The Impact of Climate Variability and Change to Cassava Yield and Valuation

การศึกษาความแปรปรวนและการเปลี่ยนแปลงของสภาพภูมิอากาศที่มีต่อผลผลิตมันสำปะหลัง

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Abstract

The climate variability and change have affected to crop yield all over the world. While, Thailand is one of the world's top cassava exporters with a market share of 79.56 percent. The objectives of this study were to investigate the impact of climate variability and change to cassava yield and its valuation, and to become a guideline for adaptation under climate variability and change. The result showed that the relative humidity (mm/month), wind speed (km/day), and maximum temperature/mean temperature ratio become the influencing factors on the cassava yield (tons ha^{-1}) whereas the coefficient of determination was at 0.519, that is, the relative humidity (mm/month), wind speed (km/day), and maximum temperature/mean temperature ratio could explain the changes in cassava yield for 51.9% while the rest 48.1% was influenced by other variables, which were not considered, at the .000 level of significance. In addition, if the ratio of maximum temperature/mean temperature is increases by 0.01. Cassava yield and cassava valuation will decreases 3.89% and 68.70 US$ ha^{-1}respectively. The regression formula of correlation coefficient between cassava yield with meteorological data and temperature variability ratio was cassava yield = 0.903(relative humidity) + 0.035 (wind speed) – 99.842 (maximum temperature/mean temperature ratio) + 57.500

Keywords: Climate variability and change, Cassava yield, Cassava valuation

บทคัดย่อ

ความแปรปรวน และการเปลี่ยนแปลงของสภาพภูมิอากาศ ส่งผลกระทบกับผลผลิตของพืชทั่วทุกมุมโลก ในขณะที่ประเทศไทยซึ่งเป็นหนึ่งในผู้ส่งออกมันสำปะหลังชั้นนำของโลกด้วยส่วนแบ่งการตลาดร้อยละ 79.56 วัตถุประสงค์ของการศึกษาครั้งนี้เพื่อการคาดการณ์ผลกระทบของความแปรปรวน และการเปลี่ยนแปลงของสภาพภูมิอากาศ ต่อผลผลิตและมูลค่าของมันสำปะหลังเพื่อนำมาใช้เป็นแนวทางในการปรับตัวของภาคการเกษตรของประเทศไทยภายใต้สภาวะความแปรปรวนและการเปลี่ยนแปลงของสภาพภูมิอากาศ ผลการศึกษาพบว่า ความชื้นสัมพัทธ์ ความเร็วลม และ ค่าอัตราส่วนระหว่างอุณหภูมิสูงสุดกับอุณหภูมิเฉลี่ย เป็นปัจจัยที่มีอิทธิพลต่อปริมาณผลผลิตมันสำปะหลัง โดยสามารถ

คณะวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยราชภัฏนครราชสีมา
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อธิบายการเปลี่ยนแปลงของปริมาณผลผลิตมันสำปะหลังได้ 51.9% ส่วนอีก 48.1% เกิดจากอิทธิพลจากตัวแปรอื่นๆ ซึ่งไม่ได้พิจารณาโดยมีค่านัยสำคัญทางสถิติเท่ากับ .000 โดยหากค่าอัตราส่วนระหว่างอุณหภูมิสูงสุดกับอุณหภูมิเฉลี่ยเพิ่มขึ้น 0.01 ผลผลิตมันสำปะหลังลดลงเท่ากับ 3.89% และคิดเป็นมูลค่ามันสำปะหลังเท่ากับ 68.70 US$ ha^{-1} โดยมีสมการความสัมพันธ์ระหว่างผลผลิตมันสำปะหลังกับข้อมูลอุตุนิยมวิทยา และค่าอัตราส่วนความแปรปรวนของอุณหภูมิ ได้แก่ ผลผลิตมันสำปะหลัง = 0.903(ความชื้นสัมพัทธ์) + 0.035 (ความเร็วลม) – 99.842 (ค่าอัตราส่วนระหว่างอุณหภูมิสูงสุดกับอุณหภูมิเฉลี่ย) + 57.500

คำสำคัญ: ความแปรปรวน และการเปลี่ยนแปลงสภาพภูมิอากาศ ผลผลิตมันสำปะหลัง มูลค่ามันสำปะหลัง

Introduction

Climate change is major and important environmental issue of 21^{st} century. It refers to any significant change in the measures of climate lasting for an extended period of time (USEPA, 2016). In other words, climate change is long-term continuous change (increase or decrease) to average weather conditions or the range of weather, and the climate fluctuates yearly above or below a long-term average value called “climate variability” (Dinse, 2011).Climate factors are key determinants to crop production processes; solar radiation, rainfall and temperature fluctuations lead to water deficit, flood, changing in soil moisture content, pest and diseases outbreak that constraint crop growth and can account for 15-80 percent of the variation of inter-annual yield resources (Nguyen Thi Chung, A.J., 2015; Oreke, E.H., 2012; Gommes, R.A., 2010; Lansigan, F.W., 2000; Yoshida, S.A., 1976)

Cassava is one of the most important commercial crops since it becomes a key raw material for manufacturing products which include food, flour, animal feed, alcohol, starches for sizing paper and textiles, sweeteners, and bio-degradable products. The products are derived from many forms of cassava, ranging from fresh leaves and roots to processed cassava starch (Agricultural Research Council, 2014). The cassava market is divided into 4 categories: cassava chip, cassava starch, processed starch and so on. The top 5 world cassava producing countries are Nigeria, Thailand, Indonesia, Brazil, and Congo. Those countries account for the proportion of 19.15, 10.92, 8.65, 7.76 and 5.96 respectively (Food and Agriculture Organization of the United Nations, 2014). In the field of export, Thailand is one of the world's top exporters with a market share of 79.56 percent. 85% of Thai cassava chip and cassava starch are exported to China followed by Vietnam and Indonesia with a market share of 9.73 and 2.42 percent respectively (Starch Industrial Association of China, 2015).

The current dynamic situation in the cassava trade, Thailand will maintain the world exporting champion by increasing its export up to 8 MT (cassava chip) due to the imposing of 5% tax on cassava export per ton by China over Vietnam therefore Vietnam will decrease her cassava export to China. The policy has been implemented since June 2015 (United Nations Development Programme, 2015). In opportunity have threats, climate variability and change are important threats of Thailand’s cassava production.

Furthermore, cassava is one of important raw material for ethanol production. Ethanol is the most widely used biofuel in the world. Over 64 countries now have active programs promoting the use of ethanol as a mainstream fuel (Biofuels Association of Australia, 2015). The International Energy Agency predicts that together, conventional and advanced biofuels will represent 8%, or 400 billion liters, of transport energy consumption by 2025. Moreover, Thailand's 10-year Alternative Energy Development Plan (2012-2021) remains unchanged targeting the use of ethanol at 9 million liters/day by 2021. Ethanol production is forecast to increase around 1.4 billion liters in 2016, up to 10 percent from 2015 due to growing demand for E20 and E85 gasohol. The higher demand is being fueled by the government's price subsidies and the expansion of E20 and E85 gasohol stations and cars. Cassava-based ethanol dominates the ethanol market, accounting for 30 percent of total ethanol production in Thailand, with the rest from Molasses. The number of ethanol plants is expected to increase from 21 plants in 2015 to 22 plants in 2016 with production capacity of 5.2 million liters per day, up 8 percent from 2015. The new plant will produce cassava-based ethanol. Production capacity of cassava-based ethanol plants will increase to about 1.9 million liters per day (USDA, 2015).

The use of ethanol blended fuel is another vital tool in our fight against climate change and global warming. Ethanol blended fuels can significantly reduce greenhouse gas emissions over the entire life cycle, from production through to use in the vehicle. Therefore, the US EPA estimates that on a Life Cycle Analysis basis, one liter of cellulosic ethanol reduces net emissions of CO_2 by over 90.9 percent, so one liter of ethanol will save 2.11 kg CO_2 (Biofuels Association of Australia, 2015). It was correlated with Thailand submission at COP21 in Paris. Thailand intends to reduce its greenhouse gas emissions by 20 percent from the projected business-as-usual (BAU) level by 2030. The level of contribution could increase up to 25 percent, subject to adequate and enhanced access to technology development and transfer, financial resources and capacity building support through a balanced and ambitious global agreement under the United Nations Framework Convention on Climate Change (UNFCCC). In addition, Thailand's national greenhouse gas (GHG) emissions represent only 0.84% of global emissions in 2012. The country's share of cumulative emissions from 1990-2012 is 0.75%. In 2012, per capita GHG emissions is at 5.63 t CO2e and emissions per GDP (US$ million) is 409.54 tCO2e, which is lower than world average. In terms of emission profile, the Second National Communication indicates that 67% of total GHG emissions in Thailand in 2000 is from the energy sector. In 2012, CAIT data indicates 73% is from energy. Consequently, Thailand's mitigation efforts have focused primarily on the energy, including transport sector (ONEP, 2015)

From the importance of Cassava, the main goal of this research were to study the impact of climate variability and change to cassava yield and cassava valuation, and the findings will become a guideline for adaptation in Thailand agriculture under climate variability and change.

Research Methodology

The study was conducted by meteorological data including average monthly data for annual temperature (mean, minimum and maximum), precipitation, water evaporation, relative humidity, wind speed, and solar radiation from three meteorological stations (Nakhon Ratchasima District, Pak Chong District, and Chok Chai District) in Nakhon Ratchasima Province, Thailand during 1983-2014 the period for finding the average in each parameter of meteorological data. All observed meteorological data that were used in this study were provided by the Northeastern weather network of Thailand Meteorological Department. The data gathered was used to analyze the climate variability and enter multiple regressions of meteorological data and cassava yield of Nakhon Ratchasima Provincewere provided by Agricultural Statistics of Thailand during the period 1983-2014.

In addition, Nakhon Ratchasima province is situated on Korat plateau of the North-east region of Thailand covering about 2.05 million hectare. The climate is tropical savannah with minimum and maximum temperature ranging from 14.1 to 39.5 °C. The area receives an annual rainfall of 1,062.4 mm in average annual rainy days of 104. Cassava is the principal crop on the upland followed by sugarcane and corn. Nakhon Ratchasima province is the largest among the cassava producer provinces, about 60 percent of total cassava production.

Results and Discussion

1. Climate variability

In the initial analysis, long-term variability of climate in Nakhon Ratchasima province was investigated. The average temperature over a period 1983-2014 including mean, maximum, and minimum was 27.12°C, 30.34°C, and 24.48°C respectively. In addition the annual of precipitation, evaporation, relative humidity, solar radiation, and wind speed equal to 100.44 mm/month, 143.91 mm/month, 71.36%, 4.63MJ/m^2-day, and 101.60 km/day respectively. By anomalies of annual temperature, precipitation, evaporation, relative humidity, solar radiation, and wind speed showed in Figure 1and Figure 3 - 5.

However, the imbalance of annual precipitation and evaporation showed in Figure 2 was explaining the requirement of water resource management. Therefore, the precipitation and evaporation are the major of inlet and lack of water in hydrological system. Hence, the trend of precipitation was decreasing and evaporation was increasing that means Nakhon Ratchasima province is facing the water shortage in the future. In addition, water resources and it ecosystem are highly sensitive to variations in weather and climate. The changes in global climate that are occurring as a result of the accumulation of greenhouse gases in the atmosphere will affect patterns of water availability and will alter the frequencies of floods and droughts as well as water quality. It was related with Viriya Laung-Aram, Chalermrat Sangmanee, Jutatip Thanakitmetavut. (2008) studied climate change trends in Thailand and surrounding countries using high resolution climate data model. High resolution of grid size 20x20 km. and covers a baseline period from the year 1960 – 1999 were used for comparison, and the future period covers the year 2010 – 2099. From this research, it was also reported that the future climate projection shows increasing trend of temperature throughout Thailand, especially in the central plain of Chao Phraya river basin and lower part of north-eastern region. There has been the prediction on the increase in mean annual temperature with the longer period of summer and more days of higher temperature than 33°C. The number of cold days will decrease, but with higher rainfall intensity. Water shortage and increasing in drought and flood frequency in some river basins are predicted. Total annual precipitation may fluctuate in the early part of the century but the projection shows clear trend of increasing precipitation from middle of the century onward, especially in the area near Mekong River as well as the southern region, except the western border, where future precipitation may remain almost unchanged. Change in wind speed and wind direction can be detected in the coastal zone, where south-west wind speed may increase by 3-5% in the future.

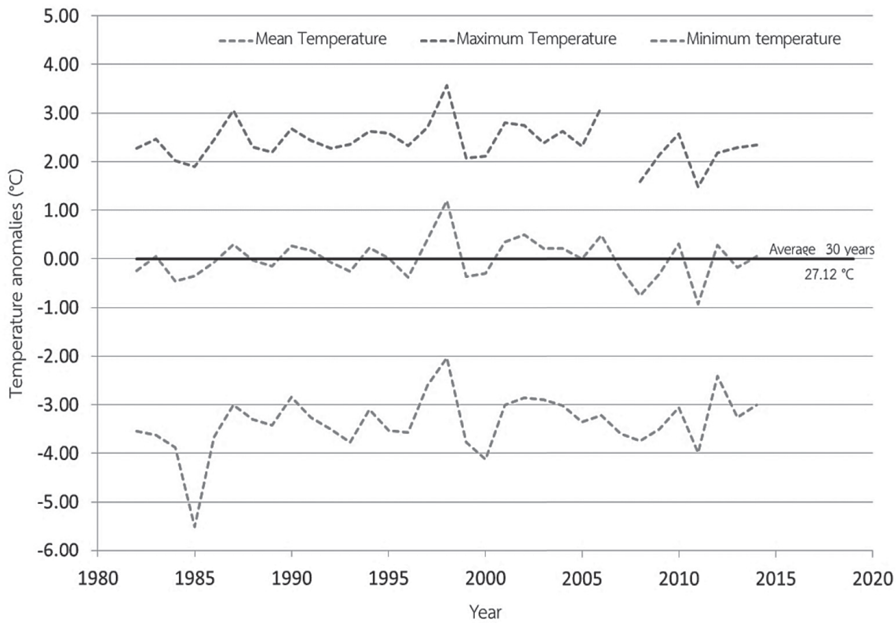

Figure 1. Annual temperature anomalies (℃) of Nakhon Ratchasima province during the period 1983-2014.

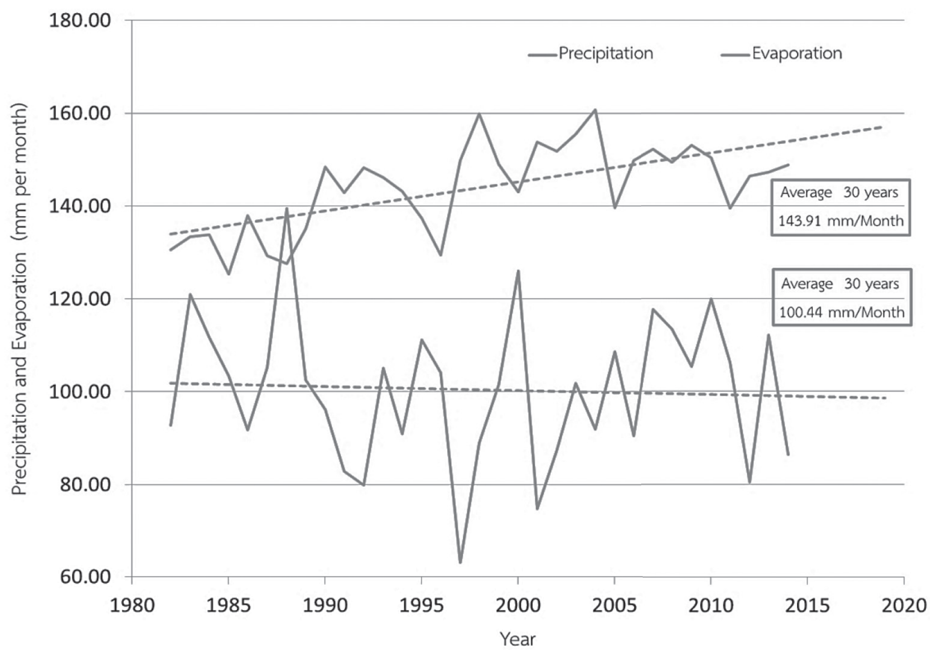

Figure 2. Annual precipitation and water evaporation (mm/month) of Nakhon Ratchasima province during the period 1983-2014.

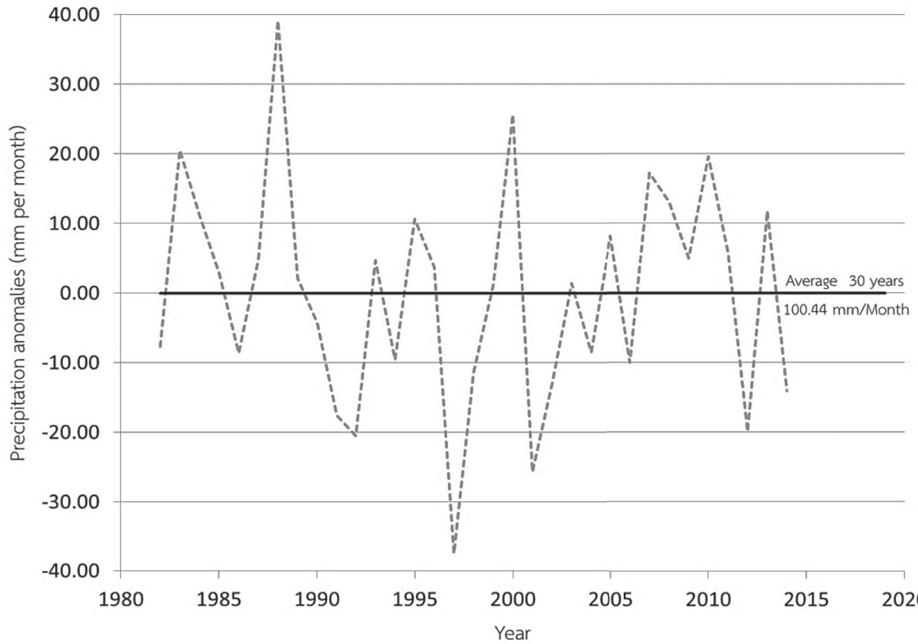

Figure 3. Annual precipitation anomalies (mm/month) of Nakhon Ratchasima province during the period 1983-2014.

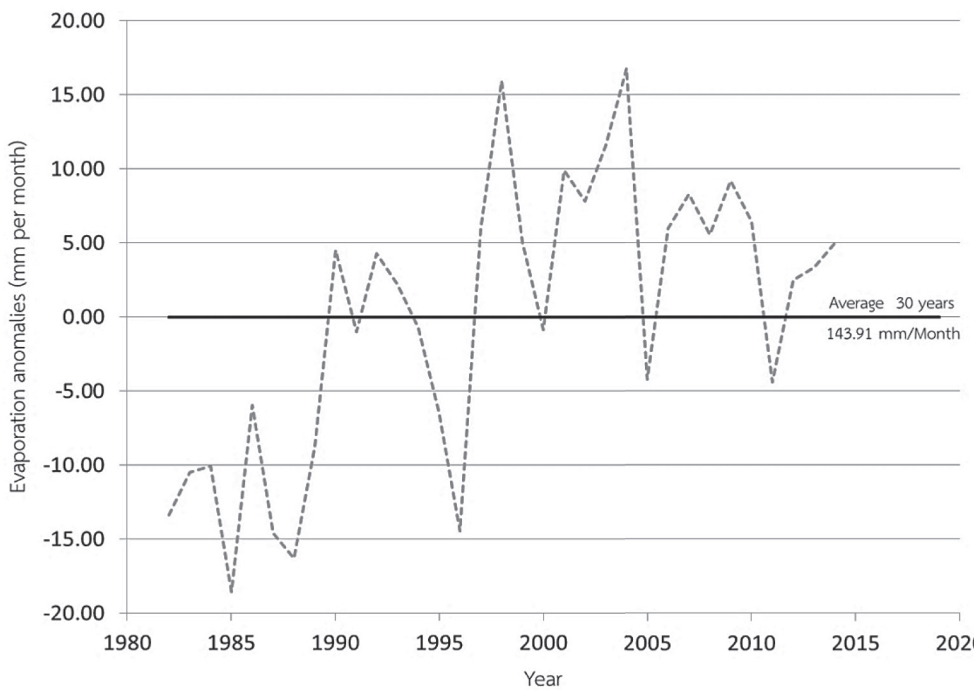

Figure 4. Annual water evaporation anomalies (mm/month) of Nakhon Ratchasima province during the period 1983-2014.

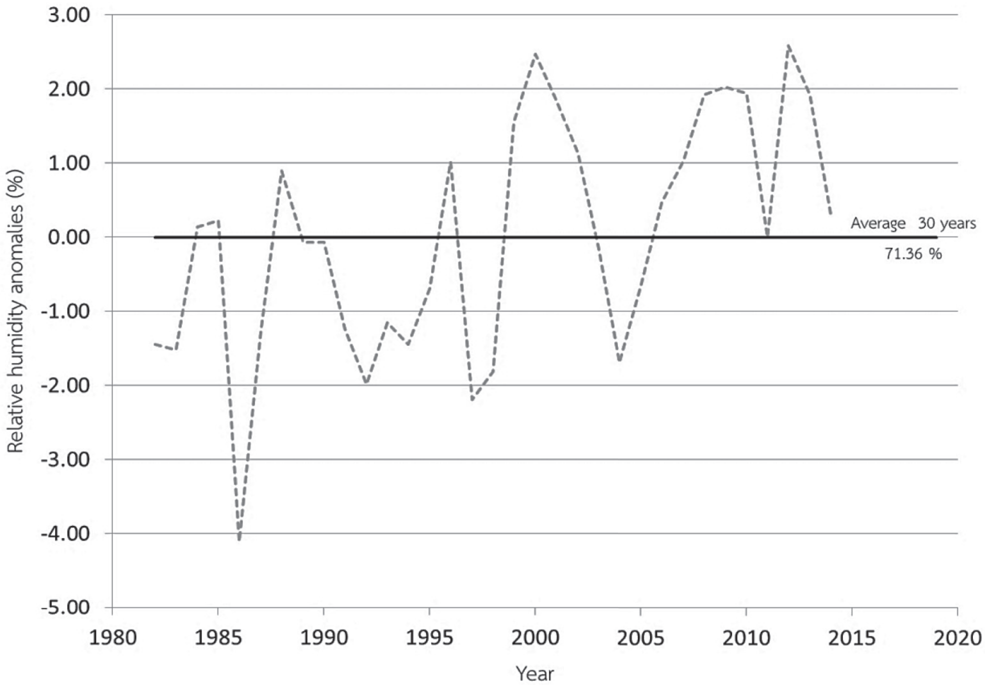

Figure 5. Annual relative humidity anomalies (mm/month) of Nakhon Ratchasima province during the period 1983-2014.

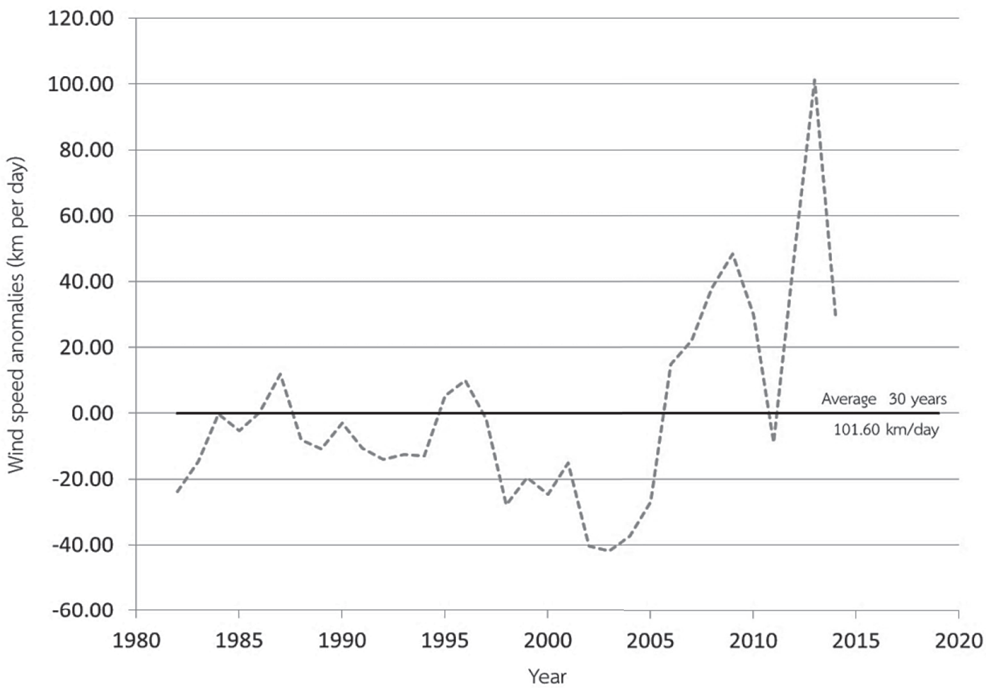

Figure 6. Annual wind speed anomalies (km/day) of Nakhon Ratchasima province during the period 1983-2014.

2. The impact of climate factors on cassava yield

Analysis using multiple regression of 6 meteorological data and 2 temperature variability ratio including annual temperature, annual precipitation, annual evaporation, annual relative humidity, annual wind speed, solar radiation, maximum temperature/mean temperature ratio and minimum temperature/mean temperature ratio and the cassava yield is used in order to select certain appropriate variables. The result showed that the relative humidity (mm/month), wind speed (km/day), and maximum temperature/mean temperature ratio become the influencing factors on the cassava yield (tons ha-1) whereas the coefficient of determination was at 0.519, that is, the relative humidity (mm/month), wind speed (km/day), and maximum temperature/mean temperature ratio could explain the changes in cassava yield for 51.9% while the rest 48.1% was influenced by other variables, which were not considered, at the .000 level of significance as shown in Table 1 and 2. Hence, equation predicted cassava yield is presented below.

$$\text{Cassava yield (tons ha}^{-1}) = 0.903(\text{Relative humidity}) + 0.035\,(\text{Wind speed}) - 99.842\,(\text{Maximum temperature/mean temperature ratio}) + 57.500 \quad [1]$$

Table 1 Results of multiple regression analysis between meteorological data and cassava yield of Nakhon Ratchasima Province

	Meteorological data	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	57.500	44.224		1.300	.205
	Relative humidity	.903	.298	.416	3.029	.005
	Wind	.035	.017	-.287	2.065	.049
	Maximum temperature/ minimum temperature ratio	-99.842	34.464	-.382	-2.897	.008

a. Dependent Variable: Cassava yield (tons ha^{-1})

Table 2 Coefficient of Determination

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.754a	0.569	0.519	2.50409

a. Predictors: (Constant), Relative humidity, Wind speed, Maximum temperature/mean temperature ratio

b. Dependent variable: Cassava yield (tons ha-1)

In 2015 COP21, also known as the 2015 Paris Climate Conference, 195 countries in the conference stated their determination to limit global warming to 2°C from 2015 to 2100. (UNEP Climate Action, 2015). According to the analysis in January 2014 from NASA's Goddard Institute for Space Studies (GISS), the average global temperature has risen by 0.8 °C (1.4 °F) since 1880 (NASA's Jet Propulsion Laboratory: California Institute of Technology, 2016).

Hence, temperature variability by the average 30 years of maximum temperature/mean temperature ratio is 1.05. If the ratio of maximum temperature/mean temperature is increases by 0.01. The impact of changing of maximum temperature/mean temperature ratio to cassava yield and cassava valuation can be predicted by the equation [1] (base on the assumption of average relative humidity and wind speed equal to 71.36% and 101.60 km/day during the period 1983-2014 is constant), as showed in Table 3 and Figure 7

Table 3 Impact of changing of maximum temperature/mean temperature ratio to cassava yield and cassava valuation

Change of maximum temperature/ mean temperature ratio	Cassava yield (tons ha^{-1})	Cassava valuation (US$ ha^{-1})
1.02	23.66	1,627.48
1.04	21.66	1,49010
1.06	19.66	1,352.72
1.08	17.66	1,215.33
1.10	15.67	1,077.95
1.20	5.68	391.04

Note: Average Thailand domestic Cassava Root Price period 2014/2015 = 68.80 US$/Tons (Thai Tapioca Development Institute, 2016)

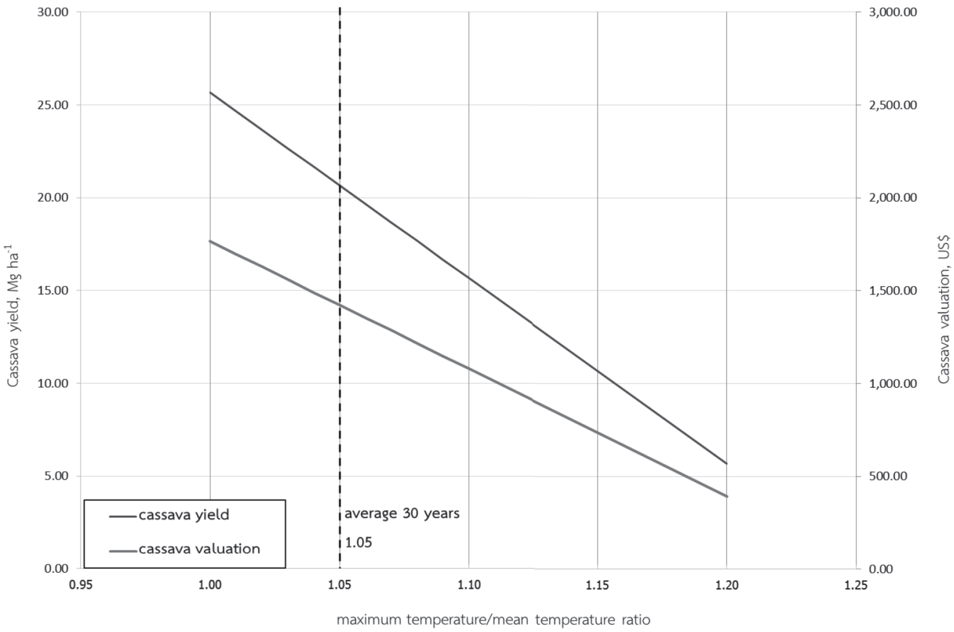

Figure 7 Change of cassava yield and cassava valuation

Conclusion

The finding of this research was to study the impact of climate variability and change to cassava yield and cassava valuation, and to become a guideline for adaptation expected climate variability and change. While, the relative humidity (mm/month), wind speed (km/day), and maximum temperature/mean temperature ratio become the influencing factors on the cassava yield (tons ha-1) whereas the coefficient of determination was at 0.519, that is, the relative humidity (mm/month), wind speed (km/day), and maximum temperature/mean temperature ratio could explain the changes in cassava yield for 51.9% while the rest 48.1% was influenced by other variables, which were not considered, at the .000 level of significance.

Thus, if the ratio of maximum temperature/ mean temperature is increases by 0.01. Cassava yield decreases 3.89%. Such as, when maximum temperature and mean temperature is equal 30°C and 25°C respectively the maximum/mean temperature ratio and cassava yield is equal 1.20 and 5.68 tons ha-1 respectively.

However, the imbalance of annual precipitation and evaporation explained to trend to lack of water in future. Therefore, Thailand should improve cropping systems, drainage and flood control facilities suitable to changing environment, and developing the high efficient plan for managing water resources. In addition, water resource management should balance the water demand from residential sector, agricultural sector, industrial sector, and other sectors in line with the philosophy of sufficient economy for sustainable development.

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References

Agricultural Research Council. (2014). Cassava. Retrieved march 23, 2016, from Agricultural Research Council: http://www.arc.agric.za/arc-iic/Pages/Cassava.aspx.

Biofuels Association of Australia. (2015). *Ethanol and emission reductions.* Retrieved July 21, 2016, from Biofuel Association of Australia: http://biofuelsassociation.com.au/biofuels/ethanol/Effect-of-ethanol-on-emissions.

Dinse, K. (2011). Climate Variability and Climate Change, What is the Difference? *MICHIGAN SEA GRANT.*

Food and Agriculture Organization of the United Nations. (2014). *FAOSTAT.* Retrieved March 24, 2016, from Food and Agriculture Organization of the United Nations, 2014: http://faostat3.fao.org/home/index.html#DOWNLOAD.

Gommes, R.A. (2010). *Guide to Agricultural Meteorological Practices.* World Meteorological Organization: No.134.

Lansigan, F.W. (2000). Agronomic Impacts of Climate Variability on Rice Production in the Philippines. *Agricultural Ecosystems and Environment.82(1),* 129-137.

NASA's Jet Propulsion Laboratory: California Institute of Technology. (2016, March 10). Graphic: Global warming from 1880 to 2013. Retrieved April 2, 2016, from Global Climate Change: http://climate.nasa.gov/climate_resources/28.

Nguyen Thi Chung, A.J. (2015). Impacts of Seasonal Climate Variability on Rice Production in the Central Highlands of Vietnam. *Agriculture and Agricultural Science Procedia,* 83-88.

ONEP. (2015). Thailand's Intended Nationally Determined Contribution (INDC). Office of Natural Resources and Environmental Policy and Planning. Thailand.

Oreke, E.H. (2012). *Crop Production and Crop Protection: Estimated Losses in Major Food and Cash Crops.* Elsevier.

Starch Industrial Association of China. (2015). Future Prospects for Tapioca Production and Trade in East Asia. *World Tapioca Conference 2015.* Chon Buri, Thailand.

Thai Tapioca Development Institute. (2016, February 15). *Domestic Root Price.* Retrieved March 23, 2016, from Thai Tapioca Development Institute: http://www.tapiocathai.org/M2.html.

UNEP Climate Action. (2015). *UNEP Climate Action.* Retrieved April 2, 2016, from Sustainable Innovation Forum 2015: http://www.cop21paris.org/about/cop21.

United Nations Development Programme . (2015). Cambodia Export Diversification and Expansion Programme (CEDEP II-Cassava).

USDA. (2015). Global Agricultural Information Network: Thailand Biofuels Annual 2015. USDA Foreign Agricultural Service.

USEPA. (2016, February 24). *Climate Change.* Retrieved March 23, 2016, from United States Environmental Protection Agency: https://www3.epa.gov/climatechange/basics.

Yoshida, S.A. (1976). Climatic Influence on Yield and Yield Components of Lowland Rice in the Tropics. *Climate and Rice,* 20, 471-494.

Viriya Laung-Aram, Chalermrat Sangmanee , Jutatip Thanakitmetavut. (2008). Simulating future climate scenarios for Thailand and surrounding countries, Thailand Research Fund (TRF).