Estimating the Impacts of Climate Changes on Agricultural Productivities in Thailand, Using Simulation Models

Chapter 1. Introduction

Climatic information is essential for the systematic analysis of natural and agricultural ecosystems. Generally, climatic conditions are important in characterizing natural vegetation, land use and agricultural production systems. Unfortunately, in the tropics, it is frequently difficult to obtain sufficient spatial-temporal climatic data. Precise estimation of land productivity is the basis for the sustainable development of agriculture and appropriate land use. This research was implemented in order to appropriately estimate the impacts of climate changes on agricultural productivities in Thailand, with crop simulation models. The basic idea of this research was to evaluate the long-term changes of air temperature and rainfall, and their impacts on agricultural productivities.

Chapter 2. The long-term trends of the air temperature and precipitation changes and their possible impacts on agriculture in Thailand

In this study, the long-term trends of the air temperature and precipitation changes through the past 65 years from 1951 to 2015 in Thailand and the possible impact on agriculture were examined. It was found that the air temperature in the agricultural areas did not change too much, whereas some urban areas showed significant warming trends, and especially in recent decades the warming trends in the urban area seemed to be more conspicuous (Table 1).

Table 1. Average annual air temperature every 10 years from 1981 to 2015 in representative stations in Thailand.

Period	Average annual temperature (°C)							
	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

It was observed that in the spatial and temporal rainfall distribution in Thailand was uneven and unstable (Figure 1). Each individual station demonstrated large yearly fluctuations in annual rainfall, duration of rainy season, number of rainy days during rainy season and rainfall intensity during rainy season.

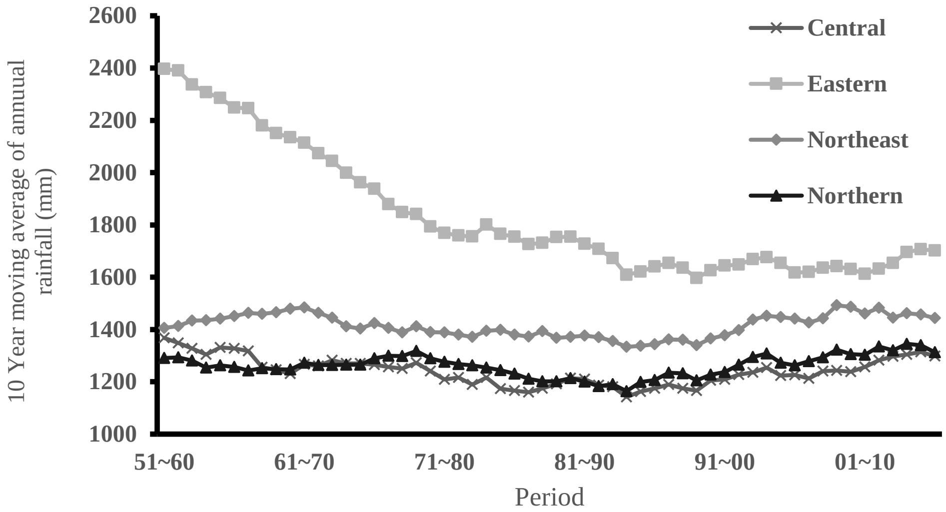

Figure 1. Ten-year moving average of annual rainfall in Central, Eastern, Northeast and Northern Thailand (mm).

It was also found that the major El Nino events had large impacts on the rainfall distribution patterns, especially after the 1980s. The El Nino events usually caused the decrease of rainfall by increasing the frequency of dry spell, making a sparser rainy pentads distribution (Figure 2), and delaying the onset of rainy season and accelerating the end of rainy season.

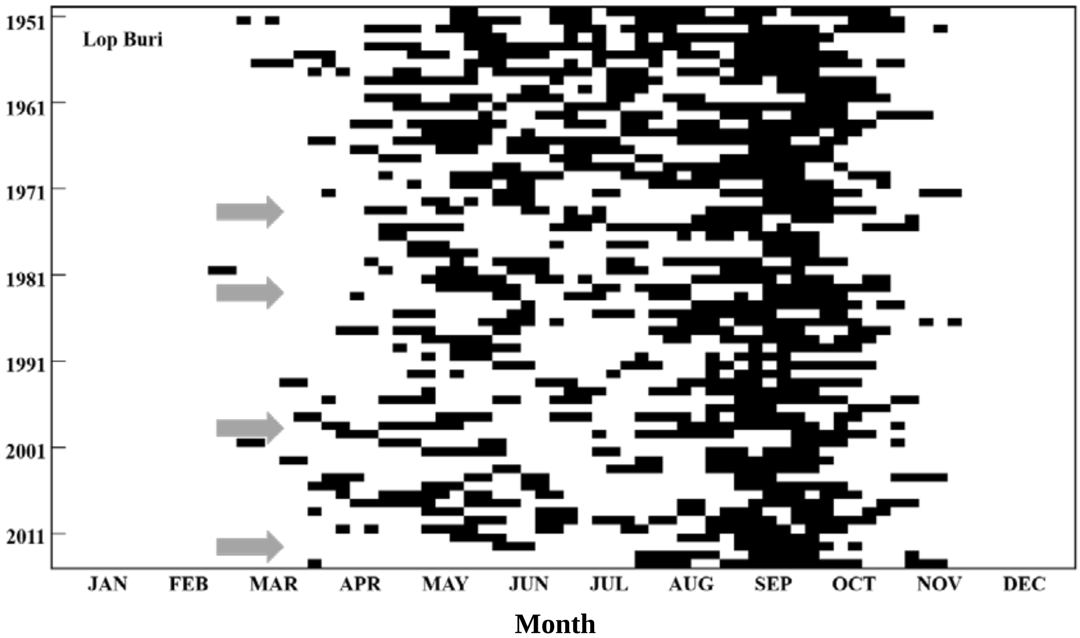

Figure 2. Rainy pentads in the Lop Buri station (Grey arrows indicate the 4 major El Nino events in 1972-73, 1982-83, 1997-98 and 2014-16).

Chapter 3. Estimating crop yields of maize, cassava and sugarcane in Thailand

Modeling the long-term potential and attainable yields of maize, cassava and sugarcane in mainland area of Thailand was performed and discussed. Each crop demonstrated relatively high potential yields in Central, Eastern, Northeast and Northern Thailand. When both drought and waterlogging effects were incorporated into the models, all crops showed large fluctuations in attainable yields. Drought affected the attainable yields of all these 3 crops to different extent. Maize was found to be affected by both the drought and waterlogging effects, and at the beginning of rainy season, the attainable yields of maize were affected by drought. As the planting date moved on, the attainable yields was more likely to be affected by waterlogging effects. Cassava was found to be relatively tolerant to drought, but extremely vulnerable to waterlogging stress (Figure 3). Sugarcane was found to be less sensitive to waterlogging effects, but more likely to be affected by drought with most of the ratio less than 50% as shown in Figure 4.

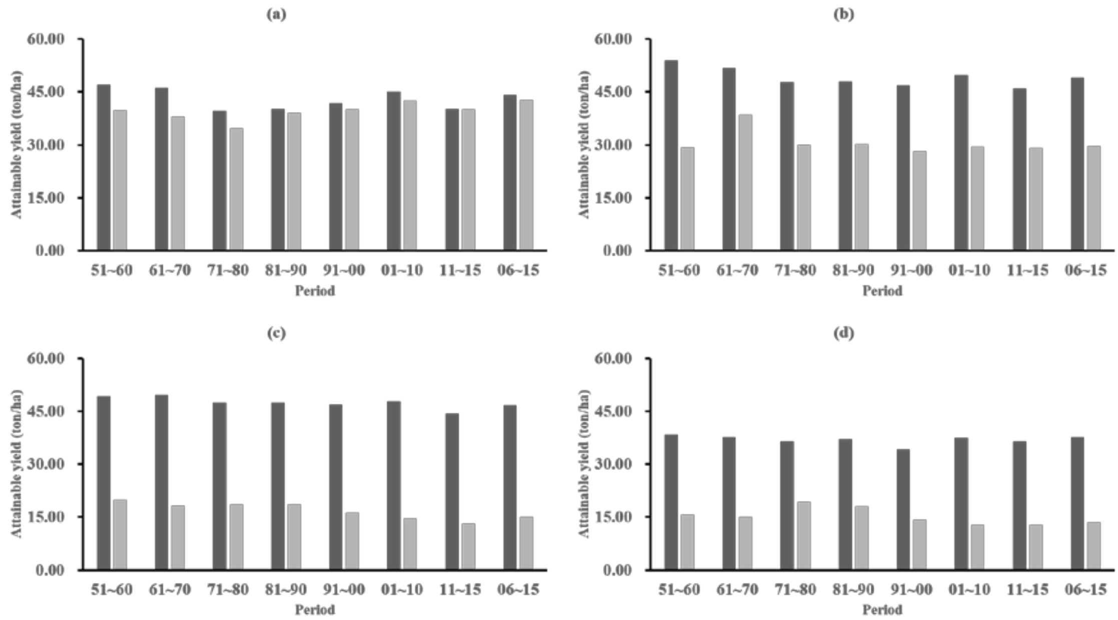

Figure 3. Attainable yields of cassava in Central (a), Eastern (b), Northeast (c) and Northern (d) Thailand with (black bars) and without waterlogging effects (grey bars).

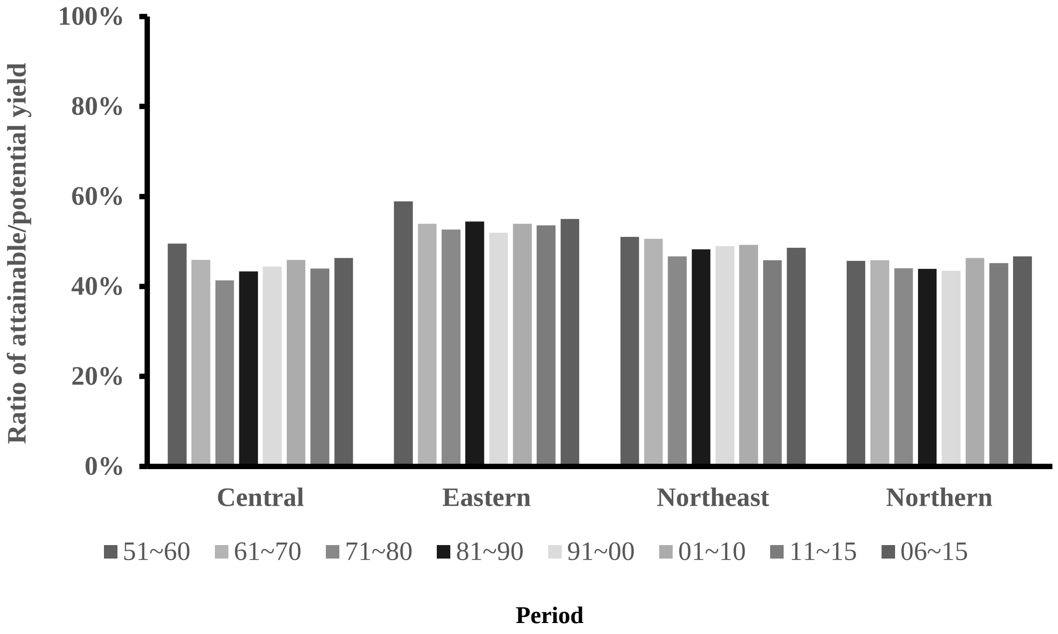

Figure 4. The ratio of attainable/potential yield of sugarcane (K88-92) in all four areas of Thailand.

Chapter 4. Long-term trends of climate changes and their impacts on simulated crop yields

Based on the results, the relationship between the long-term trends of climate change and the simulated crop yields were analyzed and discussed. It was found that with a higher temperature, higher potential yields were generally expected (Table 2).

Table 2. Ten-year average potential yields of cassava in 6 stations (ton/ha).

Period	10-year average of potential yield					
	Stations					
	455201 Bangkok	459201 Chon Buri	354201 Udon Thani	431201 Nakhon Ratchasima	327501 Chiang Mai	378201 Phitsanulok
51~60	72.55 ± 1.86	74.58 ± 1.75	59.10 ± 1.86	61.76 ± 1.71	50.67 ± 1.57	65.78 ± 2.06
61~70	71.75 ± 1.60	73.70 ± 1.75	59.60 ± 1.74	63.27 ± 1.98	52.64 ± 1.77	68.25 ± 1.84
71~80	70.23 ± 1.62	67.24 ± 1.21	63.64 ± 1.55	66.05 ± 1.26	54.25 ± 2.78	72.48 ± 1.55
81~90	72.77 ± 1.47	71.72 ± 2.55	63.84 ± 0.91	66.63 ± 1.58	59.14 ± 1.11	73.80 ± 1.20
91~00	74.73 ± 1.87	75.41 ± 2.09	61.59 ± 2.30	68.30 ± 1.86	52.51 ± 1.37	70.98 ± 2.22
01~10	75.72 ± 0.75	73.54 ± 1.01	62.30 ± 1.39	69.28 ± 0.96	56.52 ± 1.75	72.98 ± 1.21
11~15	74.85 ± 1.83	76.28 ± 1.63	60.74 ± 2.38	68.77 ± 3.08	61.48 ± 2.64	72.04 ± 2.60
06~15	75.10 ± 1.06	74.06 ± 1.28	61.53 ± 1.76	69.28 ± 1.68	59.87 ± 2.10	72.46 ± 1.70

In the case of rainfall distribution, in stations showing descending trends of annual rainfall, significant decreasing of attainable yields was also observed. For each 10-year period, the attainable yields showed large fluctuations, which indicated that under rainfed conditions, the uneven and unstable rainfall distribution seriously affected the crop yields (Table 3).

Table 3. Ten-year average attainable yields with waterlogging effects of maize in 8 stations**.**

Period	10-year average attainable yield (ton/ha)							
	Stations							
	425201 Suphan Buri	**426201** Lop Buri	**459201** Chon Buri	**430201** Prachin Buri	**354201** Udon Thani	**381201** Khon Kaen	**327501** Chiang Mai	**351201** Uttaradit
51~60	9.46 ± 0.74	10.33 ± 0.80	10.16 ± 0.63	4.84 ± 1.27	9.20 ± 1.02	11.07 ± 0.79	6.40 ± 0.90	8.64 ± 1.16
61~70	8.80 ± 0.96	10.26 ± 1.06	9.60 ± 0.93	5.78 ± 1.49	9.60 ± 1.05	10.55 ± 0.60	8.47 ± 0.93	7.87 ± 1.15
71~80	7.93 ± 0.98	8.44 ± 0.82	7.83 ± 0.69	5.22 ± 1.54	10.85 ± 0.55	7.52 ± 1.16	7.99 ± 0.80	8.56 ± 0.92
81~90	7.05 ± 0.77	9.83 ± 0.51	9.10 ± 0.69	8.47 ± 1.47	11.58 ± 0.23	11.26 ± 0.53	8.28 ± 1.04	8.73 ± 1.16
91~00	7.03 ± 1.04	8.20 ± 0.99	7.72 ± 1.29	6.64 ± 1.52	7.35 ± 1.60	9.48 ± 0.58	6.63 ± 1.01	6.36 ± 1.24
01~10	6.70 ± 0.61	9.42 ± 0.60	9.45 ± 0.68	7.67 ± 1.52	9.33 ± 0.96	9.41 ± 0.65	7.23 ± 0.90	8.56 ± 0.92
11~15	5.83 ± 1.66	6.89 ± 1.66	8.31 ± 1.00	4.77 ± 0.85	9.66 ± 0.85	7.63 ± 1.18	4.57 ± 1.28	7.34 ± 1.56
06~15	6.17 ± 0.86	8.66 ± 1.02	9.57 ± 0.66	7.28 ± 1.01	10.05 ± 0.49	8.37 ± 0.84	6.68 ± 1.05	8.72 ± 0.92

Chapter 5. General discussion

Based on the results in Chapter2, the air temperature in Thailand in the past 65 years did not show conspicuous warming trends, and the spatial and temporal rainfall distribution was uneven and unstable. The changes of air temperature and rainfall distribution must to be observed carefully. The relatively simple simulation models used in this research have been proved to be effective for evaluating land productivity on regional basis, but still there were rooms for the improvement of the models. To adapt to climate changes, new varieties could be developed, sowing time, cultivars and land use options could be shifted, and social and economic factors also needs to be taken into consideration.