Effects of Climate Change on Crop Production in Thailand

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Introduction

- Rising global population has increased the concern about food security
- A future challenge will be to secure the food supply for people and double the food production to feed a population that is projected to reach 9.73 billion by 2050 (FAO, 2017)
- Several studies found that food security can be affected by several other factors, including climate change, which influences food production through changes in crop yields and cropland and hence food availability (e.g., IPCC, 2019; Attavanich and McCarl, 2014)
- Studies also concluded that climate change is projected to negatively affect the global food system and food availability especially in the developing countries (e.g., Brown et al., 2015)

Introduction

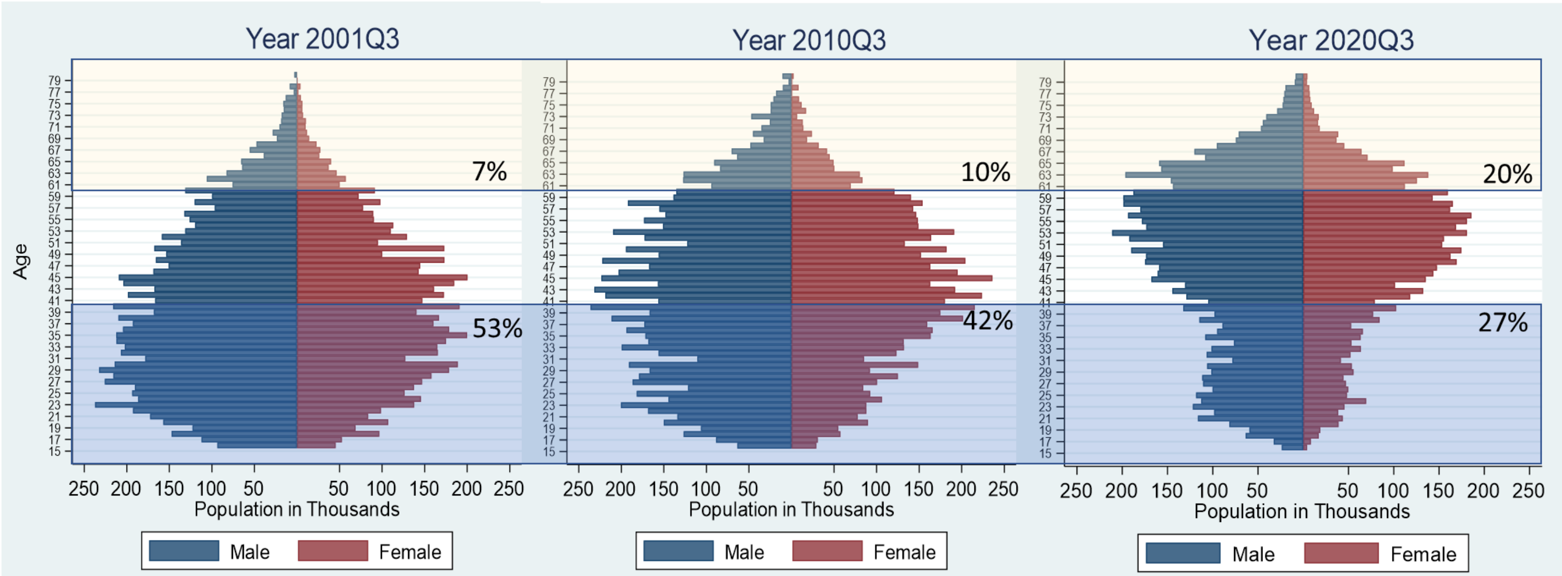
Agriculture plays a crucial role in Thailand:

- 8.1 million households (OAE, 2021)
- 34.1% of total labor force (NSO, 2020)
- 8.6% of GDP (NESDC, 2021)

It has likely been affected by climate change…

- Low education (4.46% of farmers graduated at least grade 12)
- Most of the farmers are smallholders

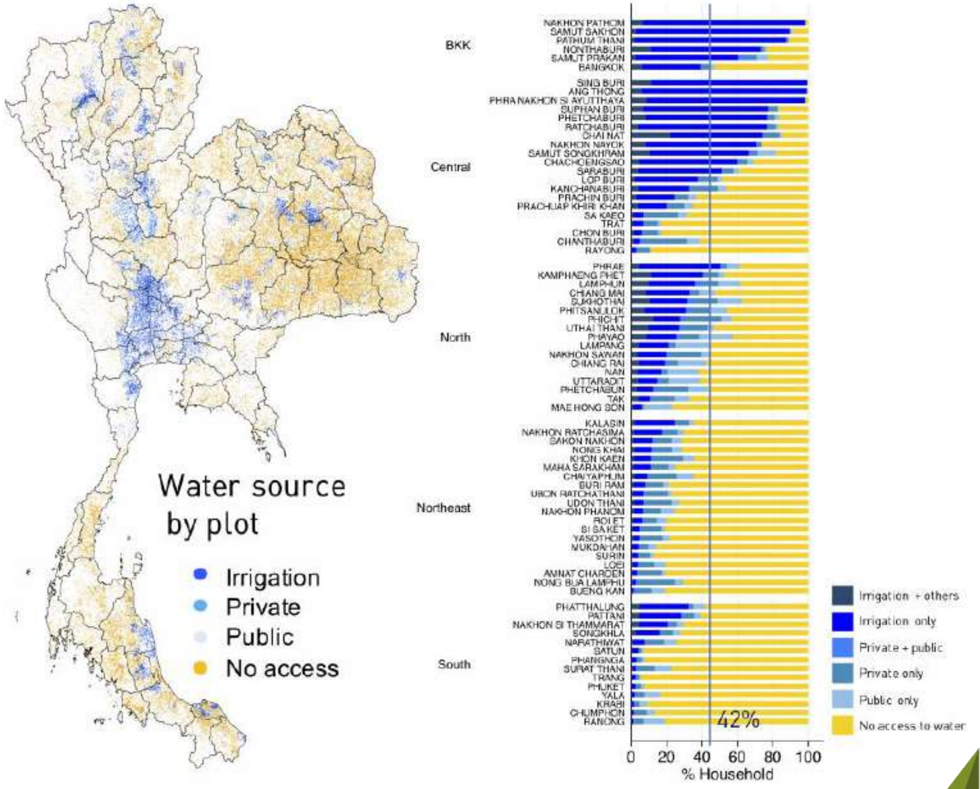
- Thai agriculture is facing the aging problem



Source: Attavanich et al. (2021)

- Only 26% of the agricultural households could access irrigation systems

Farmers' registration 2017



Source: Attavanich et al. (2019)

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Introduction

- Among food crops, rice, sugarcane and cassava have been widely planted in Thailand accounting for approximately 58% of the country's total cropland in 2020 with 4.64 million farm households (OAE, 2021; OCSB, 2021)

- Previous studies explored impacts of climate change on rice in Thailand (e.g., Felkner et al. 2009; Boonwichai et al. 2018), while studies on the impacts of climate change on sugarcane and cassava are limited

- Past studies investigated climate change impacts on Thai rice production, but they mostly focused on small area in the northern region. As a result, the full impact of climate change remains unrevealed

- Sinnarong et al. (2019) was the only study that investigated impacts of climate change on rice yield for a whole country, but their study did not separate the impact of climate change by growing season and irrigation system as suggested by previous studies

- Moreover, previous studies only investigated the impact of climate change on crop yields without taking into account the impact of climate change on farmland acreage, which could potentially affect food production and hence food security (e.g., Miao et al. 2016)

Objectives

- To estimate the effect of climate change on yield and harvested area of major food crops (rice, sugarcane and cassava)

- To project future yield, harvested area and supply of major crops under climate change scenarios

  - Rice is a major staple food in many countries that contain half of the world's population
  - Sugarcane accounts for approximately 80% of global sugar production
  - Cassava is the greatest supplier of carbohydrates among staple crops and has played a crucial role in the developing world, especially in Sub-Saharan Africa
  - Thailand ranked 1st for cassava and 2nd for rice and sugarcane in terms of global export value over the last decade

Contributions

- Data are comprised of new fine-scale weather outcomes merged together with a provincial-level panel of crop yields, harvested area, and production that spans most provinces in Thailand from 1981–2016
- Our analysis also takes into account the demand of land for non-agricultural development captured by the population density
- Breaks down rice into three types based on irrigation system and growing period to differentiate climate change impacts as suggested by literature and can be used to quantify greenhouse gas emission
- Moreover, we added output and input prices in the model and addressed the issue of endogeneity bias in economics using the spatial econometrics, as suggested by Miao, Khanna and Huang (2016)
- In addition, the new AR5 downscaled projections of rainfall at the watershed level are introduced to determine the variation in future precipitation at the local level

Model Specification and Methodology

Expected yield model and harvested area model are as follow

$$Y_{ijt} = \beta_o + \boldsymbol{\beta_1 Climate_{ijt}} + \boldsymbol{\beta_2 Price_{ijt}} + \beta_3 PctIrrig_{ijt} + \beta_4 T_{jt} + \beta_5 T_{jt}^2 + u_{ij} + \epsilon_{ijt} \quad (1)$$

$$H_{ijt} = \alpha_o + \boldsymbol{\alpha_1 Climate_{ijt}} + \boldsymbol{\alpha_2 Price_{ijt}} + \alpha_3 PctIrrig_{ijt} + \alpha_4 Popden_{ijt} + \alpha_5 T_{jt} + \alpha_6 T_{jt}^2 + v_{ij} + e_{ijt} \quad (2)$$

- *i*, *j*, and *t* are indexed for crop type, province, and year, respectively
- *Y* is the yield and *H* is the harvested area of the selected crops (Rice, Sugarcane, Cassava)
- ***Climate*** consists of the growing season temperature, extreme maximum temperature, total rainfall, maximum rainfall in 24 hours, and the dummy representing El Niño–Southern Oscillation (ENSO)
- ***Price*** is the vector capturing output and input prices (i.e., Farm received price & minimum wage rate)
- *PctIrrig* is the percent of irrigated area to total area in the province
- T and T^2 are time trends capturing technological progress.
- *Popden* captures population density
- *u* and *v* are fixed effects, and ϵ and e are error terms

Model Specification and Methodology

- This study separated rice into three types to capture the different growing seasons and irrigation statuses of rice production:
  - In-season rice: (growing season N, NE, C, E = May-Oct ; S=Jul-Feb)
    → separated into 2 types; irrigated area & non-irrigated area
  - Off-season rice: (growing season N, NE, C, E = Jan-Apr ; S=Mar-Jun)

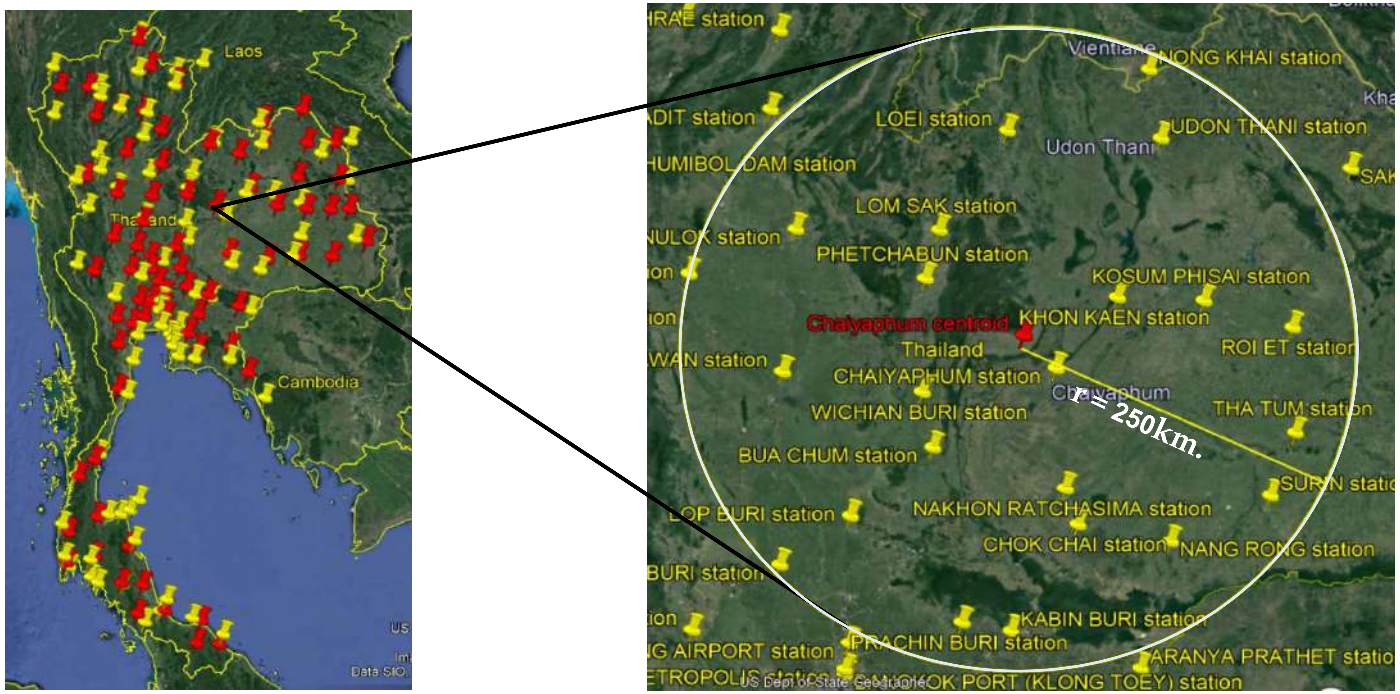
- For sugarcane and cassava, growing season is from January to December in all areas

- Use spatial regression to address spatial bias from crop yield & harvested area

- Employ the instrumental variable (IV) approach together with the generalized method of moment (GMM) suggested by Miao, Khanna and Huang (2016) to addressed endogeneity bias resulting from the use of crop price and wage rate

Construction of Climate Data

- Calculate the weighted average of climate data for each province to link the agricultural data which are organized in the provincial-level and the climate data which are organized by station (Mendelsohn, Nordhaus, Shaw 1994)
- Locate the centroid of each province(*red pin*) and then draw a circle within the r=250 km
- All climate data from stations (*yellow pin*) in the circle are weighted using the weighted regression by controlling for the distance from the centroid, latitude, longitude and height (77p x 36y x 12m x 4var estimated regressions)



ที่มา: Pipitpukdee, Attavanich & Bejranonda (2021)

Summary Statistics

	In-season irrigated rice	In-season rainfed rice	Out-of-season rice	Sugarcane	Cassava
Crop yield (kg/HA)	3,005.00	2,447.73	3,328.19	58,652.50	17,440.85
Harvested area (1,000 HA)	29.62	96.67	16.69	22.89	26.74
Average temperature(°C)	28.27	28.18	27.57	27.59	27.46
Total annual rainfall (mm)	1,493.41	1,559.74	1,487.59	1,331.35	1,346.04
Maximum rainfall in 24 hours(mm/day)	36.68	37.68	36.46	33.69	33.87
Extreme maximum temperature (°C)	35.62	35.59	35.51	35.91	35.92
Observations	1,998	1,809	2,625	1,242	1,242

Estimated Yield Model

Yield	(1) In-season irrigated rice	(2) In-season rainfed rice	(3) Out-of-season rice	(4) Sugarcane	(5) Cassava
Time Trend	93.58***	84.72***	43.02***	-1,68***	82.29
Time Trend_sq	-2.25***	-2.65***	-0.28	127.6***	13.63***
%Irrigated area per province area	-	-	-	100.5***	-21.85***
Average temperature	-908.80	5,21***	1,069**	165,11***	18,965***
Average temperature_sq	17.53	-96.84***	-19.60**	-2,94***	-365.7***
Total rain	0.18	-0.022	-0.75***	-37.08***	-6.467***
Total rain_sq	-7.85e-05	-5.04e-05	0.00015***	0.0099**	0.0006
Maximum rain in 24 hr	5.27	4.16	-7.64*	274.6**	78.03***
Extremely max. temperature	-106.70***	-43.46	-101.40**	-8,593***	1,438***
El nino	11.18	-13.77	8.70	-513.0	-1,495***
La nina	-102.90***	-14.96	6.79	-2,244***	1,198**
Lag price	-0.39	1.63*	0.118	-645.31***	-59.16**
Lag wage	46.63	202.78***	-60.78	-8,765.63***	-617.81***
Constant	18,074	-67,65***	-6,143	-1.86e+06***	-270,597***
Observations	1,998	1,809	2,625	1,242	1,242
R-square_adj.	0.6359	0.6162	0.5934	0.49	0.75

****, **, and * are significant at 1%, 5% and 10%, respectively. Regional fixed effect also added to the model*

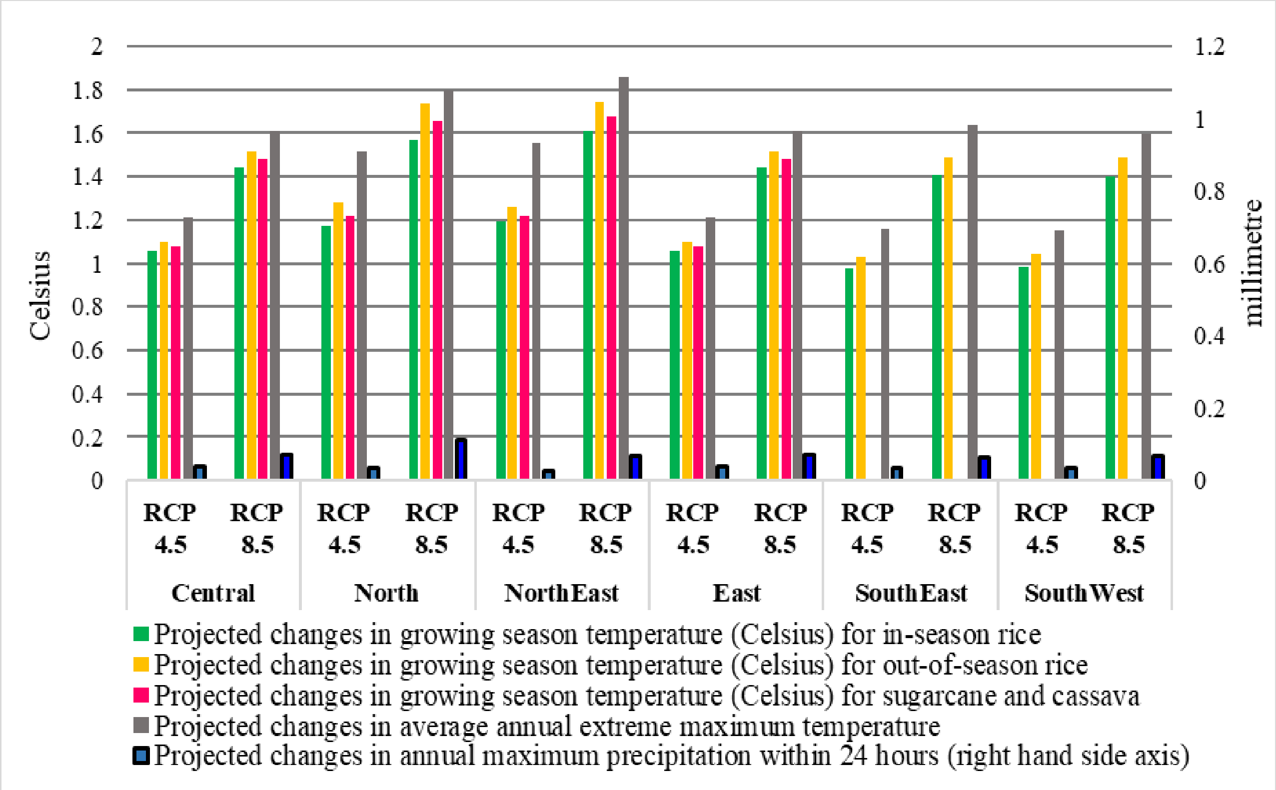
Estimated Harvested Area Model

Harvested area	(1) In-season irrigated rice	(2) In-season rainfed rice	(3) Out-of-season rice	(4) Sugarcane	(5) Cassava
Time Trend	-0.65	0.97	-0.09	1.04**	-2.92***
Time Trend_sq	0.093***	-0.08	0.007	-0.05**	0.12***
Population density	-0.005**	0.14***	-0.009***	-0.07***	-0.09***
%Irrigated area per province area	-	-	-	-0.09**	0.25**
Total rain	-0.04***	-0.04*	0.004	0.05*	0.02
Total rain_sq	4.9e-06***	9.8e-07	-1.9e-06	-2.2e-05**	-1.9e-05*
Maximum rain in 24 hr	0.45***	1.14**	0.04	-0.44	-0.44
Extremely max temperature	8.73***	-2.49	1.28	-0.43	-0.48
El nino	-2.50***	-4.95*	-4.89***	-0.67	-3.80
La nina	1.10	0.96	-3.40***	7.65***	20.24***
Lag price	-0.14***	0.17	0.098**	0.23	-0.66**
Lag wage	-10.59***	4.19	-1.64	10.78***	2.22
Constant	-137.2*	18.64	-27.80	-36.04	76.22
Observations	1,998	1,809	2,625	1,242	1,242
R-square_adj.	0.23	0.53	0.22	0.11	0.84

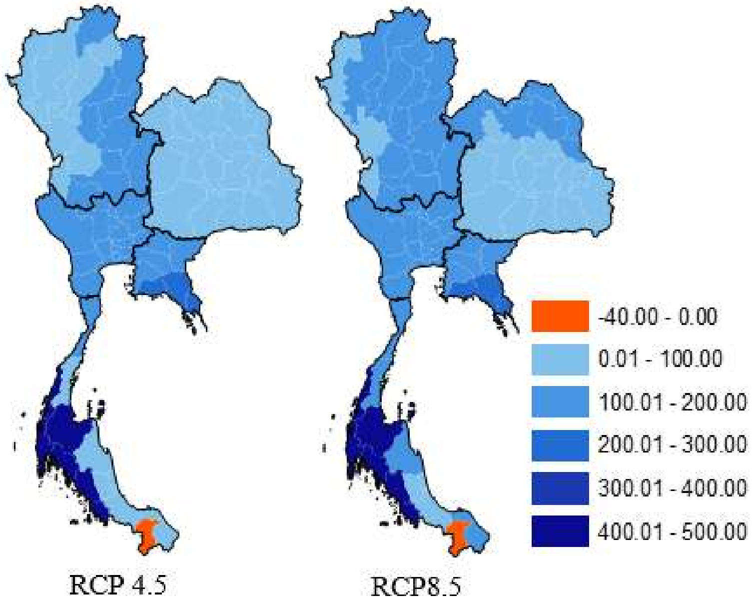
****, **, and * are significant at 1%, 5% and 10%, respectively. Regional fixed effect also added to the model*

Projections of Climate & Population Density during 2046-2055 from the Baseline 1992-2016

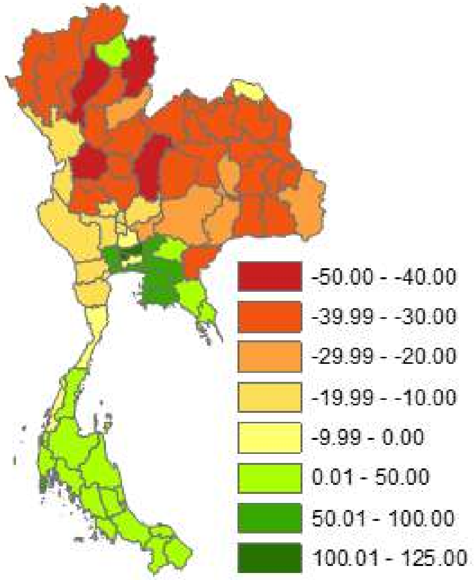
- Overall, growing season temperatures and annual rainfall are projected to increase in both RCPs 4.5 & 8.5
- Population density is expected to increase in the Central, Eastern and Southern regions with moderate fertility rate
- The study divides the analysis of rice into two types (i.e., in-season rice and out-of-season rice)



Projected changes in annual rainfall(mm.)



Projected changes in population density (%)



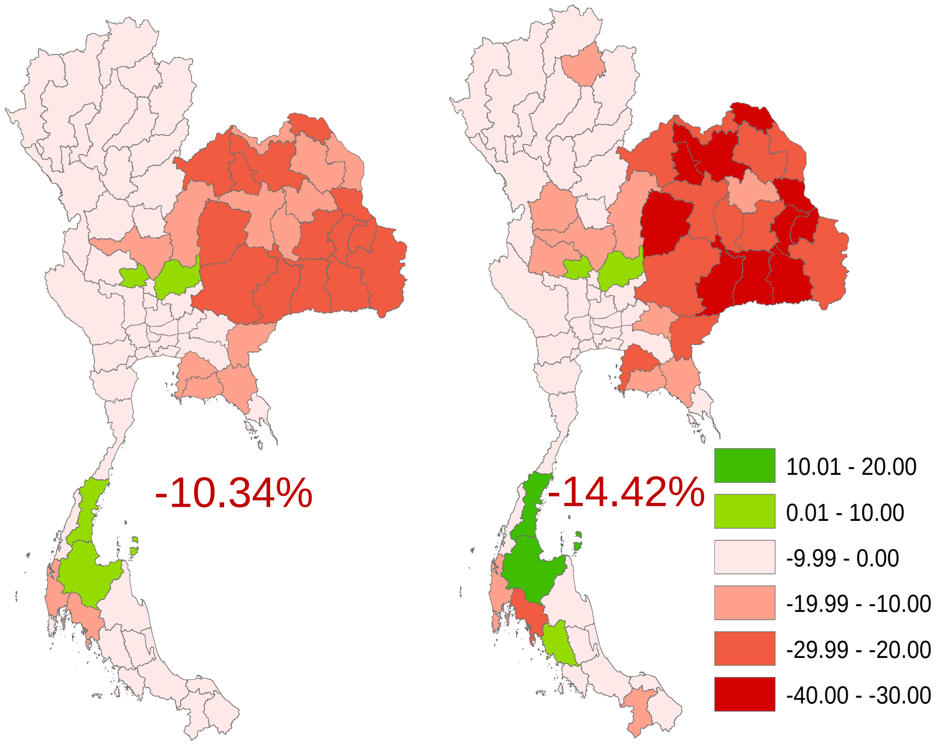
Source: Pipitpukdee and Attavanich (2021)

Projected Impacts of Climate Change on Rice Yield and Harvested Area

Northeastern rice yields will decline the most

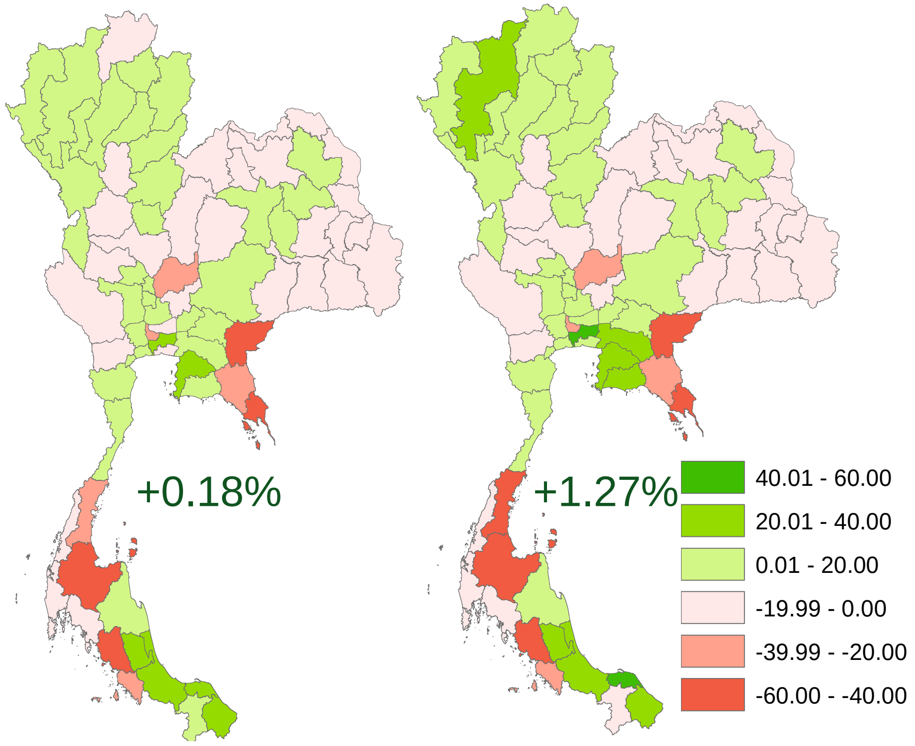
Heterogenous effects of climate change on rice harvested area are revealed across regions

% changes of yield & harvested area in 2046-2055 under scenarios from the baseline 1992-2016



RCP 4.5 RCP 8.5

%Change in total-rice yield



RCP 4.5 RCP 8.5

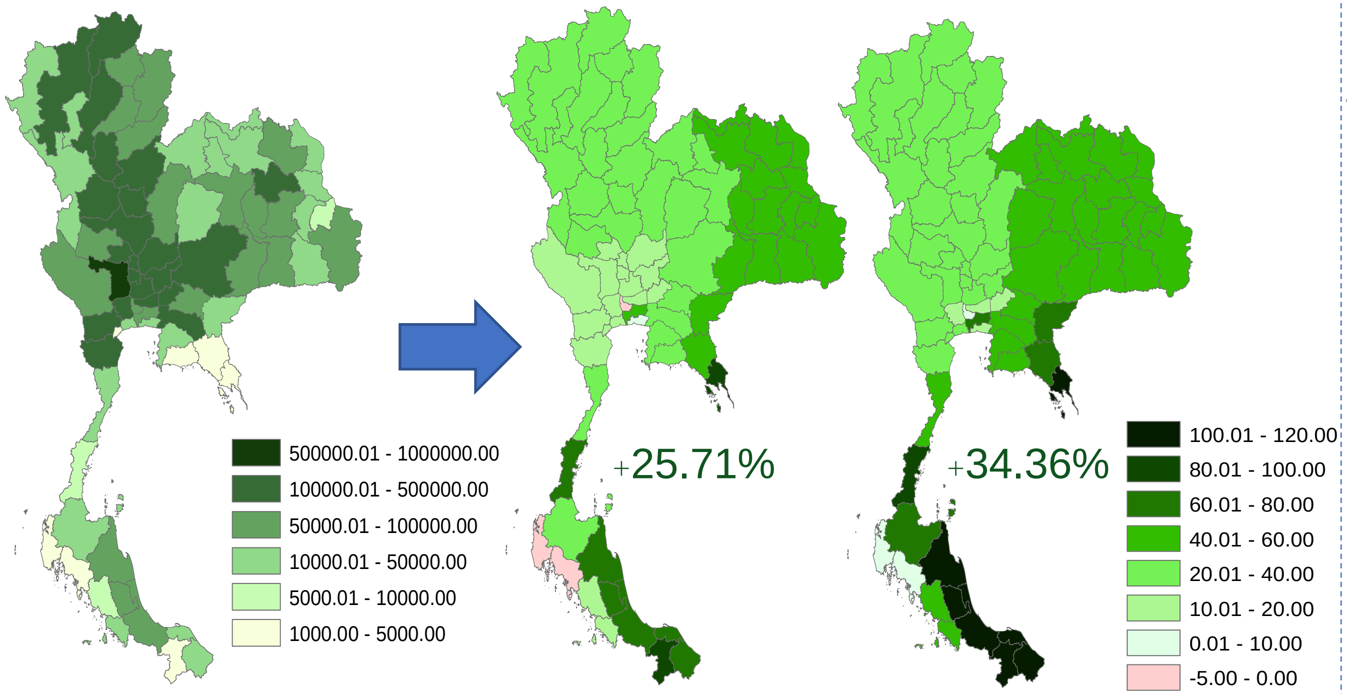
%Change in total-rice harvested area

Projected Impacts of Climate Change on Rice Production

In-season rice production in the irrigated area is expected to increase, while its production tends to decline in the rainfed area

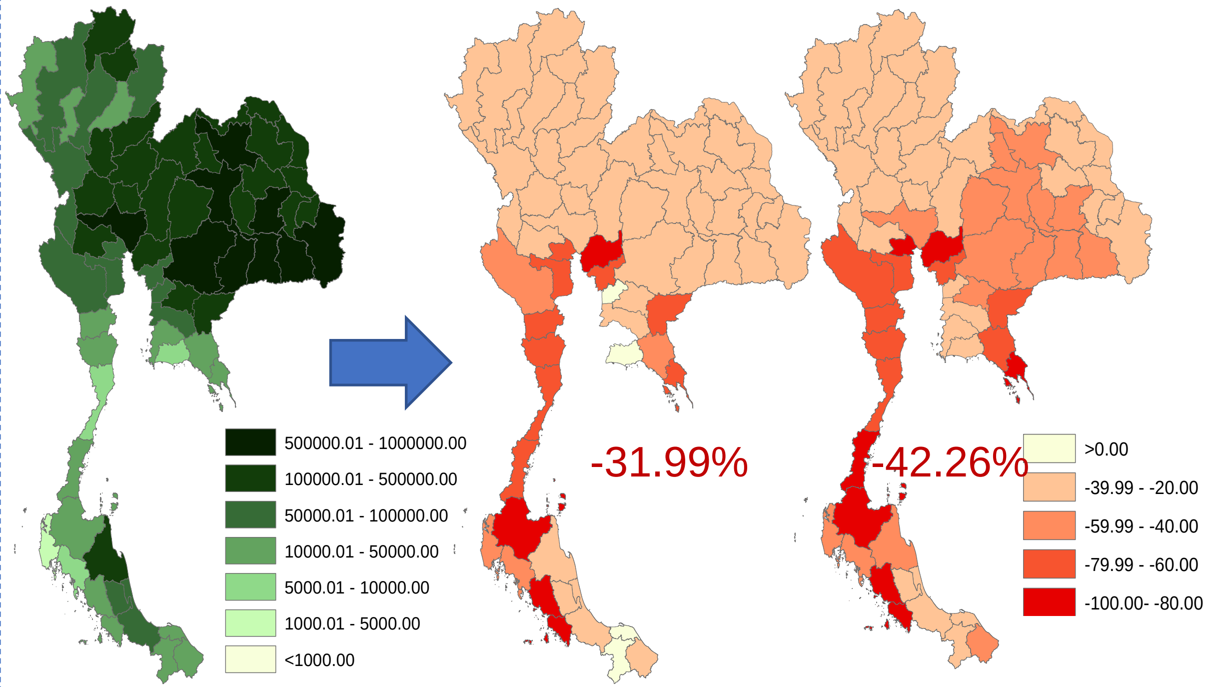
% changes of total production in 2046-2055 under scenarios from the baseline 1992-2016

In-season rice in the irrigated area



Baseline production (MT) | % change of production with RCP 4.5 | % change of production with RCP 8.5

In-season rice in the non-irrigated area



Baseline production (MT) | % change of production with RCP 4.5 | % change of production with RCP 8.5

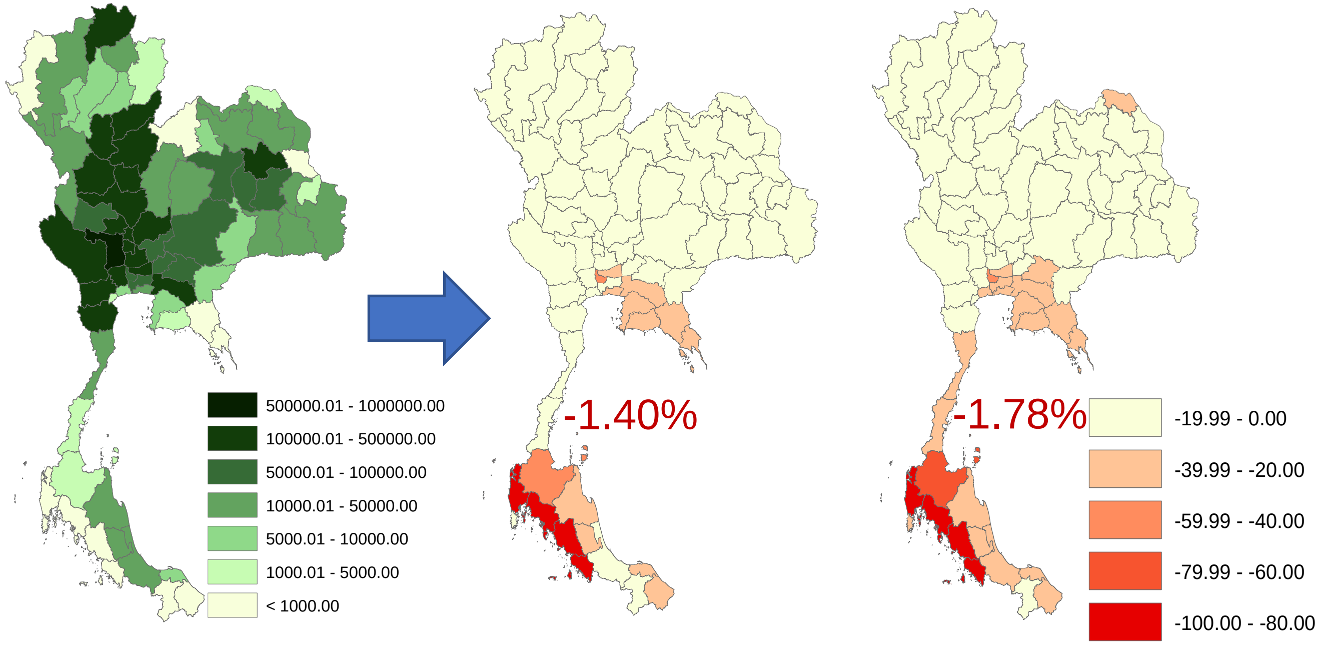
Source: Pipitpukdee and Attavanich (2021)

Projected Impacts of Climate Change on Rice Production

- Out-of-season rice production is expected to decrease
- Total annual rice production of all types is expected to decrease, but heterogenous impacts are revealed across provinces

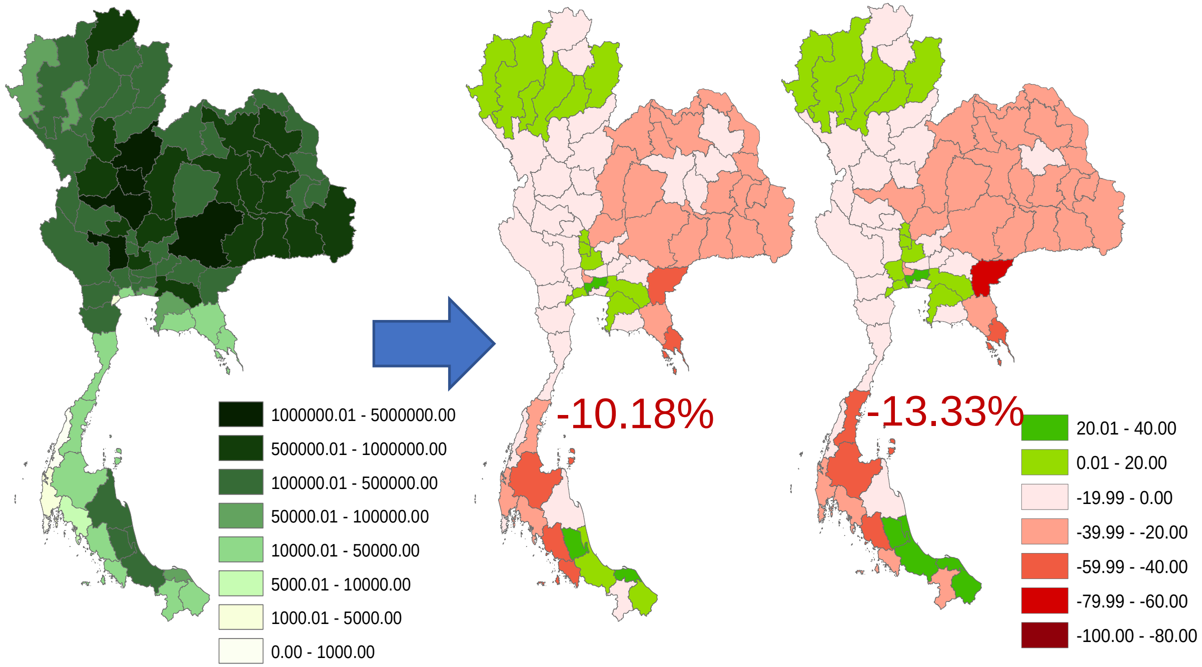
% changes of total production in 2046-2055 under scenarios from the baseline 1992-2016

Out-of-season rice



Baseline production (MT) | % change of production with RCP 4.5 | % change of production with RCP 8.5

All types of rice



Baseline production (MT) | % change of production with RCP 4.5 | % change of production with RCP 8.5

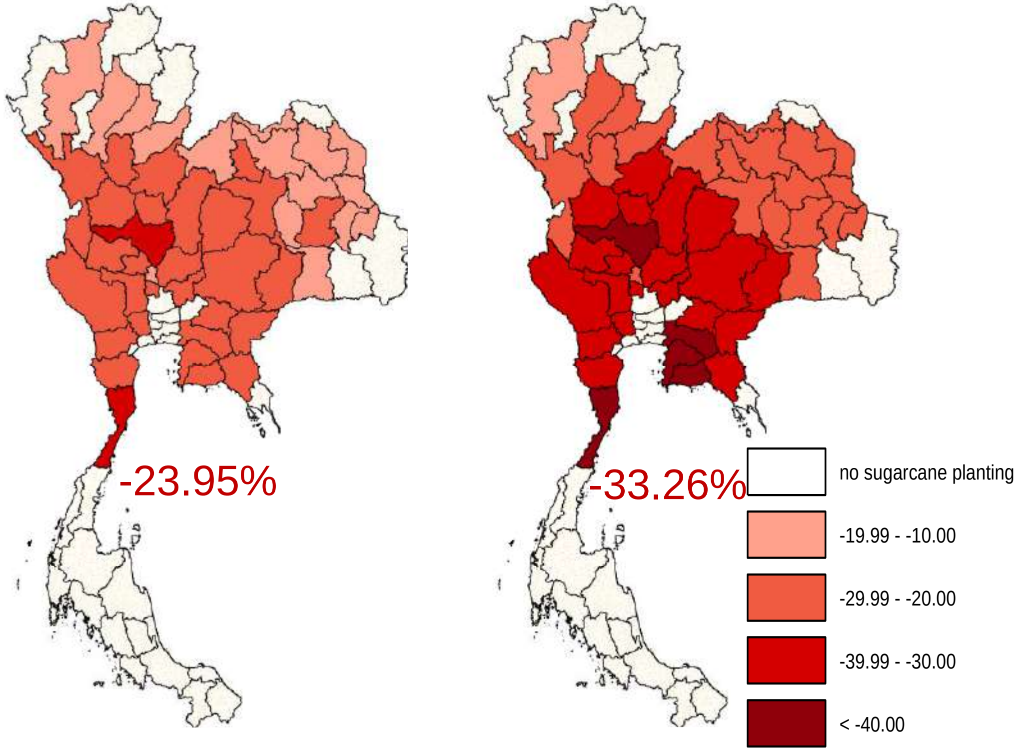
Source: Pipitpukdee and Attavanich (2021)

Projected Impacts of Climate Change on Sugarcane Yield & Harvested Area

Sugarcane yield will be declined in all regions

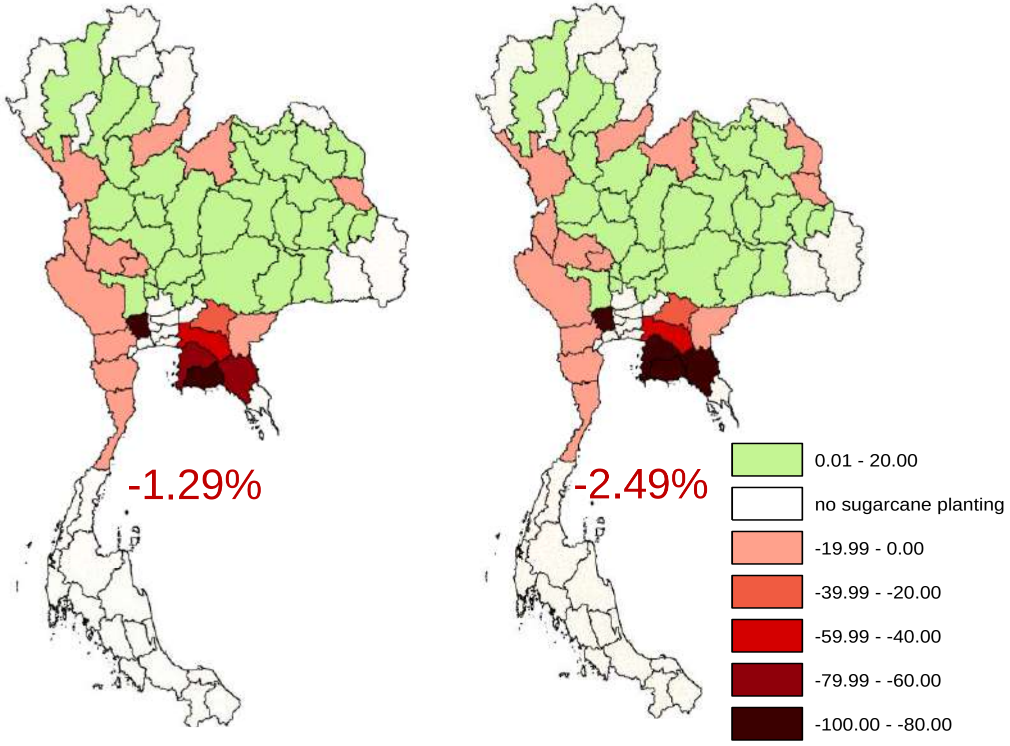
Harvested area of sugarcane will be increased in the northern and northeastern regions

% changes of yield & harvested area in 2046-2055 under scenarios from the baseline 1992-2016



RCP 4.5 RCP 8.5

%Change in sugarcane yield



RCP 4.5 RCP 8.5

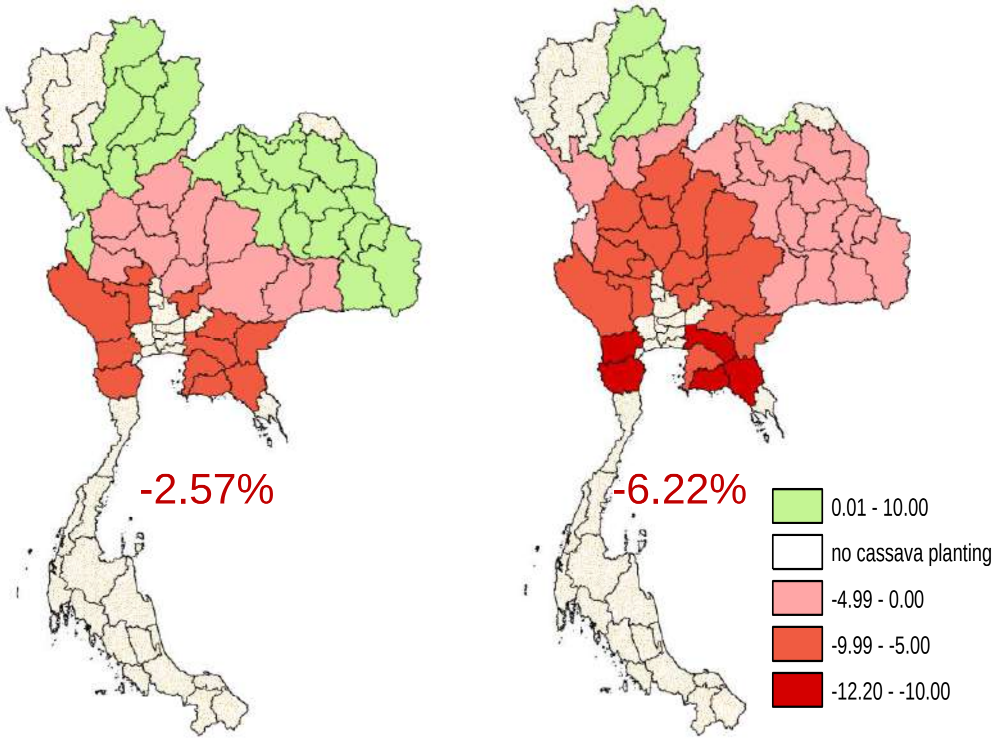
%Change in sugarcane harvested area

Projected Impacts of Climate Change on Cassava Yield & Harvested Area

Cassava yield will be declined in the lower section, while its yield in the northern region will be increased

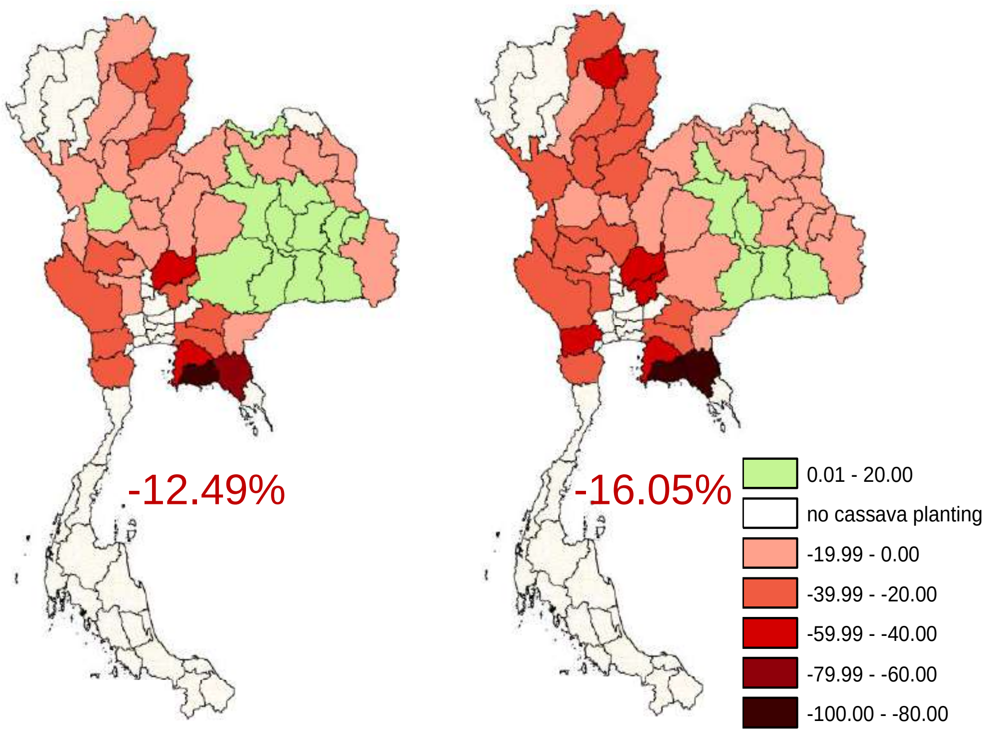
Harvested area of cassava will be decreased in almost all regions (except for some provinces in the northeastern region)

% changes of yield & harvested area in 2046-2055 under scenarios from the baseline 1992-2016



RCP 4.5 RCP 8.5

%Change in cassava yield



RCP 4.5 RCP 8.5

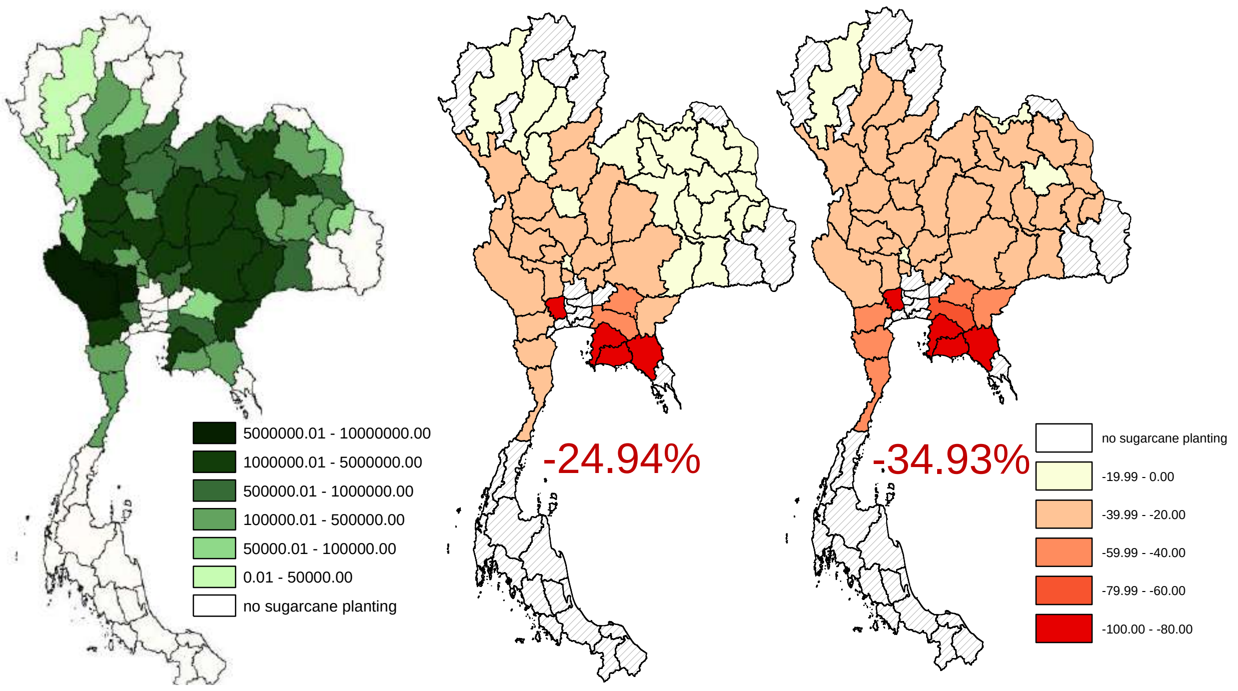
%Change in cassava harvested area

Projected Impacts of Climate Change on Production of Sugarcane & Cassava

Production of sugarcane and cassava will be adversely affected by climate change

% changes of total production in 2046-2055 under scenarios from the baseline 1992-2016

Sugarcane



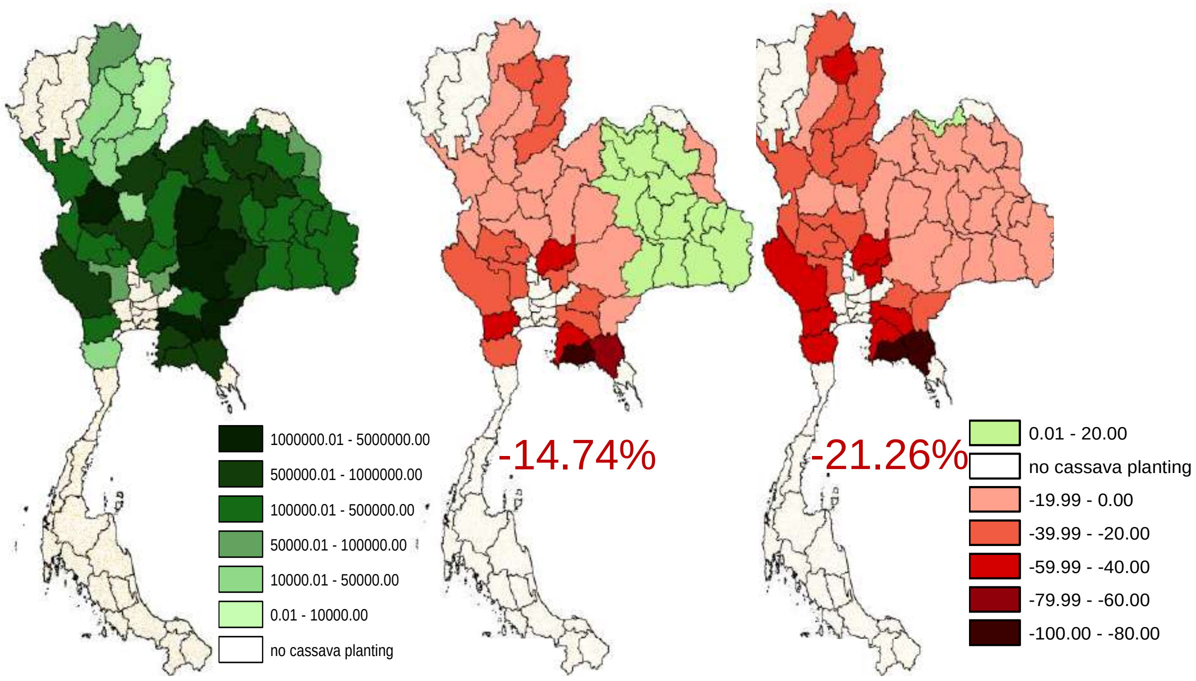
Baseline production (MT)

% change of production with RCP 4.5

% change of production with RCP 8.5

Source: Pipitpukdee and Attavanich (2020a)

Cassava



Baseline production (MT)

% change of production with RCP 4.5

% change of production with RCP 8.5

Source: Pipitpukdee and Attavanich (2020b)

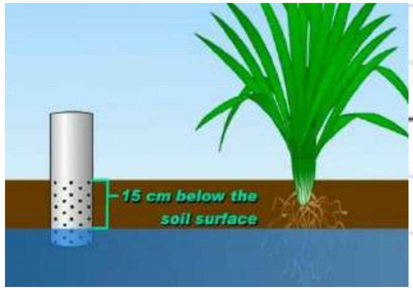
Conclusion

Crops type	In-season rice in the irrigated area	In-season rice in the nonirrigated area	Off-season rice	Total rice	Sugarcane	Cassava
Yield baseline (kg/HA)	3,376	2,281	4,193	2,798	61,360	18,400
%Changes under RCP4.5	-2.72	-23.72	-6.14	-10.34	-23.95	-2.57
%Changes under RCP8.5	-2.51	-34.04	-8.07	-14.42	-33.26	-6.22
Harvested area baseline (1,000 HA)	2,212	6,485	1,484	10,183	1,078	1,212
%Changes under RCP4.5	29.22	-10.84	5.05	0.18	-1.29	-12.49
%Changes under RCP8.5	37.82	-12.47	6.84	1.27	-2.49	-16.05
Production baseline (1,000 MT)	7.47	14.80	6.22	28.49	66.17	22.32
%Changes under RCP4.5	25.71	-31.99	-1.40	-10.18	-24.94	-14.74
%Changes under RCP8.5	34.36	-42.26	-1.78	-13.33	-34.93	-21.26

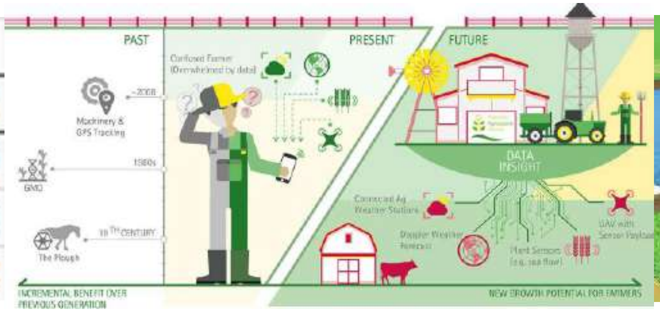
- Total supply of world exports for rice, sugarcane and manioc starch will be reduced by 7, 3 and 13%, respectively
- Given the thin global market and the role of Thailand as a global exporter of these crops, the projected declines in the production could subsequently cause a spike in crop prices creating the concern for global food security

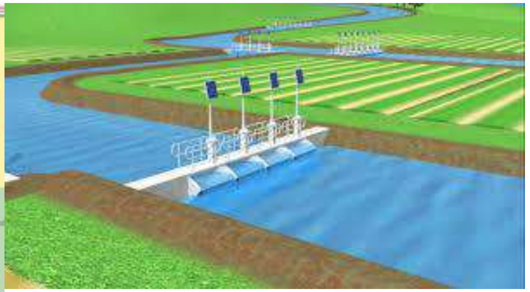
Policy Recommendations

- ❑ Raise awareness to farmers in the affected areas
- ❑ Invest in expanding irrigation areas and promote the efficient use of water
- ❑ Encourage small farmers to access to modern technology and innovation
- ❑ Provide knowledge of risk management and accelerate development of risk management systems
- ❑ Promote mitigation and adaptation practices such as alternative wet and dry for rice production
- ❑ Emphasize the development of heat resistant plant species to sustainably adapt to the future warming world
- ❑ Support the central database development for climate change analysis



	Percent change from BAU (%)		
	Low	Medium	High
2020	-0.37	-0.73	-1.10
2025	-1.17	-2.31	-3.42
2030	-2.32	-4.54	-6.33





Source: Attavanich and Pengthamkeerati (2018)

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