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The Future of Rice Security Under Climate Change

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Glossary of Terms

AFSIS:	ASEAN Food Security Information System
ASEAN:	Association of Southeast Asian Nations
CIMMYT:	International Maize and Wheat Improvement Centre
CMIP5:	Coupled Model Intercomparison Project – Phase 5
CMIP3:	Coupled Model Intercomparison Project – Phase 3
CSIRO:	Commonwealth Scientific and Industrial Research Organisation
FAO:	Food and Agriculture Organisation
GCM:	General Circulation Models
GSO:	Government Statistical Office
IMHEN:	Institute for Meteorology, Hydrology and Environment Vietnam
IPCC:	Intergovernmental Panel on Climate Change
IR/R:	Irrigation/rainfed
IRRI:	International Rice Research Institute
MRC:	Mekong River Commission
MRD:	Mekong River Delta
NIE:	National Implementing Entity (NIE)
NAFCC:	National Adaptation Fund on Climate Change
NOAA:	National Oceanic and Atmospheric Administration
ODI:	Overseas Development Institute
RCP:	Representative Concentration Pathways
RRD:	Red River Delta, Vietnam
SDG:	Sustainable Development Goal
SLR:	Sea Level Rise
SRES:	Special Report on Emissions Scenarios
THI:	Temperature-Humidity Index
T:	Average near surface temperature
Tmax:	Maximum temperature (at noon)
Tmin:	Minimum temperature (at night)
USDA:	United States Department of Agriculture
UNFCCC:	United Nations Framework Convention on Climate Change
WFP:	World Food Programme

Executive Summary

Food systems are climate and weather dependent; heat stress and changes in rainfall patterns and relative humidity are likely to regulate crop yields. Elevated carbon dioxide (CO_2) are likely to directly and indirectly bring new challenges to the stability and sustainability of global food production including rice.

This report provides a brief overview of projected rice security indicated by future potential yield under elevated carbon dioxide levels. This research aims to identify the downscaled impact of climate change on rice production which includes climate change impact assessment at sub-national levels in the world's top three rice exporters namely Thailand, Vietnam and India. This paper also identifies some of the downscaled impacts of climate change that may continue to affect rice production in these regions until the end of the 21st century. We also identify public actions and policy responses in India, Thailand and Vietnam. Policy recommendations as well as possible climate change adaptations and mitigation measures are also provided.

Key Findings on Projected Climate Impact on Rice

The aggregate impact of climate change on rice will be more negative than positive. Heat stress will continue to be a constant threat to rice crops. A lack of anticipatory adaptation to change in temperature and rainfall regime (e.g. through water and soil moisture content management) will lead to significant losses in yield and production.

Climate change impact on rice in India.

India may lose its status as exporter by 2050 due to climate change coupled with demographic change. By 2030, it is likely that rice yield in India is likely to be -4% in Uttar Pradesh, -3 to - 4% in Punjab and -2 to -3% in West Bengal. This trend is predicted to continue to 2050 where the yield will likely to be -10 to 15% in Uttar Pradesh & Punjab, -5% in West Bengal and -3 to 4% in Tamil Nadu. However, by 2080, projections are unclear with mixed yield changes informed by models. One of the arguments is that yields are dependent upon the emissions trajectories applied. Areas such as Tamil Nadu are likely to experience yield of +11% given the potential excessive rainfall that may offset warming. Orrisa and Chhattisgarh may experience a decline in yield by -14 to - 15%. [See the details in Section 7.1, Table 5]

Climate change impact on rice in Thailand

Thailand can still increase its rice yield potential. In addition, its present yield is still far below its yield potential. Based on the current trend, by 2030, overall rice production in Thailand is likely to increase as it is still producing below its yield potential. By 2050, mixed results may occur given the fact that in some parts, rice yield may increase by 28% in the north-east or decrease by 23% in the Roi Et region. However, Thai rice yields are still expected to increase overall. By 2080, Thailand may suffer a 45% overall decrease in rice yields if adaptation measures are not implemented. Conflicting downscaled reports for Thailand's top producing regions such as Khon Kaen and Chayaphom show that there may be a positive yield of 28.4% or a decline of 14.6%. In provinces such as Roi Et, there could be a decrease in yields of 32% if there are no adaptation measures being applied. [See the details in Section 7.2, Table 6]

Climate change impact on rice in Vietnam

Vietnam needs to deal with its decline in agricultural land for rice as well as future climate shocks including sea-level rise. Based on status quo, by 2030, Projected decline in yields of rice in Vietnam in North Delta could be -2.2% and in South Delta could be -5.6%. This trend continues till 2050 where an overall Vietnam could experience yield loss by 20%; Subsequently, yield loss could be 32.6% in North Delta and 7.8 to 8.6% in South Delta. By 2080, the picture continues to be negative. Predictions suggest that North Delta may experience loss of 16.5% annually. However, yield changes may vary between the seasons: -17.5% (summer/autumn), +11% (autumn/winter) in the South Delta; -23.5% (summer/autumn), +17.2% (autumn/winter) in the Ca Mau region of the South Delta, Vietnam. [See the details in Section 7.3, Table 7]

Key Findings on Existing Public Action and Policy Response

The Government of India's Sustainable Agricultural Mission is planning to identify and develop new varieties of crops that can withstand abiotic stresses including drought and floods. Its Ministry of Environment and Forests has recently established the National Adaptation Fund on Climate Change, aiming at supporting the states governments to incentivize farmers to be adaptive to climate change. These initiatives are still at the initial stages.

In general, there is still limited information regarding public action and policy response to climate change in rice sectors in the ASEAN region. In many cases, national and local initiatives are often seen in the form of international cooperation and in many cases limited to international research projects. Typical initial public actions in developing countries, including in Asia, often manifest in the forms of pilot projects with international scientific institutions such as IRRI. However, Thailand and Vietnam have been developing their climate adaptation plan and strategy. Even so, specific public actions for rice and other crops remain to be investigated further.

Policy Recommendations

We suggest some of the following policy options for rice exporters and importers. Rice producers are not immune from potential price shocks that may arise from climate shocks.

- Increase adaptive capacity and ensure multiple-dimension adaptation actions to climate change. These include ensuring countries invest in technology (from production to post harvesting to transporting), creating incentives for farmers and producers to adopt adaptive technology, improving irrigation infrastructure and capacity building of agricultural extension officers and farmers.

- Support market integration to help mitigate price shocks. ASEAN Economic Integration can be a solution in rice market integration, allowing rice surplus in one particular place to flow into rice-deficit regions.

- Strengthen regional cooperation framework to help reduce uncertainty and information asymmetry in the market. In the case of ASEAN Food Security Information System (AFSIS), it can strengthen cooperation with organisations such as APEC and others in order to strengthen data and information system.

- Build a global dataset on adaptation knowledge in such a way that can be accessible to rice farmers around the world. International research organisations such as IRRI and universities can work together to take stock on knowledge and experiences in rice adaptation and resilience-building projects.

- Spread adaptation knowledge using smartphones and web-based application. IRRI recently started to use *apps via smartphone* to transmit knowledge on rice planting in the Philippines. This initiative can be extended to India, Thailand and Vietnam.

- Promote the inclusion of crops including rice and livestock to be part of the implementation agenda of the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts (Loss and Damage Mechanism).

1. Introduction

Food security is obviously not only about physical food availability achieved via production, but also about economic and physical access to food, food utilization and stability of availability, access and utilization over time.[1] Abundant literature has suggested to policy makers to move beyond rice crops. We are mindful of the fact that the future of food should include all crops, including native crops and orphan crops that often not only tend to be ignored by policy makers but lack investment in their development too (Naylor et al., 2004). However, our focus of this research is about the future availability of rice under climate change.

Why should we worry about rice security? Rice is a primary staple food for about three billion people in Asia and increasingly in Africa (see Africa Rice Project at africarice.org). There will be at least one billion additional rice eaters in Asia and Africa by 2050. Asia faces the immense task of feeding a growing rice eating population that will reach 4 – 5 billion people in the next 35 years. Based on the current rice yield growth rate, the total supply will fall short of rice demand as a result of population growth. In addition, the sustainability (of rice for availability) is likely to be at risk due to climate change.

The effects of climate on rice crops do not stop at planting period but continues during harvest and post-harvest stages. Ideally, once rice is cut from the field, the process of threshing, drying, and safe storage should occur within 24 hours. Failure to achieve this ideal condition often leads to physical grain loss to farmers and loss of grain quality to consumers (Brolley, 2015). Annual losses from these harvest and post-harvesting stages is about 30% of yield. Loss of grain quality reduces not only farmers' income but also rice supply in the market.[2] Unfortunately, in many parts of Asia including India, Thailand, Vietnam and the rest of the Southeast Asian regions, these process are manually laboured and often by women (Ibid.).

This policy report provides a brief overview on how climate change will impact rice production by 2030, 2050 and 2080/2100. It examines the impact of changing

[1] See FAO's glossary on Food Security at http://www.fao.org/hunger/glossary/en/ [Last accessed 29 March 2016].

[2] See IRRI's basic notes on post-harvest losses: http://irri.org/our-impact/increase-food-security/reducing-rice-losses-after-harvest. [Last accessed on 28 Dec 2015].
[2] See IRRI's basic notes on post-harvest losses: http://irri.org/our-impact/increase-food-security/reducing-rice-

temperature (e.g. minimum and maximum temperatures at day and night), sea level rise (SLR), salinity and rainfall delays. This research identifies climate change at sub-national levels in the top three rice exporting countries namely India, Thailand and Vietnam. Observed climate extremes such as droughts, floods, cyclones and their impact on rice crops will also be presented. Furthermore, it also identifies climate change impact on rice production in the selected regions of the countries by 2030, 2050 and 2080.

This paper further identifies existing public actions and policies in the respective countries. This paper also highlights policy recommendations on possible climate change adaptation and mitigation measures for both producing countries and importing countries.

2. Research Methods

This research uses both qualitative and quantitative methodologies. The qualitative methods include the use of extensive literature review to understand rice production context, climatic context, policies and identification of regions prone to extreme weather events in India, Thailand and Vietnam. The qualitative approach also uses the approach of 'meta study' of existing research on projected climate change in India, Thailand and Vietnam as well as rice-relevant studies in the regions. India, Thailand and Vietnam are chosen as they are the top rice exporters of the world.

Uncertainty in the climate and crop models

Literature suggests that there are 40 existing global climate models and about various downscaling methods (Rosenzweig et al., 2013). There are also differences between observed values at weather stations and climate projections.[3] For rice crop models, there are more than 13 models available[4]. In this research, we combine both literature studies of rice yield as well as a meta-analysis of projected and empirical

[3] See notes on IPCC climate data at http://www.ipcc-data.org/guidelines/index.html [Last accessed on 26 Dec 2015]

[4] See The Agricultural Model Intercomparison and Improvement Project at http://www.agmip.org/rice/ [Last accessed on 29 October 2015]

rice losses. Policy and adaptation contexts often play significant roles in the present crop production.

3. Conceptual Frameworks

We have developed a generalised framework that guides our research (Figure 1). The first step includes a comprehensive review of rice crop production context in the last 100 years. We further analyse the downscaled climate analysis based on IPCC 2014 datasets. The abiotic stressors associated with climate change include changes in long term trends in temperature, rainfall, soil moisture contents and increasing trend in extreme events including heat, drought, salinity, and submergence/floods (Figure 1).

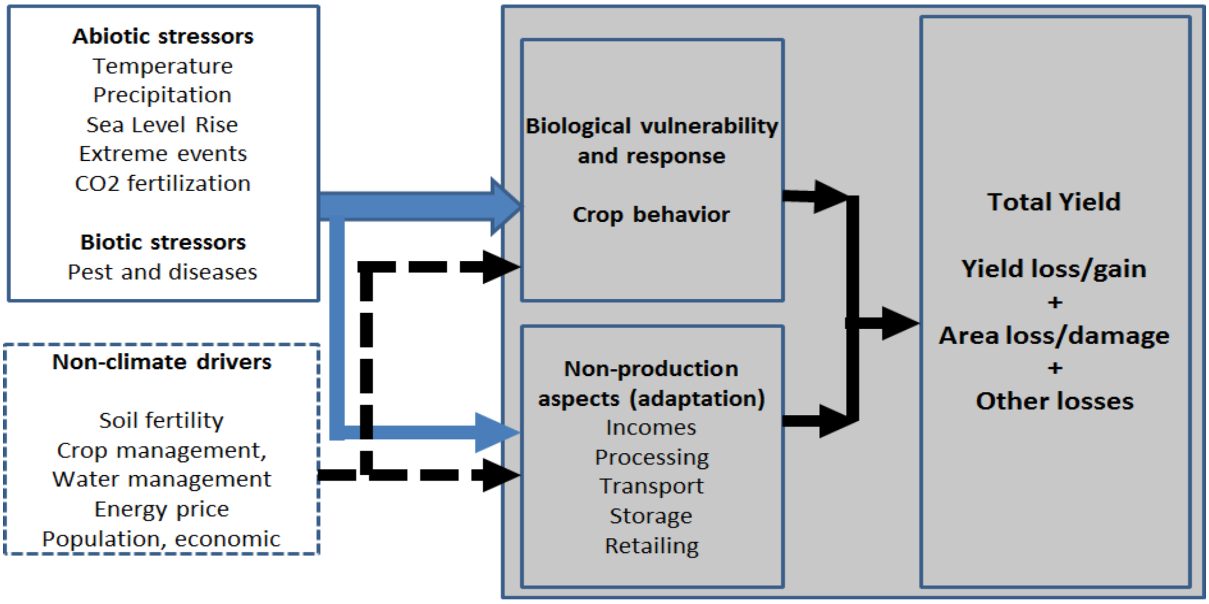

Figure 1. Research framework for rice under climate change
Source: Authors

Note. Non-climate drivers will not be the focus of this paper.

Biotic stressors include pests and diseases. The future of rice production will depend on water availability which is altered by changing natural climate and the ability of human systems to manage water and land (adaptation through irrigation water saving techniques during droughts, flood management, etc.). The stressors could combine to create an aggregative impact on rice crops. However, biological vulnerability of rice depends on the level of its tolerance to the stressors and crop management and technology of adaptation (e.g. genotype, germ-plasm development and improved water management practices) (Wassmann et al., 2009b).

The projected climate change scenarios (temperature and rainfall) are based on 2030, 2050 and 2080 scenarios. However, some new studies have used new timelines such as 2040 and 2100. We apply the climate scenario to the biological response to the projected climate change informed by extensive literature review and empirical information.

How will climate change affect rice crops?

Rice growth cycle can be broadly divided into three stages, namely, vegetative, reproductive, and grain filling or ripening phases. Rice response to high temperatures varies according to different stages of its biological development (Krishnan et al., 2011 – Figure 2). Critical period occurs at the time when stressors (e.g. heat or delayed rainfall known as water stress) is set to happen at a particular development stage which may lead failure to harvest. Furthermore, rice heat stress tolerance at one developmental stage may or may not necessarily lead to the same level of tolerance in other stages.

Climate change may have an impact on freshwater systems – there has been evidence of decline in the rice production in some parts of Asia due to water stress triggered by increasing temperature, reduction of number of rainy days and increasing dry spells (Wassmann et al., 2009a, b; Cairns et al., 2012). In the context of India, water stress is often manifested in the form of droughts (Udmale, 2015). However, some rice cultivars may stand against drought better than other rice cultivars (Ward et al., 2014).

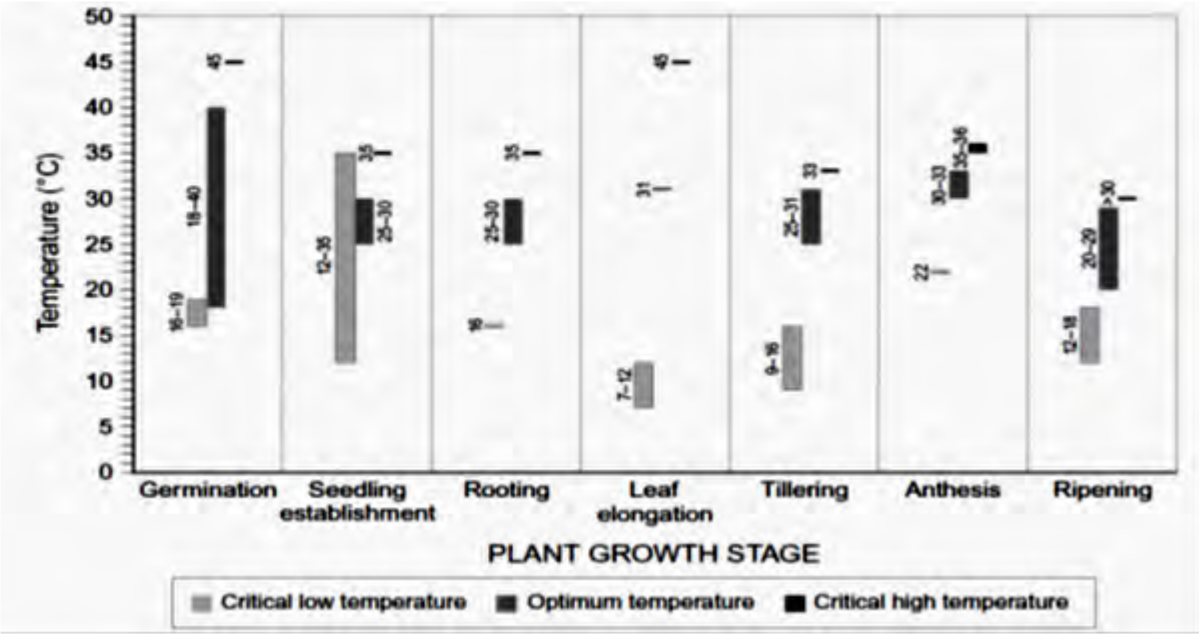

Figure 2. Temperature and biological developmental stages of rice
Source: Krishnan et al., 2011.

Temperature Change

Rice is relatively more tolerant to high temperatures during the vegetative phase but highly susceptible during the reproductive phase, and particularly so at the flowering stage (Jagadish et al., 2007). Unlike other abiotic stresses, heat stress occurring either during the day or night has differential impact on rice growth and production. With rapid increase in the minimum (nighttime) temperature during the last 2 – 3 decades compared to the maximum (daytime) temperature, and predictions that this trend will continue, impacts that, for now, are being identified in select vulnerable regions will be felt on a global scale (Welch et al., 2010).

Existing knowledge on rice suggests an average threshold of 24°C: If rice plants are exposed to an increase of 1°C warming for a number of days, rice could experience a 10% reduction in yield and biomass (Peng et al., 2004). An increase in temperature of up to 3°C (or beyond the limit of heat tolerance) may affect growth duration of the rice crop, reduce grain-filling duration and enhance respiratory losses, resulting in lower yields and lower-quality rice grains. Rice field experiments suggest that an increase of 3.6 – 7°C could lead to 12.2 to 35.6% photosynthesis reduction (Oh-e et al., 2007; Wassmann et al., 2009a). Delays due to shifts of the onset of rainfall: +/- 14 days in the planting calendar could lead to 12.5 to 25% yield loss (Naylor, 2007).

Rainfall

Recent research points to significant interaction between high temperatures and relative humidity, with higher humidity levels accompanied by moderate-to-high temperatures having a more pronounced negative impact when compared to conditions with lower relative humidity (Wassmann et al., 2009b). On the basis of the above-stated interaction, rice cultivation regions in the tropics and subtropics can be classified into hot/dry or hot/humid regions. It can be confidently assumed that rice cultivation in hot/dry regions, where temperatures may exceed 40°C (e.g., Pakistan, Iran, India), “have been facilitated through unintentional selection for efficient transpiration cooling” (an avoidance mechanism) under sufficient supply of water (Ibid., 68).

Floods and submergence

Floods and submergence are a significant problem for rice farming, especially in the lowlands of South and Southeast Asia. Rice is generally intolerant to complete submergence and plants die within a few days when completely submerged. Septiningsih et al. categorised yield losses due to unpredictable flood events into three damage categories: first, complete submergence (often referred to as flash flooding), causing plant mortality after a few days, second, partial submergence over durations (often referred to as stagnant flooding), triggering substantial yield losses and lastly, water logging in directly seeded rice, creating anaerobic conditions that affect germination. Submergence is likely to increase considerably in the future given the increase in sea water level as well as increases in the frequency and intensity of flooding caused by extreme weather events (Septiningsih et al., 2009; IPCC, 2014).

Drought stress

Drought stress is the largest constraint to rice production in rain-fed systems. India has been under constant pressure of drought events. Panday et al. (2007) documented the 2002 drought event that affected 55% of India’s rice area and 300 million people. Thailand is often affected by drought which generally results in production losses during the years of complete crop failure, with dramatic socioeconomic consequences on human populations leading to substantial loss in production.

Salinity

Salinity limits the growth of rice. However, certain rice genotypes can withstand a moderate salinity environment. Salt stress response in rice varies with the developmental stage. Furthermore, rice can be relatively more tolerant during germination, active tillering and toward maturity but sensitive during the early vegetative and reproductive stages (Asch & Wopereis, 2001). IPCC 2014 considers the increasing threat of salinity on rice, which is linked to the consequences of climate change in the form of sea level rise and coastal flooding, in the coming 50–100 years.

Composite risks and stresses

Abiotic stresses, such as heat, drought, submergence and salinity, are the major factors responsible for significant annual rice yield losses. However, these often occur in combination in the fields, causing incremental crop losses.

4. Global Overview of Rice Production

The future of rice production should be a global concern because rice remains the most important staple food for Asia and continues to be an important crop for the African continent in recent years. Asia remains the center of global rice production where about 66% is grown by Southeast Asian and East Asian farmers. In South Asia, India has emerged as a global player in rice. Rice is still an important foundation of the Asian food economy that produces most of the world’s total rice. Besides driving the economy, rice has also been a source of income and livelihood security of the region. Despite currently enjoying the status of being a net producer and exporter of rice, top rice producing regions such as India, Vietnam and Thailand face pressures from the steady growth of the middle class, urbanisation, changing dietary preferences and greater economic integration (Teng et al., 2015).

As of 2012, at least 37.6 million out of 482.3 million tons of produced rice is being traded internationally. About 90% of the world's rice is produced in Asia (GRISP 2013). More than 90% of the produced rice is directly consumed within the production area. Over the last 50 years, rice has been one of the least traded commodities (as compared to corn, wheat and others) as it ranged from about 5% in the 1960s to slightly above 7% in recent years. This small percentage of internationally traded rice is often called the 'thin market' phenomenon (Timmer, 2010) and is vulnerable to any disturbances that may arise from extreme climate events or from any speculative behavior from top rice players or a combination of both. As a result, some governments such Indonesia and to some degree India, often lack trust in the international rice market as a means of safeguarding their rice security (Dawe, 2008).

Top rice exporters evolve over time, reflecting the dynamic production and demand for rice. China, Thailand and United States were among the world's top exporters during the 1960s – 1980s. After the mid-1990s, Vietnam and India emerged as global players while China lost its global market share (Figure 3). Vietnam recently has 15 – 20% share in world rice exports while India maintains an average 10 – 15% share. The United States still shares about 10% of the total world rice exports. Thailand maintains its share above 25% since 1980s.

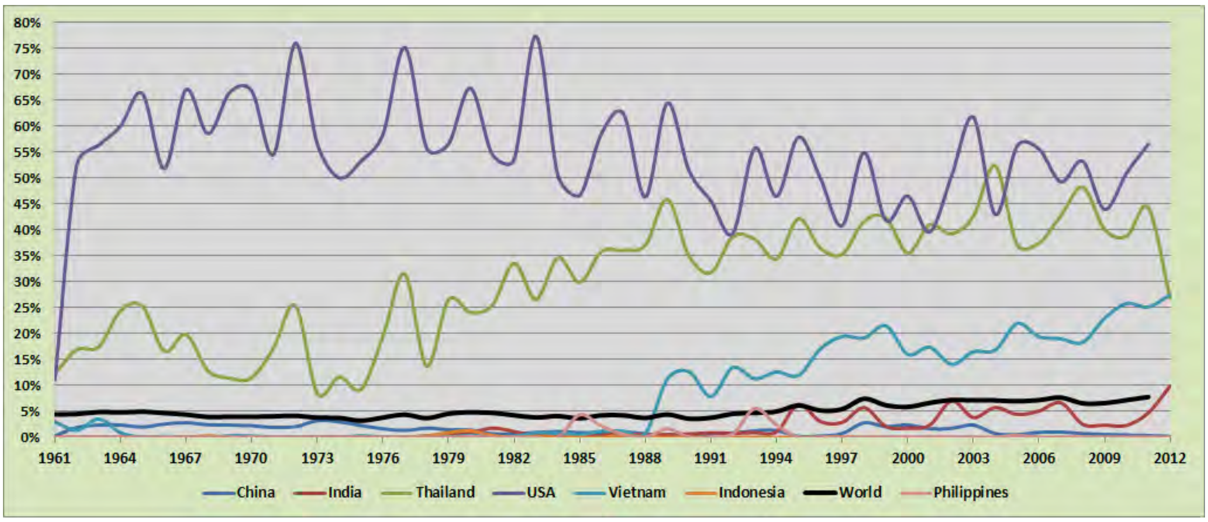

Figure 3. Selected regions based on rice exports-production ratio
Source: Authors based on FAO Database 2015.

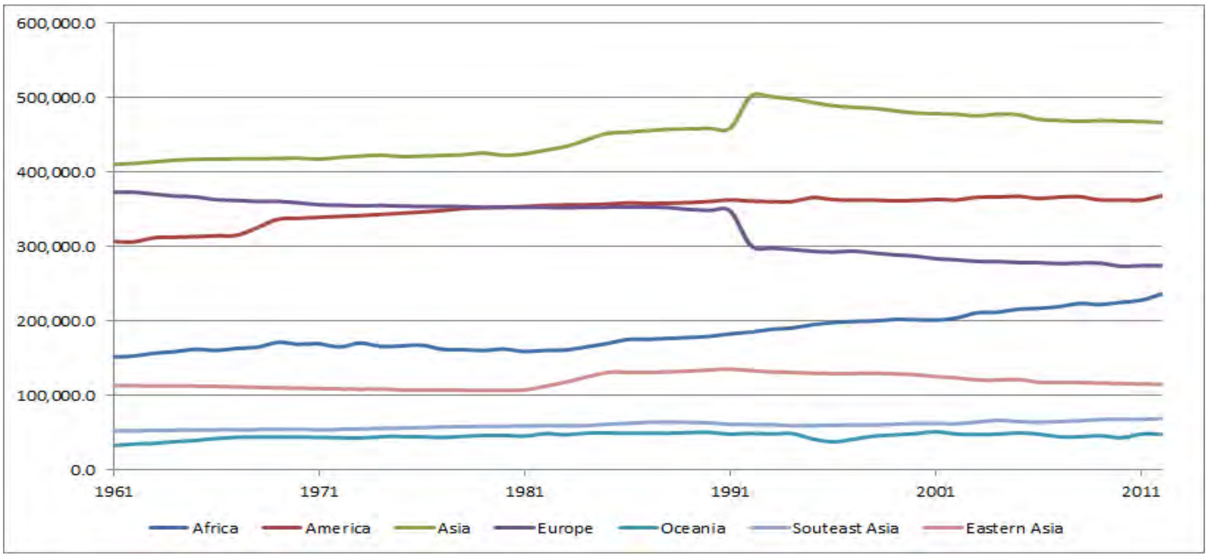

Figure 4. Trend in rice land area in top producer ('000 ha)
Source: Authors' based on FAO Database – average year on year by decade

Growth in rice production depends on rice yields and expansion in arable land allocated to rice. These variables, in combination with increase in cropping intensities (i.e. by increasing the number of planting seasons), often lead to an expansion in the actual harvested area as often reported by key global data sources, namely Food and Agricultural Organisation (FAO) and United States of Department of Agriculture.

Unfortunately, there is a declining trend in land allocation for rice. Today, everywhere in the world but Africa, a declining trend in rice land has been observed. While the world has nearly doubled its rice yield since the 1960s, world rice land is in a declining trend notably since the 1990s. In general, Asia has experienced a consistent decline in rice land. China and India are the largest contributors to the annual decline with at least 0.1% of land since the end of the second millennium. The United States has also experienced a decline of 0.6% compared to 1999 and 2013. In general, the decline of rice land is a reflection of the global decline of arable land.

5. Overview of Rice Yield in Asia Since 1900

Bossino and van Der Eng (2010, p.1) argue that "current discussions of climate change are overly focused on the science underpinning environmental impact, with little attention to socioeconomic consequences. The economics of environmental change in particular is insufficiently informed by the lessons that past experiences can yield." In fact, agriculture has responded dynamically to variation and change in climate system. Therefore, looking back to the past history of rice yield in Asia may provide insights for the future.

Worldwide, farmers and governments have made great strides in improving rice yield from 2.38 t/ha in 1970 to 4.49 t/ha in 2013 (on average, 2.1% annually). The highest yield growth occurred in the Americas, mainly North America, where the nation enjoyed a 3.7% increase annually, followed by Asia's 2.1% annual increase. There is a variation in rice yield improvement in Asia where Southeast Asia recorded an increase from 2.02 t/ha to 4.19 t/ha per annum (2.5% annually) while South Asia increased its yield from 1.72 t/ha in 1970s to 3/72 t/ha in 2013. The lowest rate occurred in Africa where the farmers have increased rice yield from 1.83 t/ha in 1980 to 2.64 t/ha in 2013 (it equals to 0.9% annually).

In general, all the countries began to escape their millennial stagnation in yield after the 1960s and 1970s (Figure 5). Rice yield in Asia (Indonesia, Thailand and Vietnam) once stayed below 2 t/ha during the first half of the 20th century until the 1960s. Fortunately, in general, rice yield in Southeast Asia and South Asia has been consistently increasing nowadays. This is particularly due to the adoption of new crop technology promoted by the Green Revolution in the 1960s. The first half of the 20th century has been marked by instability of 10Y-o-10Y yield as seen in Figure 6. Thailand was the most volatile in rice yield. India and Indonesia were also highly volatile during 1920-1960. Vietnam continued to poorly perform in rice yield till the end of the 1960s. Great strides by the rice nations were made in general during the 1960s-1980s. Entering the period of 1990s, the decadal yield rate has been slowing down till very recently.

5.1 India Rice Yield Since 1900

India in particular had the lowest rice yield compared to the rest of the Southeast Asian top producers until it gradually surpassed Thailand's rice yield in the mid-1980s. Rice yield in India can be categorised into three distinct periods, namely, pre-1950s, between 1950-1970s and post-1970s (Figure 5). The pre-1950s period has been marked by a long period of stagnation with an average yield below 1 t/ha annually, with some variation.

The Punjab region tended to keep its yield above 1.3 t/ha and eventually declined during the World War II period. Recently, Punjab has still been ranked highest for rice yield in India where it has reached an average yield of almost 4 t/ha annually. Tamil Nadu had also maintained its yield consistently slightly above national average. Tamil Nadu continued to be above national annual average yield from the 1960s – 1980s. However, it recently experienced yield volatility. During the drought period, rice yield in Uttar Pradesh only stood at 0.5 t/ha. Uttar Pradesh just graduated from 0.5 to 1 t/ha in the late 1970s. Today, Uttar Pradesh has been able to reach 2.45 t/ha (Table 1), signalling some opportunity to improve the state's yield potential. In fact, Uttar Pradesh is a very important rice region as it contributes the largest rice land in India (14% or 5.98 million out of 44 million ha in 2013/2014) (See Table 2).

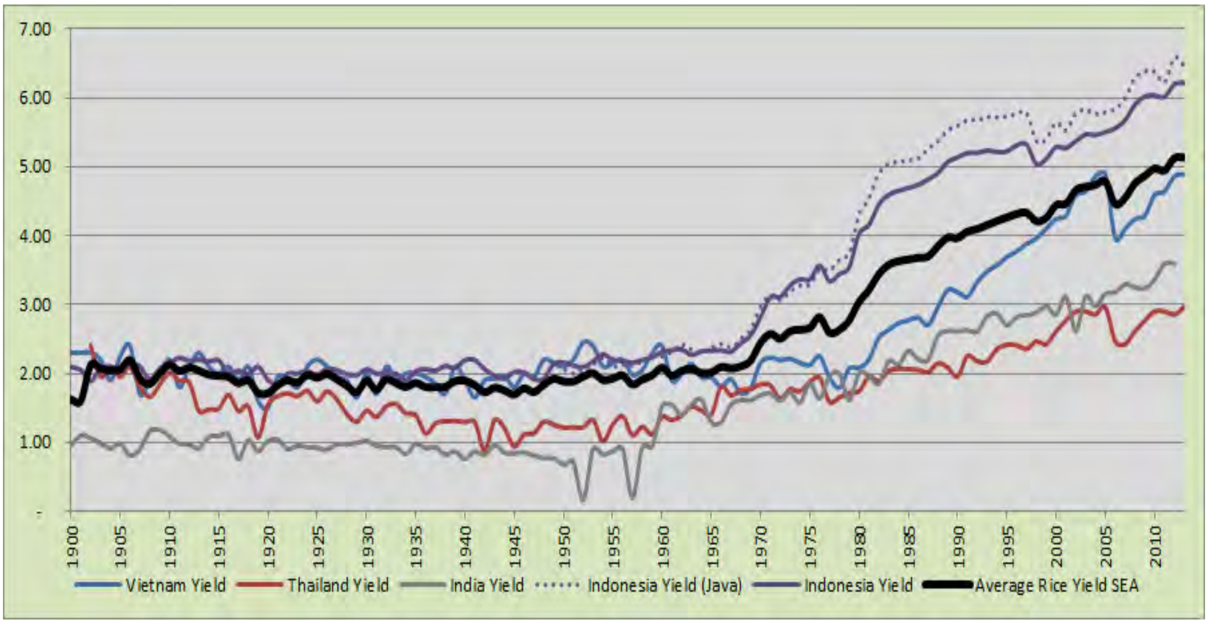

Figure 5. Rice yield in selected rice procedures in Asia since 1900
Source: Authors, 2015.

Note: Data is adapted from historical records. Data from Vietnam is based on both formal reports from FAO (for data since 1960) and the French colonial period collected by Bassino, 2006; Indonesian data is based on the generous contribution from Pierre Van der Eng at the Australian National University (via personal communication) and Lassa, 2012; data from India is based on various publications such as Pathak, 1991, Ali and Bose, 1943; data on Thailand is based on author's compilation of data from Thai's Government Statistical Office since 1912.

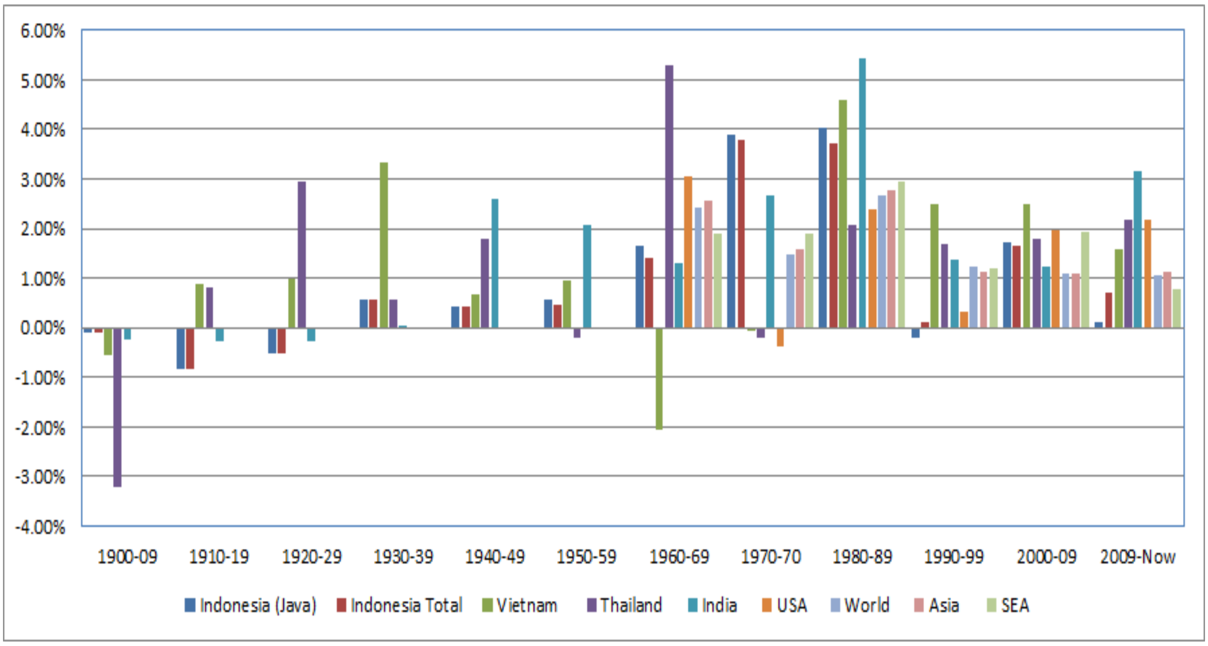

Figure 6. Yield change trend by decades: 1880-2019
Source: Authors, 2015

Data is adapted from historical records. Data from Vietnam is based on both formal reports from FAO (for data since 1960) and the French colonial period collected by Basino, 2006; Indonesian data is based on the generous contribution from Pierre Van der Eng at the Australian National University (via personal communication) and Lassa, 2012; data from India is based on various publications such as Pathak, 1991, Ali and Bose, 1943; data on Thailand is based on author's compilation of data from Thai's Government Statistical Office since 1912.

Droughts have been recognised as one of the problems in ensuring stability of food production in India. The widespread and frequent droughts in the last few years have added more pressure on water for crop production (Shah and Mishra, 2015). In fact, droughts have negative impacts on rural livelihoods in vulnerable areas (Udmale, 2015). However, the situation has improved due to adaptation via shifts in planting dates, use of better crop varieties, increased and efficient use of irrigation, fertilizers, etc. (Birthal et al., 2015)

There is variation of production volatility measured by area and yield volatility. Drought-prone areas such as Uttar Pradesh, Tamil Nadu and West Bengal have often been challenged by heat stress. Table 3 shows that Bihar, Tamil Nadu and Jharkhand are the regions with the most volatile yield, with a standard deviation subsequently at 0.49, 0.42 and 0.30. Andhra Pradesh, Jharkhand, West Bengal and Uttar Pradesh are the areas with top volatility in rice land area (SDev subsequently at 0.47, 0.35, 0.31 and 0.29).

Table 1. Recent trend in yield in India across states

State	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14#
Andhra Pradesh	3.34	3.25	3.06	3.04	3.15	3.17	2.89
Assam	1.43	1.61	1.74	1.84	1.78	2.06	2.10
Bihar	1.24	1.60	1.12	1.10	2.16	2.28	1.77
Chhattisgarh	1.45	1.18	1.12	1.66	1.60	1.75	1.77
Gujarat	1.94	1.74	1.90	1.85	2.14	2.20	2.05
Haryana	3.36	2.73	3.01	2.79	3.04	3.27	3.26
Jharkhand	2.02	2.03	1.55	1.54	2.13	2.24	2.24
Karnataka	2.63	2.51	2.48	2.72	2.79	2.63	2.83
Kerala	2.31	2.52	2.56	2.45	2.73	2.58	2.55
Madhya Pradesh	0.94	0.93	0.87	1.11	1.34	1.47	1.44
Maharashtra	1.90	1.50	1.49	1.78	1.84	1.96	1.89
Orissa	1.69	1.53	1.59	1.62	1.45	1.81	1.82
Punjab	4.02	4.02	4.01	3.83	3.74	4.00	3.95
Tamil Nadu	2.82	2.68	3.07	3.04	3.92	2.71	3.10
Uttar Pradesh	2.06	2.17	2.08	2.12	2.36	2.46	2.45
West Bengal	2.57	2.53	2.55	2.64	2.69	2.76	2.79
All India	2.20	2.18	2.13	2.24	2.39	2.46	2.42

Source: Government Statistical Office of India, 2015.

Table 2. Recent trend in rice land allocation in India

STATES	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14#
Andhra Pradesh	4.0	4.4	3.4	4.8	4.1	3.63	4.51
Assam	2.3	2.5	2.5	2.6	2.5	2.49	2.27
Bihar	3.6	3.5	3.2	2.8	3.3	3.3	3.11
Chhattisgarh	3.8	3.7	3.7	3.7	3.8	3.78	3.8
Gujarat	0.8	0.7	0.7	0.8	0.8	0.7	0.79
Haryana	1.1	1.2	1.2	1.2	1.2	1.22	1.23
Jharkhand	1.7	1.7	1.0	0.7	1.5	1.41	1.22
Karnataka	1.4	1.5	1.5	1.5	1.4	1.28	1.33
Kerala	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Madhya Pradesh	1.6	1.7	1.4	1.6	1.7	1.88	1.93
Maharashtra	1.6	1.5	1.5	1.5	1.5	1.56	1.56
Odisha	4.5	4.5	4.4	4.2	4.4	4.02	4.18
Punjab	2.6	2.7	2.8	2.8	2.8	2.85	2.85
Tamil Nadu	1.8	1.9	1.8	1.9	1.9	1.49	1.79
Uttar Pradesh	5.7	6.0	5.2	5.7	5.9	5.86	5.98
West Bengal	5.7	5.9	5.6	4.9	5.4	5.44	5.5
India	43.9	45.5	41.9	42.9	44.0	42.75	43.95

Source: Government Statistical Office of India, 2015.

Table 3. Volatility in rice yield and rice land area

States	Volatility in Yield	Volatility in Area
Andhra Pradesh	0.15*	0.47*
Assam	0.24*	0.11
Bihar	0.49*	0.25*
Chhattisgarh	0.26	0.05
Gujarat	0.16	0.06
Haryana	0.25	0.06
Jharkhand	0.30*	0.35*
Karnataka	0.13	0.10
Kerala	0.13	0.02
Madhya Pradesh	0.26*	0.17
Maharashtra	0.19	0.04
Orissa	0.14	0.16
Punjab	0.11	0.09
Tamil Nadu	0.42*	0.15*
Uttar Pradesh	0.17*	0.29*
West Bengal	0.10	0.31*
All India	0.13	1.17

Source: Government Statistical Office of India, 2015.

5.2 Vietnam Rice Yield Since 1900

There is an increase in research on climate change impacts on rice in the Mekong Delta Region due to the fact that the delta has been the primary source of traded rice in international food markets. In addition to the Mekong River Delta (MRD), Vietnam's production regions include the other five regions, namely Red River Delta (RRD), Northern Midlands and Mountain areas (NMM), North Central area and Central Coastal area (NCCC), Central Highlands and South East.

Based on both formal reports from the French colonial period and also estimated figures of paddy yield, especially in MRD of Vietnam since 1870s – 1970s, yield has been very volatile (Bassino, 2006). Such volatility has been attributed to the occurrence of recurrent hazards such as floods and storms. Winter rice yields in the Central Highlands have recently increased from around 2.2 t/ha to above 3 t/ha while Mekong River Delta's spring rice yields have increased from 5.2 t/ha to 6.8 t/ha in the last few years. This suggests that differences in the natural climate between the regions play important roles in present and future yield projections.

As of 2013, Red River Delta occupies 1.1 million ha of planted paddy areas (14% of the country's total). NCCC constitutes 16% of the total planted paddy area (1.2 million ha). The Mekong River Delta (MRD) is the largest rice production region of Vietnam that constitutes 55% of the total (4.3 out of 7.9 million planted paddy area) (Figure 7). The top five largest rice producing provinces are all in the MRD area namely Kien Giang (0.77 million ha), An Giang (0.64 million ha), Dong Thap (0.54 million ha), Long An (0.52 million ha) and Soc Trang (0.37 million ha).

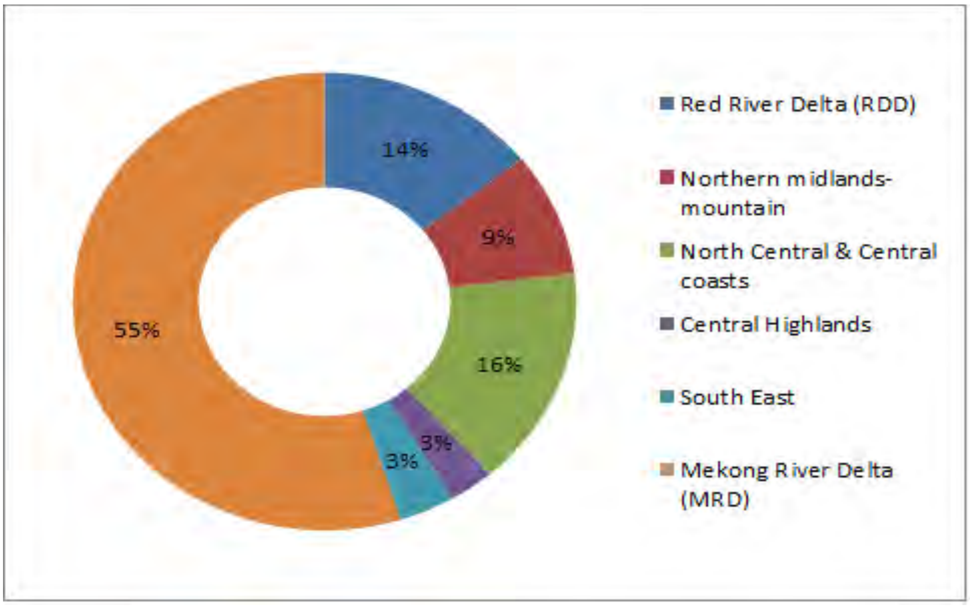

Figure 7. Regional share in rice production in Vietnam
Source: Authors, 2015. Adapted from data from GSO Vietnam 2014.

As elsewhere in Southeast Asia, Vietnam's agriculture is divided into irrigated land where farmers can ensure two planting crops (i.e. Summer-Autumn during April-June and Autumn-Winter during August-November/December) and rain-fed land where farmers may produce during Autumn-Winter or Winter-Spring period. Despite general perception of the annual rice crop planting seasons stated above, the

Government Statistical Office (GSO) of Vietnam often reports its rice production into three seasons, namely spring, autumn and winter seasons. This means spring rice is harvested in spring and planted during winter time.

Cropping intensity on existing rice land could be increased, largely through investment in flood control and drainage on the southern coast, where dry-season salinity is a problem. The potential for yield increases is more difficult to estimate. Average yields have grown 2.8% since 1985, at more than 4 t/ha in 2001. Historical rates of yield growth, however, may not be sustainable. Pingali et al. (1998) argue that further increases in Vietnamese yields may be difficult to achieve. For example, fertilizer use expanded rapidly over the 1980s in response to market liberalisation, but application rates in the two main deltas are now similar to those in other irrigated regions of Asia. Furthermore, the high yields depend on labour-intensive cultivation methods that farmers may not be willing to continue as wage rates rise.

Low volatility suggests that the rice land is often cultivated with less or without disruption. However, yield is more volatile because the rice system has been exposed to different types of risks. Table 4 shows that nationwide, Vietnamese rice yield and area volatility is relatively high (0.27 and 0.65 subsequently). In regions like Red River Delta, especially Hanoi, the yield volatility has reached 0.93. This suggests that the rice system in the delta has been subject to constant droughts and floods.

Figure 9 shows that in the case of autumn rice yield, there is a greater tendency of volatility as the volatility during 2004 – 2013 (0.18) has been almost double the volatility during 1995 – 2003 (0.38).

The Mekong River Delta, where 55% of rice is produced in Vietnam (Figure 9), is also volatile. For instance, Long An and Soc Trang provinces show stability (very low STDEV – Table 4) in its rice land cultivation. However, the MRD delta has been exposed to multiple challenges as exemplified by its high volatility (0.79 and 0.74 subsequently).

As of 2013, the Red River Delta and NCCC occupy 1.1 million ha (14% of national total) and 1.2 million ha (16%) of planted paddy land respectively. The Mekong River Delta (MRD) is the largest rice production region of Vietnam that contributes 55% of the total (4.3 out of 7.9 million ha planted paddy area).

Table 4. Volatility in rice yield and rice land area in Vietnam

	Rice area volatility	Yield volatility
WHOLE COUNTRY	0.27	0.64
Red River Delta (RDD)	0.05	0.54
Hà Nội - Ha Tay (RRD)	0.01	0.93
Northern midlands-mountain	0.02	0.67
North Central & Central coasts	0.02	0.72
Central Highlands	0.02	0.83
South East	0.04	0.74
Mekong River Delta (MRD)	0.26	0.65
Long An (MRD)	0.05	0.74
Đồng Tháp (MRD)	0.04	0.64
An Giang (MRD)	0.07	0.69
Kiên Giang (MRD)	0.10	0.77
Cần Thơ (MRD)	0.11	0.57
Sóc Trăng (MRD)	0.02	0.79

Source: Authors, 2015
Data calculated based on last 15 years of yield and rice land area, GSO Vietnam.

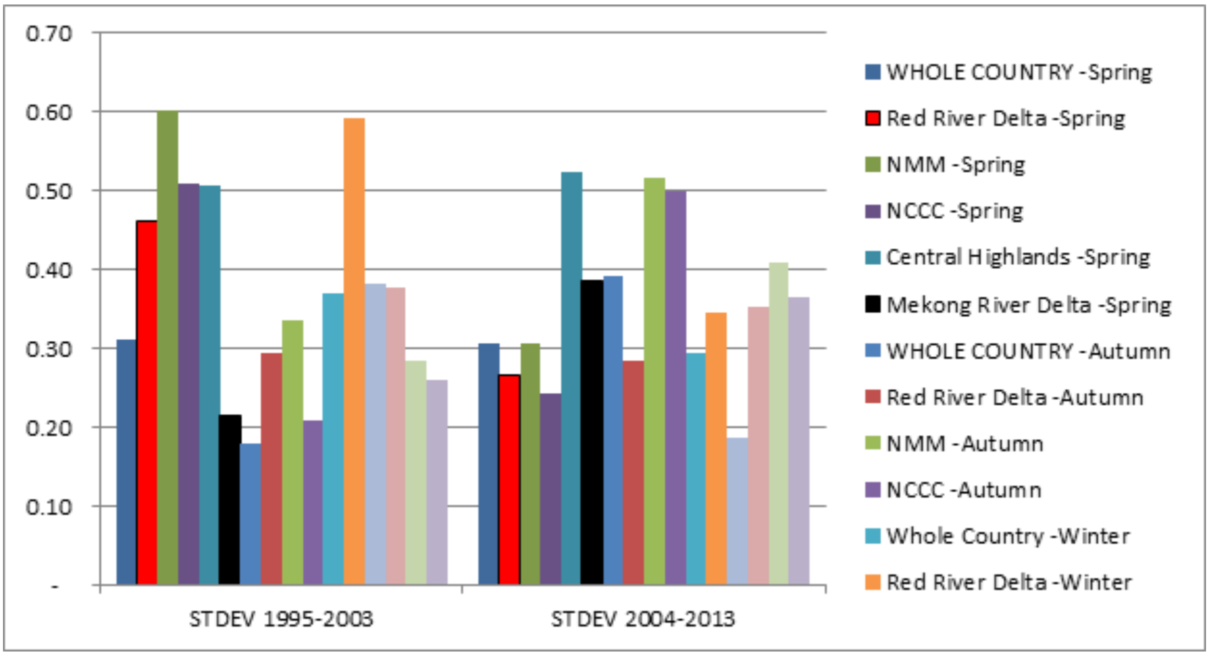

Figure 8. Volatility in rice yield in Vietnam
Source: Authors, 2015. Adapted from data from GSO Vietnam 2014

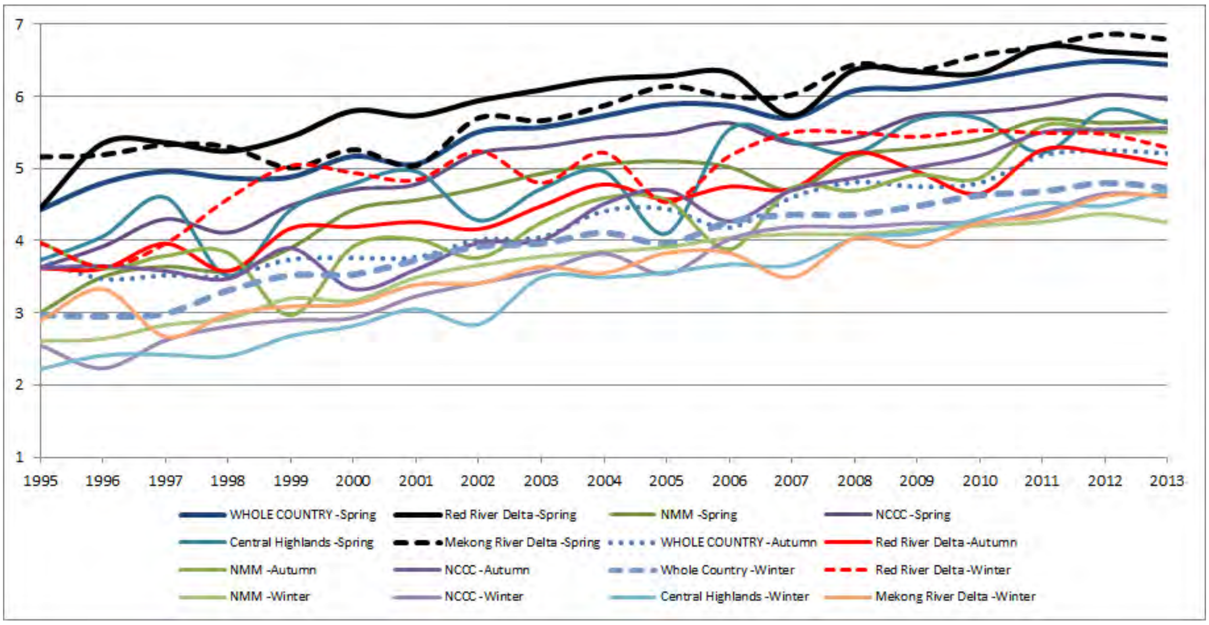

Figure 9. Recent rice yield by regions in Vietnam
Source: Authors, 2015. Adapted from data from GSO Vietnam 2014

5.3 Thailand's Rice Yield Since 1900

Statistics in Thailand recognize two rice systems, namely, Major Rice and Second Rice. Major Rice refers to the rice grown between May and October. Second Rice refers to rice grown between November and April of the following year. Rice production in Thailand is concentrated in the three main regions namely Northeastern, Northern and Central Thailand. The total agricultural area in the Northeastern region (as of 2012) was 42.6 million ha, of which 39.6 million ha is cultivated during the main season and 3 million ha during the secondary season. The second largest concentration of rice farming is in Northern Thailand (22.7 million ha) and the third largest production area is in Central Thailand where 6.3 million ha are cultivated for rice.

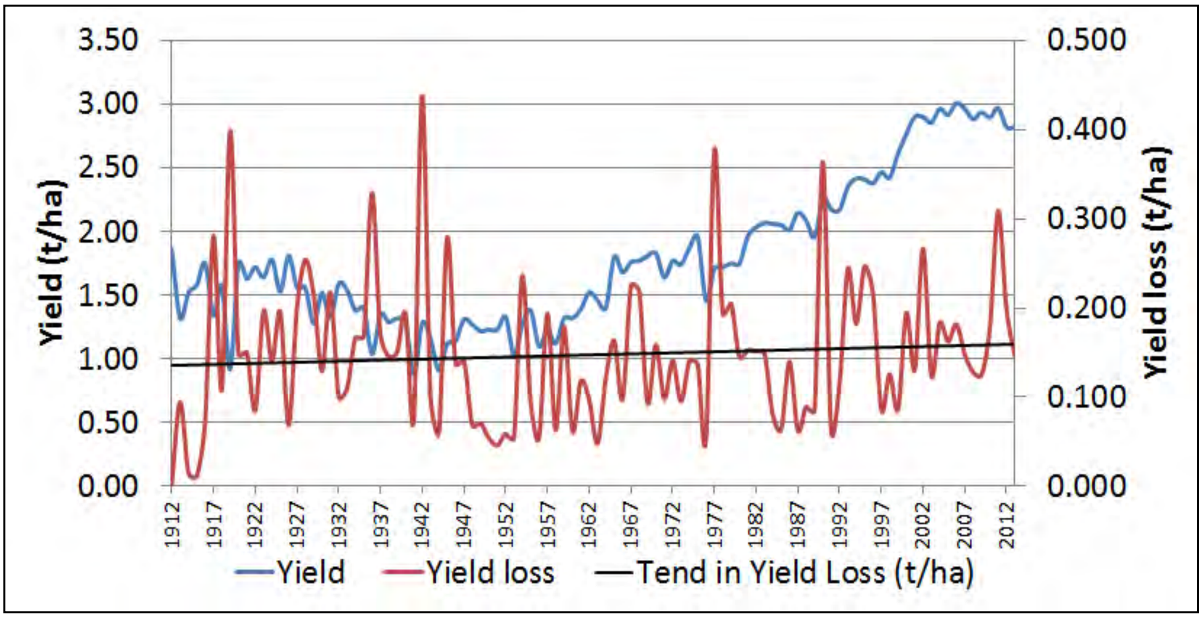

Figure 10. Thailand's rice yields 1912-2012
Source: Authors, 2015 and Lassa et. al., 2016

Studies on climate impacts on rice in the temperate regions of Thailand often show mixed outcomes as a result of climatic change. Matthews et al. (1997) argue that rain-fed rice yield may range from -12% to +10% in Ubon Ratchathani province. In Roi-et province, rice yields could drop by 57% but increase by 25% in Surin.

One of the expected effects of temperature rise is the shift in the geographical zones for specific rice diseases and insects. In the case of the devastating rice blast disease, work by Luo et al. (1998) has shown that Northern Thailand and certain central areas will become more prone to rice blast disease.

One hundred years of yield data in Thailand (Figure 10) suggests that national annual yield loss as a direct result of damages and losses from climate-related events such as floods, drought and pest attacks is increasing. This means that despite consistent increase in technology, technology has yet to keep up with climate-related losses or is not geared towards responding to such losses. In fact, the yield losses above are calculated in a modest way as it is based on the differences between the total area for planting and harvesting.

6. Climate Change Projection in India, Thailand and Vietnam

6.1 Climate Change Projection in India

IPCC Assessment Report 5 (Working Group I) has provided key conclusions on macro climate trend for South Asia, including Indian regions (Christensen et. al., 2013). There is already evidence of an increase in temperature and heat extremes across most of South Asia over the past century. Documented numbers of warm days show an increasing trend. On the other hand, the number of cold days has been decreasing. This warming trend will continue in the future at high confidence level (Ibid.).[5]

India is likely to experience increases in the range 1.7 to 2°C by the 2030s and 3.3 to 4.8°C by the 2080s relative to preindustrial times while all-India rainfall under RCP 6 is projected to increase from 4 to 5% by the 2030s and from 6 to 14% towards the end of the century (the 2080s) compared to the 1961–1990 baseline (Chaturvedi et al., 2012).

[5] See IPCC 2014 WG II AR5 Chapter 24 and IPCC WG I AR5 Chapter 14. The analysis is based on CMIP5 models (CMIPS is Coupled Model Intercomparison Project) – See Taylor et al., 2012.

By 2030, all over India, the mean temperature is projected to increase by at least 0.5°C in both summer and winter. In Northern India and Northwest India, the temperature is likely to increase by 1°C during winter. Based on the projection under RCP 6.0 (Figure 12), in all regions in India, the temperature is likely to experience an increase of 1 to 1.5°C by 2050 but in northern India, including rice production centers such as Punjab and Uttar Pradesh, the mean temperature is likely to increase by 2°C. By 2080, hotter summers and winters are likely to be seen in northern parts of India such as Punjab and Uttar Pradesh, with temperatures increasing up to 3°C, while in the rest of India's rice production regions, the temperature is likely to increase by at least 2°C (CMIP5 models, Figure 12).

High variation in rainfall, including extreme events, has been observed in different parts and seasons of India (Figure 17). It is likely that by 2030, during the June-August period, southern India, with the exception of the southeast areas (part of Tamil Nadu and Andhra Pradesh), will experience wetter months between 0.1 to 0.2 mm/day (equivalent to 3 to 6 mm/month). The trend will continue in the whole of South and Southeast as well as Central India and Northeast India. The models also show that by 2080, India is likely to experience wetter summers. It is predicted that some parts of Southeast and Southwest India will experience monthly excess in rainfall between 6 to 60 mm/month from the baseline during summer. During the winter period, it is likely that by 2030, most parts of Central and Southwest India will experience drier winters. The models also suggest that by 2050, the northern parts (especially the Indo-Gangetic Plains from Punjab to Northeastern India) are likely to be drier by 6 to 15 mm/month.

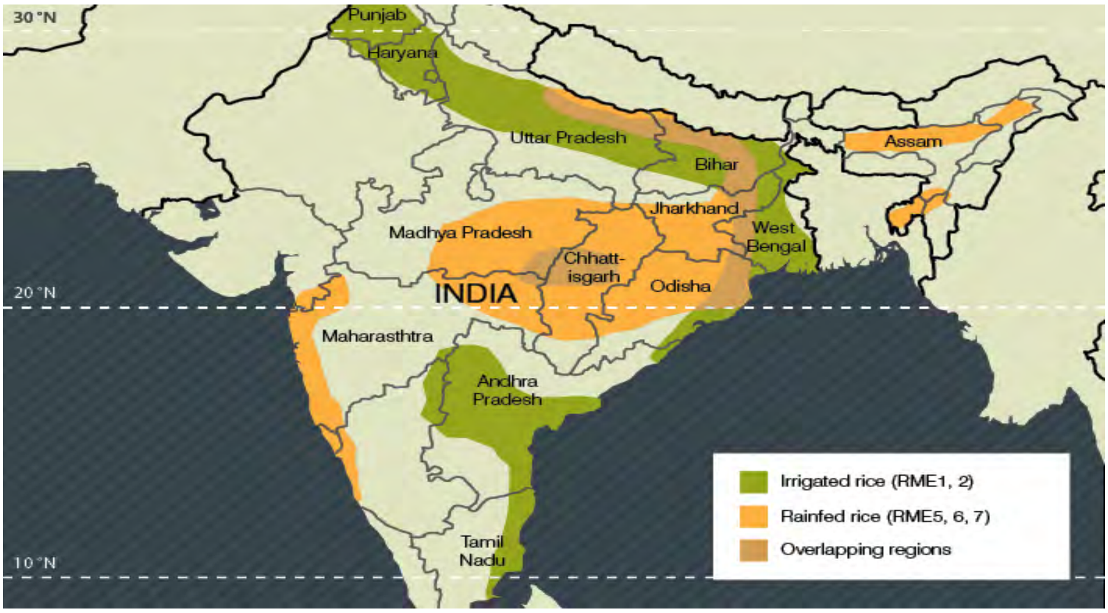

Figure 11. Map of India's irrigated rice
Source: ACIAR [http://aciar.gov.au/files/mn-158/s4_4-gangetic-plain-india.html]

By 2030, it is projected that the Indo-Gangetic Plains will experience hotter summers and winters with temperatures rising between 0.5 to 1°C. By 2050, the Indo-Gangetic Plains continue to be warmer during the daytime by 1 to 1.5°C especially in summer while most of Northwest India is likely to be warmer by up to 1.5°C [Figure 13], based on RCP 6 scenario]. By 2080, heat stress is likely to occur in most parts of India, indicating hotter day temperatures in most parts of India in the summer period where temperatures are likely to rise to 3°C during the daytime (Figure 13). The most northern parts of India (Jammu and Khasmir) are likely to be 4°C hotter during summer in the 2080s. Hotter winters will also likely to be seen in Central India and most part of the Indo-Gangetic Plains from Punjab to Northeast India.

Projection from this research (Figure 15) shows that warmer nights are likely to be experienced in all of India by 2030. In Southern and Eastern India, the temperature is likely to increase by 0.5°C during summer; while in the central and northern parts, the temperature is likely to increase by 1°C. By 2050, most parts of India will be warmer by 1 to 2°C. The temperature is projected to be above 3°C in winter in all regions while during summer, most parts of the North and Indo-Gangetic Plains will be warmer by 3°C.

Increase in night temperatures has been identified as a threat to the biological vulnerability of rice (See Section 3). Since the Indo-Gangetic Plains (See Figure 11) is likely to be hit by hotter day temperatures and night temperatures by 2080, combined with the likelihood of having less rainfall from about -6 to -30 mm/month in summer, India is likely to experience more drought incidents by 2080.

Using worst case scenario, CMIP5 models (See Figure 15), shows that under RCP 8.5, night temperature (TMin) may increase from 24 to 26°C in 2050 and could reach 28°C by 2080 – 2100. Under RCP 6 scenario, night temperatures could increase up to 26°C by 2050 and 26.3°C by 2080 – 2100. CMIP5 models project a clear increase in temperatures over India especially in winter with enhanced warming during the night than the day and over northern India (See Figure 11).

There is high confidence in the projected rise in temperature (Figure 12). Under RCP 8.5, mean temperatures in India could increase from 28 to 32°C by 2080 – 2100. Under RCP 6.0, the temperature could increase up to 30.5°C. Figure 13 shows that on average, day temperatures (Tmax, under RCP 6.0) during summer could increase up to 40°C according to some CIMP5 models with an average Tmax of 32.9°C from baseline (1985 – 2005) up to 34.7°C by 2050 and continue to increase up to 35.9°C.

Overall, North Indian regions are likely to experience higher temperature incidents. Under 0.50 percentile RCP 6, all of India will experience higher temperatures by 2080 – 2100 where North, Northeast and South India's annual mean temperatures could increase by 2 to 3°C. The same scenario suggests that the rest of India is predicted to increase by 1 to 1.5°C.

In Uttar Pradesh, the model suggests that during the whole year, Tmax during daytime is likely to be higher in all models; Conversely, Tmin (night temperature is likely to be lower). The biggest different is under B1 emission scenario (Figure 15).

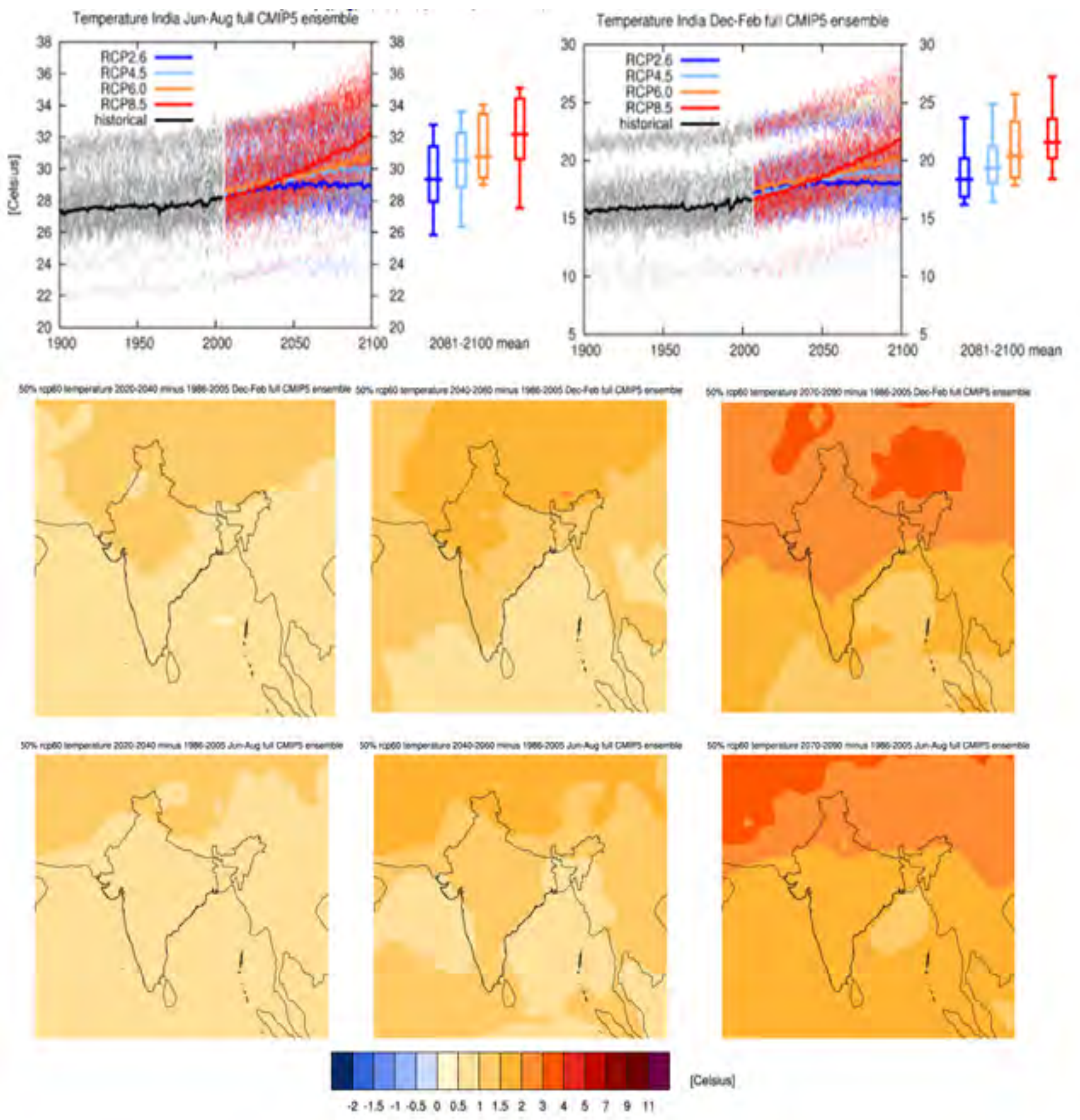

Figure 12. India temperature (T) projections
Source: IPCC 2014

Note. The projections are based on 26 CIMP5 models from IPCC 2014. The figures on top exhibit the temperature variation based on all RCP: 2.6; 4.5; 6.0 and 8.5; figures in the middle show potential spatial variation in mean temperature and day temperature during Dec-Feb in 2030, 2050 and 2080 based on RCP 6 with 50 percentile, indicating degree of uncertainty; figures at the bottom show potential spatial variation in mean temperature (Tmin) during Jun-August with 2030, 2050 and 2080 scenarios based on RCP 6.0.

Measured against baseline, 75% RCP6 (compared with 1990 baseline), the winter temperature in North, Northwest, Northeast and to some degree Central India, could increase by 3 to 4°C by 2080 – 2100. Under 25% RCP 6.0 scenario, winter temperatures in those places could increase by 2 to 3°C. This suggests new potential for growing not only winter rice but also other crops.

The increase in the number of monsoon break days and the decline in the number of monsoon depressions are consistent with the overall decrease in seasonal mean rainfall. Increases in floods and droughts will exacerbate rural poverty in India as a result of negative impacts on the rice crop and resulting increases in food prices and the cost of living. The increase in the number of monsoon break days over India (Dash et al., 2009), and the decline in the number of monsoon depressions (Krishnamurthy and Ajayamohan, 2010) are consistent with the overall decrease in seasonal mean rainfall.

India is also projected to experience a dry spell by 2050. GCM CMIPS5 extremes suggest that under RPC 6 (50 percent), the dry spell is at 4 – 6 days per year and likely to occur in the Southern region, Central and Eastern regions. A stronger dry spell (above 8 to 10 days per year) is likely to be seen in Southeastern regions like Odisha (Orissa) and Northeastern region or Eastern part of the Indo-Gangetic Plains (Figure 11).

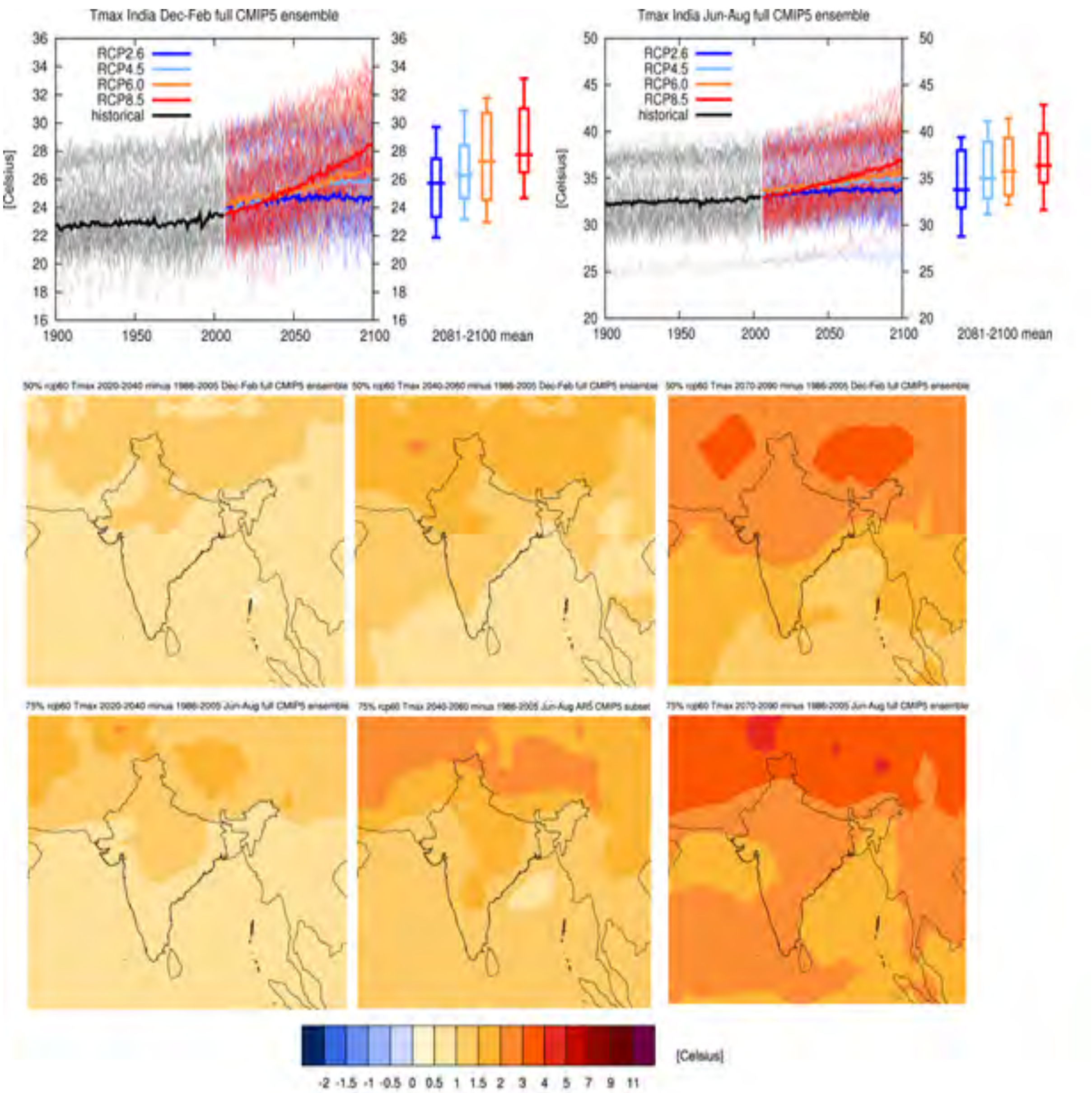

Figure 13. India day temperatures (Tmax) trends and projections
Source: IPCC 2014

Note: The projections are based on full CIMP5 models from IPCC 2014. Figures on top exhibit the day temperature variation during June-August and December-February based on all RCP: 2.6; 4.5; 6.0 and 8.5. Figures in the middle show potential spatial variation in mean temperature and day temperature during Dec-Feb in 2030, 2050 and 2080 based on RCP 6.0 with 50 percentile, indicating degree of uncertainty. Figures at the bottom show potential spatial variation in day temperature (Tmax) during Jun-August period based on RCP 6.0 with 75 percentile.

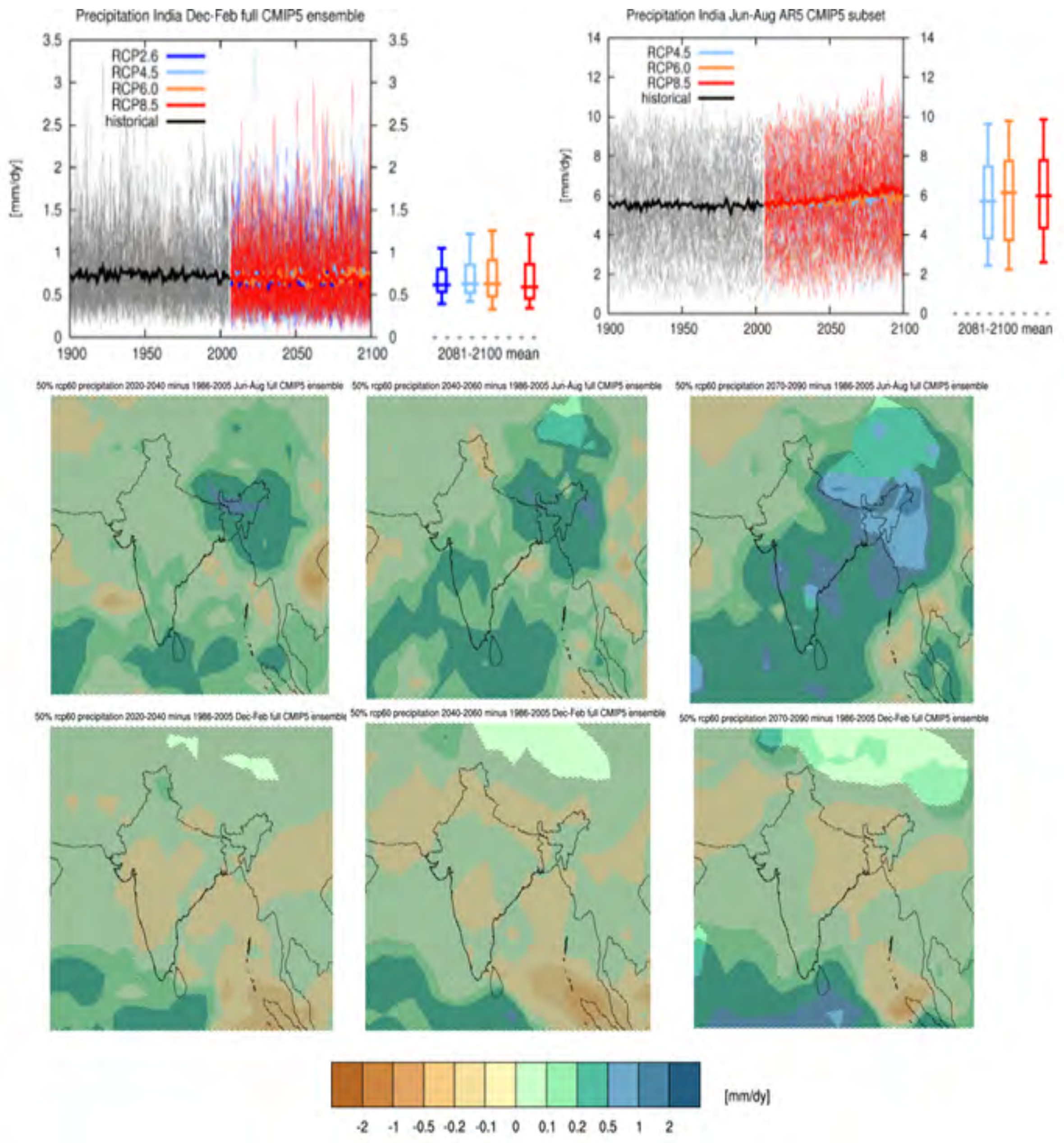

Figure 14. Projected rainfall in India (Jul-Aug and Dec-Feb).

Note: Figures at the top show summer rainfall under different RCPs according to all percentiles; figures in the middle show projected summer rainfall by 2030, 2050 and 2080 with 50 percentile; figures at the bottom show projected summer rainfall with a similar scenario under RCP 6.0 using CMIP5 full set.

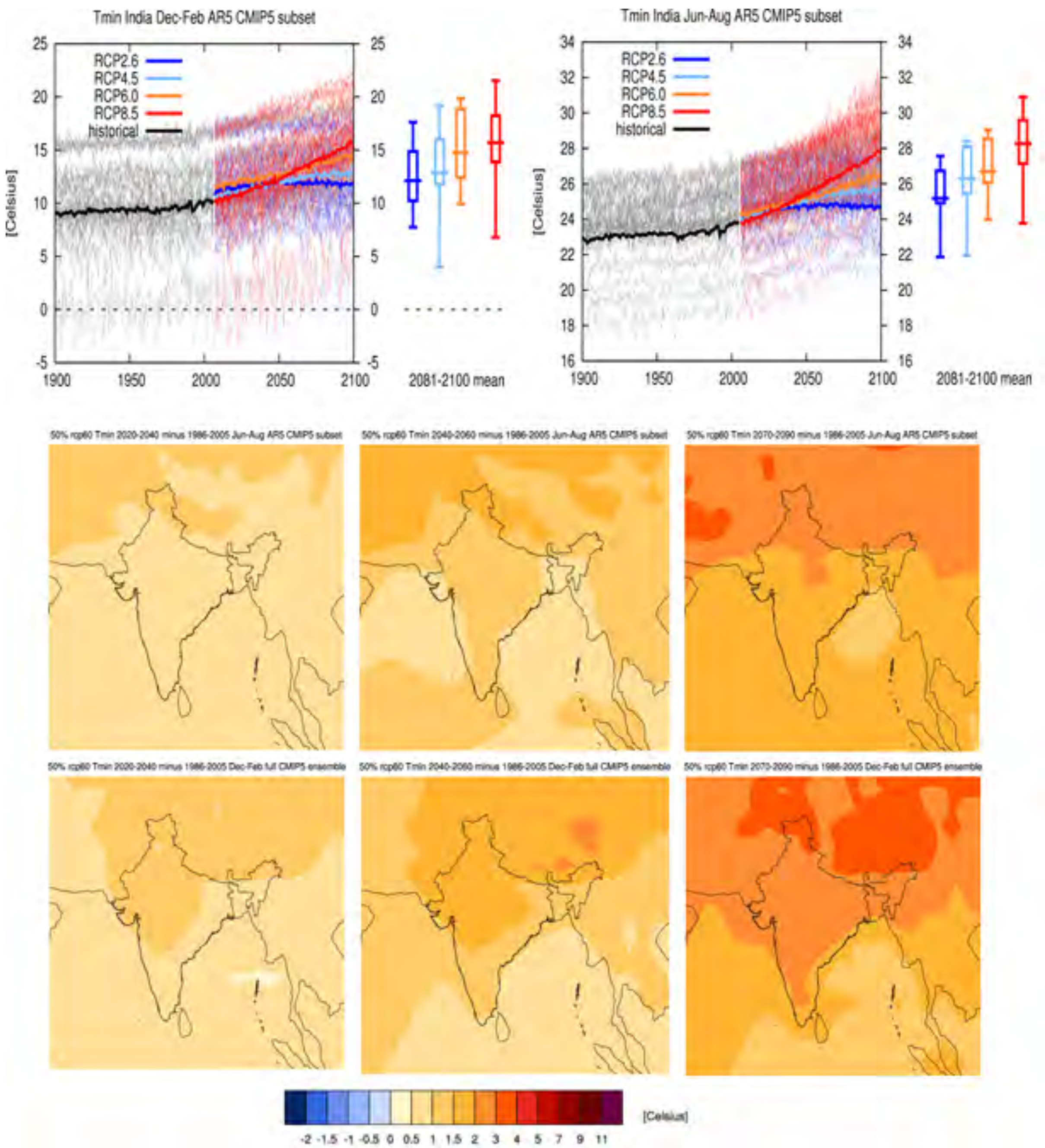

Figure 15. Projected night temperatures (Tmin) in India

GCM Models: CMIP5 subset. Figures on top show winter and summer night temperatures under different RCPs according to all percentiles; figures in the middle show projected summer night temperatures by 2030, 2050 and 2080; figures at the bottom show winter night temperature scenario under RCP 6.0 for 2030, 2050 and 2080 with 50 percentile.

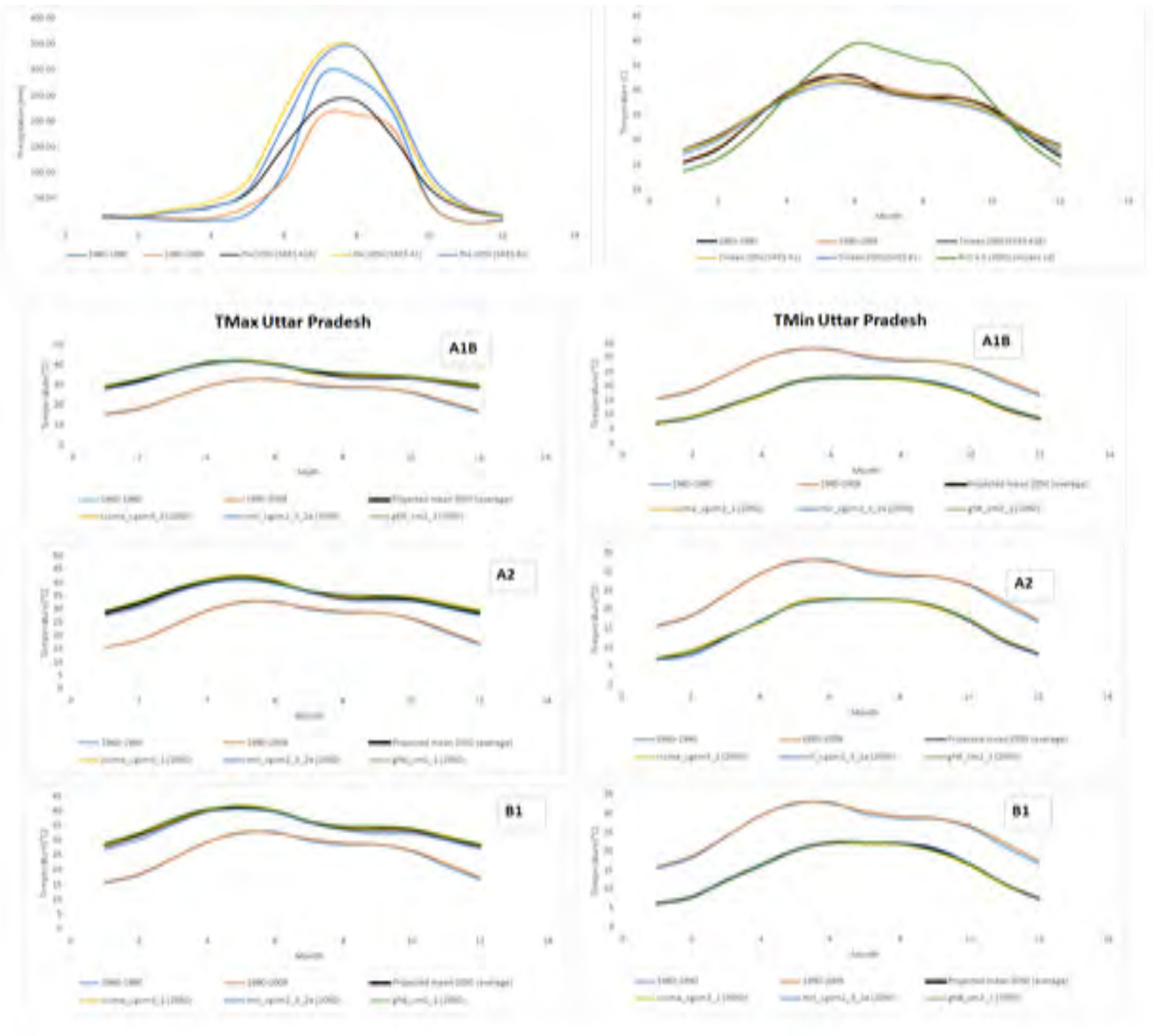

Figure 16. Temperature and rainfall shifts in Tamil Nadu and Uttar Pradesh.

The models (CCCMA, MRI and GFDI and mean) are based on SRES scenarios (A1B, A2 and B1). [Based on 50% rcp60 ALTCDD 2040-2060 with baseline 1986-2005 GCM: CMIP5 ensemble. GCM: CMIPS5 extremes (full set) CDD]

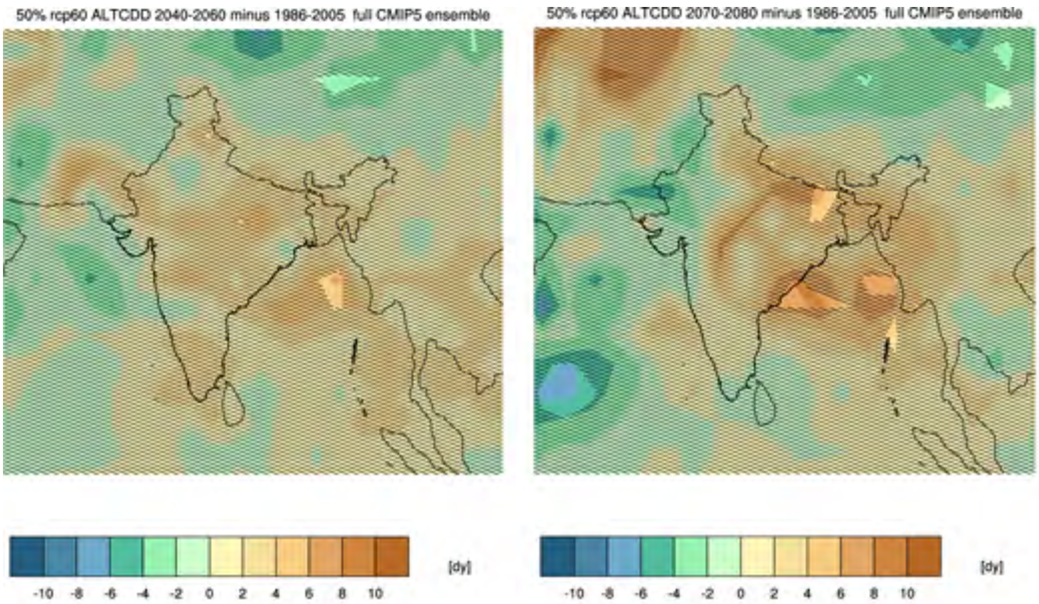

Figure 17. Maximum length of dry spell by 2050 and 2080

6.2 Climate Change Projection in Thailand

Observed data from IPCC shows that in general, annual total wet-day rainfall has increased by 22 mm per decade, while rainfall from extreme rain days has increased by 10 mm per decade in Southeast Asia, but climate variability and trends differ vastly across the region and between seasons (Christensen et al. 2013, p.1273).

Thailand is likely to experience more rainfall during summer in its northern region ranging from an increase of 3 to 15 mm/month but will likely to experience dryer winters (ranging from -3 up to -6 mm/month by 2030. Northeast Thailand (especially in areas such as Nakhon Phanom in Mekong Delta) will experience drier summers but will likely to have wetter winters – this is not only projected for 2030 but also 2050 and 2080. Most parts of the southern region (see Figure 18) will likely to be wetter during summer and drier during winter by 2030 and 2050. Lower parts of Central Thailand and Eastern Thailand will likely to be moderately drier (-3 to -6mm/month) in 2050 and 2080 (Figure 19).

Thailand's annual temperature is projected to increase by 0.37°C by 2030, 0.7°C by 2050 and 1.5°C by 2080. The same GCM model above also suggests that daytime temperature is projected to increase by 0.15°C in 2030, 0.97°C in 2060 and 1.56°C by 2080. Night temperatures are likely to increase by 0.69°C in 2030, 1.14°C in 2050 and 2.2°C in 2080 (Based on GCM-HadGEM2-ES, with RCP 6.0, see Santisirisomboon and Singhruck, 2014). However, there is spatial variation of temperature change. In general, under RCP 6.0, day temperatures in Southern Thailand will be cooler by about <1°C. This could not be beneficial for rice production because at present this region contributes to only 4% of the total national production. Present rice production regions such as Northeastern Thailand is projected to by warmer >1.5°C by 2100.

Thailand's annual temperature in 2030s is projected to remain more or less the same with the baseline years under CIMP5 models, RCP 6.0, with 50 percentile. However, it is projected to increase by 1 to 1.5°C during June-August in 2050, notably in areas such as Northern and Northeastern Thailand and to some degree in the upper central region. Moderate increase (0.5 to 1°C) is about to be seen in the southern region. During December-February period in 2050, most regions are projected to experience such moderate temperature increases. Unfortunately, by 2080, the CIMP5 (50 percentile) suggests that all regions are likely to be warmer by 1.5 to 2.0°C (Figure 20).

Night temperatures are projected to increase by up to 0.5°C by 2030 for Dec-Jan but it is likely to remain the same as the baseline for Jun-Aug period (models, RCP 6.0, with 50 percentile). In 2050, it is predicted that nights will be warmer (+0.5°C) during Dec-Feb period in Southern and lower parts of Central Thailand. It is projected to be warmer (up to +1°C) during Jun-Aug in most parts of Thailand except the regions of mid-Southern Thailand Central. By the 2080s, the CIMP5 (50 percentile) projects that all regions are likely to be warmer by 1.5°C to 2.0°C (Figure 21) with some exceptions in mid-Southern Thailand (up to +1°C only).

Thailand's day temperatures are projected to increase by up to 0.5°C by 2030 for both Dec–Jan and Jun-Aug periods (models, RCP 6.0, with 50 percentile). In 2050, it is predicted that there will be variations in day temperatures between areas where all parts of Northeastern region will be warmer (+0.5°C) during Dec–Feb period. It is projected to be warmer (up to +1°C) during Jun-Aug especially in Central Thailand and Northeastern regions. Similar to the projection above, in 2080s, the CIMP5 (50 percentile) projects that all regions are likely to be warmer by 1.5 to 2.0°C (Figure 22).

Figure 18. Thailand regional map
Source: www.maps-thailand.com

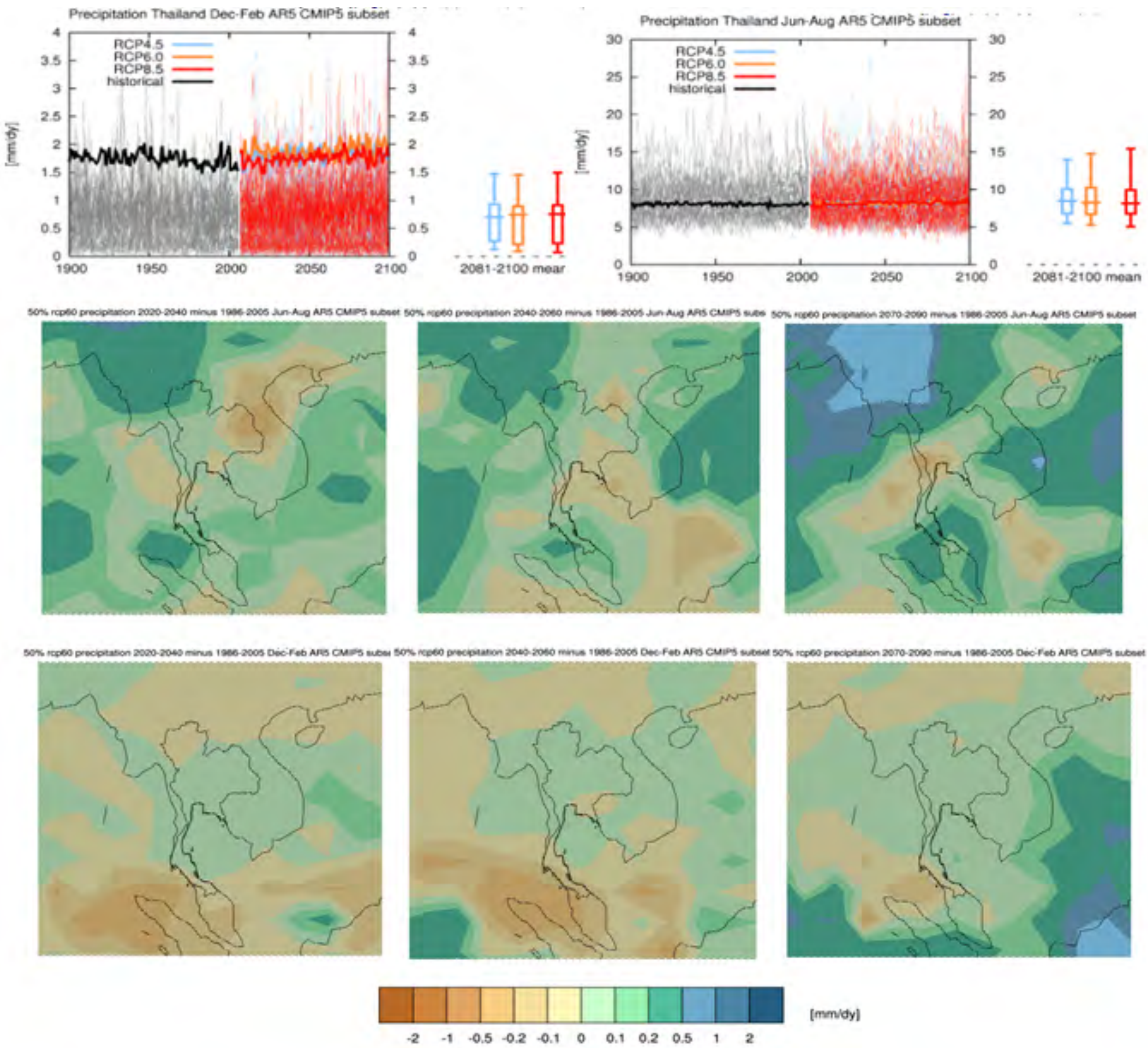

Figure 19. Projected rainfall in Thailand (Jul-Aug and Dec-Feb)

Figures on top show summer rainfall under different RCPs according to all percentiles. Figures in the middle show projected summer rainfall by 2030, 2050 and 2080 with 50 percentile. Figures at the bottom show projected summer rainfall with similar scenario under RCP 6.0 using CMIP5 full set.

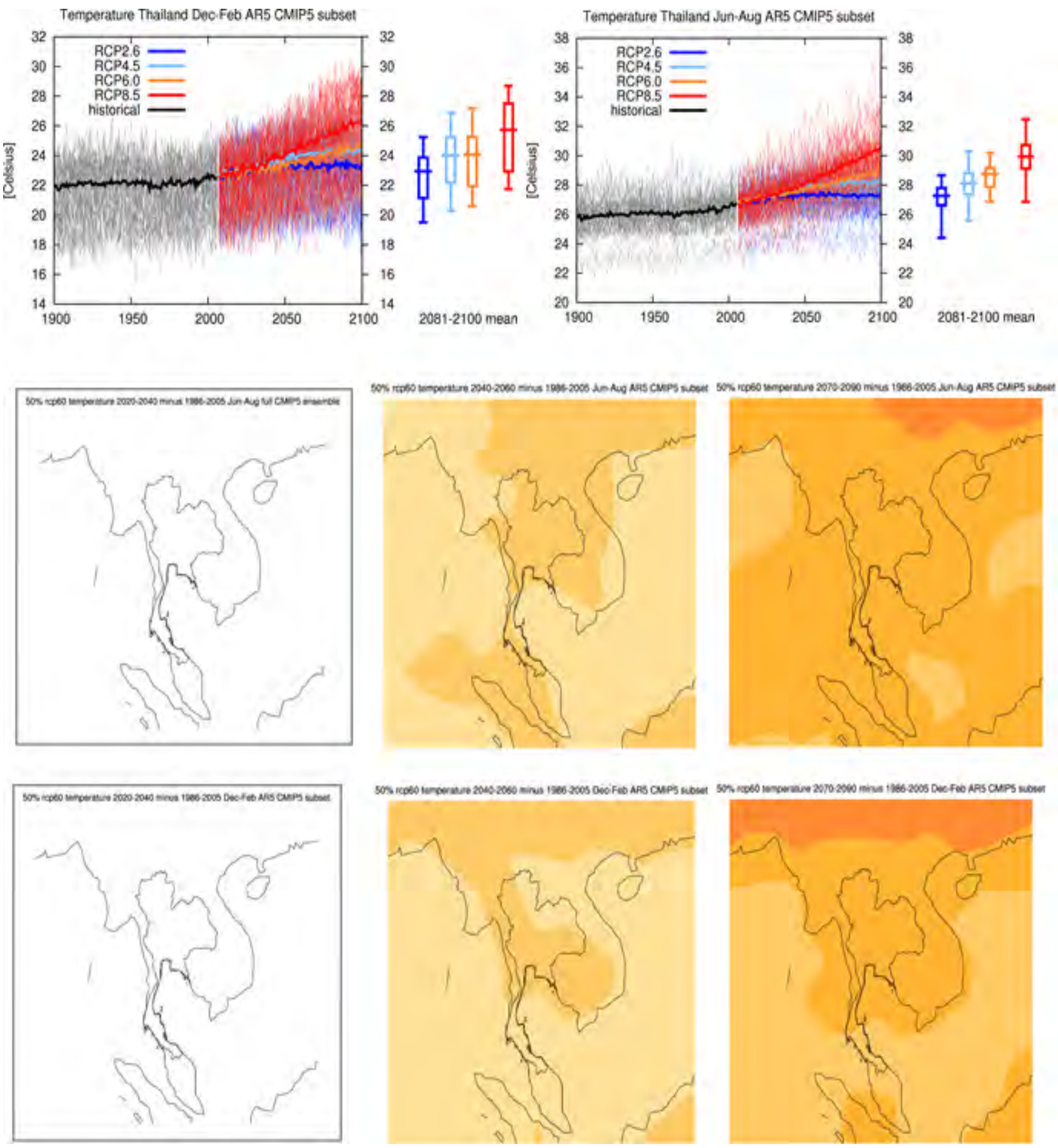

Figure 20. Projected average temperatures in Thailand

GCM Models: CMIP5 subset. Figures on top show winter and summer temperatures under different RCPs according to all percentiles; figures in the middle show projected average summer temperatures by 2030, 2050 and 2080; figures at the bottom show winter temperature scenario under RCP 6.0 for 2030, 2050 and 2080 with 50 percentile.

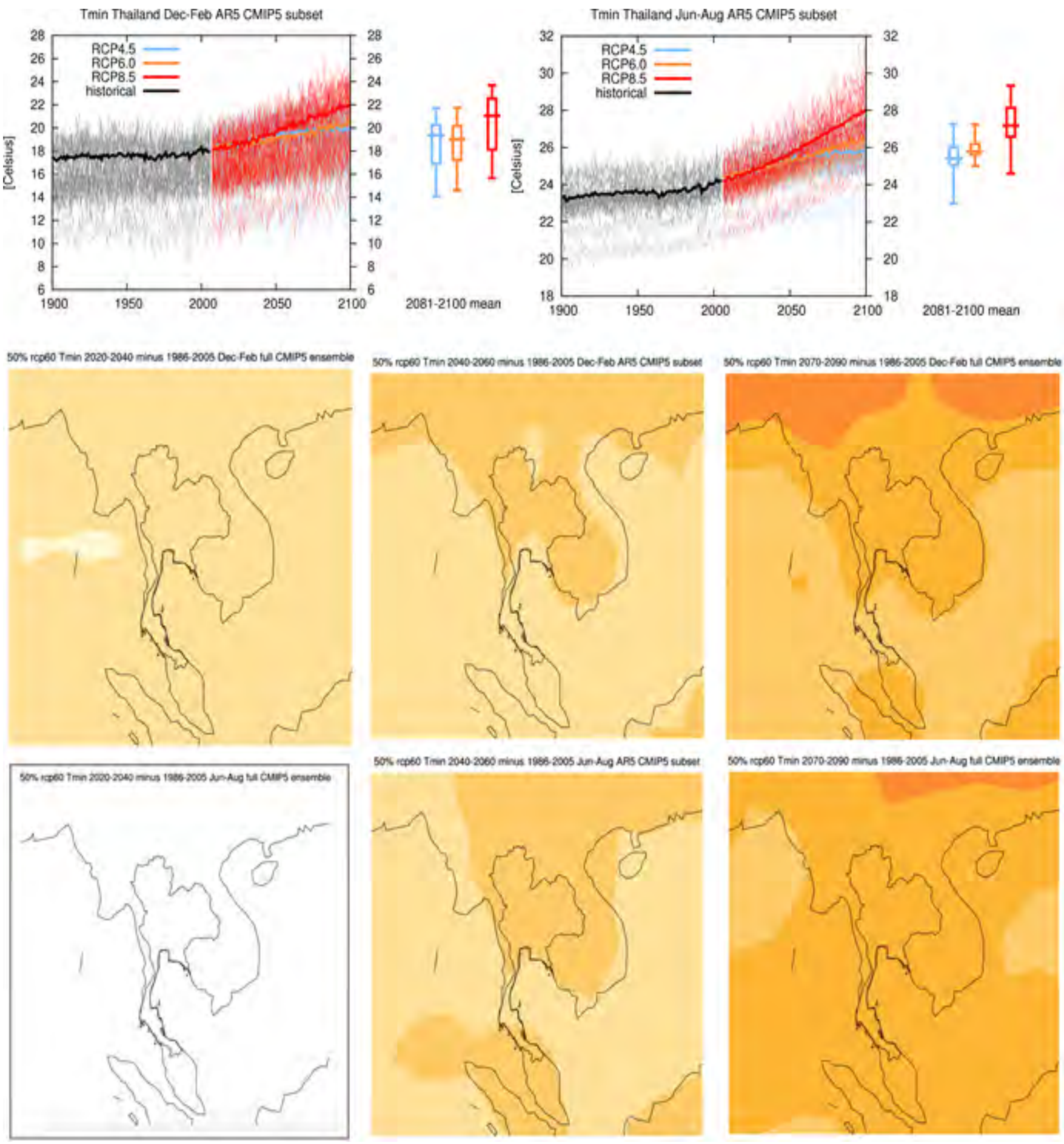

Figure 21. Projected night temperatures in Thailand

GCM Models: CMIP5 subset. Figures on top show winter and summer night temperatures under different RCPs according to all percentiles; figures in the middle show projected summer night temperatures by 2030, 2050 and 2080; figures at the bottom show winter night temperature scenario under RCP 6.0 for 2030, 2050 and 2080 with 50 percentile.

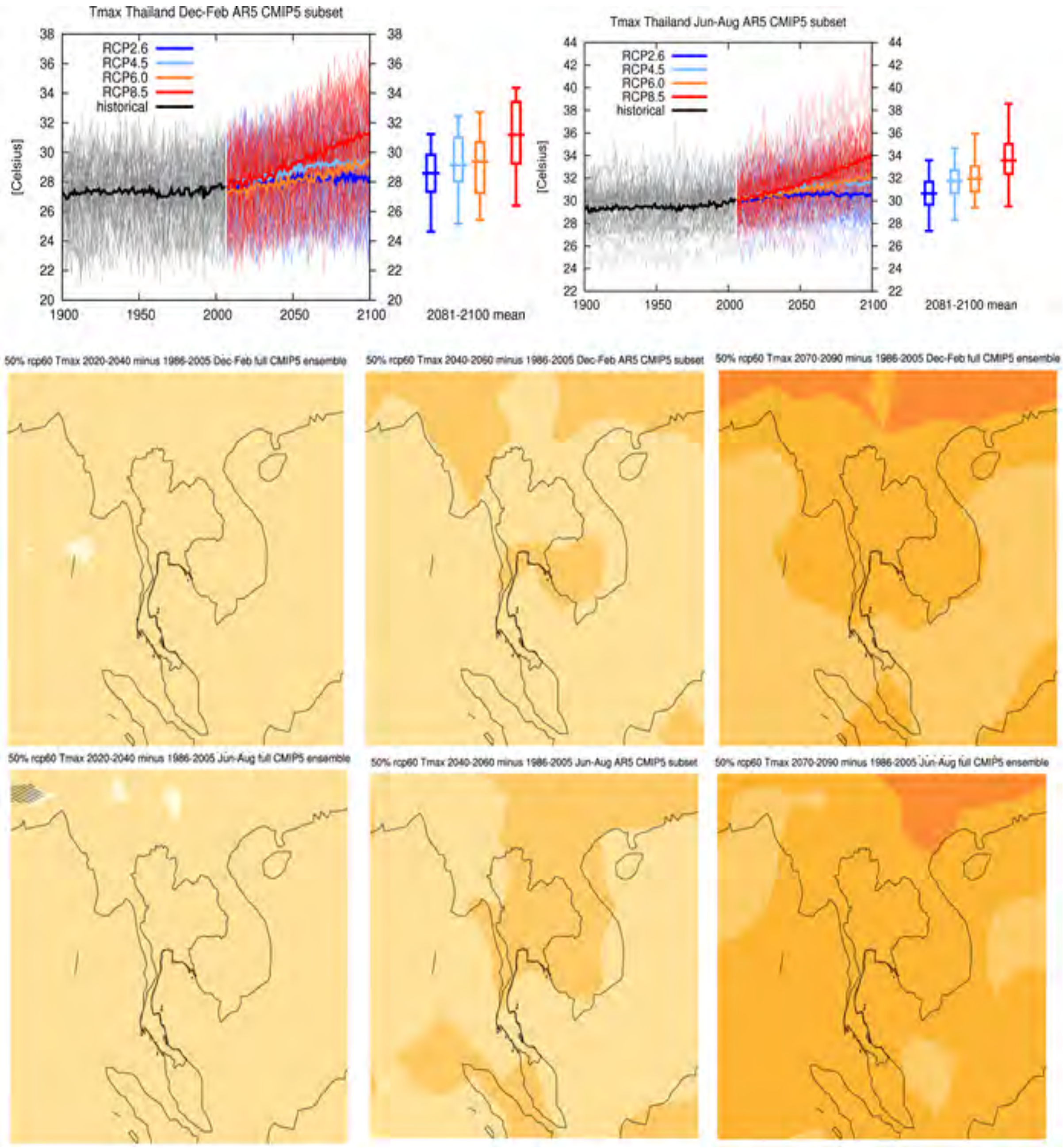

Figure 22. Projected day temperatures in Thailand
Source: IPCC 2014

GCM Models: CMIP5 subset. Figures on top show winter and summer night temperatures under different RCPs according to all percentiles; figures in the middle show projected summer night temperatures by 2030, 2050 and 2080; figures at the bottom show winter night temperature scenario under RCP 6.0 for 2030, 2050 and 2080 with 50 percentile.

Figure 23. Regions of Vietnam
Source: Binh Giang, 2008. Creative Commons.

6.3 Climate Change Projection in Vietnam

Under SRES B2 Scenario, all regions in Vietnam (See Figure 23 above) are likely to experience more rainfall (MoNRE 2009). In Red River Delta, rainfall is likely to increase by 2.3% by 2030, 4.1% by 2050 and 7.3% by 2080, while in the South (including Mekong Delta), rainfall may increase by 0.4% by 2030, 0.8% by 2050 and 1.2% by 2080 (MoNRE 2009).

CIMP5 models under RCP 6.0 predict that during Jun-August, Northwestern and Red River Delta regions of Vietnam are likely to be drier by -3 to -15mm by 2030. However, most part of these regions and North Central Vietnam are going to be wetter by having increased rainfall of 3 to 6mm in 2050. The South Central coast of

Vietnam will be likely to be wetter by 6 to 15mm per month by 2050 and this trend will continue till the 2080s, where some spots in the North Central may experience higher rainfall by 15 to 30mm per month. Mekong River Delta is like to be mildly wet by up to +3mm both in 2030 and 2080 but predicted to be drier by up to +6mm/month by 2050 (Figure 24).

CIMP5 models under RCP 6.0 provide different mixed results. It predicts that for Dec-Feb period, it is likely that most South Central parts will likely to be wetter by 3 to +6mm per month by 2030. This trend will remain similar for the 2080 scenario. However, interestingly, for the 2050 scenario, the rainfall is predicted to be less, ranging from -3mm to -6mm/month in most of Mekong River Delta (Figure 24)

MoNRE (2009) provides an observed temperature change in Vietnam over the last 50 years, showing that there has been an increase in temperature between 0.5°C to 0.7°C. Under SRES B2 (medium emission scenario), temperatures in Vietnam Red River Delta (North Delta) is about to increase by 0.7°C by 2030, 1.2°C by 2050 and 2.0°C by 2080. In the South (Mekong Delta), it is likely that the temperature will increase by up to 0.6°C in 2030, 1.0°C in 2050 and 1.8°C in 2080 (MoNRE 2009). For Jun-August period, temperatures in Mekong region are likely to increase by 0.7°C (Under B2 Scenario); It is projected to be warmer by 1.1°C by 2050 and 1.5°C by 2080. For Dec-Feb, it is predicted that the temperature is likely to increase by 0.5°C by 2030, 0.8°C by 2050 and 1.1°C by 2080.

CIMP5 models provide a general prediction that on average under RCP 4.5, the mean temperature tends to slightly increase from about 1.5°C by 2030 and 1.6°C by 2080. Under RCP 6.0 (mean), this increasing trend will be less pronounced in 2050. However, it will be higher than 2080. However, Figure 26 below shows that under 75 percentile RCP 6 scenario, all parts of Vietnam, except western part of Mekong Delta as well as Southeast Vietnam, are likely to experience an increase of 4 – 5°C in 2080. (Figure 25)

Nighttime temperatures during Dec-Feb by 2030 are predicted to increase by 0.5°C but it remains the same as the baseline during June-August. Nighttime temperatures are going to increase by up to 1°C by 2050 during Jun-Aug. However, in South Central Coast region, nighttime temperature will likely to increase by only 0.5°C by 2050 during Jun-Aug. It is very likely that by 2080, in all scenarios and periods, nighttime temperatures are going to increase by 1.5 to 2°C. (Figure 26)

Daytime temperatures are going to be warmer by up to 0.5°C by 2030 by Jun-Aug and Dec-Feb period for RCP 6.0 with 50 percentile. Northern parts of Mekong River Delta and northwest parts of Vietnam are likely to be warmer by up to 1°C during Dec-Feb by 2050. Northcentral, Northwest and Northeast regions including Red River Delta are likely to be warmer by 1°C by 2050. While it is very likely that all parts of Vietnam are going to be warmer by 1.5 to 2°C in 2080, the Northeastern region and some parts of Red River Delta are likely to be reaching an increase of 3°C in daytime temperature. (Figure 27)

With rising temperatures, the process of rice development accelerates and reduces the duration for growth. There are parts of Asia where current temperatures are already approaching critical levels, causing increased heat stress during the susceptible stages of the rice plant. These regions include Vietnam (June-August).

Sea level rise (SLR) in Vietnamese coasts including Mekong Delta has been reaching +20cm. MoNRE also recorded an annual increase in SLR by 3mm/year. It is predicted that the delta is about to experience up to 1m sea level rise by 2080 (Dasgupta et al., 2009). With 65cm SLR, it is predicted that about 12.8% area (5,133km^2) will be submerged. With 75cm SLR, it is predicted that about 19% of the total area in Mekong Delta will be submerged. With 100cm SLR, the inundation may submerge Vietnamese Mekong Delta by 37.8% (MoNRE, 2009). A more recent assessment suggests that the Mekong Region is predicted to experience SLR of 30 cm by 2050 which may accelerate salinity intrusion (Smajgl et al., 2015).

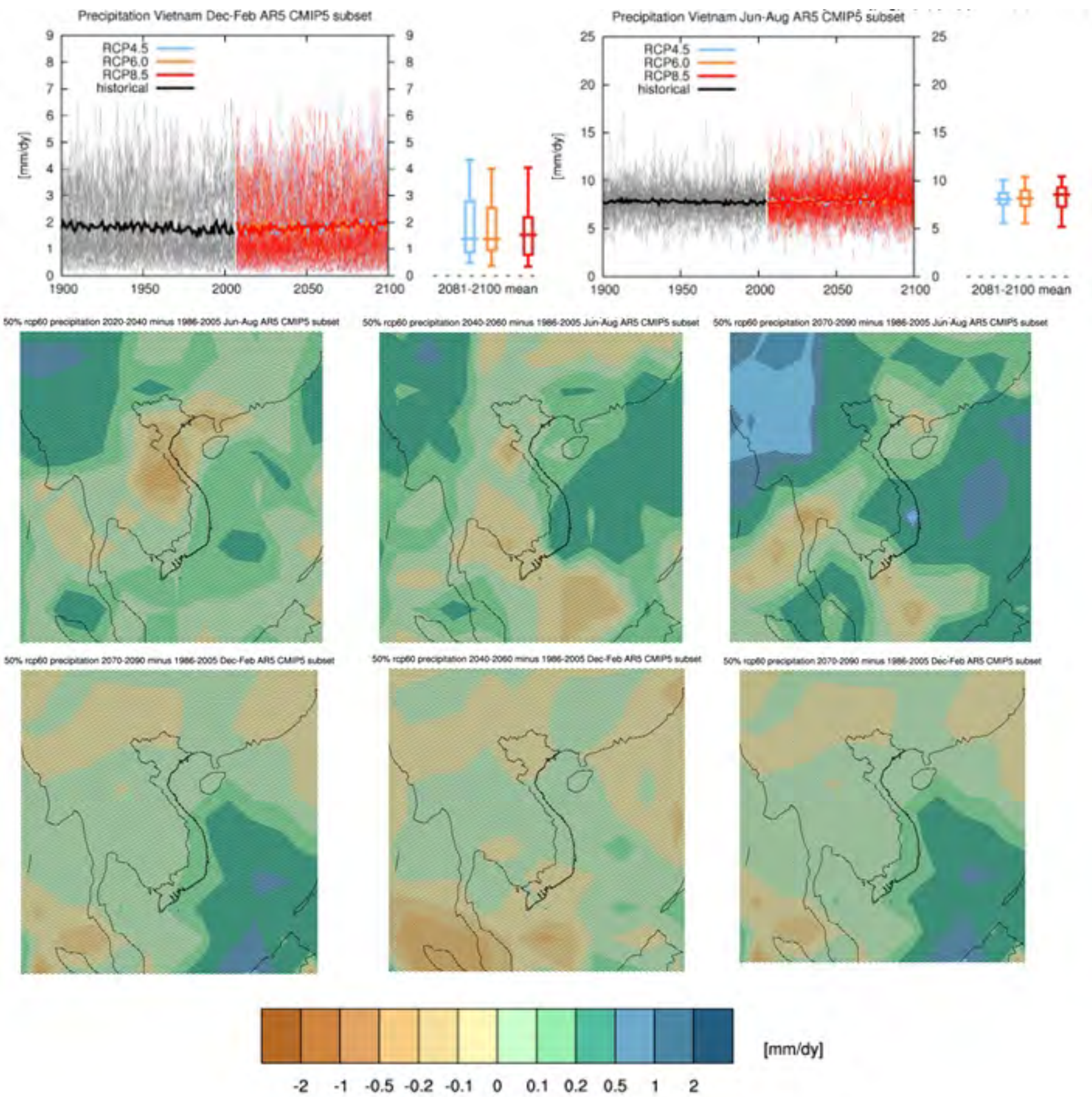

Figure 24. Projected rainfall in Vietnam (Jul-Aug and Dec-Feb).

Figures on top show summer rainfall under different RCPs according to all percentiles; figures in the middle show projected summer rainfall by 2030, 2050 and 2080 with 50 percentile; figures at the bottom show projected summer rainfall with similar scenario under RCP 6.0 using CMIP5 models full set.

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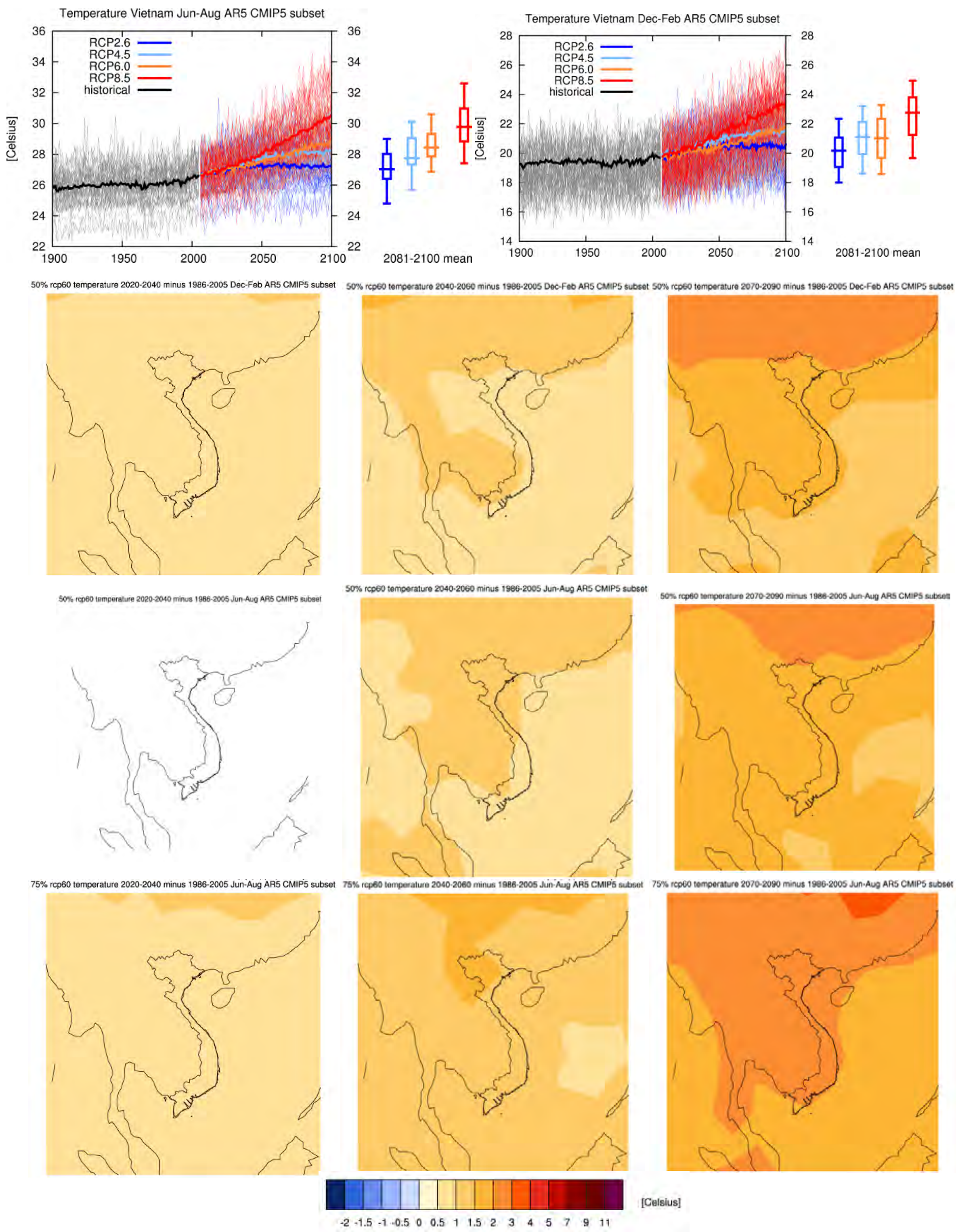

Figure 25. Projected temperature in Vietnam

GCM Models: CMIP5 subset. Figures on top show winter and summer night temperature under different RCPs according to all percentiles; figures in the middle show projected summer night temperature by 2030, 2050 and 2080; figures at the bottom show winter night temperature scenario under RCP 6.0 for 2030, 2050 and 2080 with 50 percentile.

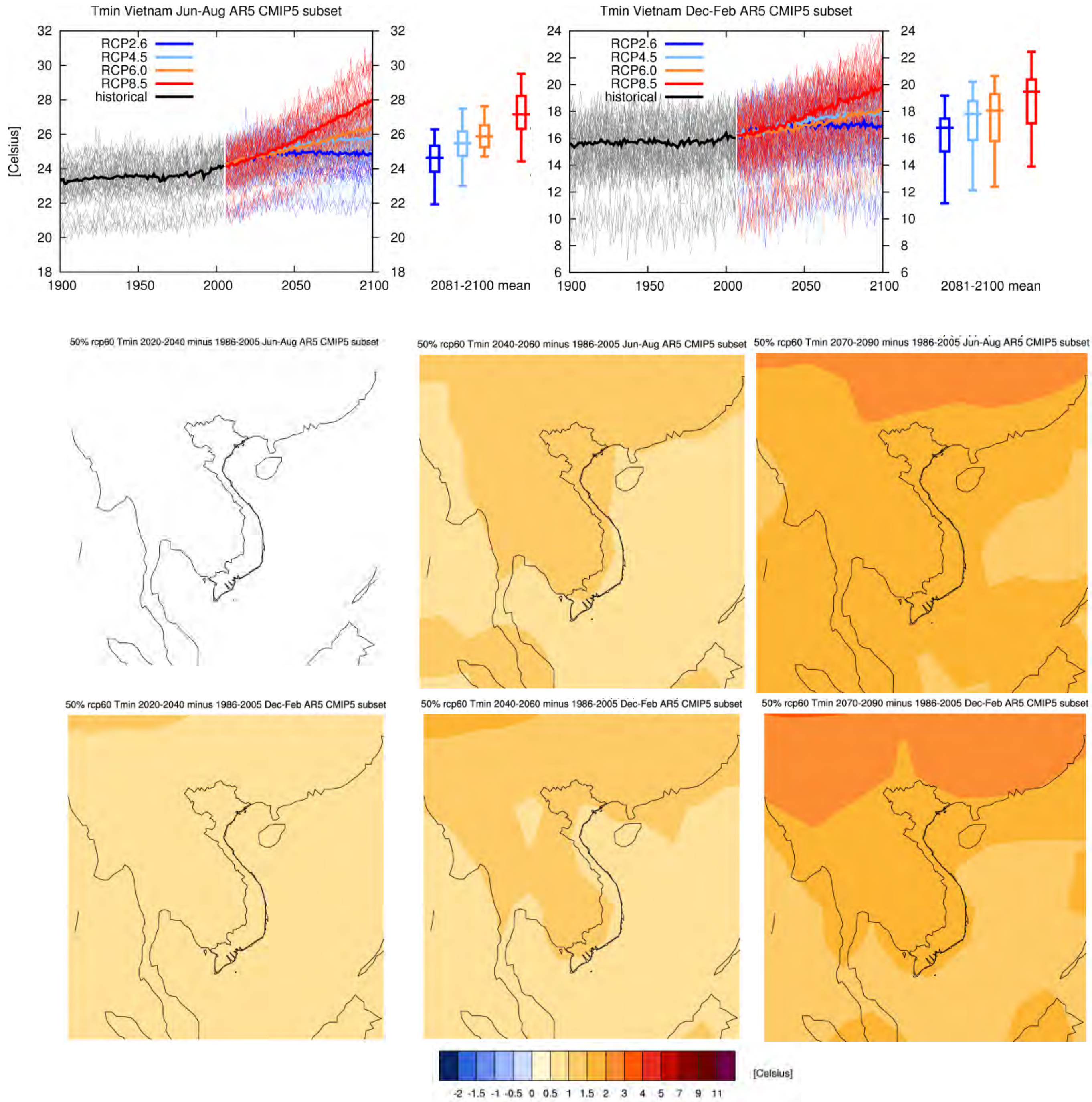

Figure 26. Projected night temperature in Vietnam

GCM Models: CMIP5 subset. Figures on top show winter and summer night temperature under different RCPs according to all percentiles; figures in the middle show projected summer night temperature by 2030, 2050 and 2080; figures at the bottom show winter night temperature scenario under RCP 6.0 for 2030, 2050 and 2080 with 50 percentile.

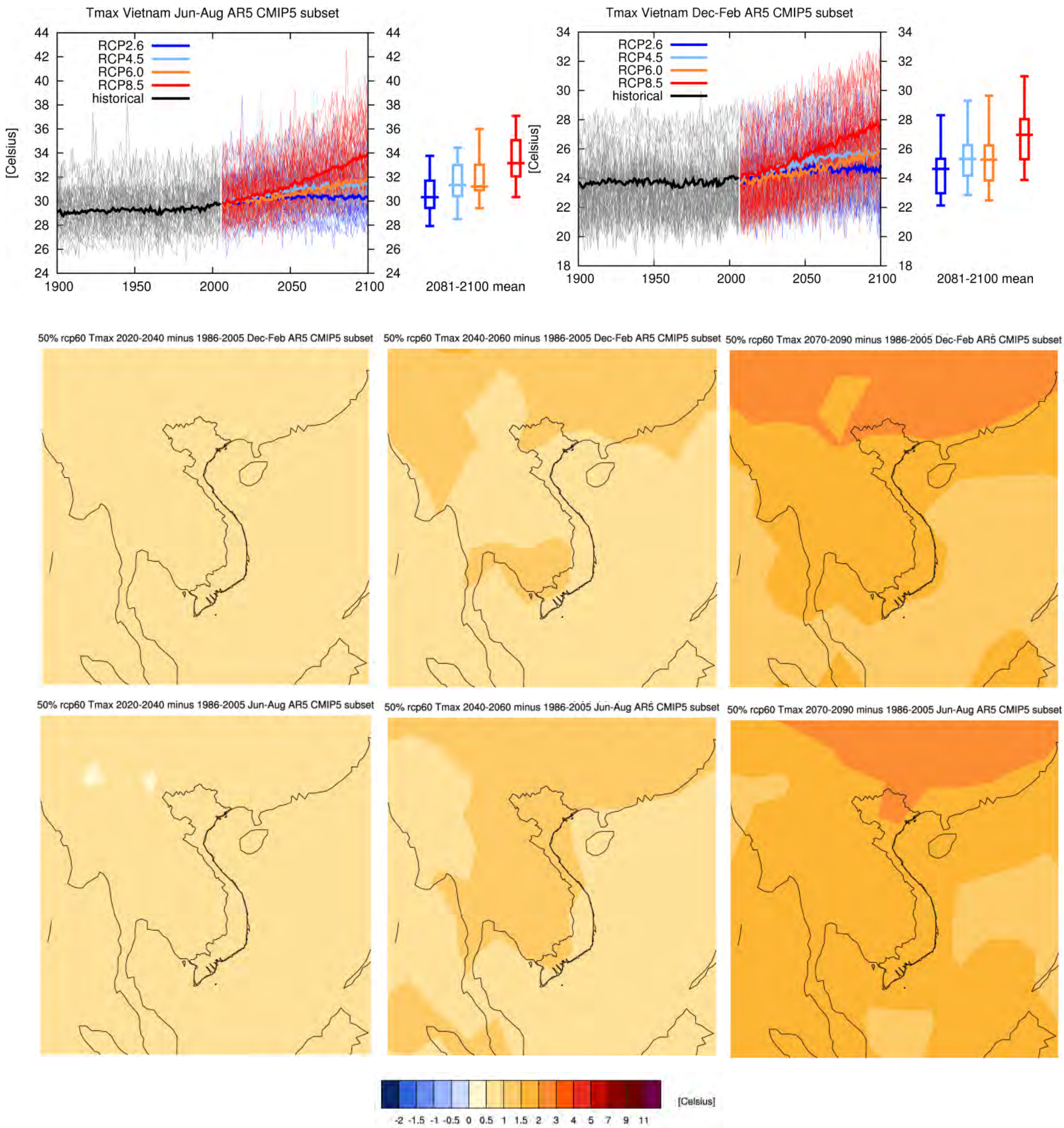

Figure 27. Projected day temperature in Vietnam

GCM Models: CMIP5 subset. Figures on top show winter and summer night temperature under different RCPs according to all percentiles; figures in the middle show projected summer night temperature by 2030, 2050 and 2080; figures at the bottom show winter night temperature scenario under RCP 6.0 for 2030, 2050 and 2080 with 50 percentile.

7. Projected Change in Rice Yield by 2030, 2050 and 2080

7.1. Projected Yield Loss in India by 2030, 2050, 2080/2100

Section 5.1 shows variation of yield across states in India. Section 6.1 shows that temperature and rainfall varies across the states in India. Crops' response to climate change depends on adaptation measures (e.g. irrigated versus rained). Figure 28 shows that under scenario A (with climate change adaptation), with the increase in temperature, irrigated rice fields can still adapt to climate change. Under scenario B (without adaptation, most likely rain-fed rice fields), yield is likely to be much lower. For instance, Punjab may experience yield losses of 15%, from 4.02 t/ha from the baseline in 2005, to only 3.9t/ha or in the worst-case scenario, its yield may reduce to 3.7t/ha. In Tamil Nadu, with a temperature increase of 2°C, the yield is likely to go down from 2.82t/ha (baseline) to 2.3 t/ha.

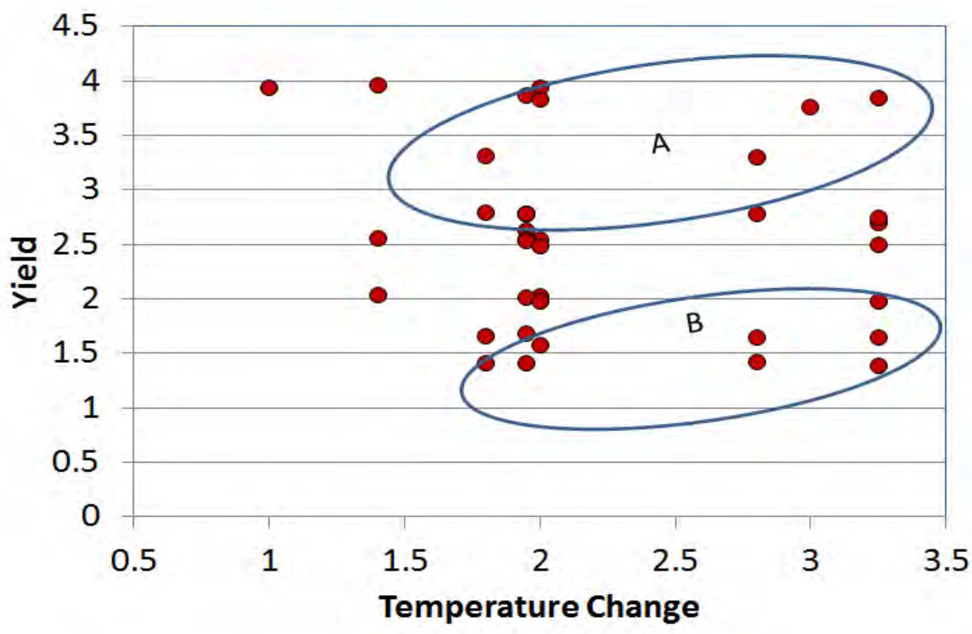

Figure 28 Projected yield according to change in temperature

In Orrisa, it is projected that with an increase in temperature of 2°C to 3°C, it is likely that its yield may be reduced from 1.69 t/ha (baseline) to 1.58 t/ha. What is certain is with the recent experience of drought at a return period of 5 years, 40% of its rain-fed rice would not be cultivated. In addition, Orrisa is prone to both annual cyclones as well as coastal flooding.

The summary below is of projected rice yield in India by 2030, 2050 and 2080. Details of the referred studies can be seen in Table 5.

India Rice Yield by 2030

Temperatures in Uttar Pradesh are predicted to increase by 1.4 to 2°C by 2030. Such changes could negatively impact irrigated rice yield by 4%. Punjab is expected to have higher temperature changes of between 1.8 to 2.8°C, with projected negative impact on irrigated rice of about 3 to 4% by 2030. West Bengal may experience an increase of 1.4 to 2°C by 2030 with an impact on yield of -2 to -3%. Tamil Nadu is likely to experience increase in day temperatures of 2.2°C and increase in night temperatures of 1.7°C by 2030 with potential impact on rice yield ranging from -4 to -19%, depending on adaptation via irrigation or rain-fed (See Table 5).

India Rice Yield by 2050

Even with the best irrigation, India may experience yield loss amid warmer temperatures. For example, West Bengal is projected to experience a loss of 5%. Punjab may experience a loss of 15%; Tamil Nadu may experience a modest loss of 3 to 4%.

India Rice Yield by 2080

Uttar Pradesh temperatures are projected to increase by 3 to 3.5°C with the possibility of a very modest yield loss of 1% because of the possible 10-35% increase in rainfall. Such an increase in rainfall may cause yield loss in Orrisa and Chhattisgarh by 14 to 15%. In Tamil Nadu, with an increase in 15 to 25% in rainfall, it could experience an increase in yield by up to 11%.

Table 5. Projected rice yield in India by 2030-2080

Region (IPCC)	States of interest	IR/R	Climate Variables of interest	CC Scenario	CC Scenario Description	Projected Year	Projected change in Yield (%)	Reference	Remark
NE India	West Bengal	IR	T, Precipitation, CO_2 effects	2020	T increase by 1.4 to 2°C	2010-2039	-2% to -3%	Kumar et al (2013)	
N India	Uttar Pradesh				T increase by 1.4 to 2°C		-4%		
NW India	Punjab				T increase by 1.8 to 2.8°C		-6 to -8%		
East	Orissa						-2 to -3%		
East	Chhattisgarh						-3% to -4%		
South	Tamil Nadu						-3% to -4%		
South	Andhra Pradesh						-3% to -4%		
Western Ghats	NW Tamil Nadu	IR	T, Precipitation, CO_2 effects	2030, A1B	Tmax 2.2°C and Tmin by 1.7°C; -20% rainfall	2020-2050	0 to -4%	Kumar et al (2011)	
		R					0 to -19%		
NE India	West Bengal	IR	T, Precipitation, CO_2 effects	2050		2040-2069	-3% to -4%	Kumar et al (2013)	
N India	Uttar Pradesh						-5%		
NW India	Punjab						-15%		
East	Orissa						-1%		
East	Chhattisgarh						-3% to -4%		

South	Tamil Nadu						-3% to -4%		
South	Andhra Pradesh						-3% to -4%		
NE India	West Bengal	IR	T, Precipitation, CO_2 effects	2080	T +3 to 3.5°C	2070-2099	-6 to -7%	Kumar et al (2013)	
N India	Uttar Pradesh				T +3 to 3.5°C		-7 to -8%		
NW India	Punjab				T +4 to 5.3°C		-17 to -18%		
East	Orissa						-3% to -4%		
East	Chhattisgarh						-5% to -6%		
South	Tamil Nadu						-11 to -12%		
South	Andhra Pradesh						-6 to -7%		
NE India	West Bengal	R	T, Precipitation, CO_2 effects	2020	T +1.4 to +2°C; +5 to +15% R	2010-2039	-9%	Kumar et al (2013)	High rainfall area (>1000mm)
N India	Uttar Pradesh				T increase by 1.4 to 2°C, 10% reduction in rainfall		-7 to -8%		Low rainfall area
East	Orissa				5 to 15% increase in rainfall		-11%		High rainfall area (>1000mm)
East	Chhattisgarh						-10 to -11%		
South	Tamil Nadu				5 to 15% increase in rainfall		4%		Low rainfall area (400 - 800mm)
South	Andhra Pradesh						2 to 3%		

NE India	West Bengal	R	T, Precipitation, CO_2 effects	2050		2040-2069	-7 to -8%	Kumar et al (2013)	High rainfall area (>1000mm)
N India	Uttar Pradesh						-5%		Low rainfall area
East	Orissa						-14 to -15%		High rainfall area (>1000mm)
East	Chhattisgarh						-16 to -17%		
South	Tamil Nadu						9%		Low rainfall area (400 - 800mm)
South	Andhra Pradesh						10%		
NE India	West Bengal	R	T, Precipitation, CO_2 effects	2080	T increase by 3 to 3.5°C, 10 to 35% increase in rainfall	2070-2099	-6%	Kumar et al (2013)	High rainfall area (>1000mm)
N India	Uttar Pradesh				T increase by 3 to 3.5°C		1%		Low rainfall area
East	Orissa				10 to 35% increase in rainfall		-14%		High rainfall area (>1000mm)
East	Chhattisgarh						-15%		
South	Tamil Nadu				15 to 25% increase in rainfall		10 to 11%		Low rainfall area (400 - 800mm)
South	Andhra Pradesh						2 to 3%		

East	Orissa	R	Drought	observed	severe droughts once in 5 years	observed	-40%	Wassman et al. (2009), Pandey et al. (2007)	Rain fed rice are particularly drought-prone.
East	Chhattisgarh								
IGP region	Orissa Chhattisgarh	IR/R	Increase rainfall, Flash floods	predicted	More frequent flash floods predicted in Eastern India			Wassman et al. (2009)	
	Orissa, Chhattisgarh, West Bengal and Punjab	IR	Soil Moisture	predicted	reduction in glacier melt by 30%	next 50 years		Wassman et al. (2009), IPCC AR4 (2007)	Some tributaries of the IGP may not flow in the dry season
NW India	Punjab	IR	T	observed	0.03°C/yr	past 32 years		Pathak and Wassman (2007)	
				predicted	1°C	-	-8.10%	Hundal and Kaur (1996)	
					2°C		-18.70%		
					3°C		-25.70%		

7.2 Projected Yield Loss in Thailand 2030, 2050, 2100

Future projected change of rice yield in Thailand depends on the emission scenarios as well as potential adaptation. Thailand's rice vulnerability to climate change is real. At the moment, its irrigation infrastructure can only serve less than 22% of the total agricultural area (Arunrat and Pumijumnong, 2015). Reda et al. (2015) show that due to climate variability, the Ping River Basin in Northern Thailand has experienced 48% in yield gap, and recently experienced planted area loss of as much as 55% and observed a yield loss of 32%.

The Government of Thailand anticipates both positive and negative changes in yield by 2050/2080 across the region. For example, the Ministry of Environment and Rural Development predicted that the country may either benefit from climate change up to 10% or may experience a decline in yield by 20%. At the local levels, there are substantial variations in projected change in rice yield in Thailand. The summary below shows the projected rice yield in Thailand by 2030, 2050 and 2080 (See the details in Table 6).

Thailand Rice Yield by 2020/2030

By 2030, some parts of Northeast including Mekong Delta of Thailand (e.g. Roi Et and Surin) will experience either positive or negative yield changes from the current level. Some regions may experience positive yield (up to 49%) while some may experience negative yield change by as much as 17.8%.

Thailand Rice Yield by 2050

By 2050, some regions may benefit up to 78.7% if the climate is conducive (Felkener, 2009). A more realistic calculation also suggests that some parts of the Northeastern regions may experience positive yield of up to 28%.

Some estimates predict an all negative decline from 10% to 17% by 2050 (ADB, 2009). Places like Roi Et are predicted to experience a dip of 1.4% to 22.9% by 2050. Depending on the emission in the future and its impact on rainfall and

evapotranspiration (given the potential change in temperature), some authors provide
a more positive projection for regions such as Roi Et and Surin as they may have an increase in yield from 6.6 to - 2% by 2050.

Thailand Rice Yield by 2080

Some estimates suggest that nationwide, Thailand could experience a decline in yield from 40 to 45% by 2080 (ADB, 2009). However, there are variations from region to region. For instance, it is likely that areas such as Southern Thailand may experience positive changes in yield. However, such regions contribute marginally to the total rice production. Top rice production regions such as Khon Kaen and Chaiyaphum provinces are likely to experience either an increase in yield (up to 28.4%) or a decline of 14.6% by 2080. In areas such as Sakon Nakon and Sisaket, Mainuddin et al. (2013) estimate that there could be an increase in yield from 8.5 to 21.9%. Without adaptation, places like Roi Et are predicted to experience a loss in yield from -14 to -32% by 2080.

Table 6. Projected rice yield in Thailand by 2020-2080

Exporters	Downscaled	Yield Impacts %	Climate Scenario	Model Scenario	Reference
Thailand	Nationwide	+10/-20		N/A	T-MoNRE 2009
	Nationwide	-17 -45		SRES A1F1 2050 SRES A1F1 2080.	ADB 2009
	Nationwide	-10 -40		SRES B1 2050 SRES B1 2080	ADB 2009
	Nakon Phanom; Ubon-R	+6.0 +9.6 +18.0 +12.1	>R; >PET >R; >PET <R; >PET <R; >PET	SRES A2 2020 SRES A2 2040 SRES B2 2020 SRES B2 2040	Mainuddin et al., 2013.
	Sisaket; Sakon Nakon	+12.8 +21.9 +14.2 +8.5	>R; <PET >R; <PET >R; >PET >R; >PET	SRES A2 2020 SRES A2 2040 SRES B2 2020 SRES B2 2040	Mainuddin et al., 2013.
	Surin; Roi Et	+6.6 +15.2 +20.2 +9.9	>R; >PET >R; >PET >R; >PET >R; >PET	SRES A2 2020 SRES A2 2040 SRES B2 2020 SRES B2 2040	Mainuddin et. al. 2013.
	Khon Kaen; Chaiyaphum	+18.3 -14.6 +28.4 +26.9	>R; >PET >R; >PET >R; >PET >R; >PET	SRES A2 2020 SRES A2 2040 SRES B2 2020 SRES B2 2040	Mainuddin et. al. 2013.
	N.E Thailand	+49/-33.9; +78.7/-43.5; +21.5/-8.6		DSSAT Model	Felkener, 2009
	N.E (Roi Et) N.E (Surin)	0.53; -1.4; -19.7 -3.1; -13.3; -13.4		2030, 2050, 2080 CGCM1 [0-N]	Kuneepong et al., 2001. *
	N.E (Roi Et) N.E (Surin)	-17.8; -22.9; -32.2 -56; -23.8; -25.7		2030, 2050, 2080 ECHAM [0-N]	Kuneepong et al., 2001.
	N.E (Roi Et) N.E (Surin)	-2.3; -14.2; -14.8 -1.7; -11.3; -12.9		2030, 2050, 2080 CSIRO [0-N]	Kuneepong et al. 2001.

7.3 Projected Yield Loss in Vietnam 2030, 2050, 2100

In general, Vietnam will experience substantial yield losses indicated by projected change in yield by 2030, 2050 and 2080. However, there are variations in projected yield loss across the region of Vietnam. For example, the DES DINAS-COAST

Model, a Dynamic-Ecological simulation model developed by the DINAS-COAST consortium, predicts a decrease in spring rice yield of 2.4% by 2020 and 11.6% by 2070 under scenario A1B (Table 7). Summer rice will be less sensitive to climate change impact than spring rice, but the yield will also decrease by 4.5% by 2070 according to one prediction. Rice planted in Northern and Central Vietnam will be affected more than rice grown in the southern part of the country.

Climate change impacts on yield in Vietnam depend on the planting seasons. Spring rice often gives the highest yield. Winter (or Autumn-Winter) rice often provides the lowest yield. Autumn (or Summer-Autumn) rice often provides modest yield (as of 2013, whole country autumn yield was 5.2 t/ha; whole country spring yield was 6.5 t/ha; whole country winter yield was 4.6 t/ha – See the variations among the regions in Section 5.2).

Vietnam is particularly susceptible to inundation and salt water intrusion due to its reliance on low-lying coastal and deltaic regions for rice production. Tran, Pham and Bui (2014) suggest that climate change may create shocks on rice production in the Red River Delta and MRD regions. Dasgupta et al. (2007, 2009) predict that about 7% of Vietnam’s agriculture land may be submerged due to sea level rise. The Vietnam Institute for Meteorology, Hydrology and Environment (IMHEN), in their 2007 study, projected significant increases in annual average temperature in 2100 - IMHEN estimates that an increase of 1m in sea level would affect over 10% of the country’s population (the Mekong and Red River Deltas); seasonal rainfall in all regions would increase up to 5% in 2050 (except in the central region, where seasonal rainfall would increase up to 10%). According to the Ministry of Agriculture and Rural Development, in 2014, 100,000 ha of farmland in the Mekong delta were affected by salt water intrusion.

Below is a summary of projected rice yield in Vietnam by 2030, 2050 and 2080 (See the details in Table 7)

Vietnam Rice Yield by 2020/2030

A few models have suggested one-digit loss by 2020/2030 from 2.2% (nationwide, see MONRE 2009) to 5.6% in Lower Mekong Delta (Tran et al., 2014).

Vietnam Rice Yield by 2050

Some estimates suggest that by 2050, Vietnam may experience a serious decline of 7.2% to 32.6% in Red River Delta and 6.3% to 12.0% in the Mekong Delta (World Bank, 2010).

By 2050, rice yield may on average decline by 10 to 20% across the region in Vietnam. MoNRE (2009) however provides a slightly modest decline in yield (3.4%) by 2050. However, a downscaled calculation suggests that during Summer-Autumn, regions such as Ca Mau may experience a decline in yield from 1.6 to 17.5%. The same season may lead to a decline in yield by 1.7%, 3.7%, and 4.2% subsequently in Ho Chi Minh, Hanoi and Danang.

Vietnam Rice Yield by 2080

Regions such as the Red River Delta (including Hanoi) may experience negative yield of as much as 16.5% (ADB, 2009, Tran et al., 2014). Depending on the season, in general summer rice will experience less yield loss than spring rice. Deb et al. (2015) suggested that in the most southern part of Vietnam such as Ca Mau, climate change may result in more yield loss during Summer-Autumn season (from -2 to -17.5%, depending on the emission scenario) than Autumn-Winter rice where potential increase in yield is likely (from 1.1 to 12.1%). By 2070/2080, Ca Mau region may experience an increase in yield of 3.3 to 17.2% during Autumn-Winter. However, during Summer-Autumn, rice yield may decrease by 1.6 to 23.5% (depending on emission level).

Without adaptation, Vietnam can lose total agricultural added value by 5.8 to 13.9% in 2050 compared with the present value (World Bank, 2010). Compared with the present rice yield in Vietnam (above 5-6 t/ha), a recent study projected that even with adaptive planting scheduling, yield can be reduced to 4.5 t/ha (under SRES A2) and 4.1 t/ha (SRES B2) (Mainuddin, Kirby and Chu, 2011).

Table 7. Projected rice yield in Vietnam by 2020-2080

Exporters	Downscaled	Yield Impacts %	Scenario	Reference
Vietnam	Nationwide	-2.2; -3.4	2020; 2050	MONRE 2009*
		-10/-20	2050	World Bank 2010*
	Nationwide	-22/-31	SRES A2/B2	Mainuddin 2011).
	South (Ca Mau) (SA)	-2 up to -22.0 -7 up to -17.5	2055 (A2) 2055 (B2)	Deb, Duong and Udmale (2015)
	South (Ca Mau) (SA)	-1.6 to -23.7 -8.06 to -20.15	2085 (A2) 2085 (B2)	Deb, Duong and Udmale (2015)
	South (Ca Mau) (AW)	+1.1 to +9.7 +4.7 to 12.1	2055 (A2) 2055 (B2)	Deb, Duong and Udmale (2015)
	South (Ca Mau) (AW)	+3.3 to +12.4 +6.6 to +17.2	2085 (A2) 2085 (B2)	Deb, Duong and Udmale (2015)
	Hanoi	-12.5 (Spring) -3.7 (Summer	2050	DES DINAS-COAST Model in ADB 2009
	Hanoi	-16.5 (Spring) -5.0 (Summer)	2070	DES DINAS-COAST Model in ADB 2009
	Da Nang (Spring)	-6.8 (Spring) - 4.2 (Summer)	2050	DES DINAS-COAST Model in ADB 2009
	Da Nang (Summer)	-10.3 (Spring) -5.7 (Summer)	2070	DES DINAS-COAST Model in ADB 2009
	Ho Chi Minh	-8.4 (Spring) -1.7 (Summer)	2050	DES DINAS-COAST Model in ADB 2009
	Ho Chi Minh	-11.6 (Spring) -2.8 (Summer)	2070	DES DINAS-COAST Model in ADB 2009
	Red River Delta	-7.2/-32.6 -5.6; -7.8; -8.6	2050 2030, 2050, 2080	World Bank 2010* Tran et. al. 2014*
	Mekong Delta	-6.3/-12.0 -5.6; -7.8; -8.6	2050 2030, 2050, 2080	World Bank 2010* Tran et. al. 2014*

8. Public Action and Policy Response

8.1. Public Action and Policy Response in India

The Government of India has endorsed the Eight National Missions to deal with climate change including the "Sustainable Agricultural Mission".[6] This mission becomes the key instrument to building resilient agriculture. The strategies include firstly, identifying and developing new varieties of crops that can withstand abiotic stresses including warming and drought. The new expected varieties are also expected to be resilient to extreme weather including dry spells, flooding and submergence. The second step is to monitor and evaluate climate change and recommend new relevant policy and practices accordingly. The third strategy is to capitalise the use of existing knowledge, technology, geospatial and information technology; Lastly, incentives via credit and crop insurance mechanism will be created.

Recently, the Government of India via the Ministry of Environment and Forests has established the National Adaptation Fund on Climate Change (NAFCC).[7] It aims to support the state and union territories that are particularly vulnerable to the adverse effects of climate change in meeting the cost of adaptation. The government appointed the National Bank for Agriculture and Rural Development to be the National Implementing Entity (NIE) responsible for implementation of adaptation projects under the NAFCC.

8.2. Public Action and Policy Response in Thailand and Vietnam

There is still limited information regarding public action and policy response to climate change in rice sectors in ASEAN region. In many cases, national and local initiatives are often seen in the form of international cooperation and in many cases limited to international research projects.

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[6] Please see the National Action Plan on Climate Change. Prime Minister's Council on Climate Change. Available at http://www.moef.nic.in/sites/default/files/Pg01-52_2.pdf [Last accessed on 20 March 2016]

[7] Please see http://pib.nic.in/newsite/PrintRelease.aspx?relid=124326 [Last accessed on 20 March 2016]

Typical initial responses in developing countries, including in Asia, often manifest in the form of pilot projects.[8] For example, IRRI together with ASEAN recently initiated a project namely PIRCCA, aimed at bridging "science and policy, and to establish informal and operational linkages with other stakeholders." Its goal is to enable policymakers in ASEAN member states (especially Vietnam and Myanmar), "to have improved capacity to forecast rice shortages and, thus, more effective response to climate-induced food shocks"; to promote "climate change-adaptation policies that provide institutions, decision-makers and scientists access to data that will facilitate identification and mapping of vulnerable or affected geographic areas and population groups, as well as suitable climate-smart technologies". PIRCCA claims that "ASEAN member states have committed, as one community, to improve their capacity to adapt to and mitigate the effects of climate change in their respective countries. These initiatives, however, are hampered by limited access to relevant data, information and scenarios that could help each of them decide on R&D approaches or methods that help address climate change challenges at various scales."[9]

Vietnam's Action Plan Framework for Adaptation and Mitigation of Climate Change of the Agriculture and Rural Development Sector Period 2008-2020, endorsed by the Minister of Agriculture and Rural Development in 2008 stated two objectives related to rice security: first is "Ensuring the stable agriculture production and food security with the stable area of 3.8 million ha of two seasonal rice crops;" and Second, "ensuring safety of dyke and infrastructure systems to meet requirements in disaster prevention and mitigation"[10]

Thailand's Ministry of National Resources and Environment had launched the National Climate Change Strategy 2008-2012 with an objective to "build up preparedness for adaptation and coping with climate variability and change in

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[8] See the list of adaptation pilot projects in ASEAN on several sectors. https://www.sei-international.org/mediamanager/documents/Publications/Climate/SEI-DB-2016-ASEAN-adaptation-readiness-Supplemental-tables.pdf [Last accessed on 31 March 2016]

[9] Ibid.

[10] See http://www.preventionweb.net/files/10517_ActionPlanFrameworkAdaptationMitiga.pdf [Last accessed on 31 March 2016]

extreme weather events". General and multi-sectoral adaptation policy ideas are featured in the draft National Master Plan on Climate Change 2050 (Chinvanno and Kerdsuk, 2013; Kansuntisukmongkol, 2015). Existing community actions are often isolated practices as seen in some case studies (Chinvanno and Kerdsuk 2013).

In a recent study on "Thailand Climate Public Expenditure and Institutional Review", it was found that adaptation policy receives 68% of the total national climate budget. The Ministry of Agriculture and Cooperatives received a total of THB$86 million (54.9 per cent of the total climate budget).[11] However, there is limited information on specific allocation on food commodities such as rice.

What is available is the policy narrative regarding agriculture in general, including the commitment in having better forecasting and early warning system technologies for agriculture, improved crop management technologies and ensuring better precision for farming technologies.[12] In Thailand, about 40 per cent of its labour is in the agriculture sector where most farmers are still subsistent and rely on rain-fed agriculture. In fact, about 80 per cent of the farmland in the north and northeast are without irrigation (Kansuntisukmongkol, 2015).

9. Options for Rice Adaptation

Rice can feel the stresses arising from warming temperature. Exposure to extreme heated temperature can damage rice yield and grain quality. In general, rice is more sensitive to heat stress during the reproductive and ripening or maturing stages (Laborte et al., 2012). Exposure to climate shocks and vulnerabilities varies from one farmer to the other. Likewise, adaptive capacity of rice farmers also differs across sub-national regions. Access to irrigation services also varies from place to place (O'brien et al., 2004). Access to adaptation incentives (e.g. drip irrigation

[11] Please see http://www.undp.org/content/dam/thailand/docs/CPEIR%20Thailand(English).pdf [Last access 30 March 2016]

[12] See Thailand's Intended Nationally Determined Contribution. Letter to the Executive Secretary UNFCCC secretariat in 2015, submitted by Office of Natural Resources and Environmental Policy and Planning. See http://www4.unfccc.int/submissions/INDC/Published%20Documents/Thailand/1/Thailand_INDC.pdf. [Last access 30 March 2016]

technology/facilities, rearing house and other production technology, access to credit, crop insurance and access to market) also varies from places to places.

India's climate change vulnerability informed by climate data from 1961–1990, suggests that in semi-arid regions of India, including major parts of the states of Rajasthan, Gujarat, Punjab, Haryana, Madhya Pradesh, and Uttar Pradesh, agriculture has been very sensitive to climate variation and change. Due to low adaptive capacity, many regions such as most districts in southern Bihar, are highly vulnerable to climate change. Most districts in northern Punjab have very high sensitivity to climate change, yet are found to be only moderately vulnerable as the result of high adaptive capacity (O'Brien, 2004: p.307,312)

One of the risks of climate change is the uncertainty in the onset of rainfall. Erratic rainfall, shifting of the wet season and changes in length of the wet season will impact crop yields as farmers may not be able to plant and harvest during the desired season. Accurate predictions of the shift in wet season or change in duration of the wet season will help farmers to adapt by adjusting the planting calendar.

Heat stress occurs because of rising temperatures that may have reached the limit of crops' biological tolerance level – a situation where crops begin to be more susceptible to stress during certain stages of crop development such as flowering stages. For instance, Wassmann et al. (2009a) have observed that such heat stress phenomenon in South India is commonly observed during April - August; In East India it is often observed during March - June. In Thailand, it can be observed during March - June and in Vietnam it is often observed during April - August. It is now understood that excess heat stress (e.g. indicated by temperature above 35°C) affects rice yield potential and also decreases the efficiency of photosynthesis of rice plants (Wassmann et al., 2009a; Wassmann et al., 2009b). While it is well understood by rice scientists, existing yield data, including yield losses and damages, often does not capture the phenomenon. At best, this phenomenon is often masked in reports of drought episodes which involve problems such as water stress and agricultural drought.

In general, adaptation to climate change can be achieved by technological innovation, adjustment in planting calendar, cultivation practices including water management and selection of adaptive (not always necessarily new) varieties, such as flood and drought-tolerant rice varieties that are more suitable for the future climate (Bachelet et al., 1992; Wassmann et al., 2009; Porter et al., 2014).

Context specific adaptation is a necessity. Climate change impact on rain-fed rice will be different from place to place in the Mekong Region. For instance, a climate model downscaled for the Mekong Basin using the PRECIS system predicted that yield of rain-fed rice may increase significantly in the upper part of Thailand and may decrease in the lower part of the basin in Vietnam (Mainuddin et al., 2013). In the context of Thailand, Reda et al. (2015) argued that adaptations such as crop calendar adjustment by the farmers is needed to shift rice planting to be done earlier to avoid floods in certain seasons (e.g. in the Upper and Middle Ping catchment, farmers may grow rice in May to avoid the flood season in October; in Lower Ping, farmers can grow rice between late May to first week of June – there is no need to wait until mid-June and early July).

The general impression from Section 7 suggests that Thailand is likely to be promising in terms of its leading role as a global rice exporter by 2050 if it can successfully improve the resilience of its irrigation system. India and Vietnam seem to be less promising in their projected rice yield. Based on other non-climatic variables such as a long term reduction trend in rice planting areas, these two countries may lose their status as top rice exporters in future if they are not prepared to deal with climate change. Due to climate change and its population size, India may lose its status as exporter by 2050. Vietnam needs to deal with its decline in agricultural land for rice as well as future climate shocks.

Thailand can still increase its rice yield potential. In addition, its present yield is still far below its yield potential. Thailand can increase its yield from the present level (below 3 t/ha). With existing and new technology, Thailand could yield rice from 6-8 t/ha such as that seen in Indonesia and Vietnam. With proper adaptation, Thailand can still be the leading exporter in the world rice market. Also, reduction in post-harvest losses, such as improvement in post-harvest and storage technologies and systems can help to increase the availability of rice.

10. Recommendations

Adaptation requires both decisions that come at a cost and at no-cost. No-cost decisions include changing of sowing dates and certain agrotechnological crop management that do not involve financial transaction. However, this may not always hold true as governments should also invest in early warning systems that allow better prediction for (delayed) sowing. These adaptation strategies may also include altered crops and cropping systems to maintain sustained soil fertility and improved management practices. At the farmers' level, identifying suitable response strategies is key to sustaining crops' yield. These include adjustments in sowing dates, crops breeding and genotype selection, and improvement in agronomic practices (Mall et al., 2006).

Governments in production countries can craft potential adaptation options of rice production systems. These adaptations can be achieved through technological innovation, adjustments in planting calendars and cultivation practices, changes in water management and the selection of flood or drought-tolerant rice varieties. Proper adaptation and reduction of post-harvest losses can help to increase rice yields in producing countries. In order to reduce instability in rice supplies, it is vital that potential yield losses are addressed and adaptation measures are taken to offset the negative impact of climate change. Importing countries should encourage and enhance information-pooling and experience-sharing on climate change and food security in Southeast Asia and the wider region.

We suggest some of the following policy options for rice exporters and importers. Rice producers are not immune from potential price shocks that may arise from climate shocks.

- Increase adaptive capacity and ensure multi-dimensional adaptation actions to climate change. These include ensuring that countries invest in technology (from production to post-harvesting to transporting); creating incentives for farmers and producers to adopt adaptive technology; improveing irrigation infrastructure and capacity building of agricultural extension officers and farmers.

- Support market integration to mitigate price shocks as experienced in drought/floods-affected regions in Indonesia' economic history in Java (van Der Eng, 2010). This idea is not new as historically, across Southeast Asia even before World War II, without integrated rice markets, rice prices have been seen to be sensitive to variations in rainfall and sudden increases in temperature especially during El-Nino years. ASEAN Economic Integration can be a solution in rice market integration, allowing rice surplus in one particular place to flow into rice-deficit regions.

- Strengthen regional cooperation framework to reduce uncertainty and information asymmetry in the market. In the case of ASEAN Food Security Information System (AFSIS), it can strengthen cooperation with organisations such as APEC in order to strengthen data and information system. As climate change often reduces the predictability of seasonal weather patterns, it is recommended that AFSIS work closely with the National Oceanic and Atmospheric Administration (NOAA) and multilateral institutions such as Agriculture Organisation (FAO) by, for example, integrating production data with existing global statistics from United States Department of Agriculture's (USDA) global commodities database and FAO's agricultural statistics.

- Build a global dataset on adaptation knowledge in such a way that can be accessible to rice farmers around the world. International research organisations such as IRRI and universities can work together to take stock on knowledge and experiences in rice adaptation and resilience-building projects. Existing projects include FAO's 50 global, regional, national and local projects designed specifically to address climate change adaptation[13], climate-related disaster risk management or a combination of adaptation and mitigation. PIK Potsdam has

[13] FAO 2011. FAO-ADAPT FAO'S Framework Programme on Climate Change Adaptation. Communication Division, United Nations Food and Agriculture Organisation, Rome.

recently updated at least 400 projects worldwide on adaptation – however, food and agriculture listed only 10 projects.[14]

- Spread adaptation knowledge using smartphones and web-based application as part of the solution. IRRI recently started to use *apps via smartphone* to transmit knowledge on rice planting in the Philippines.[15] This initiative can be extended to India, Thailand and Vietnam.

- Promote the inclusion of crops including rice and livestock to be part of the implementation agenda of the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts (Loss and Damage Mechanism). This idea is to ensure adequate attention to address loss and damage associated with impacts of climate change in food and agricultural sectors, including extreme events and slow onset events, in developing countries.[16]

[14] See Global database on adaptation project at: http://cigrasp.pik-potsdam.de/adaptations [Last accessed on 20 February 2016]

[15] See http://irri.org/news/media-releases/feeding-rice-just-got-easier-with-smartphones [Last accessed on 20 February 2016]

[16] See Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts http://unfccc.int/adaptation/workstreams/loss_and_damage/items/8134.php [Last accessed on 20 February 2016]

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