RCCAP | REGIONAL CLIMATE CONSORTIUM FOR ASIA AND THE PACIFIC

Developing and Applying Climate Information for Supporting Adaptation in South East Asia

Thailand Case Study: Impact of Projected Climate Change on Rice Production Systems

Attachai Jintrawet, Chitnucha Buddhaboon, Jerasorn Santisirisomboon and Boonlert Archevarahuprok

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Authors

Attachai Jintrawet, Chitnucha Buddhaboon, Jerasorn Santisirisomboon and Boonlert Archevarahuprok (Thailand Team, TA-8359 REG)

Resource persons

Department of Agricultural Extension, Land Development Department, Royal Irrigation Department, Office of Agricultural Economics, and Geoinformatics and Space Technology Development Agency (Public Organization)

Contributors

Jack Katzfey and Dewi G.C. Kirono (International Specialists, TA-8359 REG)

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CONTEXT

The Asian Development Bank (ADB) has seen that use of climate services to support climate adaptation in Asia and the Pacific, in particular, is challenged by limited reliable climate information, insufficient capacity to interpret and use of climate information, and limited technical and financial resources.

To address this challenge, the ADB supported a technical assistance (TA) project, TA-8359 REG: Regional Climate Projections Consortium and Data Facility for Asia and the Pacific. This TA aims to:

i. provide users with advice on what climate information is available, where, and how to use it;
ii. present guidelines for developing and using a range of available climate information to support climate adaption; and
iii. deliver a range of knowledge products that may be used for informing policy decisions and planning for climate adaptation.

About this case study

Purpose

The guideline developed in this TA outlines a 10-step approach to using climate data to develop climate information. The guideline is available on the RCCAP portal at www.rccap.org.

This case study complements the guideline by illustrating how climate change information can be developed and used in an impact and vulnerability assessment. It also shows how to transform the assessment results into knowledge products that are more digestible to the next- and/or end- users (e.g. planners, managers, policy makers, etc.).

Since the process of an impact and vulnerability assessment will, in most cases, be shaped by a given context including the purpose of the assessment, it must be noted that this document should be viewed as illustrative guidance, showcasing a particularly practical application.

Background

This case study was identified and planned at the RCCDF project inception workshop in Chiang Mai (Thailand) in May 2015 and the first regional workshop attended by various stakeholders in Bali (Indonesia) in July 2015.

At the inception workshop, it was decided that case studies should be real cases if possible, and simple enough to complete within available resources, and be demonstrated through a one-week workshop.

At the time, the ADB had no listed projects in Thailand that could be used for reference in making the case study. It was decided to develop a case study that used climate scenarios to assess climate change impacts on rice production in selected sites in Thailand.

Since the 1990s, the Thailand Research Fund (TRF) has provided funding support for research teams in Thailand to assess the impact of climate change scenarios from ECHAM4-PRECIS models on rice, cassava, sugarcane and maize (Jintrawet & Prammanee, 2005; Pannangpetch et al., 2009). An integrated decision support system tool, called MWCropDSS shell (Marohn et al., 2013) was designed and used to link the climate change projections under different CO_2 scenarios and the CSM-CERES-Rice simulation models under the DSSAT package (Jintrawet & Chinvanno, 2011; Jones et al., 2003; Jintrawet et al., 2012). MWCropDSS shell was used to couple the CSM-CERES-Rice model, under the DSSAT 4.6 package (Hoogenboom et al., 2010).

Case study team

The team is comprised of Attachai Jintrawet and Jerasorn Santisirisomboon, who are Thailand specialists of the TA-8359 REG, Chitnucha Buddhaboon from the Rice Department, Ministry of Agriculture and Cooperatives and Boonlert Archevarahuprok from the Thailand Meteorology Department.

This team designed and conducted all the analysis as well as wrote most parts of this case study document, with contribution and guidance provided by the international specialist from CSIRO, Australia.

About this document

Audience

This document assumes the reader has some background knowledge on climate adaptation. Examples include researchers, university lecturers and students, consultants, sectoral planners, and personnel of meteorological and climatological government departments whose mandates may include provision of climate information services.

Structure

This document has three sections. This first section provides context for the case study and this report. The second presents the development of climate change information, and is structured in line with the 10 steps outlined in the guideline. The final section provides a synthesis. Any references and data used are provided in the reference list and appendix, respectively.

CLIMATE CHANGE INFORMATION DEVELOPMENT

1 Define the requirements of the assessment

1.1 Stakeholders and engagement strategy

The scoping and implementation of the case study were conducted in a close conversation with the stakeholders. The rice technology team of Rice Research and Development Division under the Rice Department in Thailand and the staff of Thailand Meteorological Department were considered as both project team and stakeholders in the assessment of the impact of climate change scenarios on rice production in Thailand, and the Department of Disaster Prevention and Mitigation under the Ministry of Interior. Major engagement strategy was the official communication procedures and protocols of the Royal Thai Government.

The stakeholders' contributions include the provision of non-climate inputs for the rice model such as the specific cultural practices data, the rice production options, the soil layer data, and so on. The rice production options, for instance, were used to parameterized the rice model.

A capacity building workshop was held 31 May to 2 June 2016 in Pattaya, Thailand. It was attended by around 50 participants, including representatives from King Mongkut's University of Technology Thonburi, Royal Irrigation Department, and Royal Forestry Department. The workshop introduced the RCCDF project, the climate projection guidance and data facility, and provided opportunity for demonstration of the RCCAP web portal, hands-on training on the use of climate analysis and projections, and use of the rice model for impact assessment. This was followed by a group discussion and needs assessment.

1.2 Assessment objectives

The main objective of this case study is to demonstrate the use of climate projections as a component of an assessment of impact of climate change on rice production in selected sites in Thailand. It is hoped the document serves as a practical example that may be applied for assessment for other sites of interest or for the whole Kingdom of Thailand.

1.3 Scope

The scope of the case study is to demonstrate the use of climate model outputs as a component of an assessment of impacts of climate changed on rice production at selected sites in Thailand by comparing the impact of climate change on grain yields of three rice varieties during the historical period (1970–2005) and the future period (2006–2040). The three rice varieties were representations of major rice varieties in major rice production ecosystems in Thailand as represented by eight selected sites.

These sites (Figure 1 and Figure 2) were selected to represent the main rain-fed rice production areas of Thailand as well as the various climatic regions. The case study was designed to provide relevant materials for the development of a guideline for further assessment such as application of assessment for other sites of interest or for the whole Kingdom of Thailand.

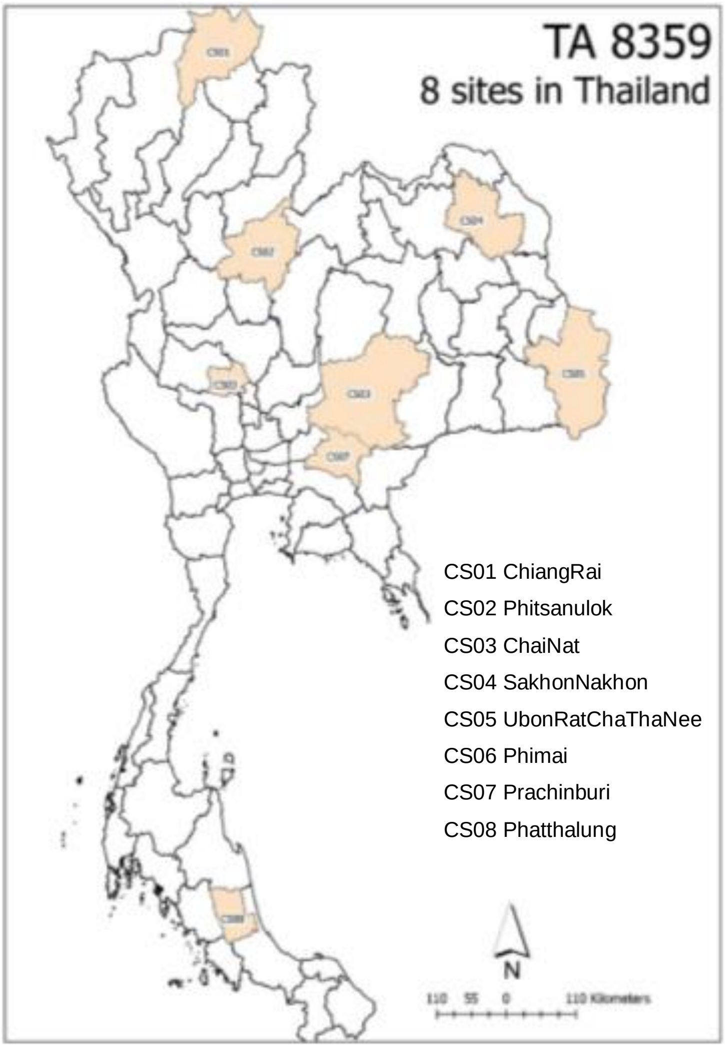

Figure 1. Selected sites for the case study

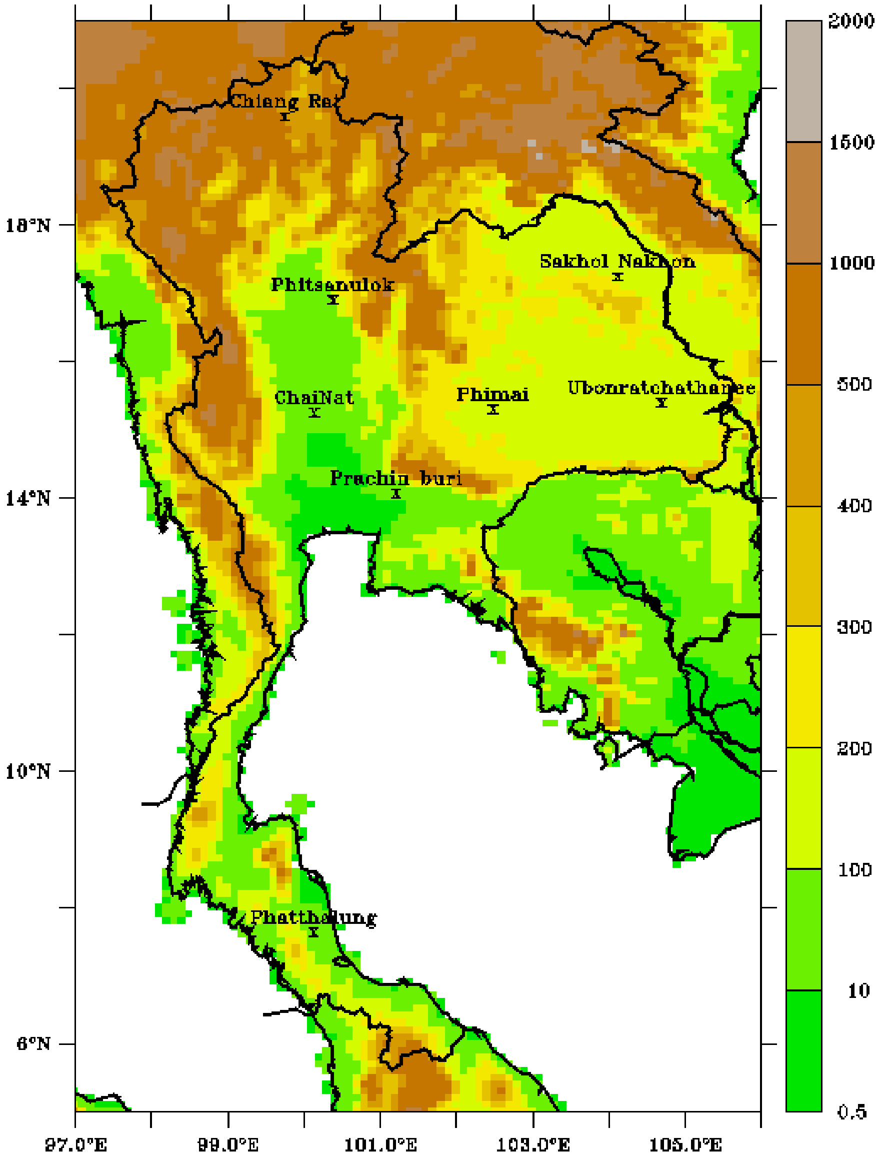

Figure 2. Terrain from model simulations (colour, m) and location of eight stations

1.4 Methodology

1.4.1 Approach

The assessment used the CSM-CERES-Rice simulation model under the Decision Support System for Agrotechnology Transfer (DSSAT) version 4.6.1.0 and climate change scenarios (CCS) from five global circulation models: CCSM4, CNRM-CM5, GFDL-CM3, MPI-ESM-LR, and NorESM1-M. Data sets covered two periods: historical (1970–2005, 36 years), and future under RCP4.5 and RCP8.5 (2006–2099, 94 years). These models were chosen after an assessment was made of all available GCMs for their performance over South East Asia (including Thailand), using both published literature and a project undertaken in Vietnam (see Katzfey et al. (2016) and Katzfey et al. (2014) for more information). The CSM-CERES-Rice model needs daily surface air temperature maximum (Tmax, °C) and minimum (Tmin, °C), daily rainfall (mm) and daily average solar radiation at ground level (MJ/d/m^2). This guideline assessment covered the historical period 1970–2005 and the future period 2006–2040.

Three rice varieties were selected as representatives of major rice production outputs, namely; KDML105, RD23 and NSPT rice varieties. RD23 as a representative of non-glutinous, white rice variety, KDML105 a representation of non-glutinous, fragrant or jasmine and photoperiod sensitive rice variety and Niew Sanpatong (NSPT) as a representative of glutinous photoperiod sensitive rice variety commonly grown in the northern region of Thailand.

1.4.2 Method for Rice Phenology and Growth Assessment

The assessment of climate impact on rice production is completed using the MWCropDSS model (Figure 3), a standalone desktop shell that links the CSM-CERES-Rice model and attribute and spatial databases.

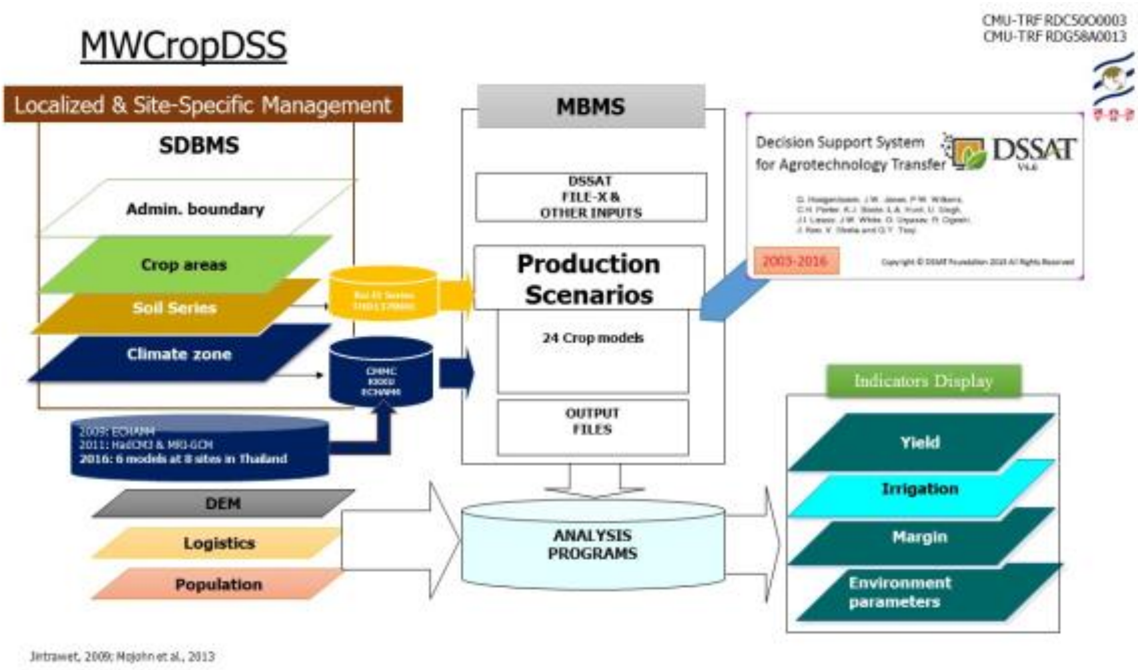

Figure 3. Schematic of the different component of the MWCropDSS

The rice model requires four minimum data sets to simulate dynamics of key phenology stages and important growth variables of a given rice variety under specific rice production system (i.e. main season or off-season rice production system). The four minimum data set requirements are listed in Table 1.

Table 1. Minimum data set requirements for rice model

Daily weather data
a. Short-wave radiation in Mega Joules per meter squared per day
b. Maximum and minimum air temperature in Celsius per day
c. Rainfall depth in millimetres per day
Soil data
1. Soil profile data
i. Soil bulk density by soil layer in gram of soil per cubic centimetre (cm) of soil.
ii. Thickness of a specific soil layer in cm.
iii. Soil water content at saturation in soil layer a given soil layer in cubic cm of water per cubic cm of soil volume
iv. Soil water content at drained upper limit in soil layer of a given soil layer in cubic cm of water per cubic cm of soil volume
v. Soil water content at the lower limit of plant extractable soil water of a given soil layer in cubic cm of water per cubic cm of soil volume
vi. pH in a given soil layer, no unit and ranges from 0 to 14.
vii. Temperature of soil surface litter
viii. Soil temperature in soil layer
2. Soil initial conditions at the beginning of simulation
i. Actual number of soil layers
ii. Change in soil water content due to drainage in each soil layer in cubic cm of water per cubic cm of soil volume
iii. Soil water content
iv. Ammonium N concentration in soil layer in milligram on Nitrogen per gram of soil
v. Soil water content in each soil layer in cubic cm of water per cubic cm of soil volume
vi. Nitrate concentration in each soil layer in milligram of Nitrogen per gram of soil
vii. Water available for infiltration-rainfall plus net irrigation minus runoff in millimetre per day
Rice genetic coefficients (GC) for a specific rice cultivar
a. Phenology coefficients
i. P1 is time period (expressed as growing degree days [GDD] in °C above a base temperature of 9 °C) from seedling emergence during which the rice plant is not responsive to changes in photoperiod. This period is also referred to as the basic vegetative phase of the plant.
ii. P2O is the critical photoperiod or the longest day length (in hours) at which the development occurs at a maximum rate. At values higher than P2O developmental rate is slowed, hence there is delay due to longer day lengths.
iii. P2R is the extent to which phasic development leading to panicle initiation is delayed (expressed as GDD in °C) for each hour increase in photoperiod above P2O.
iv. P5 is the time period (in GDD °C) from beginning of grain filling (3 to 4 days after flowering) to physiological maturity with a base temperature of 9 °C.
b. Growth coefficients
i. G1 is the potential spikelet number coefficient as estimated from the number of spikelets per g of main culm dry weight (less lead blades and sheaths plus spikes) at anthesis. A typical value is 55.
ii. G2 is the single rice grain weight (g) under ideal growing conditions, i.e. non-limiting light, water, nutrients, and absence of pests and diseases.
iii. G3 is the tillering coefficient (scaler value) relative to IR64 cultivar under ideal conditions. A higher tillering cultivar would have coefficient greater than 1.0.
iv. G4 is the temperature tolerance coefficient. Usually 1.0 for varieties grown in normal environments. G4 for japonica type rice growing in a warmer environment would be 1.0 or greater. Likewise, the G4 value for indica type rice in very cool environments or season would be less than 1.0.
Rice production management parameters
a. Cultivar name
b. Field information with a combination of weather identification code (WSTA) and a soil name identification code (ID_SOIL).
c. Planting date of a given simulation mapping unit. The user can select one from the following planting methods, transplanted, dry seeded, pre-germinated seeds, nursery, ratoon, horizontally and vertically and inclined (45 °C) plant stick.
d. Irrigation and water management. The user can define irrigation date, depth, amount and operation of irrigation application.
e. Nitrogen chemical fertilizer management. The user can define nitrogen application date, rate, depth, amount, fertilizer material for a given application decision. The model does not simulate dynamics of phosphorus and potassium fertilizer at this point.
f. Crop residues and organic fertilizer. The model allows users to apply organic amendment to the system, the user needs to provide date, residue material, residue amount, incorporation percentage, depth and method, concentration of nitrogen, phosphorus and potassium in the residue.

2 Collect and assess observed climate data

In this study, observed climate data were required to evaluate model outputs. The observed climate data were extracted for each of the eight stations (Table 2) from CRU, APHRODITE and TRMM gridded observed datasets (see Appendix).

Table 2. Names and locations of Stations used in study

NO	STATION NAME	LAT.	LON.
1	Chiang Rai	99.7444	19.52858
2	Phitsanulok	100.3773	16.83737
3	ChaiNat	100.1314	15.18944
4	Sakhol Nakhon	104.1186	17.18072
5	Ubonratchathanee	104.6909	15.33199
6	Phimai	102.4821	15.23845
7	Prachin buri	101.2115	14.00938
8	Phatthalung	100.1265	7.56618

Daily Tmax, Tmin and rainfall was extracted at each location from the version 3.24 of the 0.5 degree longitude-latitude gridded observational datasets produced by the Climate Research Unit (CRU, v3.24) (Harris et al., 2014). Daily rainfall was also extracted from the gridded 0.25 degree longitude-latitude obsevational gridded dataset Asian Precipitation-Highly Resolved Observational Data Integration Towards the Evaluation of Water Resources (APHRODITE, V1101R2) (Yatagai et al., 2009; Yatagai et al., 2012) and the gridded 0.25 degree longitude-latitude satellite-based gridded dataset Tropical Rainfall Measuring Mission (TRMM, 3B42RT) (Huffman et al., 2007).

For this study, the period 1980-1999 was used for the base line period. The time span of TRMM data is 1998–2015, for APHRODITE is 1961-2007 and CRU is 1901–2015.

3 Select representative concentration pathways

Climate model simulations forced using two representative concentration pathways (RCPs) were analysed: RCP8.5 as the higher emission scenario and RCP4.5 as the lower emission pathway. The lowest emission scenario (RCP2.6) was not chosen for this study due to: 1) lack of high resolution downscaled projection information; 2) more limited number of GCM results available; and 3) the lower likelihood that this scenario can be achieved.

4 Find relevant climate model data

There are several different approaches to dynamical downscaling, including high-resolution global models, stretched-grid models and, the most common, limited area models (Katzfey 2014). The climate projection data used here was dynamically downscaled from five global climate models (GCMs) (CCSM4, CNRM-CM5, GFDL-CM3, MPI-ESM-LR, and NorESM1-M) using CSIRO's Conformal Cubic Atmospheric Model (CCAM, Katzfey et al., 2016). These models were chosen after an assessment was made of all available GCMs for their performance, using both published literature and through the Vietnam project (see Katzfey et al. (2016) and Katzfey et al. (2014) for more information).

Global simulations of the climate were performed at 50 km resolution using bias and variance corrected sea surface temperatures generated by the above GCMs from 1971 to 2100 for two scenarios: RCP4.5 and RCP8.5. These projections were then further downscaled to 10 km resolution over South East Asia. Daily data was extracted for the historical (1980–2005) and future (2006–2040) periods for use in this assessment.

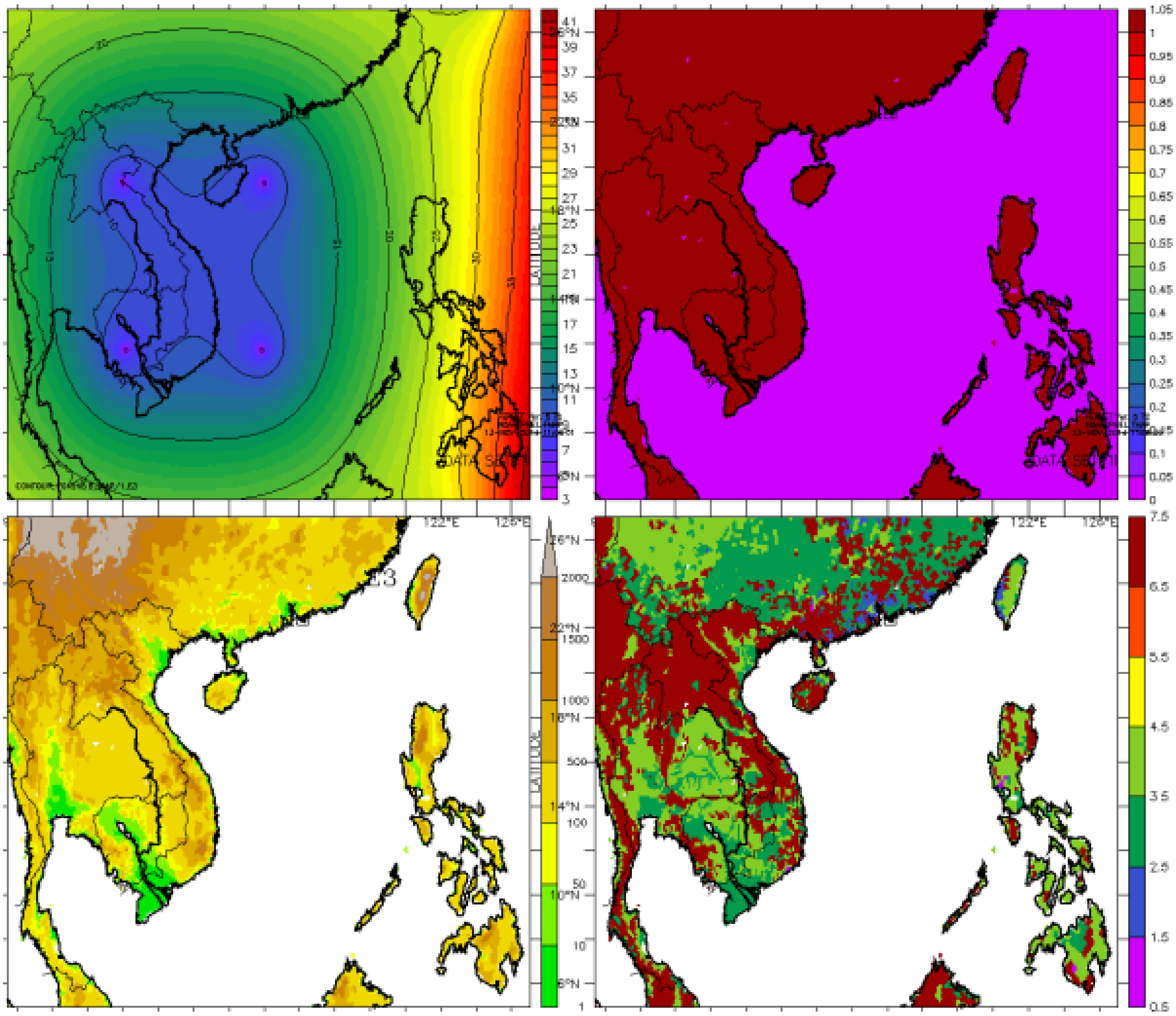

Figure 4. Grid and surface information used in 10 km simulations. Grid spacing is shown in upper left panel, land-sea mask in upper right panel, surface terrain in lower left panel and different soil types index specified in lower right panel.

5   Evaluate climate model data

The assessments comprise of evaluation of the climate information from a dynamical downscaled method. Baseline climate data for Tmax and Tmin are generated from the CRU gridded (observed) dataset and five downscaled GCMs obtained from CSIRO described above. Plots for each of the eight stations of the monthly mean Tmax and Tmin from the observations and the downscaled simulations are shown in Figure 5. For all stations, the downscaled simulations capture the annual cycle of temperature very well. For all stations except Phatthalung the bias is very small. At Phatthalung, the maximum temperture of the simulations show about a one degree cold bias. There is also a small warm bias for Tmin at Phitsanulok.

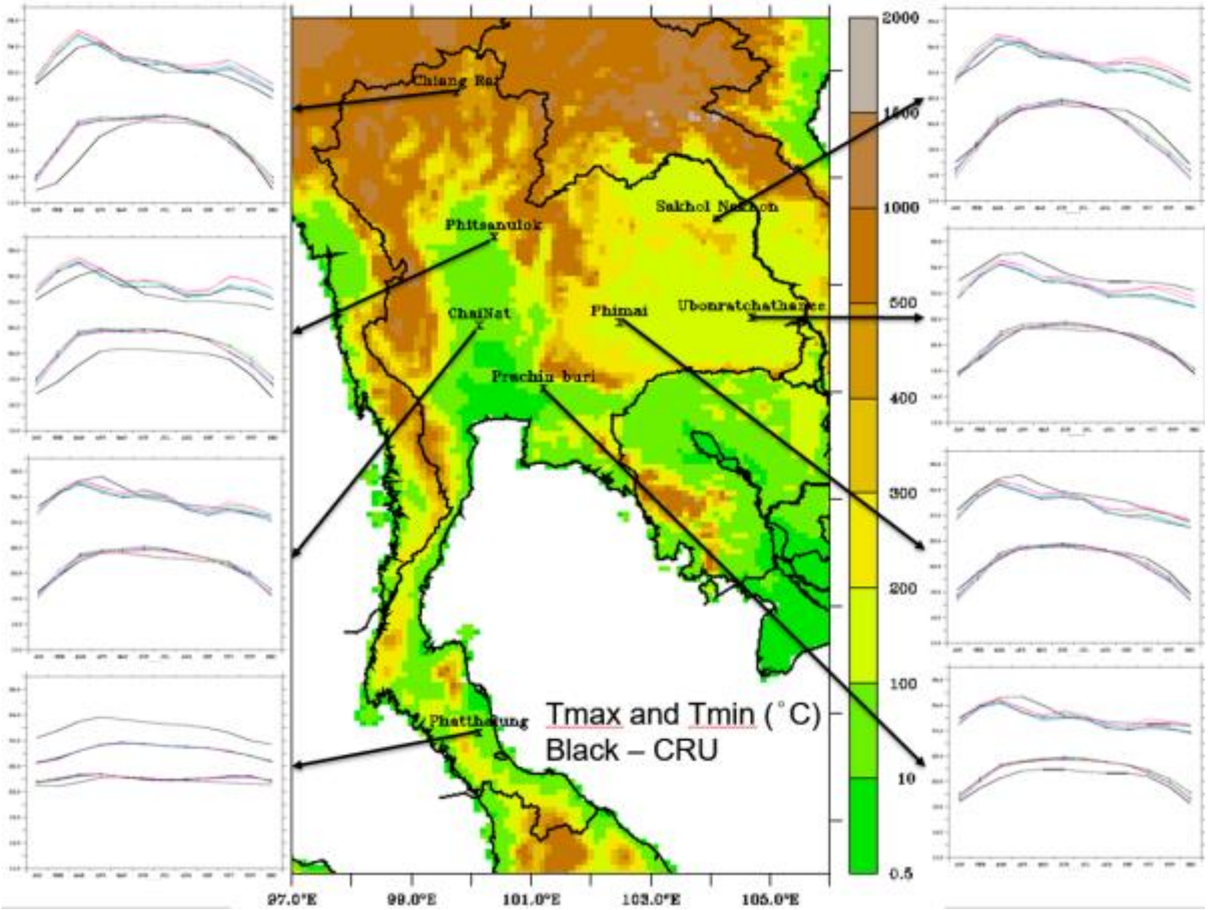

Figure 5. Annual cycle of monthly mean maximum and minimum surface air temperature (°C) for the period 1980–1999 for the eight stations. The thicker black line is the observed data from CRU. The coloured lines are from the five downscaled simulations. The colouring on the map is the model terrain (m).

For rainfall (Figure 6), the downscaled simulation data, while still capturing the monsoonal annual cycle of rainfall at all stations, there are some stations with significant biases. It is interesting that the northernmost and two easternmost stations have a dry bias during the wet season. There is also a slight wet bias during the dry season at the southernmost station. It is interesting though that the simulated results all tend to capture the double peaks in rainfall: one peak at start of monsoon season (around May) and second peak later in the monsoon season (around September).

In summary, the downscaled simulations capture the temperature and rainfall patterns across Thailand reasonably well, which gives one confidence in the projected changes into the future.

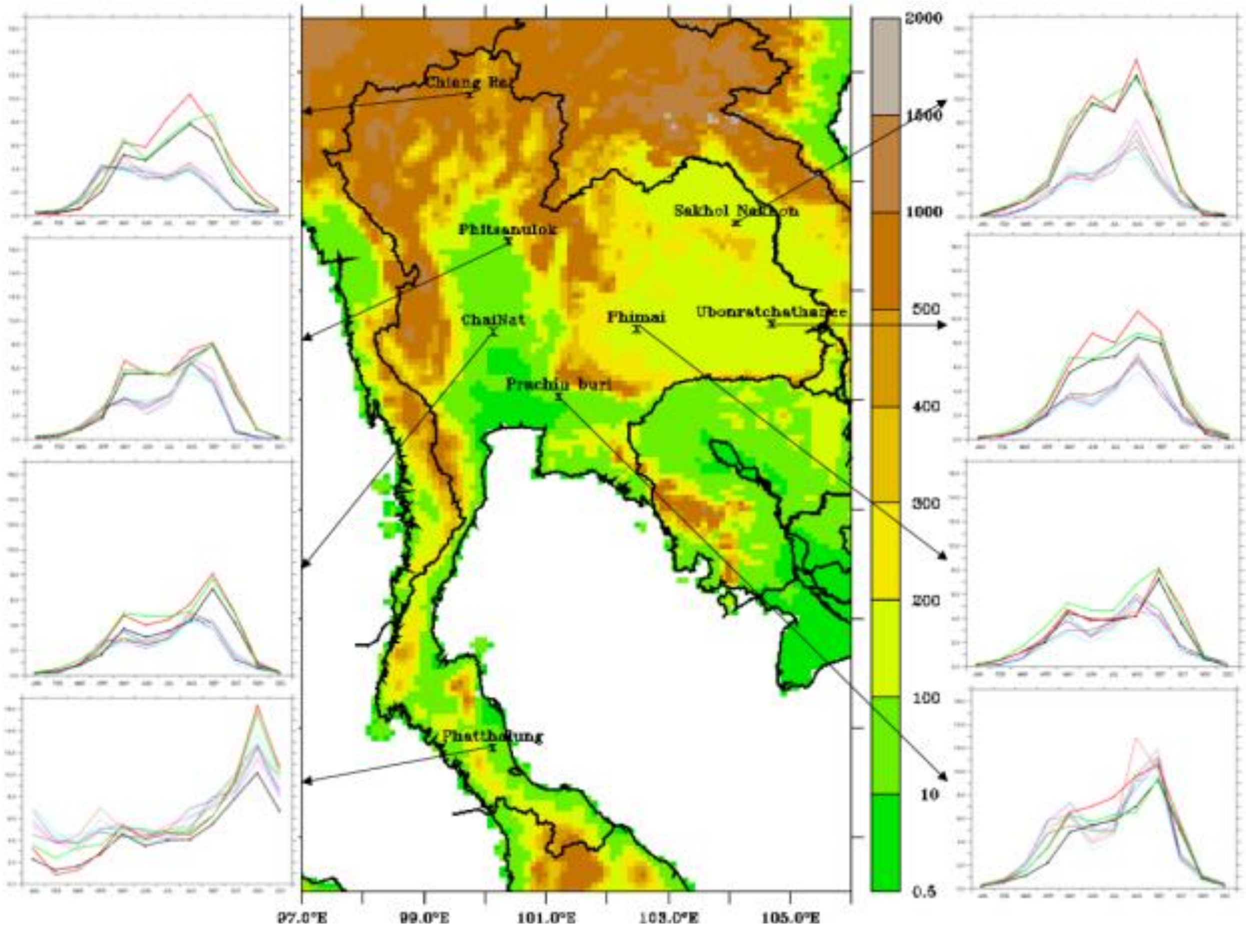

Figure 6. Annual cycle of monthly mean rainfall rate (mm/day) for the period 1980–1999 for the eight stations. The thicker black line is the observed data from APHRODITE, the thick red line is from CRU and the thick green line is from the TRMM dataset. The coloured lines are from the five downscaled simulations. The colouring on the map is the model terrain (m).

6 Select model

To decide which models' simulations to use, the case study considered results of model evaluation conducted in Step 5 which suggest that the downscaled simulations capture the temperature and rainfall patterns across Thailand reasonably well. In addition, the team analysed the range of uncertainty using the Climate Futures Tool's principle and assess the models that capture the spread of all plausible scenarios.

To provide a quick assessment of the range of possible futures, changes in annual mean surface air temperature and rainfall were computed for all available GCMs and the five downscaled simulations. By comparing these changes, one can assess how well the downscaled simulations capture the range indicated by the global models. This was only done for RCP8.5 and for differences in the 20-year means for the period 2040–2060 minus 1980–1999.

For the northernmost station, Chiang Rai, (Figure 7), there is a large range of projected rainfall changes, from some decreases (–0.3 mm/day) to larger increases (0.9 mm/day) with the downscaled results spread from the lower to middle values. None of the downscaled simulations indicate the larger rainfall increases. For temperature, all models indicate warming of around 2°C, ranging from about 1°C to 3°C.

For the southernmost station, Phatthalung, (Figure 8), there is also large range of projected rainfall changes, from decreases of about 1.5 mm/day to increases of about 1.2 mm/day. The downscaled results reasonably capture the spread except maybe the more extreme drying. For temperature, all models indicate warming of around 1.5 to 2°C, ranging from about 1°C to 2.5°C.

All the dynamically downscaled runs were used in this analysis. No sub-selection was done. While not capturing the full range of possible projected changes, the downscaled simulations do capture a significant portion of the range. Due to time constraints, it was not possible to extract GCM data to more fully capture the range. This could be a subject of future work.

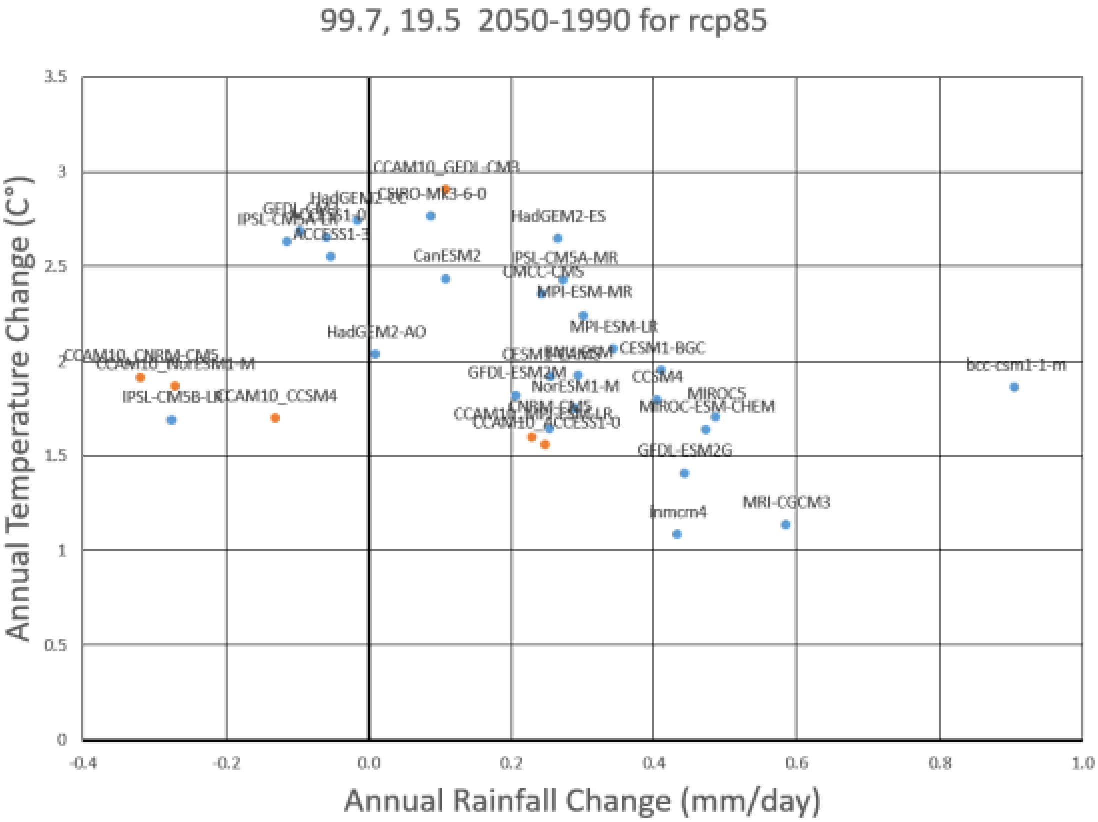

Figure 7. Scatter plot of the changes in annually-averaged rainfall rate (horizontal axes, mm/day) and annually-averaged temperature (vertical axis, °C) for Chiang Rai. Blue dots are from the global climate models while the orange dots are from the CCAM downscaled projections.

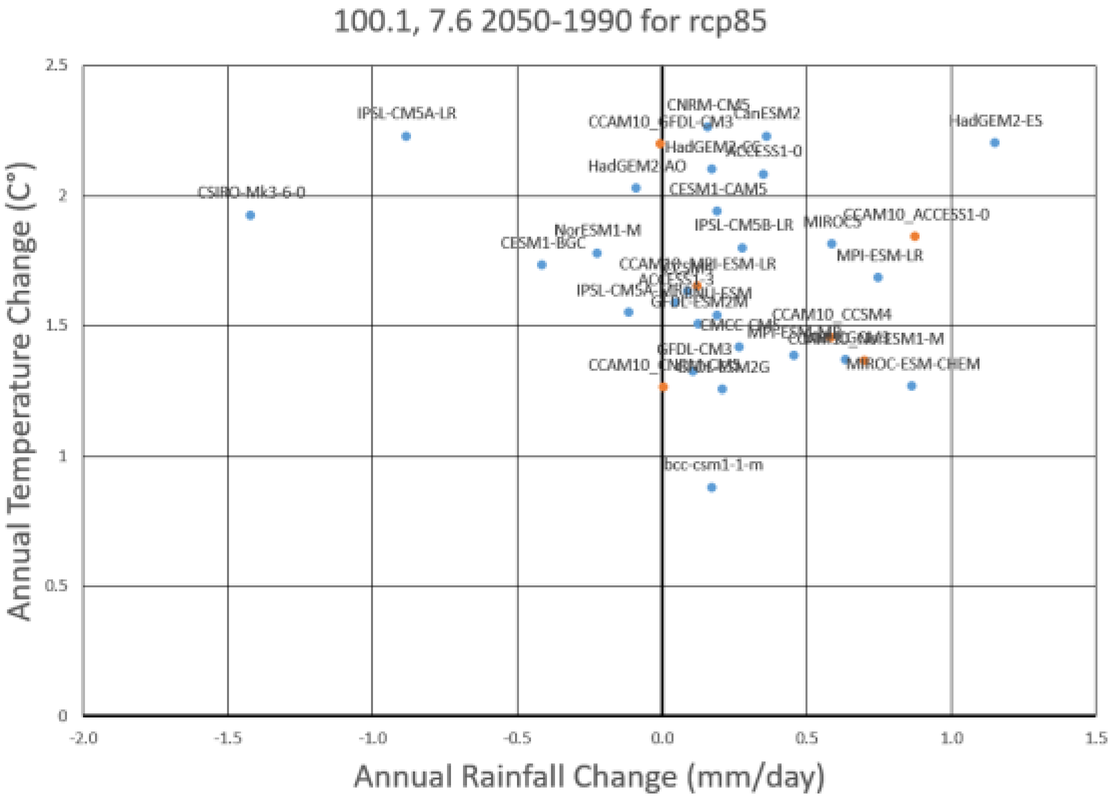

Figure 8. Scatter plot of the changes in annually-averaged rainfall rate (horizontal axes, mm/day) and annually-averaged temperature (vertical axis, °C) for Phatthalung. Blue dots are from the global climate models while the orange dots are from the CCAM downscaled projections.

7 Construct projections and data for input to rice model

The time series of the temperature and rainfall fields were extracted from CCAM outputs by five GCMs for both RCPs (RCP4.5 and RCP8.5). The median, minimum and maximum values of the annual maximum temperature (Tmax) and rainfall of the six downscaled model data were calculated and plotted for each of the eight locations.

In addition, daily rainfall, solar radiation and temperature data was extracted from all the downscaled simulations to be used in the CSM-CERES-Rice model. The data had to be converted to an ASCII (text) format with very strict structure, headings and filename conventions (see Figure 9).

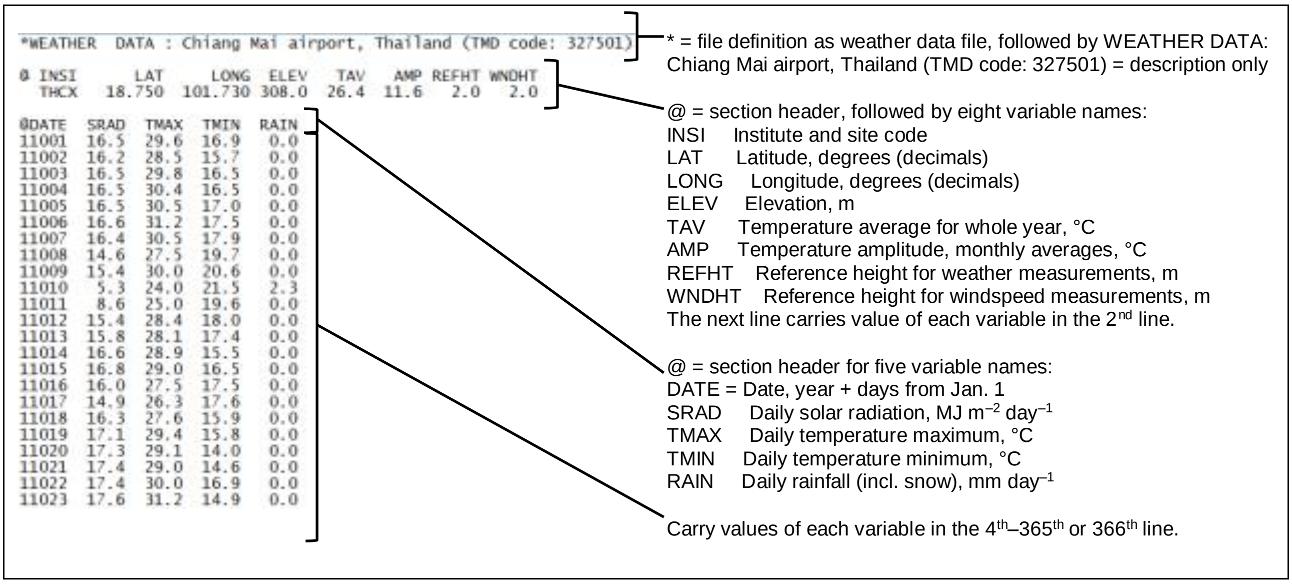

Figure 9. Illustration and explanation of the format of data used as input to the CSM-CERES-Rice model

8 Analyze projections

The time series of maximum surface air temperature (Tmax) for the historical and future periods until 2099 for both RCP8.5 and RCP4.5 is shown in Figure 10. For the historical period (1970–2005), the simulations show a slight warming trend. Note that these predicted changes in mean do not exceed the natural variability of temperatures as indicated by the standard deviation of the annual mean temperatures (horizontal dotted lines). The significance of these results would need to be tested more rigorously.

Beyond 2005, the projected annual mean Tmax shows definite warming signal, which exceeds the natural variability of the historical period by around 2010 in RCP8.5 and 2030 with RCP4.5. However, note that throughout the time series, there is an overlap of the annual maximum and minimum values of the two RCPs for all stations except the southernmost station, Phatthalung. By the end of the century one can see that the higher emission scenario (RCP8.5) has potential for significant hotter years (some with more than 6°C warmer than current baseline mean). Also note that by around 2040, the lowest annual mean Tmax projected is above the baseline mean, indicating the projections show that by 2040 there are no more years with annual mean Tmax equal or less than the current mean. Finally, Phatthalung shows the largest amount of warming.

Changes in the annually-averaged minimum surface air temperature are similar to maximum temperature and are not shown.

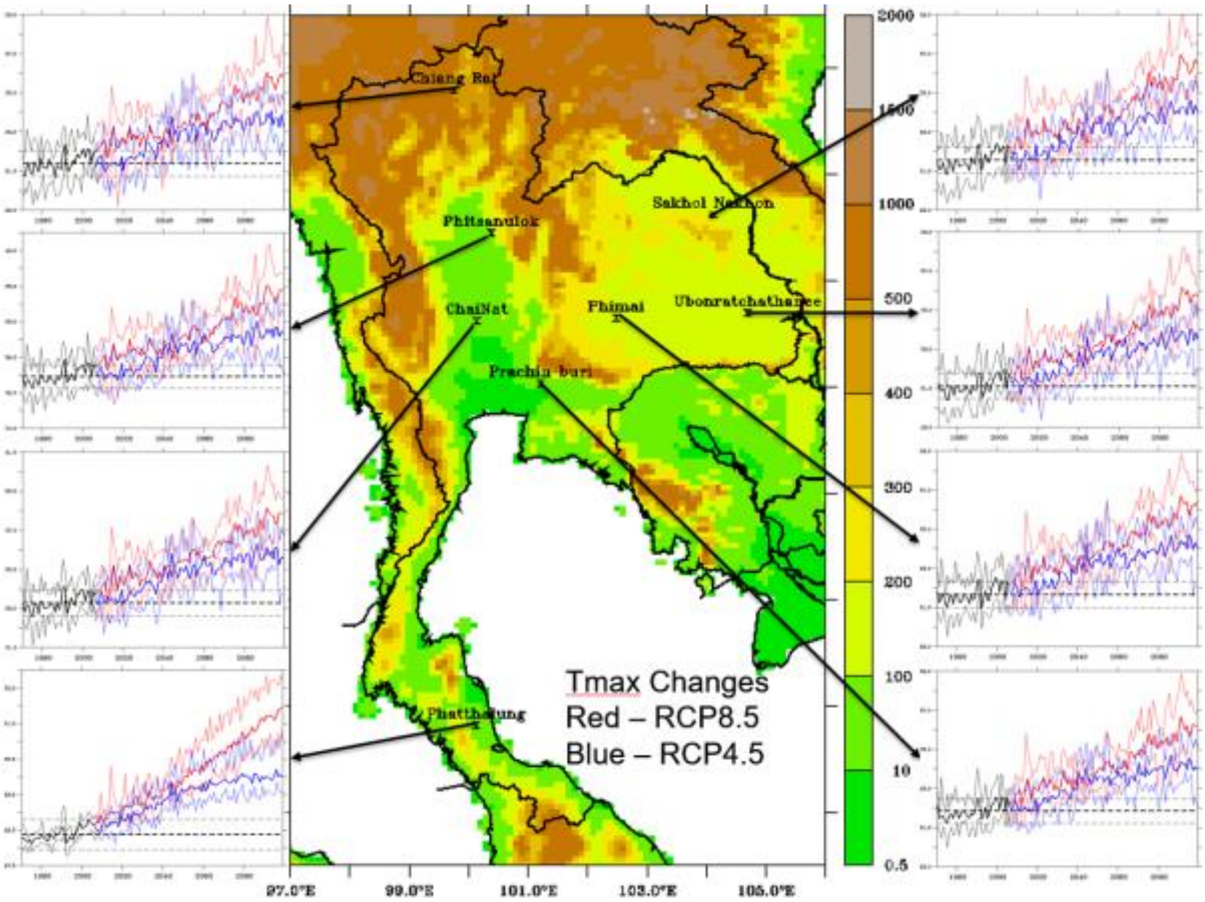

Figure 10. Time series of annually-averaged maximum surface air temperatures (°C) from the five 10 km CCAM downscaled simulations for 1970-2099. The historical period (1970-2005) is indicated in black. The projections (2006–2099) are shown in red for RCP8.5 and blue for RCP4.5. The ensemble mean is indicated be a solid line, while the maximum and minimum for each year is indicated as dashed lines. The horizontal black dashed line is the 1980–1999 mean, with plus and minus one standard deviation indicated in the dotted black horizontal lines.

The time series of annual mean rainfall (Figure 11) is quite different than that for Tmax. First, the historical period shows little obvious trend at any station with large interannual variability. The projections into the future continue this trend with only small long-term trends until the end of the century for both RCPs. Note that the decreases in Figure 7 and Figure 8 show both increases and decreases for the downscaled results which is consistent with the trends indicated here. The extreme annual rainfalls from all the simulations also show little change over time. However, this does not mean all extremes are not changing and more analysis need to be done.

The high resolution (e.g. 10 km) of the downscaled simulations and the closeness of the simulated climatologies to the observed gives us good confidence in the projections. A more thorough evaluation for the model results against observations should be completed in order to further document the accuracy off the simulations. As was noted in the comparison against changes from the GCMs (Figure 7 and Figure 8), the spread of the changes from the downscaled simulations were similar to the GCMS, apart from some more extreme values. If future opportunity exists, it might be useful to do some additional tests of the rice model using some of the more extreme GCM values to further test the results.

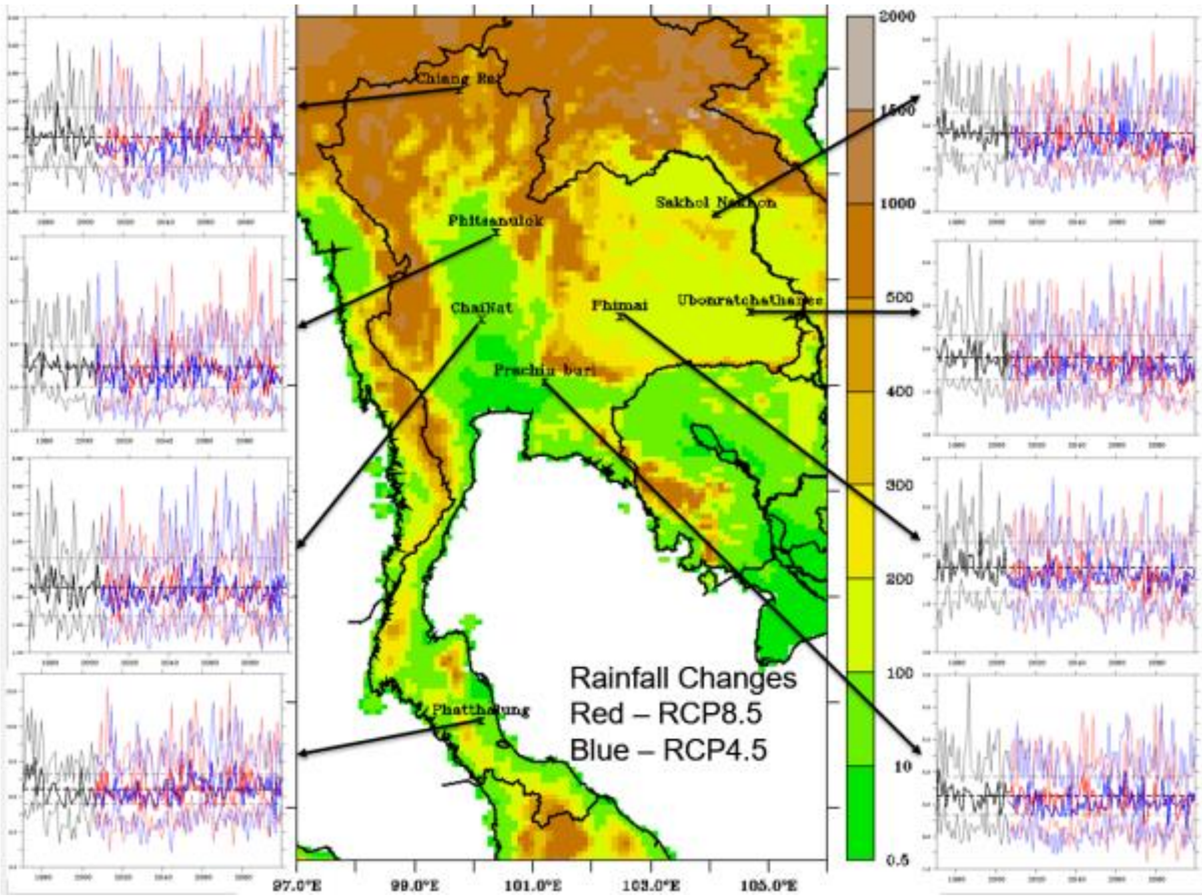

Figure 11. Time series of annually-averaged daily rainfall rate (mm/day) from the five 10 km CCAM downscaled simulations for 1970-2099. The historical period (1970-2005) is indicated in black. The Projections (2006-2099) are shown in red for RCP8.5 and blue for RCP4.5. The ensemble mean is indicated be a solid line, while the maximum and minimum for each year is indicated as dashed lines. The horizontal black dashed line is the 1980-1999 mean, with plus and minus one standard deviation indicated in the dotted black horizontal lines.

9 Correct possible biases

In the analysis of the dynamically downscaled climate simulations for the current period (see Figure 5 and Figure 6), no significant biases were noted for most stations. The small biases that do exist will unlikely have significant impact on the results, though this should be tested.

Model bias correction was not done for three reasons. First, the assessment of the simulated data against the observations indicated the RCM was capturing the current climate reasonably well. Thus it was not expected that the climate model bias would not influence the key results. Second, observational station data required to conduct the bias correction were not provided during the study. Third is time and resource constraint. While outside the scope of this project, bias correction of the dynamically downscaled simulations could have been done.

10 Communicate information

The downscaled daily rainfall, Tmax, Tmin and solar radiation data was provided and used as input to the Rice Model. Simulated rice grain yields are provided in Table 3.

Comparing the simulated rice grain yield during the historical period (1970–2005) at eight locations in Thailand under five GCMs with the simulated rice yields during the future period, we have mixed results.

Most projections give a decrease in rice yields during 2006–2040. These results are in line with results reported by Matthews et al. (2003), Pannangpetch et al. (2009) and Jintrawet and Chinvanno (2011).

When comparing results under RCP4.5 and RCP8.5, a slight decrease in simulated rice grain yields was observed under RCP8.5 by most simulations (e.g. Figure 12).

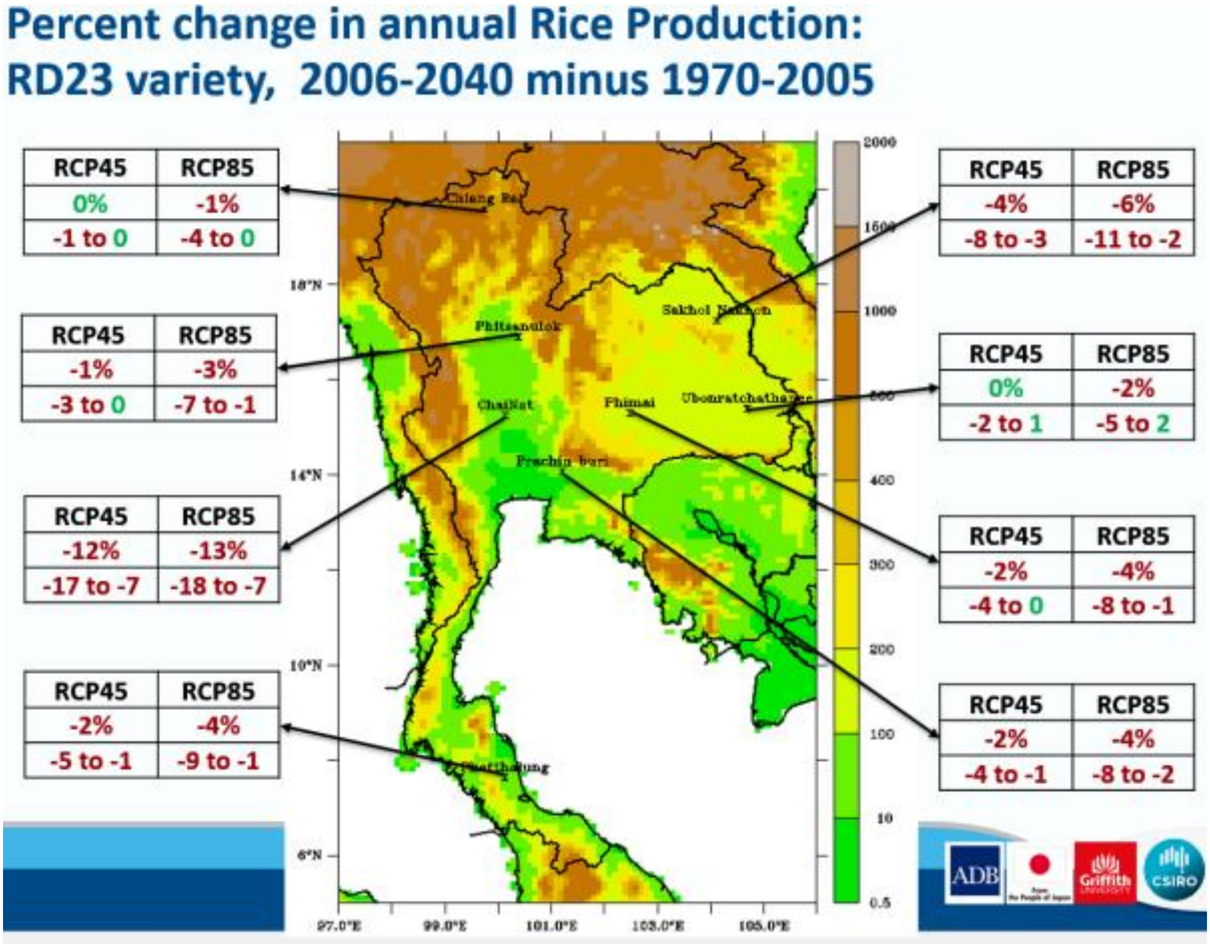

Figure 12. Summary of the percent change to rice production for the RD23 rice variety at each location for bath RCP4.5 and RCP8.5 scenarios for period 2006–2045 relative to the 1970–2005 period. The five-member ensemble mean and the range is presented. Colours on the map are elevation in meter above mean sea level.

More testing of simulated rice grain yield during the historical period are needed and may be carried out as a joint project between the stakeholders under funding from all concerned agencies and/or from research funding agency, i.e., the Thailand Research Fund (TRF), local rice cooperatives and commercial rice mill and rice processing companies, and the National Research Council of Thailand (NRCT).

Site	Rice Variety	Climate Model	1970-2005 historical	2006-2040 RCP4.5	2006-2040 RCP8.5	2006-2040 RCP4.5	2006-2040 RCP8.5	ensemble mean changes RCP4.5	ensemble mean changes RCP8.5
Chiang Rai	NSPT								
		CCSM4	2,380	2,399	2,374	19	-6		
		CNRM-CM5	2,362	2,329	2,394	-33	32		
		GFDL-CM3	2,360	2,329	2,362	-31	2		
		MPI-ESM-LR	2,394	2,324	2,349	-70	-45		
		NorESM1-M	2,356	2,342	2,382	-14	26	-26	2
	RD23								
		CCSM4	3,210	3,215	3,157	5	-53		
		CNRM-CM5	3,197	3,156	3,204	-41	7		
		GFDL-CM3	3,188	3,192	3,171	4	-17		
		MPI-ESM-LR	3,181	3,173	3,065	-8	-116		
		NorESM1-M	3,201	3,202	3,215	1	14	-8	-33
Phitsanulok	RD23								
		CCSM4	4,786	4,748	4,659	-38	-127		
		CNRM-CM5	4,810	4,735	4,709	-75	-101		
		GFDL-CM3	4,807	4,659	4,571	-148	-236		
		MPI-ESM-LR	4,772	4,786	4,458	14	-314		
		NorESM1-M	4,803	4,811	4,752	8	-51	-48	-166
ChaiNat	RD23								
		CCSM4	6,383	5,910	5,681	-473	-702		
		CNRM-CM5	6,465	5,693	5,995	-772	-470		
		GFDL-CM3	6,467	5,345	5,286	-1,122	-1,181		
		MPI-ESM-LR	6,204	5,600	5,100	-604	-1,104		
		NorESM1-M	6,466	5,725	5,838	-741	-628	-742	-817

Site	Rice Variety	Climate Model	1970-2005 Historical	2006-2040 RCP4.5	2006-2040 RCP8.5	2006-2040 RCP4.5	2006-2040 RCP8.5	ensemble mean changes RCP4.5	ensemble mean changes RCP8.5
Sakhon Nakhon	NSPT								
		CCSM4	3,798	3,725	3,661	-73	-137		
		CNRM-CM5	3,822	3,652	3,780	-170	-42		
		GFDL-CM3	3,825	3,589	3,663	-236	-162		
		MPI-ESM-LR	3,793	3,586	3,609	-207	-184		
		NorESM1-M	3,800	3,592	3,710	-208	-90	-179	-123
	RD23								
		CCSM4	5,661	5,495	5,394	-166	-267		
		CNRM-CM5	5,694	5,451	5,576	-243	-118		
		GFDL-CM3	5,679	5,236	5,134	-443	-545		
		MPI-ESM-LR	5,597	5,413	4,979	-184	-618		
		NorESM1-M	5,725	5,496	5,519	-229	-206	-253	-351
Ubonratchanee	KDML105								
		CCSM4	2,954	2,959	2,950	5	-4		
		CNRM-CM5	2,970	2,921	2,925	-49	-45		
		GFDL-CM3	2,990	2,925	2,970	-65	-20		
		MPI-ESM-LR	2,969	2,923	2,910	-46	-59		
		NorESM1-M	2,936	2,881	2,964	-55	28	-42	-20
	RD23								
		CCSM4	3,430	3,473	3,414	43	-16		
		CNRM-CM5	3,492	3,432	3,448	-60	-44		
		GFDL-CM3	3,515	3,450	3,342	-65	-173		
		MPI-ESM-LR	3,452	3,482	3,301	30	-151		
		NorESM1-M	3,445	3,449	3,510	4	65	-10	-64

Site	Rice Variety	Climate Model	1970-2005	2006-2040		2006-2040		ensemble mean changes	
			Historical	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Phimai	KDML105								
		CCSM4	4,630	4,596	4,610	-34	-20		
		CNRM-CM5	4,616	4,536	4,561	-80	-55		
		GFDL-CM3	4,596	4,507	4,561	-89	-35		
		MPI-ESM-LR	4,565	4,515	4,482	-50	-83		
		NorESM1-M	4,594	4,492	4,595	-102	1	-71	-38
	RD23								
		CCSM4	5,159	5,091	5,008	-68	-151		
		CNRM-CM5	5,160	5,056	5,091	-104	-69		
		GFDL-CM3	5,150	4,954	4,835	-196	-315		
		MPI-ESM-LR	5,111	5,090	4,725	-21	-386		
		NorESM1-M	5,168	5,131	5,106	-37	-62	-85	-197
PrachinBuri	RD23								
		CCSM4	5,072	4,969	4,919	-103	-153		
		CNRM-CM5	5,081	4,982	4,982	-99	-99		
		GFDL-CM3	5,068	4,877	4,740	-191	-328		
		MPI-ESM-LR	5,028	4,999	4,609	-29	-419		
		NorESM1-M	5,107	5,076	4,977	-31	-130	-91	-226
Phatthalung	RD23								
		CCSM4	5,194	5,134	5,017	-60	-177		
		CNRM-CM5	5,195	5,089	5,124	-106	-71		
		GFDL-CM3	5,200	4,966	4,825	-234	-375		
		MPI-ESM-LR	5,159	5,101	4,710	-58	-449		
		NorESM1-M	5,218	5,161	5,125	-57	-93	-103	-233

CONCLUSIONS

This case study is designed to strengthen the technical capacity of the in-country TA team, through learning by doing, to use climate data for climate impacts assessment as per the guideline available on the RCCAP portal (www.rccap.org). In particular, this case study demonstrates how climate projection information can be used to assess the impact on rain-fed rice production in Thailand.

The work described here could have implication on potential application of climate change scenarios data sets from five climate models in combination of the CSM-CERES-Rice shell in assessing the impact of climate change on rice production system throughout Thailand and other rice production systems in ASEAN member states.

The graphs and the maps can also be used in any climate change related communication and activity. However, they may require some modifications tailored to the need of different users or audience.

The MWCropDSS tool and networking of key persons of various stakeholder organizations have been found to play important learning roles in addressing key issues and challenges common in agricultural, natural and water resource management in Thailand under climate change and variability.

Lessons learned

1. The selected topic of this case study is based on a common interest among the implementing agency of this TA (i.e. TMD), stakeholders and Thailand consultant team. This contributes to the success of the case study. For instance, all the non-climate data required by the rice model were provided by the Rice Department.
2. The case study was made possible through establishing a good communication modes and work plan among the parties involved. For example, the communication between the impact model specialist and climate model provider was made via email and telephone. Through their communication several issues were found and addressed before successfully running the climate data through the rice model.
3. The approach demonstrated through this case study can be applied to assess impacts of climate change on rice production systems in other sites in Thailand by using the climate data provided through the RCCDF portal (www.rccap.org).

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APPENDIX

Types and Sources of Data

APHRODITE: Asian Precipitation—Highly-Resolved Observational Data Integration towards Evaluation
(Yatagai et.al., 2009; Yatagai et.al., 2012)

http://www.chikyu.ac.jp/precip/index.html

CRU: Climate Research Unit
(Harris et al., 2014).

https://crudata.uea.ac.uk/cru/data/hrg/cru_ts_3.24/

CCAM

Downscaled climate change data used in case study can be accessed from:
http://www.hpc.csiro.au/users/72365/Thai/

DSSAT

Model can be accessed from dssat.net

MWCropDSS version 1.0 and 2.0

Can be accessed from http://www.mcc.cmu.ac.th/research/Software/abstract/abstract_mwcropdss.htm

TRMM: Tropical Rainfall Measuring Mission
(Huffman et al., 2007)

http://mirador.gsfc.nasa.gov/cgi-bin/mirador/granlist.pl?page=1&location=%28-90,-180%29,%2890,180%29&dataSet=TRMM_3B42_daily&version=007&allversion=007&startTime=1997-12-31T00:00:01Z&endTime=1997-12-31T23:59:59Z&keyword=TRMM_3B42_daily&longname=Daily%20TRMM%20and%20Others%20Rainfall%20Estimate%20%283B42%20V7%20derived%29&CGISESSID=2f6fa2c6d4ea5e99df0ba8114d1f0461&prodpg=http://disc.gsfc.nasa.gov/datacollection/TRMM_3B42_daily_V7.html

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