El Niño–Southern Oscillation and Rice Production in Thailand During 1980-2002 Period

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ABSTRACT

This paper aims to investigate the connection between El Niño-Southern Oscillation and total annual rainfall and rice production in Thailand during 1980-2002 periods. We retrieved monthly rainfall and main season rice yields of all provinces in Thailand. We found that El Niño events negatively influenced total annual rainfall amount during the period, but did not affect main season rice yields at the provincial and ecosystem levels. We concluded that agricultural research and development to improve understandings of relationships under climate change situations will greatly benefit and secure production supply for vulnerable population, especially those already undernourished rural poor.

Key words: ENSO, Provincial rice production

INTRODUCTION

During 1960-2009, agricultural land in Thailand has been expanded from 11.7 to 19.7 million ha. Thai population has more than doubled: from 26.3 to 66.9 million people, the annual growth rate dropped from 3.15 percent to 1.05 percent during the same period. Rice grain per capita rose to more than 400 kg per capita, the highest in Southeast Asia region. In the next 30 years, Thai population will increase by another 20 percent, reaching more than 80 million by 2050. Meeting the demand of such a large population will put enormous additional pressure on agricultural land for food production systems, especially in the Northeast and South regions of the country.

Rice planted area in Thailand has been stabilized since 1980s at about 9.3 million ha, approximately 19% of total land of the country. Thailand is a rice exporting country, yet 17% of her population is undernourished especially the rural poor groups (FIVIMS, 2004). Climate variability known as ENSO (El Niño-Southern Oscillation) will add more pressure. Thus it is important to assess its impacts on current and future rainfed production systems, which in turn may provide valuable information to deal with food security issues. Wikarmpapraharn and Kositsakulchai (2010) investigated relationship of ENSO and rainfall in Central plain in Thailand, however, there are few studies available on the assessment of impact of ENSO phenomenon on both rainfall and rice production at the regional level in Thailand.

The objective for this paper is to present the results of our investigation the link between ENSO, rainfall and rice production in Thailand during the period of 1980-2002. Section 2 covers our methods and materials, section 3 provides key findings and implications to food security and section 4 concludes our current work and suggests future research activities to gain better understanding to improve rice production systems in Thailand and similar rice ecosystems.

MATERIALS AND METHODS

The study covers some 9.3 million ha of total rice lands in Thailand, divided into six regional rice production areas, namely; Central, East, North, Northeast, West and South production areas. Based on 2002-2003 satellite image analysis, the total rice land is unevenly distributed among six rice production regions at approximately 7.8, 5.3, 23.5, 56.1, 4.7, and 2.6% of the total rice planted area during the main season (August - December) in Thailand, respectively. The rice producing regions in the Central, West and North are supplied with irrigation water (approximately 35% of the total rice planted area in Thailand), whereas the East, Northeast, and the West regions are mainly rainfed rice production areas.

We compiled the averaged main season rice yields and planted area by province as reported in the annual statistics by the Office of Agricultural Economics (OAE, 1980) during 1980-2002. In addition, we have also retrieved, from the website of regional offices of the Royal Irrigation Department (RID, 2011), the annual rainfall data from 24 stations representing six rice growing region in Thailand covering the same period.

We retrieved ENSO anomaly data set during 1980-2002 from the National Oceanic and Atmospheric Administration, Climate Prediction Center (NOAA-CPC). We calculated and classified the main rice growing season from 1980-2002 into one of the three ENSO phases (El Niño, Neutral or La Niña) based on NOAA-CPC definition (Table 1). A threshold of each phase is met when the 3-month running mean of Sea Surface Temperature (SST) anomalies in the Niño 3.4 region (5°N-5°S latitude and 120-170°W longitude) is above +0.5°C (El Niño warm phase) or below -0.5°C (La Niña cold phase). The neutral phase refers to a period in the cycle when neither El Niño nor La Niña is present. ENSO phases are defined as El Niño or La Niña when the threshold is met for a minimum of 6 consecutive months between May to November, over-lapping seasons of three month running means.

We used the Analysis of Variance (ANOVA) without replication method, available with Data analysis add-in of Microsoft EXCEL 2010 package, to analyze and identify interaction of ENSO and annual rainfall amount, rice yield and rice planted area. Correlation analysis was used to establish relationships between ENSO phases and rice yield and planted area.

Table 1. Classification of the three ENSO phases during 1980-2002 in Thailand.

ENSO Phase	Year	Month					
		MJJ	JJA	JAS	ASO	SON	OND
El Niño	1982	0.9	1.0	1.1	1.5	1.8	2.3
	1987	1.3	1.6	1.7	1.6	1.5	1.3
	1991	0.6	0.7	0.6	0.6	0.8	1.3
	1997	1.2	1.7	2.0	2.3	2.5	2.6
	2002	0.6	0.8	0.9	1.1	1.4	1.5
Neutral	1980	0.2	0.1	-0.1	-0.2	-0.1	0.0
	1981	-0.4	-0.5	-0.5	-0.3	-0.1	0.0
	1983	0.5	0.1	-0.2	-0.5	-0.7	-1.0
	1985	-0.7	-0.5	-0.4	-0.4	-0.5	-0.5
	1986	-0.1	0.2	0.4	0.6	0.9	1.0
	1989	-0.6	-0.5	-0.5	-0.5	-0.4	-0.3
	1990	0.1	0.1	0.1	0.2	0.1	0.2
	1992	0.6	0.2	0.0	-0.3	-0.2	-0.1
	1993	0.6	0.3	0.2	0.2	0.2	0.2
	1994	0.2	0.3	0.3	0.5	0.8	1.1
	1995	-0.1	-0.3	-0.5	-0.8	-0.9	-1.0
	1996	-0.3	-0.2	-0.3	-0.4	-0.4	-0.5
	2001	0.0	0.1	0.0	-0.1	-0.2	-0.2
La Niña	1984	-0.6	-0.6	-0.4	-0.5	-0.8	-1.2
	1988	-1.5	-1.6	-1.5	-1.6	-1.9	-2.2
	1998	-0.5	-1.2	-1.2	-1.3	-1.3	-1.5
	1999	-0.9	-1.1	-1.0	-1.1	-1.2	-1.4
	2000	-0.6	-0.5	-0.5	-0.5	-0.7	-0.9

El Niño > + 0.5°C of 3-month running mean of SST for six consecutive months.
Neutral <0.5°C to > + 0.5°C of 3-month running mean of SST for six consecutive months.
La Niña < + 0.5°C of 3-month running mean of SST for six consecutive months.
MJJ=May-June-July; JJA=June-July-August; JAS=July-August-September; ASO=August-September-October; SON=September-October-November; OND=October-November-December.
Source: http://www.cpc.ncep.noaa.gov/data/indices/sstoi.indices

RESULTS AND DISCUSSION

ENSO and annual rainfall

Analysis of variance reveals that three ENSO phases were significantly affecting annual rainfall in Thailand (Table 2). The average annual rainfall from selected rainfall stations were 1,174; 1,249, and 1,337 mm for El Niño, Neutral and La Niña phases of ENSO during 1980-2002, respectively. During the strongest El Niño year 1997, averaged annual rainfall was 1,044 mm, the lowest amount during the period and received only 88% of the average annual rainfall of the El Niño years, approximately 78% of the average annual rainfall of the La Niño year. Our results agree with earlier studies, i.e., Nounmusig and Wongwises (2009), Nounmusig et al. (2006) and TMD (2011). However, we did not find relationships between the 3-month running means and annual rainfall in all selected rainfall stations.

Table 2. Analysis of variance of the effects of ENSO years on annual rainfall amount from 24 stations during 1980-2002 in Thailand.

Source of variation	df	SS	F	*P*-value
ENSO years	22	10,410,357	9.9921	0.0000
Rainfall stations	36	231,548,860	135.8175	0.0000
Error	792	37,506,773		
Total	850	279,465,991		

ENSO and rice production

The average yield per unit area remains the lowest in the Southeast Asia region, Cambodia, Indonesia, Laos PDR, Malaysia, Myanmar, Philippines and Vietnam, with huge variation among six ecosystems. During 1980-2002, averaged rice yields in Central, West, North, East, South and Northeast ecosystems were 3,083; 2,796; 2,682; 2,111; 1,934; and 1,702 kg/ha, respectively, highly significant at $P < 0.0001$. These large variations of rice yield per unit area reflect large differences in natural resources endowment as well as sensitivity of ecosystems to changes in weather and climate patterns. However, rice yields of each region varied in a small range, reflecting the relative stable production.

Based on correlation analysis, we did not find relationships or interactions between ENSO phase and rice yield (Table 3) and rice planted area (Table 4) for all six rice ecosystems in Thailand. During 1980-2002 cropping season, El Niño events posed little influences on rice productivity in Thailand, with similar results in China (Deng et al., 2010) and opposite results in Northeast Thailand (Yoshino, 2000). However, research showed many reasons why Thai rice farmers should be worried about climate change, including: large proportional of rice planting area are under rainfed conditions and are likely to encounter higher temperatures that will likely be higher than growing season temperatures during the past experiences; changes in the pattern and intensity of rainfall throughout the year especially during El Niño years; and, finally, alterations in pest and pathogen pressures.

Table 3. Correlation coefficients and significant probability of four ENSO phases and rice yield (kg/ha) of six rice production ecosystems in Thailand during 1980-2002.

Correlation coefficient of ENSO phases and rice yield										
	MJJ	JA	JAS	Annual	NE	North	Central	East	West	South
MJJ	1									
JJA	0.9163	1								
JAS	1.0000	0.9796	1							
Year	0.9614	0.9567	0.8965	1						
NE	0.8874	-0.0784	-0.1124	-0.0737	1					
North	0.9835	-0.3763	-0.3207	-0.3925	0.3849	1				
Central	-0.0306	0.0328	0.0264	0.0106	0.7039	0.5175	1			
East	-0.4295	0.1734	0.1250	0.2326	0.5563	0.2650	0.6107	1		
West	0.0403	-0.0373	-0.0795	-0.0225	0.7871	0.4424	0.9073	0.6932	1	
South	0.2353	0.2601	0.2324	0.2134	0.5739	0.3256	0.8124	0.5237	0.8025	1

MJJ=May-June-July; JJA=June-July-August; JAS=July-August-September.

Table 3. Continued.

Probability value of significant of ENSO phases and rice yield										
	MJJ	JJA	JAS	Annual	NE	North	Central	East	West	South
MJJ										
JJA	0.0000									
JAS	0.0000	0.0000								
Annual	0.0000	0.0000	0.0000							
NE	0.8980	0.7424	0.6371	0.7576						
North	0.0588	0.1020	0.1680	0.0870	0.0938					
Central	0.8661	0.8909	0.9120	0.9647	0.0005	0.0194				
East	0.3180	0.4647	0.5996	0.3237	0.0109	0.2589	0.0042			
West	0.9281	0.8761	0.7392	0.9250	0.0000	0.0508	0.0000	0.0007		
South	0.2433	0.2680	0.3242	0.3663	0.0081	0.1612	0.0000	0.0178	0.0000	

MJJ=May-June-July; JJA=June-July-August; JAS=July-August-September.

Table 4. Correlation coefficients and significant probability of four ENSO phases and rice planted area (ha) of six rice production ecosystems in Thailand during 1980-2002.

Correlation coefficient of ENSO phases and rice planted area										
	MJJ	JJA	JAS	Annual	NE	North	Central	East	West	South
MJJ	1									
JJA	0.9615	1								
JAS	0.8874	0.9796	1							
Year	0.9835	0.9567	0.8966	1						
NE	-0.1070	-0.1711	-0.2124	-0.1447	1					
North	-0.5751	-0.4932	-0.4047	-0.4970	-0.3446	1				
Central	-0.2612	-0.1910	-0.1284	-0.2088	-0.8172	0.6639	1			
East	-0.2822	-0.1977	-0.1230	-0.2155	-0.7478	0.7434	0.8876	1		
West	-0.2879	-0.2304	-0.1720	-0.2468	-0.7022	0.6563	0.8176	0.8285	1	
South	-0.0469	0.0087	0.0501	0.0028	-0.8337	0.5012	0.9000	0.8572	0.6924	1

MJJ=May-June-July; JJA=June-July-August; JAS=July-August-September.

Probability of significant of ENSO phases and rice planted area										
	MJJ	JJA	JAS	Annual	NE	North	Central	East	West	South
MJJ										
JJA	0.0000									
JAS	0.0000	0.0000								
Year	0.0000	0.0000	0.0000							
NE	0.6535	0.4708	0.3686	0.5428						
North	0.0080	0.0271	0.0767	0.0258	0.1368					
Central	0.2660	0.4199	0.5894	0.3769	0.0000	0.0014				
East	0.2280	0.4035	0.6053	0.3616	0.0002	0.0002	0.0000			
West	0.2183	0.3285	0.4685	0.2942	0.0006	0.0017	0.0000	0.0000		
South	0.8444	0.9710	0.8337	0.9907	0.0000	0.0244	0.0000	0.0000	0.0007	

MJJ=May-June-July; JJA=June-July-August; JAS=July-August-September.

CONCLUSION

Although 65% of rice planted area in Thailand is classified as rainfed production system. El Niño events during 1980-2002 did not affected rice yields at the provincial and ecosystem under investigation; but negatively affected total annual rainfall amount. Rice production areas in the Central, North, Northeast and West regions, approximately 92% of the total rice planting area, have been receiving sufficient rains during the main rice growing season and allow farmers to maintain and subsequently increase rice yield per unit area over time.

Our findings suggest that it is possible to improve food security in Thailand as well as to secure foreign exchange from rice, even under rainfed rice production ecosystems. More efforts in research and extension agricultural and resource management related to rice production are needed to support understanding to increase rice production as well as grain production per capita. Public investment in data acquisition, modeling studies, and other scientific activities should lead to further improvements in ENSO prediction and, as a result, to further improvements in climate prediction, resource utilization for rice production and food security.

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