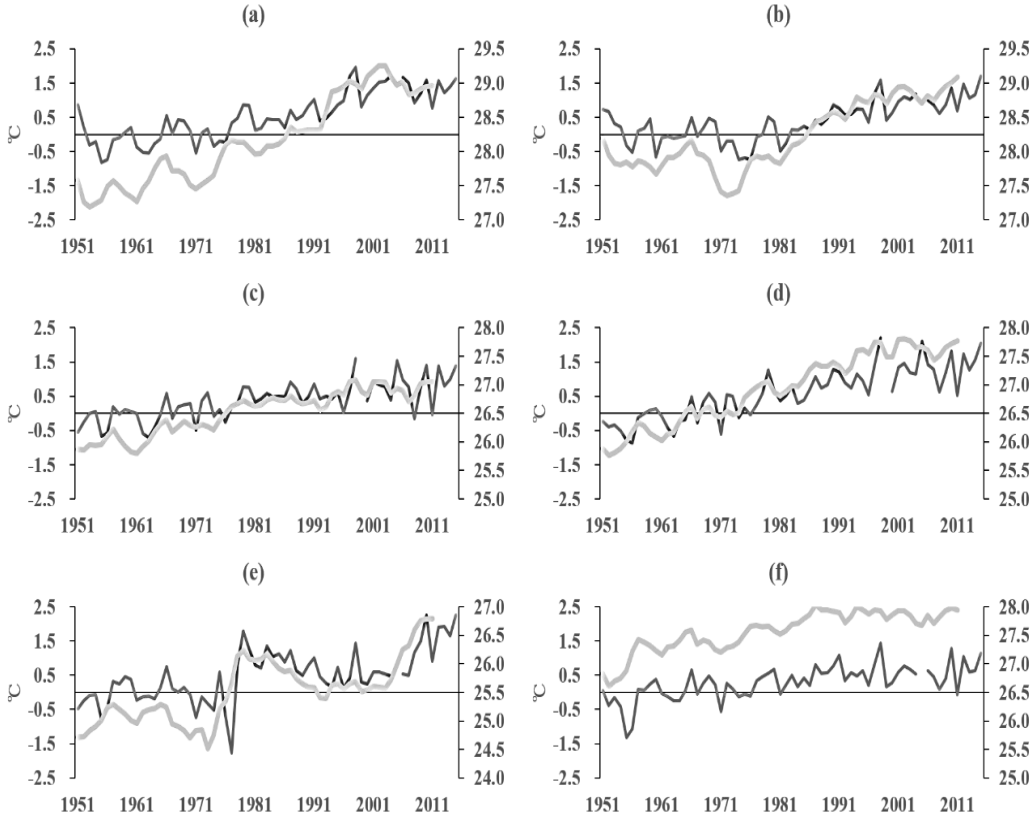

Fig. 3. Trends of annual mean temperatures in Bangkok (a), Chon Buri (b), Udon Thani (c), Nakhon Ratchasima (d), Chiang Mai (e), and Phitsanulok (f) (black lines), with 5-year moving averages (grey thicker lines).

Except for the Chon Buri station, the other 5 stations are located at the city area, which indicated that the temperature trend may have been affected by urban heat island effects rather than global warming. The Chon Buri station is located at the coastal area, facing the Gulf of Thailand and surrounded by mountainous land, and the cause of the warming trend in this station might be complicated. This result can also be supported by the Thailand Climatological Center annual report (Thailand Meteorological Development Bureau 2015). In the year 2015, all these 6 stations marked the new maximum temperature records: Bangkok marked the new records in June, August and September; Chon Buri marked the new record in June; Udon Thani marked the new record in July; Nakhon Ratchasima marked the new record in June; Chiang Mai marked the new record in August; Phitsanulok marked the new records in May, July and October.

For comparison, 4 representative stations (1 station for each area) were selected, and these stations are 455601-Don Muang Airport from Central Area, 501201-Khlong Yai from Eastern Area, 381201-Khon Kaen from Northeast Area and 300201-Mae Hong Son from Northern Area (Fig. 4). All these stations are located at the sub-urban or rural area. Don Muang Airport station [Fig. 4 (a)] is located at the sub-urban area of Bangkok with very large areas without buildings. Although Bangkok showed a conspicuous warming trend during the past 65 years, such a trend was not observed in the Don Muang Airport area. A similar trend was also observed in Khon Kaen [Fig. 4 (c)]. Khon Kaen City is considered as a big city in Northeast Area, but the Khon Kaen Station is located at the sub-urban area and surrounded by agricultural fields, and the air temperature in this station also did not show a clear sign of warming.

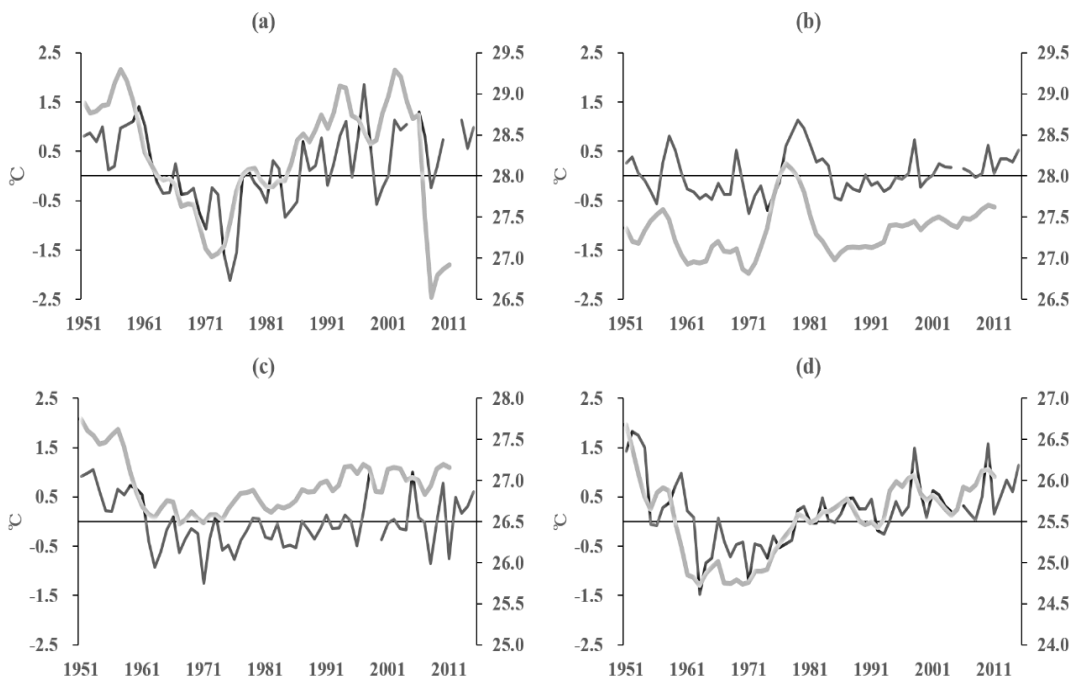

Fig. 4. Trends of annual mean temperatures in Don Muang Airport (a), Klong Yai (b), Khon Kaen (c), Mae Hong Son (d) (black lines), with 5-year moving averages (grey thicker lines)

The warming trend observed during the period from 1980s to 2015 is similar to the IPCC report (2014), and in Table 3 we compared the annual mean temperature increment every 10 years between the urban and rural areas in Thailand. From Table 3 it is shown that the warming trends in cities were more significant. When we compared the latest 10 years (from 2006 to 2015) annual mean temperature

with the earlier 10 years (from 1981 to 1990) annual mean temperature, air temperatures in Bangkok raised 0.91 ℃, whereas the temperature in sub-urban area of Bangkok (Don Muang Airport) even dropped slightly. In the other 6 stations, similar trends were observed, that the increment rates of air temperature in the cities were larger than those in the rural areas. This may indicate that in recent decades the urban heat island effect may have been more significant. But for the long-term periods, the air temperature in Thailand did not change so much during the past 65 years, except for urban areas. This result is consistent with findings of Malhi and Wright (2004), who suggested that the temperature in Southeast Asia have little changes. Since the long-term temperature trend in agricultural areas in Thailand has not changed so much, it is difficult to say that the global warming has significant direct impacts on crop productions in this country.

Table 3. Average annual air temperature (℃) every 10 years from 1981 to 2015 in representative stations in Thailand.

	Urban Area				**Rural Area**			
	Bangkok Metropolis	**Chon Buri**	**Nakhon Ratchasima**	**Chiang Mai**	**Don Muang (Airport)**	**Khlong Yai**	**Kohn Kaen**	**Mae Hong Son**
81~90	28.07	28.07	27.04	25.96	28.15	27.29	26.71	25.60
91~00	28.64	28.63	27.42	25.57	28.64	27.26	27.03	25.71
01~10	29.09	28.87	27.70	25.96	28.84	27.48	27.07	25.87
06~15	28.99	28.95	27.69	26.52	27.83	27.56	27.08	25.98

Figure 5 shows the yields of 3 main crops in Thailand, from 1961 to 2014 (FAO 2015).

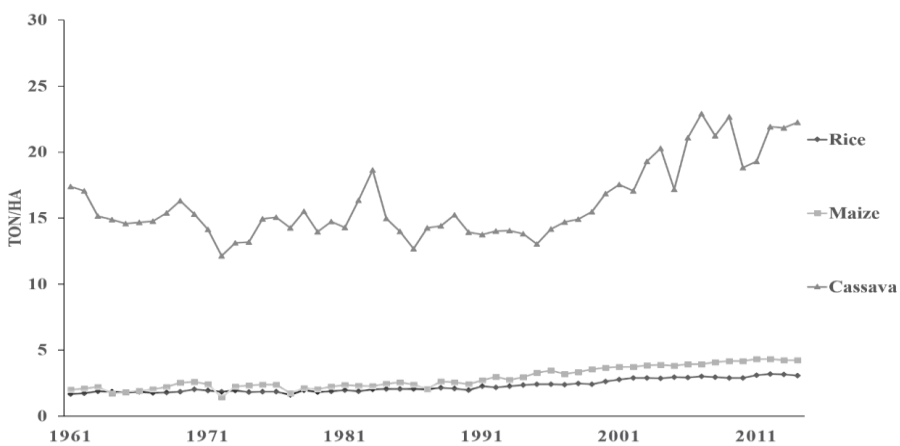

Fig. 5. National yields (ton/ha) of rice, maize and cassava in Thailand (1961 to 2014) (FAO 2015)

The yields of all the 3 crops raised significantly throughout the past 54 years (Fig. 5). Since the air temperature in agricultural regions has not changed obviously, the improvement of the crop yields may be related to various factors, such as the application of chemical fertilizers and the development of new cultivars. The national total use of fertilizers in Thailand from 2002 to 2015, may indicate that even in the recent decades the usage of nitrogen fertilizers increased from 53.9 kg/ha to 80.7 kg/ha (Fig. 6).

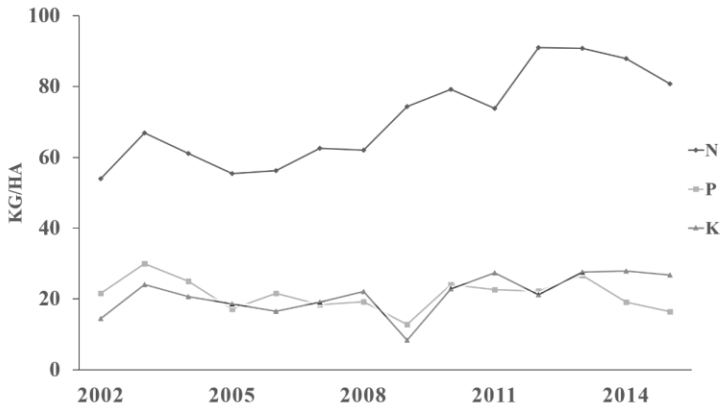

Fig. 6. Total fertilizer use (kg/ha) in Thailand (from 2002 to 2015) (FAO 2015)

In addition to fertilizers, pesticides utilization may also contribute to the promotion of crop yields, although major users of the pesticides are believed to be horticultural farmers. It was reported that Thailand relies heavily on pesticides to increase production levels, product quality and product appearance (HSRI 2005). The fluctuations of crop yields shown in Fig. 5 indicated that the climatic factor affecting crop yields could be other factors than the air temperature, such as rainfall. A research focused on Java and Bali indicated that the air temperature in Indonesia is not changed either, and the crop production was significantly linked with precipitation, and delayed rainfall and resulting delayed planting periods affected the national rice production significantly.(Naylor et al. 2007).

The air temperature in Thailand over the past 65 years did not show a significant warming trend, and especially in the sub-urban and rural area, the temperature does not tend to have big changes. But when we take a close look at the temperature in recent 35 years (from 1980), almost all the stations showed conspicuous warming trends, and these trends can be reflected at regional level (Fig. 7).

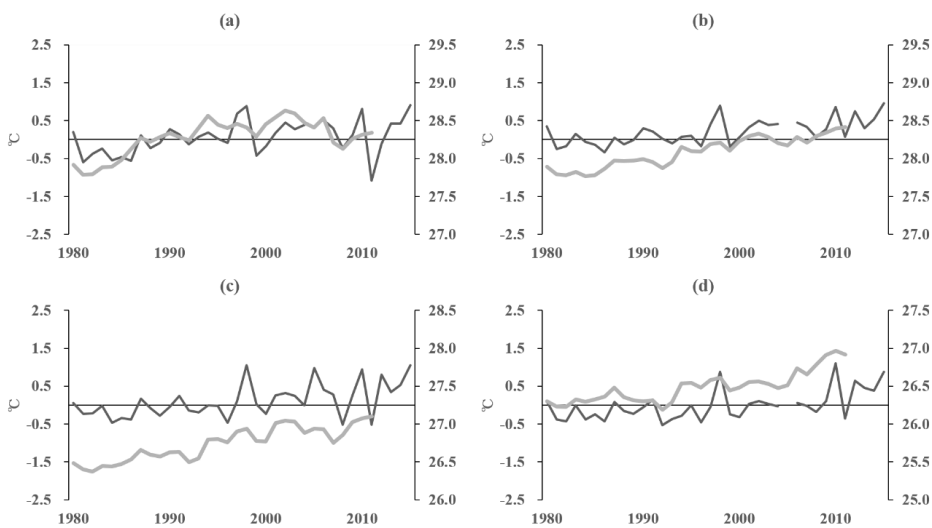

Fig. 7. Recent 35 years annual mean temperature anomalies in Central (a), Eastern (b), Northeast (c) and Northern (d) Thailand (black lines), with 5-year moving averages (grey thicker lines)

CONCLUSION

As mentioned previously, many stations in Thailand recorded the new maximum temperature records in 2015. In 2016, 50 stations in Thailand have renewed their maximum air temperature records (METEO-FRANCE 2016). Although the results of 2017 have not been published yet, it is assumed that the maximum temperature records were possibly renewed in the year 2017. Until now the air temperature in Thailand does not tend to have big changes compared with the temperature in 1950s, but the conspicuous warming trend shown in recent years needs to be carefully observed.

Since agricultural activities are frequently observed in the sub-urban and rural area, the air temperature trend seems to have limited direct impacts on crop yields. Considering that in Thailand, a huge area is depended on rainfed agricultural activities, it turns out that the key climatic issue Thai farmers are facing may be unstable and uneven rainfall distribution, which sometimes causes water scarcity or flooding. This issue will be discussed in another paper.

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