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Climatic considerations which support the choice between natural rubber and oil palm in Nakhon Si Thammarat, southern Thailand

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ABSTRACT

Four climatic variables—rainfall, number of rainy days, relative humidity, and temperature—were studied to observe the characteristics and probable occurrences outside the required bounds for the optimal growth of oil palm and natural rubber. These two economic crops have become increasingly popular among farmers in Nakhon Si Thammarat province, southern Thailand. Monthly and annual data during 1981–2011 were analyzed using appropriate time-series techniques. The out-of-bound probabilities were calculated using the counting method. Only the rainfall showed a significant and increasing trend while the trends in the other variables were not significant. All studied variables showed seasonal fluctuation and cyclical movements. No significant irregularities appeared in the data. The probable occurrences of these climatic variables are crucial in determining the regular and sufficient levels of rainfall required for oil palm and natural rubber. Climate risks were less for growing natural rubber. This study concluded that natural rubber was a more climatically suitable crop for Nakhon Si Thammarat province, if only the four stated climatic variables were considered.

Introduction

The most frequently asked question in Nakhon Si Thammarat province in southern Thailand and perhaps throughout the country is which economic crop is more viable to plant, natural rubber (*Hevea brasiliensis* L.) or oil palm (*Elaeis guineensis* Jacq.). One of the factors in crop production is climatic conditions which include, *inter alia* rainfall, temperature, relative humidity, wet/dry period, precipitation, and day length (Eksomtramage, 2011; Rubber Research Institute of Thailand, 2010).

The availability and quality of water is the most important ingredient crops require to grow, especially in areas where irrigation is limited or absent. Therefore, crop production relies primarily on rainfall. Moreover, the amount of rainfall and water retention in the soil determines yields and consequently famers' incomes. However, climate is variable and uncertain—in some years there is a water surplus while in other years there is a water shortage and drought. These variations affect the crop's ability to grow and provide a sufficient yield (Srikul, Meedej, Korawis, Nithedpattarapong, & Klodpeng, 2000).

Kang, Khan, and Ma (2009) indicated that crop production could increase in areas where water sources were available such as irrigated areas. In addition, climatic variables, such as temperature and humidity were reported to be the important determinants of rice and potato yields in Nepal (Joshi, Maharjan, & Piya, 2011). Rice yields in

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Bangladesh were also influenced by increased temperature and rainfall (Sarker, Alam, & Gow, 2012) and by rainfall, sunshine and humidity (Amin, Zhang, & Yang, 2015; Chowdhury & Khan, 2015). The rice yields increased within optimal ranges of these climatic variables.

The climate variables associated with rainfall are complex. There are micro- and macroclimatic variables that need to be considered. The complexity of these variables and their relationships are understood and the variables used to determine the amount of rain and its distribution and frequency are numerous and their occurrences are a matter of probability. Atmospheric humidity (involving moisture and temperature) is one of these variables (Kamnalrut et al., 2000).

Natural rubber and oil palm are two major economic crops grown widely in southern Thailand. They are considered compatible with local soil types and climatic conditions and give reasonable yields and attractive monetary returns to the farmers. Past success stories have encouraged new investors to encroach into public lands, upland forest, mangroves, peat swamp forest, and other unsuitable lands in the hope of similar yields. These relatively new farming practices are often carried out under the assumption that rainfall will be available at the appropriate level required to produce the desired yields. However, there has been an increasing amount of evidence that suggests droughts and floods have directly hindered the normal growth of natural rubber and oil palm, resulting in low yields and high mortality rates. The current study was undertaken in Nakhon Si Thammarat province on the east coast of southern Thailand. The two economic crops are popular choices for growing in and around the peat swamp areas. Thus, the objective of this study was to understand the patterns of the four climatic variables identified, and to determine the probabilities of exhibited risks against normal growth of natural rubber and oil palm in the study area.

Literature Review

Study Site

Nakhon Si Thammarat is a province situated on the east coast of southern Thailand and at 994,300 ha, it is the largest of all the southern provinces (Poonwong, 2007). The province's population was 1.5 million in 2014 making it the most populated southern province (Nakhon Si Thammarat Province Statistics, 2014).

There are currently 243,292 ha involving 131,000 households under natural rubber and oil palm production in Nakhon Si Thammarat province (Rubber Research Institute of Thailand, 2013). The natural rubber yield and productivity were 317,352 t and 1.8 t/ha/year, respectively, and 738,863 t and 18.3 t/ha/year, respectively, for oil palm. In 2013, the trend of planted area showed positive growth over the years for both crops as shown in Figure 1A and B.

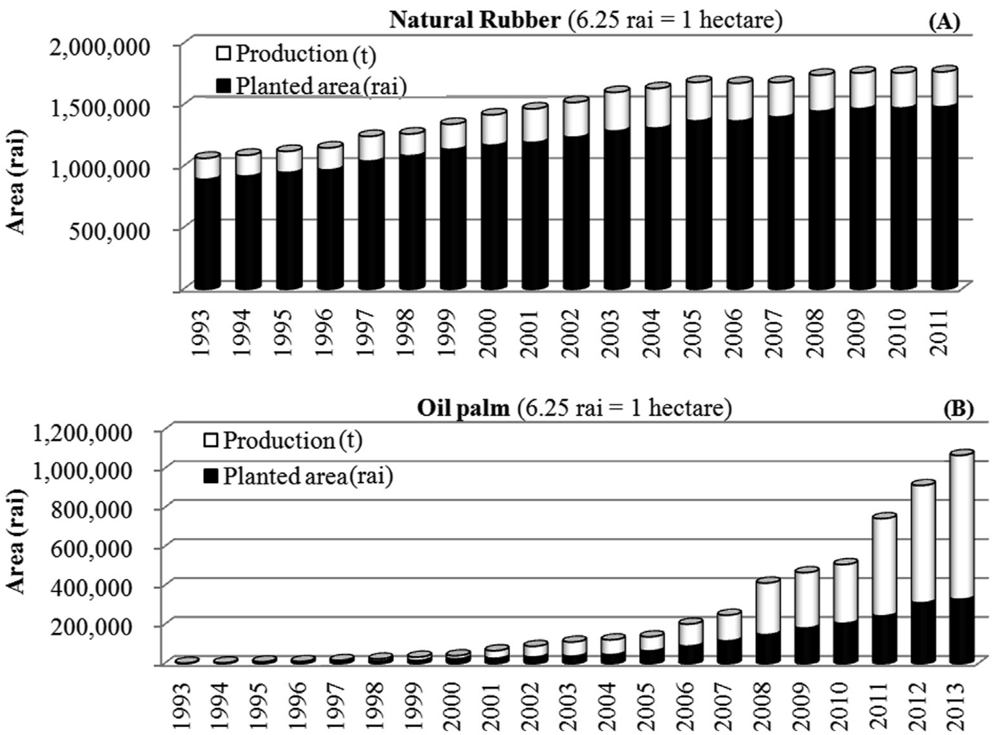

Figure 1 Trend in production and productivity of natural rubber and oil palm in Nakhon Si Thammarat province, southern Thailand during 1993–2011
Source: Rubber Research Institute of Thailand (2010)

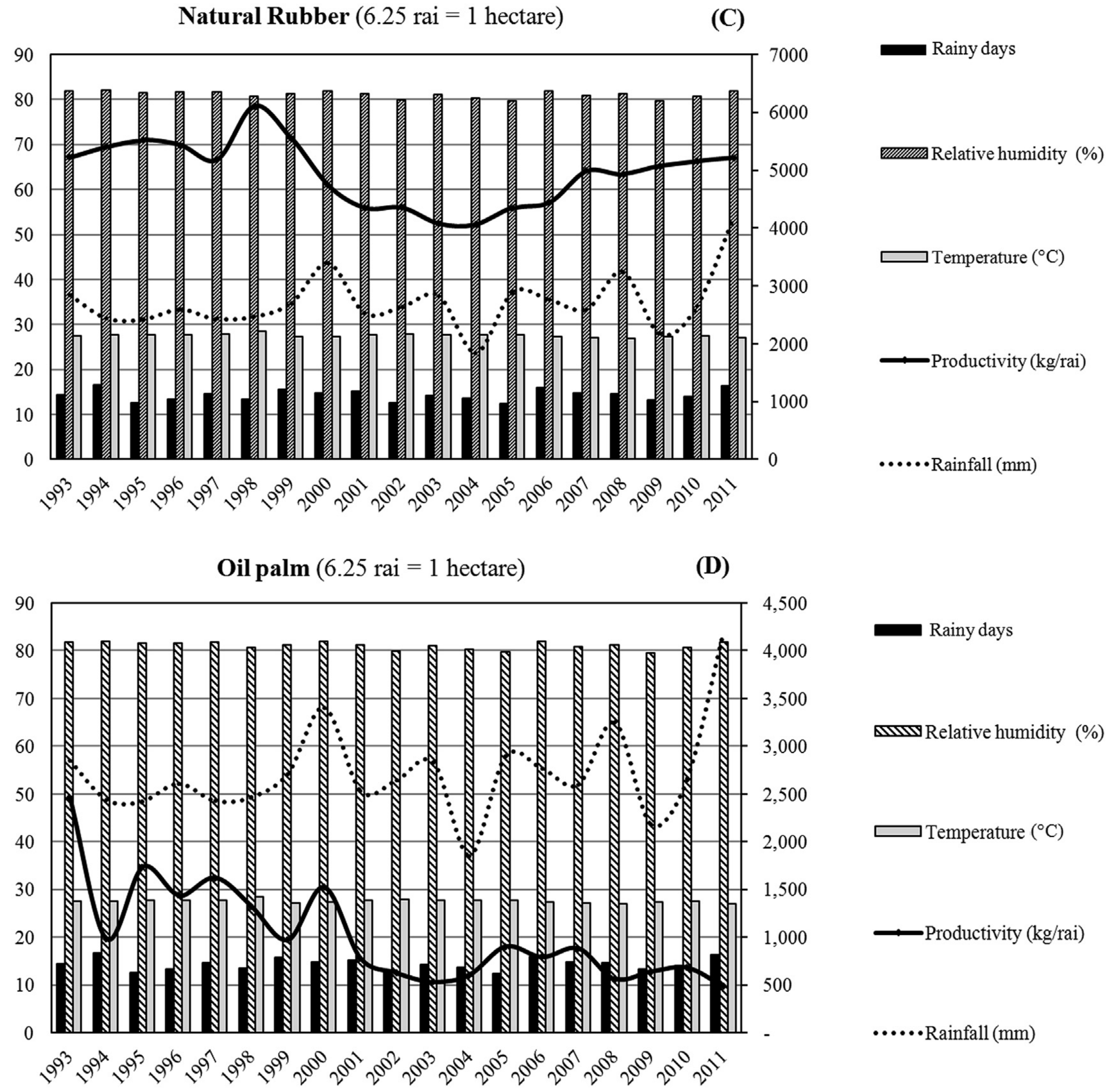

Figure 1 (*continued*)

It can be observed that the trends of production and productivity of both natural rubber and oil palm were increasing over the 1993–2011 period. The trend of natural rubber increased at a decreasing rate during 1993–2011 while in contrast, the trend of oil palm increased at an increasing rate, except during 2010–2011 where the trend increased at a decreasing rate.

Figure 1C and D shows plots of the four climatic variables and productivity of natural rubber and oil palm and there is a clear, positive relationship between the four climatic variables and the productivity of both natural rubber and oil palm.

Water Requirements of Oil Palm and Natural Rubber

Different species of plants have different levels of water requirement and drought tolerance. Plants acquire water from precipitation and irrigation, each of which has factors determining its water availability. Oil palm and natural rubber have different ranges of water requirements for their normal growth as well as their water retention for sustained growth (Chantaraniyom, 2007; Sapjareonwongse, Meedej, Nithedpattarapong, Korawis, & Klodpeng, 2001).

Water Requirements of Oil Palm

Oil palm requires water and nutrients for its growth, flowering and fruit development. Certain ranges in rainfall, its distribution and rainfall-related parameters are required. These parameters are key determinants for the selection of suitable plantation areas. It is reported that suitable rainfall for oil palm is between 2,000 and 3,000 mm/year and there should be more than 200 rainy/days/year (Chantaraniyom, 2007), with a prolonged drought period of less than 60 days/year, relative humidity between 75 and 80 percent, average temperature of 25 °C, and more than 5.5 h of sunlight per day (Chantaraniyom, 2007; Eksomtramage, 2011). Unfavorable climatic variables limit oil palm's growth, stunt the opening process of the flowers and fruit development and lower the palm oil content. If there is a prolonged drought period, female flowers reverse their development into male flowers affecting the fresh fruit bunch yield and the oil component. In addition, the moisture content in the soil has a direct impact on oil palm's somatic growth. Factors determining this moisture content are the rainfall, water evaporation from the soil and oil palm, soil capacity for water storage, and water supplements from various types of irrigation (Chantaraniyom, 2007).

Foong (1991) and Foong (1999) reported that oil palm (19 years old) receiving its full water requirement could have yields of maximum fresh fruit bunch (FFB) and crude oil of 9.44 and 2.40 t/rai/year, respectively. This finding indicated that a sufficient water level was required for maximum growth of leaves and their photosynthetic ability. Oil palm with supplemented water supply had a better growth rate, produced flowers with a favorable male-female sex ratio and consequently a higher number and weight of FFB and a higher percentage of oil content (Corley, 1976; Corley & Hong, 1982; Hong & Corley, 1976).

In Thailand, Nilnond, Chantaraniyom, Eksomtramage, Tongkum, and Suwanrat (2010) compared the FFB yields and oil contents between oil palm with and without water supplements over a 9-year period and reported that the yield of FFB was 3.45 and 2.79 t/rai/year, respectively, and the oil content was 967 and 736 kg/rai/year, respectively. Similar findings were reported in Kelantan, Malaysia and Ivory Coast where the yield of FFB of oil palm with water supplements was higher by 15 and 21 percent, respectively, than without water supplements in the respective countries.

Water Requirements of Natural Rubber

Natural rubber requires relatively less water for its normal growth, with a rainfall between 1,250 and 2,000 mm/year, the number of rainy days between 120 and 150 days in a year, an average temperature between 26 and 30 °C, and the relative humidity between 65 and 90 percent (Chantaraniyom, 2007; Somjan & Sadudee, 2008; Tavornpanitroj, 2003), and a prolonged drought period of less than 120 days. In addition, natural rubber grows normally at an altitude of less than 600 m and on slopes of less than 35°, with no water logging, a soil depth of more than 1 m and a soil pH between 4.5 and 5.5 (Rubber Research Institute of Thailand, 2010). A prolonged drought period results in a longer leaf fall and therefore a lower number of tapping days per year (Thawaroruit, 2006).

Based on the theoretical and empirical information in the literature, the framework for data analysis is presented in Figure 2.

Methods

This study used time-series data for analysis. Monthly data ranging 20 years from January 1981 to December 2011 were collected (Nakhon Si Thammarat Meteorological Station, 2010; Office of Agricultural Economics, 2013). Four important variables associated with water availability for the growth of natural rubber

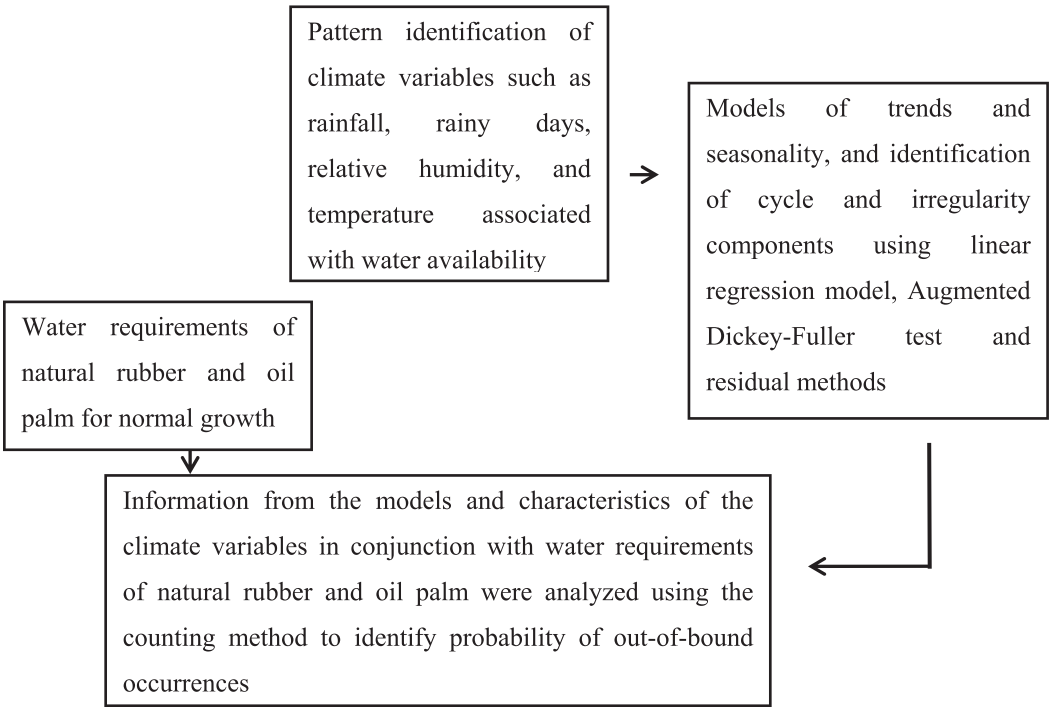

Figure 2 Framework for data analysis

and oil palm were considered—rainfall (mm), the number of rainy days, relative humidity (percentage) and air temperature (°C).

The analytical tools involved descriptive statistics such as the percentage, measures of central tendencies, and measures of variation in the univariate analytical framework. The existence of trends, seasonality, cycles and irregular components of the four variables were tested using the following analytical methods.

1) Trend and seasonality. These were detected using a time trend regression model and the specification of dummy variables. The general form of this linear regression model was written as:

$$Y_t = \beta_0 + \beta_1 t + \sum_{i=1}^{11} r_i D_i + \varepsilon_t$$

where

Y_t is a climatic variable (rainfall, rainy days, relative humidity, or temperature);
t is the time trend;
D is a dummy variable taking the value of
$D_1 = 1$ if January
$= 0$ otherwise
ε_t is a random variable (Nissapa, 2012)

2) The seasonal index was identified using the residual method. The steps involved in calculating the seasonal index were described in Gaynor and Kirkpatrick (1994) and are summarized as follows: 2.1) compute the centered moving average (CMA_t) of the monthly time-series data, 2.2) divide the data by CMA_t, 2.3) compute the average for each month, and 2.4) normalize the averaged seasonal estimates to obtain the seasonal index.

3) Cycles and irregularities were identified using the residual method similar to the calculation of the seasonal index with appropriate adjustments (Gaynor & Kirkpatrick, 1994; Getiam, 2005).

The lower and upper climatic requirement bounds of the four variables for both oil palm and natural rubber were identified using annual data. Out-of-bound occurrences were counted and the probabilities of these occurrences were calculated.

The time trend regression to detect trends and seasonality was considered appropriate as it provided the necessary statistics for hypothesis testing. In addition, the Augmented Dickey–Fuller (ADF) test was used for the unit root test of trend and it gave consistent results.

Results and Discussion

General Characteristics of the Studied Climatic Variables

The four climatic variables associated with water availability, (rainfall, rainy days, relative humidity, and temperature) are described in Table 1 and Figure 3.

The average rainfall over the study period was 211.65 mm/month with a standard deviation of 223.53, median of 143.15, maximum of 1,640.50, and minimum of 0 mm/month. The coefficient of variation for rainfall was 105.61 percent.

The average number of rainy days was 14 days/month with a standard deviation of 6, median of 14, maximum of 28, and minimum of 0 days/month. The coefficient of variation for raining days was 42.86 percent.

The average relative humidity over the study period was 80.85 percent with a standard deviation of 3.75, median of 81.00, maximum of 90.00, and minimum of 68.00 percent. The coefficient of variation for the humidity was 4.64 percent.

The average air temperature over the study period was 27.57 °C with a standard deviation of 1.14, median of 27.70 °C, maximum of 30.60 °C, and a minimum of 24.70 °C. The coefficient of variation for air temperature was 4.13 percent.

Linear trends of these variables were tested using the simple regression model. The rainfall variable exhibited a significant trend at the 95 percent confidence level, but was not significant at the 99 percent confidence level. The trends for the rainy days, relative humidity, and air temperature variables were not significant.

Seasonality was tested using regression with months as dummy variables and indicated that seasonality was present in all variables. Using December as the base month, it was found that every month was significantly different for rainfall, every month except October for rainy days and relative humidity, and every month except January for air temperature. The seasonal index computed by the decomposition method exhibited these seasonality characteristics.

Using the residual method, it was found that a 12-year cycle was present for rainfall, starting in February 1999 and ending in March 2011. Four cycles were found for rainy days. The first cycle started in February 1984 and ended in March 1994 (10 years), the second cycle was between April 1994 and April 1999 (5 years), the third cycle was between May 1999 and February 2006 (7 years), and the fourth cycle was between March 2006 and March 2011 (5 years).

Three cycles were found for relative humidity. The first cycle was between March 1984 and August 1998 (14 years), the second cycle was between September 1998 and June 2006 (8 years), and the third cycle was between July 2006 and April 2011 (8 years). A similar number of cycles were identified for temperature. The first cycle was between August 1981 and October 1987 (6 years), the second cycle was between November 1987 and March 1998 (11 years), and the third cycle was between April 1998 and May 2008 (6 years).

Irregularity testing using the residual method indicated that there was no significant irregular movement in all studied variables. Extreme values were observed but they were not found to be statistically significant.

Additionally, Figure 3 shows a graphical representation of the studied variables over the same period. It can be observed that all variables exhibited fluctuating behavior around trend (rainfall) and around constant (rainy days,

Table 1
Basic statistics for January 1981 to December 2011 in Nakhon Si Thammarat province

Statistic	Rainfall (mm/month)	Rainy days (day/month)	Relative humidity (%)	Temperature (degrees Celsius)
1. Average	211.65	14	80.85	27.57
2. Median	143.15	14	81.00	27.70
3. Maximum	1,640.50	28	90.00	30.60
4. Minimum	0.00	0	68.00	24.70
5. Standard deviation	223.53	6	3.75	1.14
6. Coefficient of variation (%)	105.61	42.86	4.64	4.13
7. Trend test using linear regression model	Significant trend at $\alpha = .05$	Not significant trend at $\alpha = .05$	Not significant trend at $\alpha = .05$	Not significant trend at $\alpha = .05$
8. Unit root test for stationary using Augmented Dickey–Fuller test	I(1) or stationary at first difference	I(0) or stationary at level	I(0) or stationary at level	I(0) or stationary at level
9. Seasonality test using seasonal dummy variables at $\alpha = .05$	Present in every month	Present in all months except October	Present in all months except October	Present in all months except January
10. Seasonal index				
January	89.28	95.66	102.41	94.80
February	36.03	37.84	98.92	96.64
March	68.47	59.06	97.95	100.17
April	64.24	67.88	97.88	103.93
May	101.08	122.27	99.12	104.36
June	168.98	97.82	96.30	104.46
July	72.97	108.12	96.34	103.12
August	77.62	110.41	95.49	102.99
September	97.25	129.69	99.82	101.47
October	183.30	154.25	104.39	98.88
November	372.33	164.16	106.93	95.92
December	269.62	146.93	105.23	94.08
11. Cycle test using residual method	Cycle 1 from February 1999 to March 2011 (12 years)	Cycle 1 from February 1984 to March 1994 (10 years)	Cycle 1 from March 1984 to August 1998 (14 years)	Cycle 1 from August 1981 to October 1987 (6 years)
		Cycle 2 from April 1994 to April 1999 (5 years)	Cycle 2 from September 1998 to June 2006 (8 years)	Cycle 2 from November 1987 to March 1998 (11 years)
		Cycle 3 from May 1999 to February 2006 (7 years)	Cycle 3 from July 2006 to April 2011 (8 years)	Cycle 3 from April 1998 to May 2008 (6 years)
		Cycle 4 from March 2006 to March 2011 (5 years)		
12. Irregularity test using residual method	Not significant	Not significant	Not significant	Not significant

Sources: Analysis of data from Nakhon Si Thammarat Meteorological Station (2010)

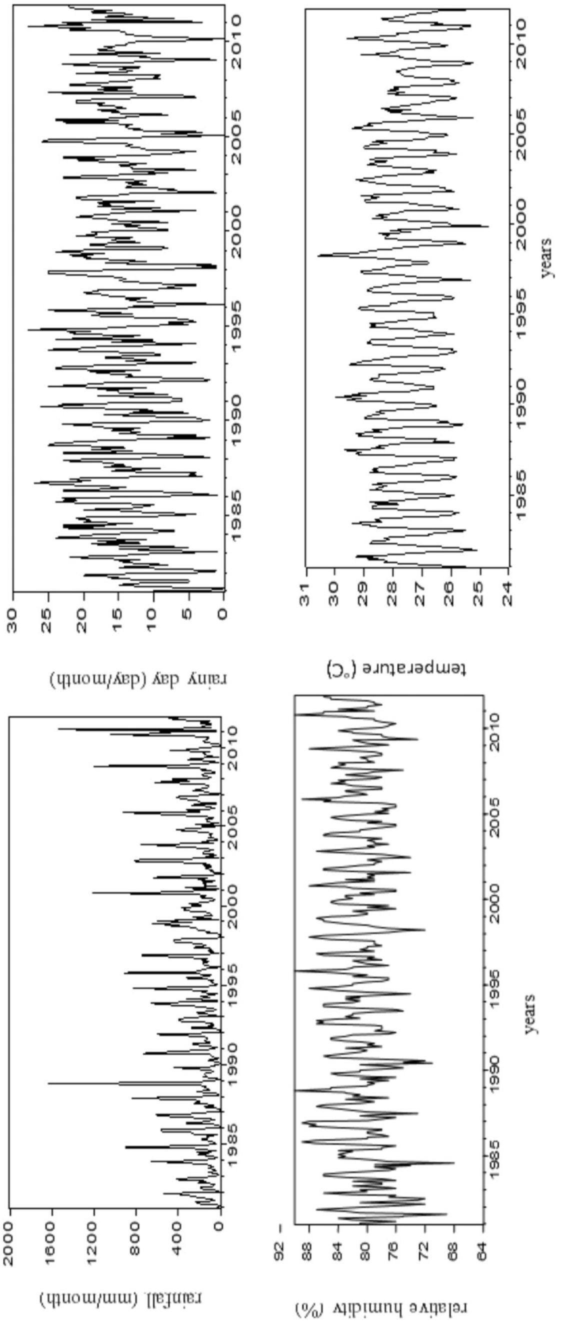

Figure 3 Trends of rainfall, rainy days, relative humidity, and temperature in Nakhon Si Thammarat province, 1981 to 2011

relative humidity, and temperature). This characteristic clearly displays stationary data (Griffiths, Hill, & Lim, 2009) and was confirmed by the Augmented Dickey–Fuller test for stationary data (Srikul et al., 2000).

Probability of Out-of-Bounds Occurrences of the Climate Variables

Table 2 presents the lower and upper bounds of the four climatic variables and the probabilities of out-of-bounds occurrences of these variables required for optimal growth of oil palm and natural rubber.

Oil Palm and Its Risk with Respect to the Climatic Variables

As reported by several studies, oil palm requires an annual average rainfall in the range 2,000–3,000 mm, more than 200 rainy days, a relative humidity between 75 and 80 percent, and an air temperature of 22–32 °C for its optimal growth and for flower and fruit development (Chantaraniyom, 2007). For the study period between 1981 and 2011 as shown in Table 2, the highest probability that the rainy days were outside the lower bound, was 0.97. This probability of rainy days less than the lower bound (200 days/years) was considerably high. The second highest probability for an out-of-bounds value was for relative humidity (0.77) and most of the out-of-bounds data were above the upper bound (80%). This was followed by the probability of rainfall (0.29) being outside the lower and upper bounds. There was no risk of air temperature outside the bounds for oil palm growth.

Natural Rubber and Its Risk with Respect to the Climate Variables

For natural rubber to grow normally, it requires between 1,250 and 2,000 mm of rainfall per year, 120–150 rainy days per year, a relative humidity between 65 and 90 percent, and an air temperature between 26 and 30 °C (Chantaraniyom, 2007; Tavornpanitroj, 2003). As shown in Table 2, the highest probability that the rainy days were outside bounds was 0.90. The number of rainy days was more than 150 days in a year. The second highest probability (0.84) was that the amount of rainfall was outside the upper bound required for natural rubber. The relative humidity and air temperature variables were well inside the required lower and upper bounds with zero probability.

It can be observed that the climatic bounds for oil palm were in more limited ranges than the bounds for natural rubber. Oil palm consumes more rainfall, requires more frequent rainy days, a higher relative humidity and a wider range of air temperature. The four climatic variables were more limiting to oil palm than natural rubber for optimal growth. On the other hand, the amount of rainfall and rainy days were more than sufficient for natural rubber which

Table 2
Lower and upper bounds of the four climatic variables and probabilities of out-of-bounds occurrences of these variables

Climatic variable	Oil palm		Natural rubber	
	Lower and upper bounds	Probabilities of out-of-bounds (1981–2011)	Lower-and upper-bounds	Probabilities of out-of-bounds (1981–2011)
Rainfall (mm/year)	2,000–3,000	0.29	1,250 to –2,000	0.84
Rainy days (days/year)	more than 200	0.97	120–150	0.90
Relative humidity (%)	75–80	0.77	65–90	0.00
Air temperature (°C)	22–32	0.00	26–30	0.00

may pose some threats in terms of water logging or fungal damage to the tapping surface.

Conclusion

Oil palm and natural rubber are two important economic crops grown widely in the south as well as in other regions throughout Thailand. Suitable areas and climatic conditions are needed for these crops to grow, in order to produce worthwhile yields. These two crops have gained in popularity in recent years, resulting in unsuitable areas being established. In addition, climatic changes observed globally are expected to pose threats to the normal growth of these important economic crops.

This study investigated the time-series data (monthly between 1981 and 2011) for four climatic variables associated with water requirements—rainfall, rainy days, relative humidity, and air temperature—for the growth of these two crops. The characteristics of these climatic variables were studied and the probabilities of occurrences falling out-of-bounds were calculated using annual data to determine the risks associated with unfavorable climatic variability. Simple descriptive statistics, regression analysis, and different forecasting techniques were used wherever appropriate to determine typical characteristics.

It was found that the rainfall variable had a significant, positive trend while the other three variables (rainy days, relative humidity, and air temperature) did not show statistically significant trends. Seasonality and cycles were identified for each variable, but there was no evidence of irregularity shown in the data set.

Oil palm appeared to have out-of-bounds probabilities involving higher risks than natural rubber with respect to rainy days, relative humidity, and rainfall. There was a high probability of insufficient water for its requirements. On the other hand, natural rubber appeared to face risks associated with water logging or tapping surface damage due to fungal infection (Sadudee & Somboonsuk, 2013).

With respect to the four climatic variables studied and the out-of-bounds probability analysis, it can be concluded that oil palm is a greater risk to grow in Nakhon Si Thammarat (especially in the peat swamp forest area) than natural rubber. The peat swamp forest area has the extreme characteristic of draining water out quickly in the dry season. Therefore, oil palm could face water shortages at levels lower than its normal growth requirements. The study by Foo (1998) confirmed that oil palm yields were influenced by the humidity as the yield could be almost doubled if the humidity were maintained within the required levels. Additionally, as reported by Nasir, Ishak, and Hamzah (2014), oil palm needs sufficient water for its flower and fruit development which consequently affect farmers' income. If farmers decide to continue to choose growing oil palm, they should make sure that adequate additional water supplementation is available to them in other forms. Natural rubber is more suitable to be grown in these areas but excess water from rainfall and frequent rainy days can be a threat to the trees and the tapping surface. Some kinds of water drainage and tapping surface protection are recommended in these cases.

Conflict of Interest

There is no conflict of interest. All stakeholders, e.g. farmers, government, researchers, private sector and local communities were consulted and working together to come up with the research results and conclusion.

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