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Climate Variability and Rainfed Sugarcane Production: Thailand a case study.

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Abstract

Sugarcane productions in the tropical climate are mostly rainfed e.g. Brazil, India, Thailand and China which are the four top producers. Rainfed sugarcanes are susceptible to climate variability since they depend on amount and distribution of annual rainfall. Climate variability is not climate change which is the trend of change, but it is the fluctuation of the climate e.g. some of wet years and then some of dry years. The two extremes, flood and severe drought, can equally affect the production of sugarcane. Climate variability is likely to be a result of the complexity of the interaction between the ocean and the atmosphere. El Nino Southern Oscillation (ENSO) is a measure of the interaction that links to climate variation then to the sugarcane production. It is our objective to survey of literature how to understand the relationship of climate variability and the rainfed sugarcane production. After scrutinizing of rainfed sugarcane literature, we found that the strong El Nino year of 2015/2016 decreased the sugarcane production in Thailand. El Nino induces drought in Thailand but promotes heavy rain somewhere else.

Keywords: Climate Variability, Rainfed Sugarcane Production

1 Introduction

Sugarcane (saccharum spp.) is believed to originate from South and Southeast Asia then spreading throughout the World in about the seventh century (Fischer et al., 2008). Sugarcane has been closely related to the Thai culture since ancient time as jaggery and juice for food ingredient and condiments. Wide spread of sugarcane cultivation in Thailand started from the construction of the first modern sugar factory in Koh Kha district of Lam Pang Province in 1937 named Lampang Thai Sugar Mill (Hongthong and Patanothai, 2017). It is now more than 50 factories all over Thailand producing more than 10 million tons of sugar annually. Thailand is a foremost world exporter of sugar second only to Brazil with its share of 12 % at present. The Thai Government has planned to increase sugar production up to 180 million tons in 2036 (Sukyai et al., 2016). This shows that sugarcane is very important to the Thai socio-economy and environment.

Thailand is one of the best location to cultivate sugarcane. Being a tropical country with suitable climate for sugarcane production, Thailand ranks fourth in the world in sugarcane production after Brazil, India, and China which are very large countries compare to Thailand. The optimum climatic conditions for rainfed sugarcane production consists of annual rainfall of 1200 to 1500 mm, warm and wet weather during vegetative growth but cool and dry during ripening, and long sunny day. Extreme weather such as severe drought and typhoon with rough wind is very disadvantage for sugarcane cultivation. The normal year of Thailand with fairly high rainfall amount is the most favorable condition for producing sugarcane, however, such climate condition is not always persistent. The climate of Thailand varies from year to year, some dry years and some of wet years, called climate variability.

Heavy flood in 2011 caused 815 deaths, economic losses totaling US$ 45.7 billion, and 21000 km^2 (Komori et al., 2012). Severe drought in 2015 was the worst damage by water scarcity in two decades in Thailand (Fox, 2016). These two examples show opposite extreme climatic conditions. These interannual climate variations are believed to cause by tropical cyclones from the south China sea and the north Western Pacific Ocean (Takahashi and Yasunari, 2008). High intensity tropical cyclone induces flood meanwhile small number or no tropical cyclone causes drought hazard in Thailand. This fluctuation of climate is called climate variability which is not the same as climate change. The primary cause of climate variability is the variation of atmosphere and ocean interaction which reveals to the El Nino Southern Oscillation (ENSO) phenomenon. ENSO affects not only rainfall amount but also the whole climatic features, such as temperature, sunlight duration, and atmospheric humidity. Not only soil moisture that influence sugarcane production, but all climatic conditions can, therefore our objective is to investigation the relationship of climate variability and sugarcane production by using the Thai situations as a case study.

2 Sugarcane production in Thailand

True sugarcane production in Thailand began around 1938, when the first sugar factory established. During that time with native varieties the sugarcane yield was very low, cane cultivation areas were small, and sugar content of the cane was also very low. When sugar consumption and export increasing, the number of sugar factories increase rapidly, so as the yield and planted areas. In1950, Thailand was 53 miilion hectares of harvested area, where was now 1,337 million hectares as shown in Table 3. Production is a combination between harvested area with yield. Thailand used to be ranked 43rd for sugarcane production of only 0.3 million tons in 1950 however in 2016 ranking 4th of 87.5 million tons. Table 2 shows tremendous progress of the Thai sugarcane production development to compare with other countries. Thailand is the most rapid development indeed. The relationship of yield and harvested area is remarkably increasing (Figure 1).

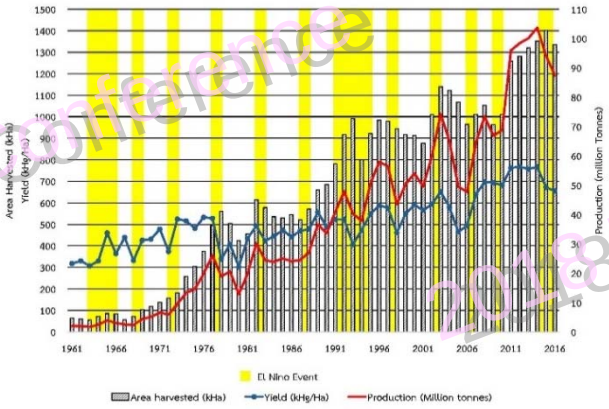

Figure 1 The relationship of harvested area and yield.

The aims of sugarcane production development of Thailand and Brazil which is the first rank are different. Brazil aimed to develop and produce bio-fuel whereas Thailand produces sugar. Sugar industry in Thailand is well success and prosperous, first establishing in the North, spreading to the Central and the Eastern part, then finally to the Northeast of Thailand, except for the South which the climate is not so suitable for sugarcane cultivation. China though of the 3rd rank imports sugar by large amount. Thailand exports sugar to several Asian countries such as Indonesian, Japan, including China. Figure 2 shows partition shares of sugar exporters showing Thailand as in second place.

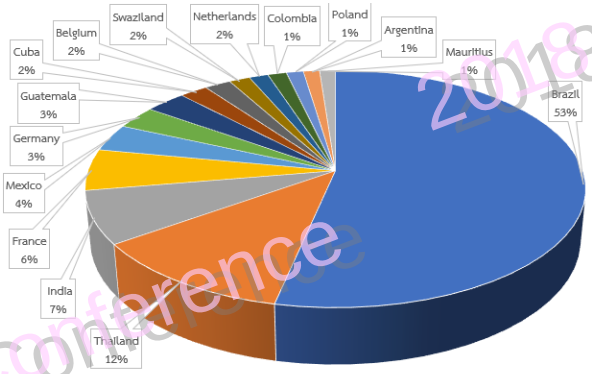

Figure 2 The partition shares of sugar exporters.

All countries of major sugarcane producers practice rainfed cultivation except Australia, United States and South Africa. Sugarcane cultivating in Thailand starts with planted sugarcane crop and follows by a few ratoon crop periods. The life cycle of tropical rainfed sugarcane in Thailand, whether planted or ratoon crops, is about one year. Normally planting date is when the rainy season end soil moisture content is still high.

Consequently, harvesting time is during winter with dry and sunny period which promoting high sugar content.

3 Effects on climate variability on sugarcane production in Thailand

Trend of sugarcane production in Thailand is rising from 0.3 million tons in 1950 to 87.5 million tons in 2016 steadily (Table 2). The Thai sugarcane production is not actually increase every year but fluctuating (Figures 4 and 6). The fluctuation is the results of harvested area and yield combined, and both are the results of climate variability. The major affecting factor of rainfed farming is definitely rainfall amount, too little and too high rainfalls are both damage sugarcane crop and decrease harvested area as well as yield (Russell, 1990). The sugarcane production including cane quality and its sugar content are not only affected by rainfall but also other climate variables such as temperature, atmospheric humidity, sunshine hour, and wind intensity, nearly all climate variables are affected to be exact.

The climate of Thailand is likely to be controlled by the dynamics of the Pacific Ocean and its interacting with the atmospheric circulation namely Walker circulation (Kirdphiboon et al., 2014). The coupled interaction is summed up as El Nino Southern Oscillation (ENSO) which consists of El Nino, normal and La Nina condition. El Nino condition happens when the upwelling of deep and cold water at eastern Pacific Ocean is slow down making warmer weather than usual, however when the upwelling is very strong producing colder weather at the east coast of South America and called La Nina. These phenomena are alternately occurred through the timeline. They can be measured by several indices however the two most popular are the Southern Oscillation Index (SOI) and Oceanic Nino Index (ONI).

The SOI may be the first known index for ENSO which is calculated from the differences of atmospheric pressures near sea surface at Tahiti in the west and Darwin (Australia) in the east (Figure 3) and divided by the mean standard deviation. High positive SOI goes to La Nina and high negative El Nino, normal condition is near zero. Figure 4 shows the time series of Thai sugar production with SOI.

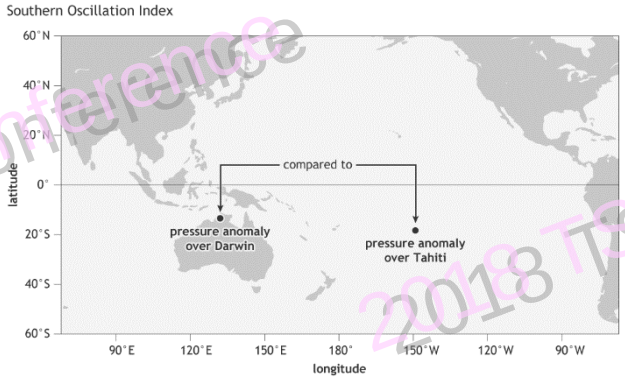

Figure 3 Illustration of Tahiti and Darwin of Australia.

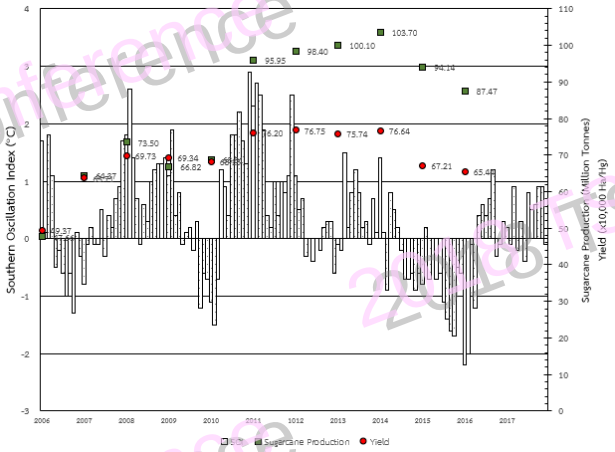

Figure 4 The time series of Thai sugarcane production and SOI.

ONI has been agreed as a standard ENSO for its correctness and simplicity. It is calculated from the anomalies of sea surface temperature at Nino 3.4 zone (Figure 5). Figure 6 demonstrates sugar production and ONI time series.

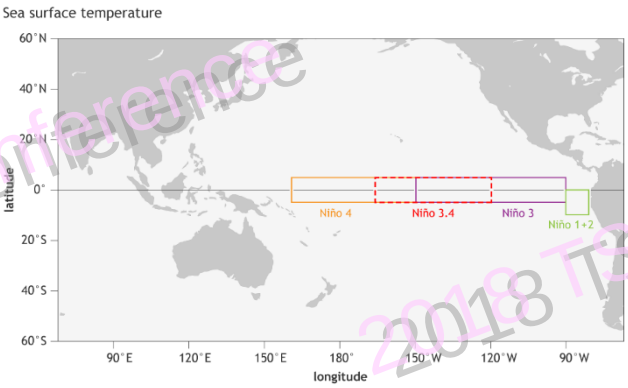

Figure 5 Illustration of several Nino zones.

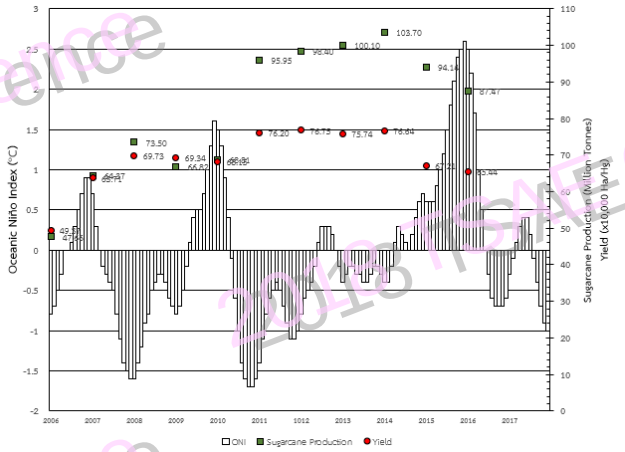

Figure 6 The time series of Thai sugarcane production and ONI.

The table 1 show the ENSO event classification during 1950-2017 by using the differences in Oceanic Niño Index (ONI) values. It shows separate the values for all two events (El Nino and La Nina) and 4 states (weak, moderate, strong, and very strong). From an overall perspective, El Nino events to be present when positive ONI values higher than or equal to 0.5°C and La Nina events to be present when negative ONI values lower than or equal to-0.5° C. During El Nino years, an apparent reduction in production, especially in very strong El Nino event (1997-1998 and 2015-2016), which found that sugarcane yield (kha/ha) and production (tonnes) were downward during El Nino event (Figure 1).

Table 1 Years in the period 1950-2017 in the ONI categories of ENSO event

ONI category		Years
El Nino	Weak	1952-53, 1953-54, 1958-59, 1969-70, 1976-77, 1977-78, 1979-80, 2004-05, 2006-07, 2014-15*
	Moderate	1951-52* 1963-64, 1968-69*, 1986-87, 1994-95*, 2002-03, 2009-10
	Strong	1957-58, 1965-66, 1972-73, 1987-88*, 1991-92*
	Very Strong	1982-83, 1997-98, 2015-16
La Nina	Weak	1954-55, 1964-65, 1971-72, 1974-75, 1983-84, 1984-85, 2000-01, 2005-06*, 2008-09, 2016-17
	Moderate	1955-56, 1970-71, 1995-96*, 2011-12*
	Strong	1973-74, 1975-76, 1988-89*, 1998-99*, 1999-00*, 2007-08*, 2010-11*

Composite rainfall was computed by averaging the monthly rainfall values when the particular ENSO event (El Nino, Normal or La Nina) prevailed (Figure 7). The composite averages of rainfall anomalies and sugarcane yield over Thailand for El Nino, Normal and La Nina periods and their differences. There were the highest rainfall in the La Nina event than other event especially during Jun-August and February-May period. On the other hand, there were lower rainfall in the El Nino event than normal event especially during June-September and February-May period. Yields were also increased in years in which the precipitation increasing values in La Nina event and decreased in years in which the precipitation falling values in El Nino event.

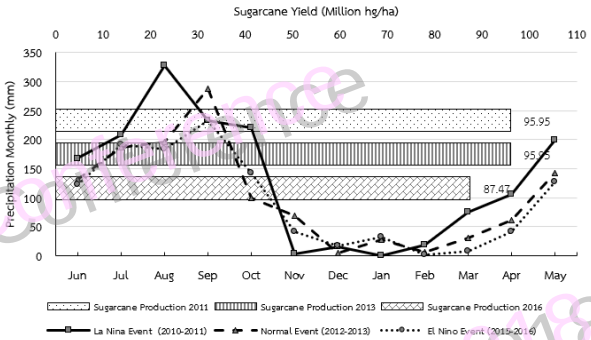

Figure 7 The composite precipitation climatology and sugarcane yield for all Thailand during El Niño, La Niña and Normal event from June to may.

4 Conclusions

Climate variability does significantly in fluence the rainfed sugarcane production in Thailand. However, the impact arising from adverse weather conditions on crop productivity is subject to the intensity of ENSO event. In our of relationship between ENSO event (EL Nino and La Nina event), precipitation and sugarcane production it was found that the differences between the La Nina and El Nino rainfall anomalies were higher during the La Nina event than normal event and lower during El Nino event than normal event. There was a reason for the El Nino effect on sugarcane production, while typically negative in Thailand, can also be positive in many regions. That is, ENSO-induced increase in sugarcane production of one country is offset by the reduction in another country. Therefore, it is important for planters to have a good water management system to reduce the impact of climate variability on sugarcane production.

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Table 2 Sugarcane production (million tons) and rank of major producers, 1950-2016.

	2016	2009-11	1999-01	1989-91	1979-81	1969-71	1959-61	1949-51
Brazil	768.7 (1)	714.4 (1)	335.8 (1)	258.6 (1)	147.8 (1)	78.5 (2)	56.6 (3)	32.2 (3)
India	348.4 (2)	306.6 (2)	297 (2)	223.2 (2)	144.9 (2)	128.7 (1)	87.3 (1)	52 (1)
China	123.1 (3)	114.3 (3)	75.1 (3)	63.9 (4)	33.8 (5)	19.6 (8)	15 (6)	8 (8)
Thailand	87.5 (4)	77.2 (4)	51.3 (4)	37 (6)	17.7 (12)	5.4 (20)	1.9 (27)	0.3 (43)
Pakistan	65.5 (5)	51.6 (5)	48.4 (5)	36.2 (7)	29.1 (7)	23.8 (6)	11.6 (9)	6.4 (12)
Mexico	56.4 (6)	49.9 (6)	46.1 (6)	40.8 (5)	34.4 (4)	33.3 (4)	18.8 (4)	9.8 (6)
Colombia	37.0 (7)	34.8 (7)	33.1 (9)	27.4 (9)	24.7 (8)	13.2 (11)	12.5 (7)	11.1 (5)
Australia	34.4 (8)	29.3 (8)	35.3 (7)	24.2 (12)	23.4 (10)	17.6 (9)	9.4 (12)	6.5 (11)
USA	29.9 (9)	26.3 (9)	32.1 (10)	26.6 (10)	24.5 (9)	21.4 (7)	9.4 (5)	6.5 (4)
Indonesia	27.2 (10)	25.7 (10)	24.2 (12)	27.6 (8)	19.5 (11)	10.3 (12)	9.6 (11)	3.1 (18)
Philippines	22.4 (11)	23.1 (11)	25.6 (11)	25.2 (11)	31.5 (6)	25.3 (5)	12 (8)	7.1 (10)
Argentina	22.0 (12)	21.9 (12)	17.9 (14)	15.9 (14)	15.6 (14)	10.2 (13)	10.4 (10)	7.6 (9)
South Africa	17.2 (13)	15.1 (14)	22.1 (13)	18.9 (13)	17.3 (13)	14.6 (10)	8.2 (15)	4.7 (13)
Cuba	12.8 (14)	18.9 (13)	34.2 (8)	80.8 (3)	69.3 (3)	60.5 (3)	58.3 (2)	44.5 (2)
Puerto Rico	0 (>100)	0 (>100)	0.1 (88)	0.9 (56)	2 (40)	5 (21)	9.4 (13)	9.7 (7)
Sum of above	1,652.35	1,508.89	1,078.20	907.1	635.5	467.1	337	216.5
World	1800.66	1718.3	1,259.40	1,053.50	768.1	576.3	413	260.8

Table 3 Sugarcane area harvested (million hectares) in major producing countries, 1950-2016.

	2016	2009-11	1999-01	1989-91	1979-81	1969-71	1959-61	1949-51
Brazil	10,226	9,099	4,901	4,092	3,130	1,330	1,400	1,307
India	4,950	4,511	4,197	3,699	3,073	2,486	2,428	2,011
China	1,675	1,711	1,171	1,230	722	566	279	414
Thailand	1,337	1,077	903	897	549	159	62	53
Pakistan	1,131	987	1,042	888	894	5,744	407	418
Mexico	781	709	628	556	520	483	352	325
Indonesia	473	438	381	392	234	77	75	62
Australia	447	363	412	333	314	234	159	131
Cuba	442	457	1,015	1,372	1,246	1,254	1,218	1,097
Colombia	417	370	400	344	270	260	294	280
Philippines	410	400	365	367	409	466	240	205
USA	371	354	412	374	306	282	184	176
Argentina	332	304	282	258	314	242	218	264
South Africa	247	267	392	272	252	181	96	110
Puerto Rico	-	-	3	16	25	61	129	133
Sum of above	23,238	21,048	16,504	15,089	12,257	9,134	7,539	6,986
World	26,774	24,314	19,476	17,729	14,708	11,028	8,946	8,302