

Climate Change Impacts on Water Resources : Key challenges to Thailand CC adaptation

Suttida Pliankarom Thanasupsin (B.Sc., M.Eng., Ph.D.)

Environment Project Group, Office of Project Management, RID

E-mail : suttidapl@hotmail.com

ABSTRACT

Climate change is a significant and lasting change in the statistical distribution of weather or climatic patterns. The most general definition of climate change is a change in the statistical properties of the climate system when considered over long periods of time. Since early period, some evidences of climatic change, for example rising of global mean temperature, glaciers retreat, have been observed.

As in Non-Anex I, Thailand is one of the major agricultural countries, of which producing about 1% of the world's carbon dioxide emissions. (0.95% of global total CO₂ emission in 2008). The impact of climate change to Thailand; such as higher surface temperatures, floods, droughts, severe storms and sea level rise, is more likely to put Thailand's food production at risk, especially rice productions. It is expected that the damage to agriculture, coastal tourism, and the capital city as consequences of climate change will have enormous economic, cultural and environmental impacts.

This article aims to summarise climate change impacts on water resources, that subsequently pose threats to agricultural sector, as well as to draw attention on the key challenges to CC adaptation in agriculture and environment. In response to Thailand recent flood 2011, examples of improvement issues that need to be achieved in the approaching years are also proposed.

KEY WORDS : Climate Change, Impact, Adaptation, Water Resources, Structural-and non-structural measure

Definition

Climate change is a significant and lasting change in the statistical distribution of weather or climatic patterns. The most general definition of climate change is a change in the statistical properties of the climate system when considered over long periods of time, regardless of cause. Accordingly, fluctuations over periods shorter than a few decades, such as El Niño, do not represent climate change. In some context, climate change may refer to “anthropogenic global warming”.

Some evidences of climatic change

Since early period, some evidences of climatic change have been observed. For example, rising of global mean temperature, As temperatures warm, glaciers retreat unless snow precipitation increases to make up for the additional melt. Over the last several decades, the decline in Arctic sea ice has been also observed, both in its extent and thickness. Considering vegetation, it is claimed that, due to an increase in precipitation and global temperature, a change in the type, distribution and coverage of vegetation can be observed. It has been also report that estimated global land precipitation has increased by approximately 2% over the course of the 20th century and similar slight overall increase in global river runoff and in average soil moisture has been perceived. The study of air trapped in bubbles in the ice core from the Antarctic has shown a link between temperature and global sea level variations. And, it has been also report that global average sea level has rose at an average rate of around 1.8 mm per year over 1961 to 2003 and at an average rate of about 3.1 mm per year from 1993 to 2003

The History of the IPCC’s Assessment Report (AR)

In order to understanding more on climate change in international context, studying the history of IPCC assessment report is one of many sources of information providing organisation. The IPCC is considered as the most important source of scientific, technical and socio-economic information. The relationship between the UNFCCC and the IPCC has become a model for interaction between science and decision-makers. The IPCC report will be released once every 5 years before the COP-meeting. As can be seen in Figure 1, it is interesting to point here is that: in second assessment report, under working group 2 was released information on the technical and economic feasibility of a range of potential Adaptation and Mitigation strategies

And in third assessment report released in 2001, WG II has provided updated information on impacts, vulnerabilities and Adaptation, and implications for sustainable development while mitigation options were assessed under the task of WG III.

The next series of IPCC’s assessment report will be released between 2013 and 2014. So, it is interesting for us, for Thailand and any country to prepare ourselves for the next 5 years. In assessment report 5, it is expected that it will focus on assessing the socio-economic aspects of climate change and implications for sustainable development, risk management and the framing of a response through both adaptation and mitigation. It will aim to provide more detailed information on regions, including on climate phenomena such as monsoons and El Niño. To enhance overall integration some aspects including water and the Earth system, carbon cycle; ice sheets and sea-level rise; and integration of Climate change with sustainable development policies, particularly the relationship between Adaptation and Mitigation will be addressed in a cross cutting manner. Attention will also

be given to consistent evaluation of uncertainties and risks; costing and economic analysis; and new scenarios.

Recently, IPCC has been preparing 2 special reports focusing on “Renewable Energy Sources and Climate Change Mitigation” and “Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation”. As expected, these 2 issues will make an alarm to the member countries to prepare themselves on renewable energy as well as risk and disaster management.

In case of Thailand, this alarm has come later than the warning of nature. As everyone knows, Thailand was facing serious flood in 2011, known as Thailand Mega-flood 2011. According to this, it’s quite obvious that risk and disaster management system was our weakness.

<p>1990 – First Assessment Report (FAR) and negotiations for a framework convention on climate change</p> <p>1992 - Supplementary Reports</p> <p>1994 - Special Report</p> <p>1995 – Second Assessment Report (SAR), 1991 - 1995</p> <p>WG I highlighted considerable progress in the understanding of CC</p> <p>WG II broadened the scope of assessment to include information on the technical and economic feasibility of a range of potential <i>Adaptation</i> and <i>Mitigation</i> strategies</p> <p>WG III addressed the social and economic dimensions of climate change over both the short and long term</p> <p>1996 – COP-2</p>
<p>2001 – Third Assessment Report (TAR), 1997 - 2001</p> <p>WG I improved understanding of climate process</p> <p>WG II provided updated information on impacts, vulnerabilities and <i>Adaptation</i>, and implications for sustainable development</p> <p>WG III assessed <i>mitigation</i> options, their costs and co-benefits as well as barriers, opportunities and policy instruments</p> <p>2002 – COP-8</p> <p>2007 – Fourth Assessment Report (AR4), 2003 - 2007</p> <p>WG I provided new knowledge on human and natural drivers of climate, a detailed assessment of past CC and its causes and stronger evidence on attribution of CC including an assessment for every continent</p> <p>WG II assessed observational evidence of impacts of CC, identified some of the most vulnerable places and people and mapped projected impacts against future warming trends</p> <p>WG III further evaluated emissions trends, mitigation options and pathways</p>
<p>2007 – COP-13 : adopted the Bali Action Plan (BAP)</p> <p>2013 - 2014 – Fifth Assessment Report (AR5)</p> <ul style="list-style-type: none"> ▪ Socio-economic aspects of CC and Implications for sustainable development ▪ Risk management and the framing of a response through both <i>Adaptation</i> and <i>Mitigation</i> ▪ More detailed information on regions, including on climate phenomena such as monsoons and El Niño ▪ Integration some aspects including water and the Earth system, carbon cycle; ice sheets and sea-level rise; and integration of CC with sustainable development policies, particularly the relationship between <i>Adaptation</i> and <i>Mitigation</i> will be addressed in a cross cutting manner ▪ Evaluation of <i>Uncertainties and risks; Costing and Economic analysis; and New scenarios</i>

Figure 1 IPCC’s Assessment Report (AR)

Facts about Climate Change in Thailand

Thailand's Situation

Thailand is one of the major agricultural countries, the largest exporter of rice. It is estimated that agriculture employs up to 49% of the population and contributes 10% of GDP. Having about 3,200 kilometres of coastline, tourism and fishery become the backbone industry of Thailand. Climate change threatens all three important sectors of Thailand's economy: agriculture, tourism, and trade.

Considering total CO₂ emission, in 2008 Thailand ranks 22 of worldwide. Today, it is estimated that Thailand produces about 1% of the world's carbon dioxide emissions. (0.95% of global total CO₂ emission in 2008)¹. Figure 2 shows that in 2007 Thailand CO₂ emission per capita equal 4.1 metric tons which ranks 96 of worldwide.

Thailand released 254.88 million metric tons of CO₂ in the year 2009, and is ranked #23 out of 217 countries. With per capita CO₂ emissions of 3.80 metric tons per year, it is in the 3rd quartile globally. Its CO₂ intensity (kg per unit GDP 2005 PPP \$) is 0.51, which is higher than the average of 0.44 for its income group--the Lower middle income countries. Regarding the trend, the total CO₂ emissions have decreased by -0.06% during 2008-09. Over the past five years, the total CO₂ emissions has worsened by 13.05%, and over the last decade the total CO₂ emissions has gone up by 48.67%.

Considering power generation, the total net generation for Thailand in 2008 was 138.99 million Mwh. Power supply from conventional thermal sources accounted for 93.75% of the total. In comparison, renewable sources including hydroelectricity contributed 8.37% of the total. The share of the non-hydro renewable component in the total generation was 3.31%. It is estimated that the coal fired power plants, the most CO₂ intensive source of power accounted for around 21.40% of the total generation (2nd quartile globally-based on 2007 data).

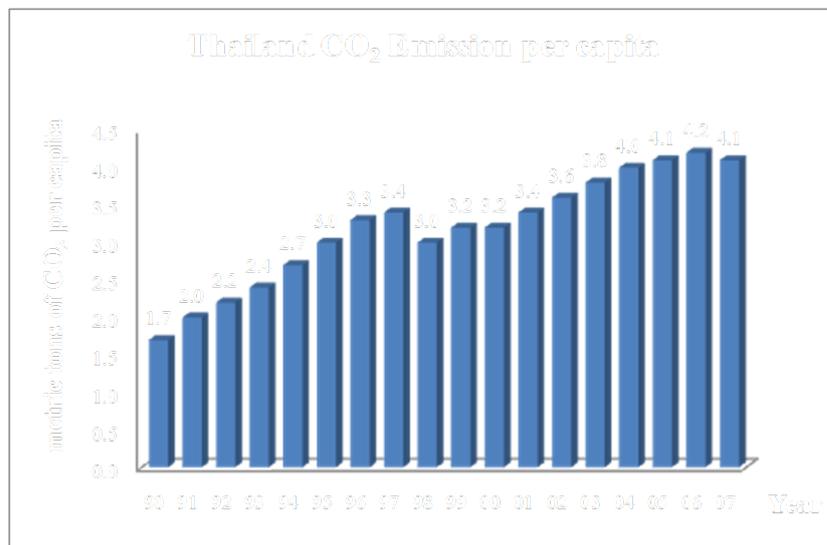


Figure 2 Thailand CO₂ Emission per capita from 1990 to 2007

¹ "List of countries by carbon dioxide emissions" The United States Department of Energy's Carbon Dioxide Information Analysis Center (CDIAC), http://en.wikipedia.org/wiki/C90_List_of_countries_producing_90%25_of_carbon

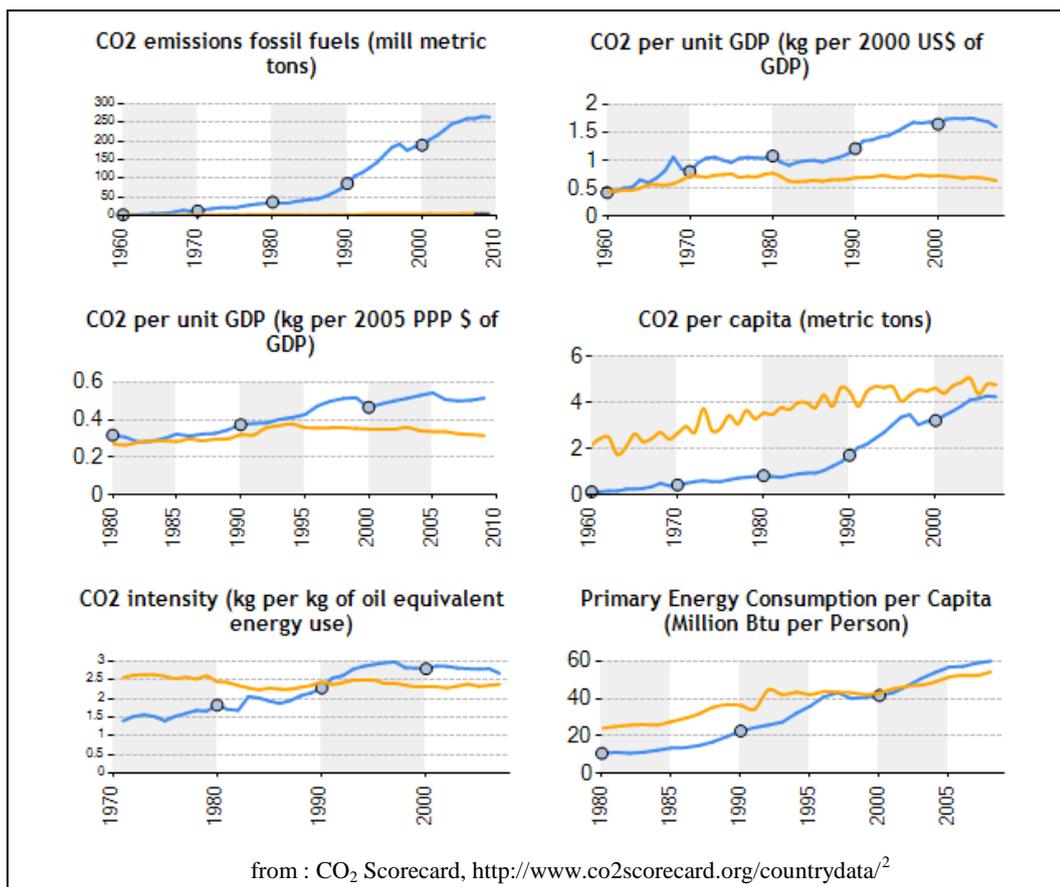


Figure 3 Thailand trend on CO₂ emissions and power generation

Thailand's Response on Climate Change

1994 : Thailand Signed the UNFCCC in June 1992 at UNCED and Ratified the UNFCCC in December 1994

1997 to 2000 : Thailand developed the initial National Communication to UNFCCC, funded by Global Environment Facility (MOSTE, 2000)

2002 : Thailand signed the Kyoto Protocol in February 1999 and Ratified in August 2002.

2004 : Thailand has designated the Office of Natural Resources and Environmental Policy and Planning (ONEP), the Ministry of Natural Resources and Environment as the national climate change focal point.

2007 : Establishment of the National Board on Climate Change Policy and the Climate Change Coordinating Unit under ONEP

: MNRE redesigned the institutional framework for Thailand's implementation to the UNFCCC and the Kyoto Protocol

: 15 May 2007 the cabinet approved the establishment of Thailand Greenhouse Gas Management Organization (Public Organization), or TGO (CDM, Clean Development Mechanism Project) to deal specifically with the clean development mechanism under the Kyoto Protocol.

Others

- Participation in the Vienna Convention for the Protection of the Ozone Layer, and the Montreal Protocol on Substances that Deplete the Ozone Layer, as well as other international co-operations.

² "Country data : Thailand" CO₂ Scorecard, <http://www.co2scorecard.org/countrydata/> date taken 1st May 2012

Thailand's strategic plan on Climate Change (2008-2012)

Having been approved by the cabinet on the 22th January 2008, Thailand strategic plan on climate change has provided a comprehensive guideline of national responses to climate change challenges, covering 6 strategies as follows:^{3,4}

- Building capacity to adapt and reduce vulnerability to climate-change impacts
- Promoting greenhouse-gas (GHG) mitigation activities based on sustainable development
 - Supporting research and development to better understand climate change, its impacts, and adaptation and mitigation options
 - Raising awareness and promoting public participation
 - Building capacity of relevant personnel and institutions and establishing a framework of coordination and integration
 - Supporting international cooperation to achieve the goal of climate-change mitigation and sustainable development.

Impacts of Climate Change to Thailand

Table 1 shows possible impact of climate change to Thailand and its consequences. Concerning to this, the impact of climate change to Thailand; including higher surface temperatures, floods, droughts, severe storms and sea level rise, is more likely to put Thailand's food production at risk, especially rice productions. It is expected that the damage to agriculture, coastal tourism, and the capital city as consequences of climate change will have enormous economic, cultural and environmental impacts.

Figure 4 shows one of possible impact from rising sea level to coastal erosion in Thailand. Reports from the Intergovernmental Panel on Climate Change state that "increases in sea level are consistent with warming. Global average sea level rose at an average rate of 1.8 mm per year over 1961 to 2003 and at an average rate of about 3.1 mm per year from 1993 to 2003." The consequences of sea level rise are abundant; millions of people will be subjected to floods, coastal ecosystems will be destroyed, and sea level rise will exacerbate freshwater constraints due to salinisation of estuaries and groundwater supplies.

Table 1 Possible impact of climate change to Thailand and its consequences

Impact	Effect	Consequences
Sea level ↑	Regional	Inundation
Sea Temperature ↑	Regional	Acidification
Variable climatic patterns	Rainfall pattern change e.g. Precipitation ↑ Drought ↑	Flooding Bad harvest
Ecosystem Changes ↑	Regional	Disappearance of species e.g. biodiversity ↓

³ Wijarn Simachaya (2010) "Climate Change Impacts to the Water Environment: Thailand" for The 2nd International Workshop (Climate change and the Water Environment) WEPA International Workshop, 23 February 2010, Shiba-Park Hotel, Tokyo, Japan

⁴ Tubtim Limsoontorn (2010) "National Strategy of Climate Change Management : Modeling and Data Application", Data Democracy Workshop on Climate Change Geo-Informatics and Space Technology Development Agency 7-10 June, 2010 Bangkok Thailand

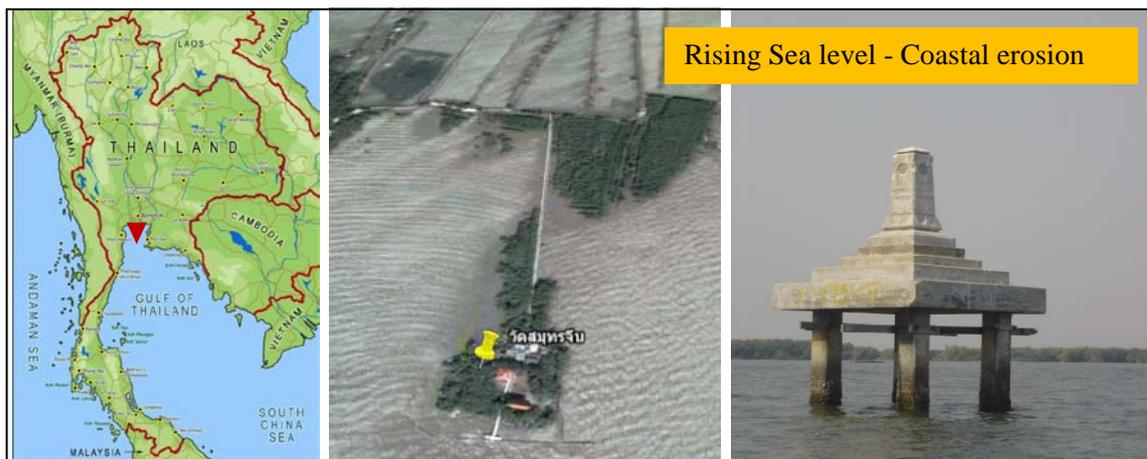


Figure 4 Example of possible impact from rising sea level to coastal erosion in Thailand

The IPCC also warns that Cities locating in the mega-deltas, e.g. Bangkok is vulnerable to climate change. A coincidence of several phenomena; such as frequent and intense flood, flood drainage and storm surges, is likely to occur and may put communities, biodiversity and infrastructure at risk of being damaged.

Climate Change Impacts on Water Resources and Agricultural Sector

Freshwater resources and its ecosystem are highly sensitive to variations in weather and climate. The changes in global climate that are occurring as a result of the accumulation of greenhouse gases in the atmosphere will affect patterns of freshwater availability and will alter the frequencies of floods and droughts as well as water quality.

Climate model simulations and other analyses suggest that total flows, probabilities of extreme high or low flow conditions, seasonal runoff regimes, groundwater-surface water interactions and water quality could all be significantly affected by climate change. The distribution of precipitation in space and time is very uneven, leading to tremendous temporal variability in water resources worldwide.² Figure 5 shows an evidence of variability of rainfall pattern in Thailand.

Viriya Laung-Aram et al (2008)⁵ has studied climate change trends in Thailand and surrounding countries using high resolution climate data model. High resolution of grid size 20x20 km. and covers a baseline period from the year 1960 – 1999 were used for comparison, and the future period covers the from year 2010 – 2099. From this research, it was also reported that the future climate projection shows increasing trend of temperature throughout Thailand, especially in the central plain of Chao Phraya river basin and lower part of north-eastern region. Hot period over the year will also be longer in the future. Total annual precipitation may fluctuate in the early part of the century but the projection shows clear trend of increasing precipitation from middle of the century onward, especially in the area near Mekong River as well as the southern region, except the western border, where future precipitation may remain almost unchanged. Change in wind speed and wind direction can be detected in the coastal zone, where south-west wind speed may increase by 3-5% in the future.

⁵ Viriya Laung-Aram, Chalermrat Sangmanee, Jutatip Thanakitmetavut (2008) "Simulating future climate scenarios for Thailand and surrounding countries", Thailand Research Fund (TRF)

Also, there has been the prediction on the increase in mean annual temperature with the longer period of summer and more days of higher temperature than 33°C. The number of cold days will be decreased, but with higher rainfall intensity. Water shortage and increasing in drought and flood frequency in some river basins are predicted. There is also expectation of climate change impacts on rice productivity change. Wet season crop might increase in some areas and might decrease in other areas. Water quantity decrease will damage the wetlands areas, while the coastal zones will be damaged by the increasing severe coastal erosions and changes in the accretion patterns. The current severe coastal erosion has been reported that 23 coastal provinces in Thailand have lost 599 square km or 21% of 2,667 km. Bangpakong and Maeklong coastal ecosystems are the most at risk. (More than 25 m. per year)

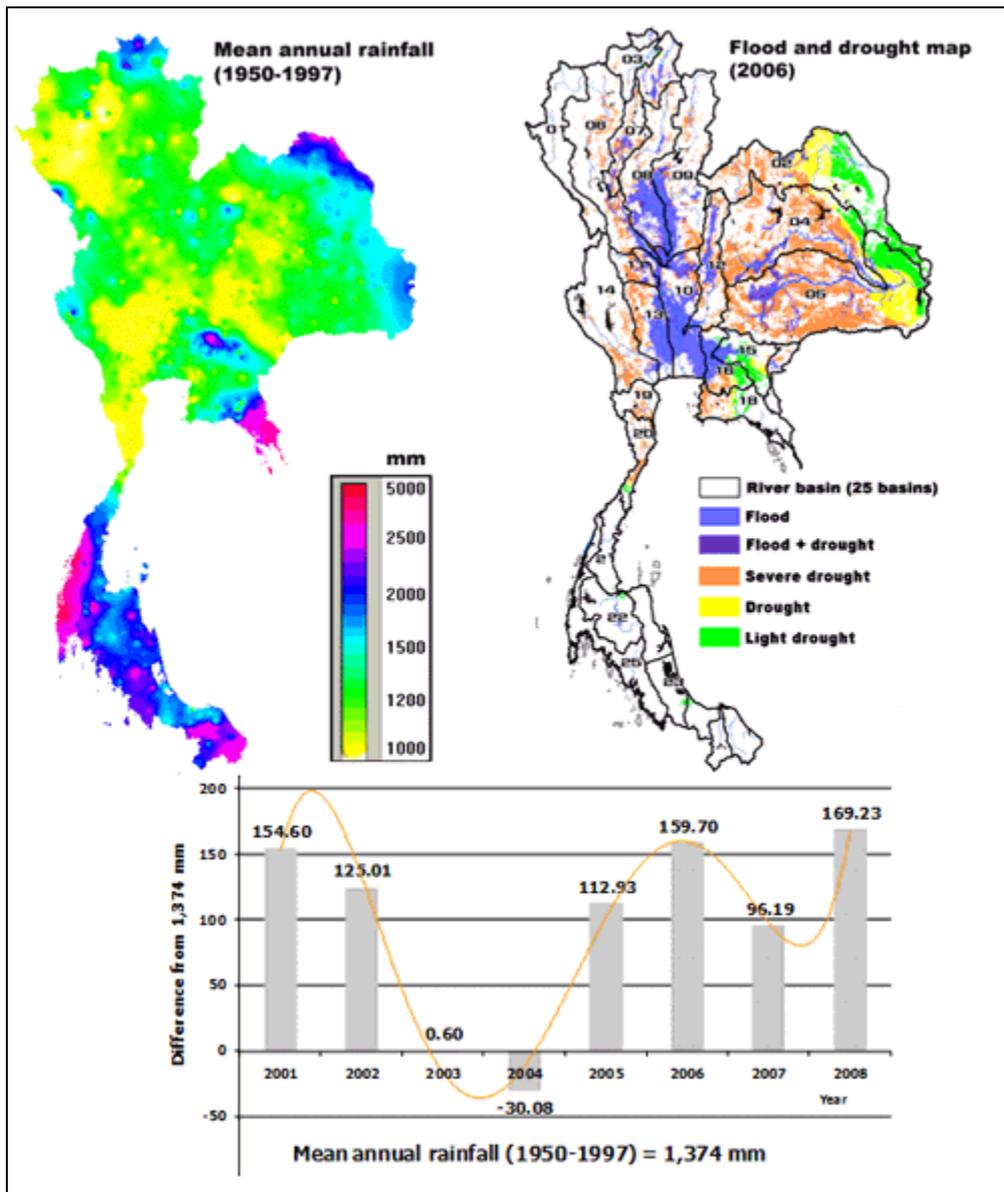


Figure 5 Variability of rainfall pattern in Thailand

While Thailand is considered as a rice bowl of the world, rice cultivation is forced to face many pressures; for example, Environmental issue and erratic weather patterns. Considering the more concern issue of erratic weather pattern, during the past decade, weather patterns in Thailand have fluctuated from severe droughts to severe floods.

Between 1990 and 1993, rainfall was below normal levels, causing water shortages in 1993. An intense rainfall in 1994-1995, in 2010 and just recently in 2011 has resulted in the worst floods in Thailand's recent history. In 2005, 11 million people in 71 provinces were affected by water shortages. In 2008, the population suffers from severe drought again, with over ten million people in the rural agricultural region affected. According to Thailand's Disaster Prevention and Mitigation department, 55 of the country's 76 provinces have suffered, damaging over 150,000 rai (60,000 acres) of farmland, primarily rice paddies. The drought has contributed to global concern of food crisis and soaring grain prices.

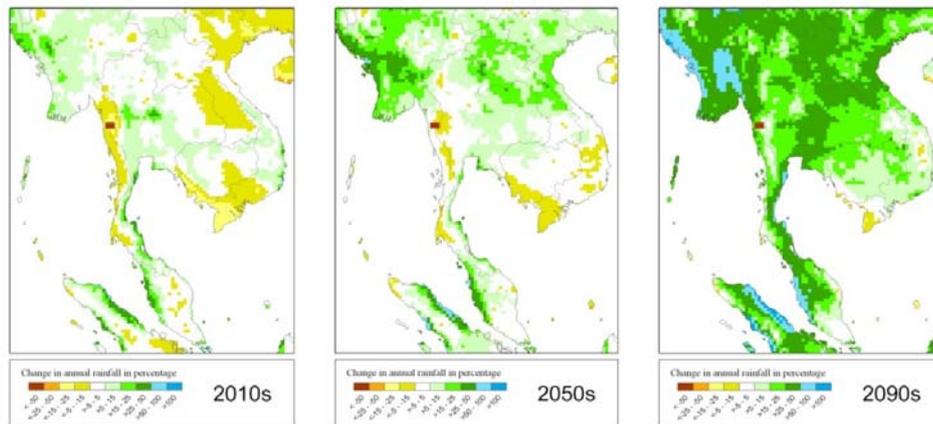


Figure 6 Projection of change in precipitation (%) over 2010s to 2090s

Example of severe flood phenomena

2011 Thailand floods (started from to 25 July 2011 to 16 January 2012)

Various regions of Thailand are prone to seasonal flash-flooding due to their tropical savannah climate. The floods often occur in the North and spread down the Chao Phraya River through the central plains, in the Northeast along the Chi and Mun Rivers flowing into the Mekong, or in the coastal hillsides of the East and South. Drainage control systems, including multiple dams, irrigation canals and flood detention basins, has been implemented, but is inadequate to tackle such immense flood volume as well as to prevent the cities from flood damage, especially to rural areas. A lot of effort, including a system of drainage tunnels begun in 2001, has been put into preventing the enormous flooding of the capital city, which lies near the mouth of the Chao Phraya and is prone to flooding, with considerable success, Bangkok having seen only brief and minor flooding since the major flood of 1995. Figure 7 shows Thailand flood history (2005 to 2010). Ominously, rainfall for March over the area of northern Thailand was an extraordinary 344% above the mean. Bhumibol Dam in particular got 242.8 mm of rain, 224.7 mm above the normal 25.2 mm; since 1 January the dam had accumulated 245.9 mm, 216.0 mm or 186% above normal. In October floodwaters moved downward and reached the Chao Phraya basin as well as inundated parts of the capital city of Bangkok. Flooding persisted in some areas until mid-January 2012. According to this, there has been report of 815 deaths (with 3 missing) and 13.6 million people affected. Sixty-five of Thailand's 77 provinces were declared flood disaster zones, and over 20,000 square kilometres (7,700 sq mi) of farmland was damaged. The disaster has been described as "the worst flooding yet in terms of the amount of water and people affected."⁶ Figure 8 shows affected area of 2011 floods (October).

⁶ "รายงานสรุปสถานการณ์ อุทกภัย วาตภัย และดินโคลนถล่ม ฉบับที่ 129 วันที่ 17 มกราคม 2555" (Flood, storm and landslide situation report)" (in Thai). 24/7 Emergency Operation Center for Flood, Storm and Landslide. 17 January 2012. Retrieved 25 January 2012.

Based on the World Bank (2012)⁷, it was claimed that the 2011 flood has caused an estimate 1,425 billion baht (US\$ 45.7 Bn) in economic damages and losses, as of 1 December 2011. Most of this was to the manufacturing industry, as seven major industrial estates were inundated by as much 3 meters (10 feet) during the floods. Disruptions to manufacturing supply chains affected regional automobile production and caused a global shortage of hard disk drives, which is expected to last throughout 2012. It was also claimed that this disaster has ranked as the world's fourth costliest disaster as of 2011 surpassed only by the 2011 earthquake and tsunami in Japan, 1995 Kobe earthquake, and Hurricane Katrina in 2005.

The flooding has also been described as "the worst flooding yet in terms of the amount of water and people affected". Employment has been hurt when factories flooded and workers were laid off or fired. Not all factories are expected to reopen causing significant long term job loss in Central Thailand.

Figure 9 shows Satellite photographs of flooded area in Ayutthaya and Pathum Thani Provinces in October (right), compared to before the flooding in July (left)

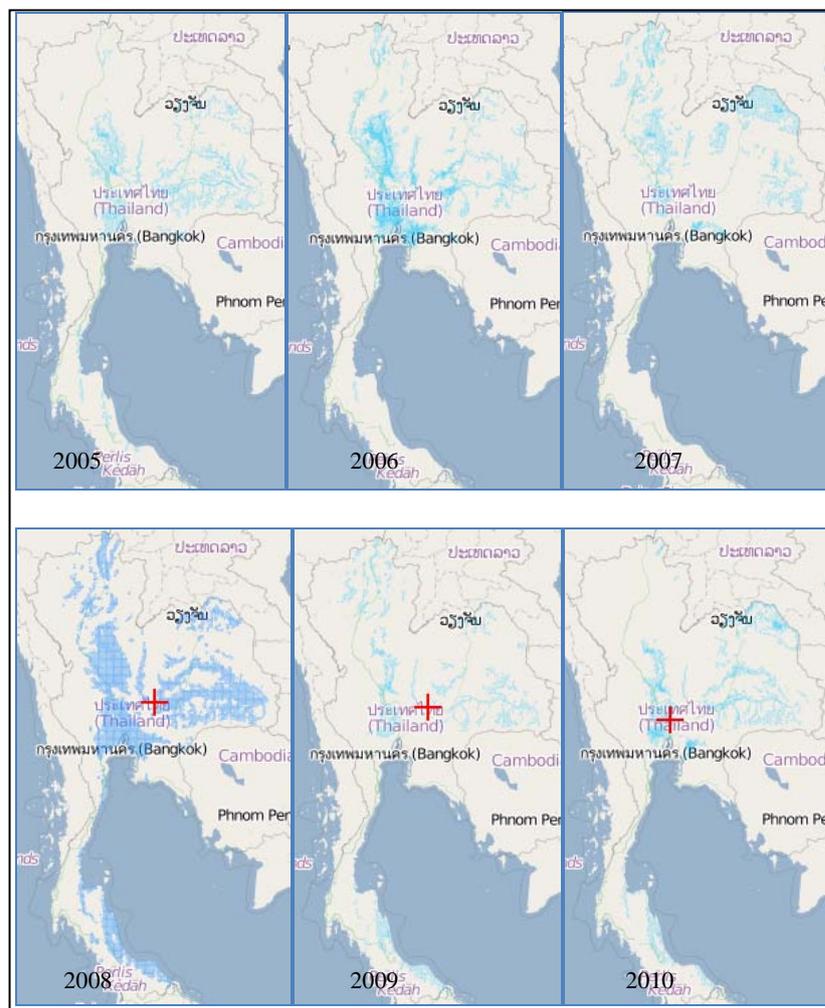


Figure 7 Thailand flood history (2005 to 2010)⁸

⁷ The World Bank Supports Thailand's Post-Floods Recovery Effort". World Bank. 13 December 2011. Retrieved 25 January 2012.

⁸ Thailand Flood Monitoring : <http://flood.gistda.or.th/>, Date taken 7 October 2011

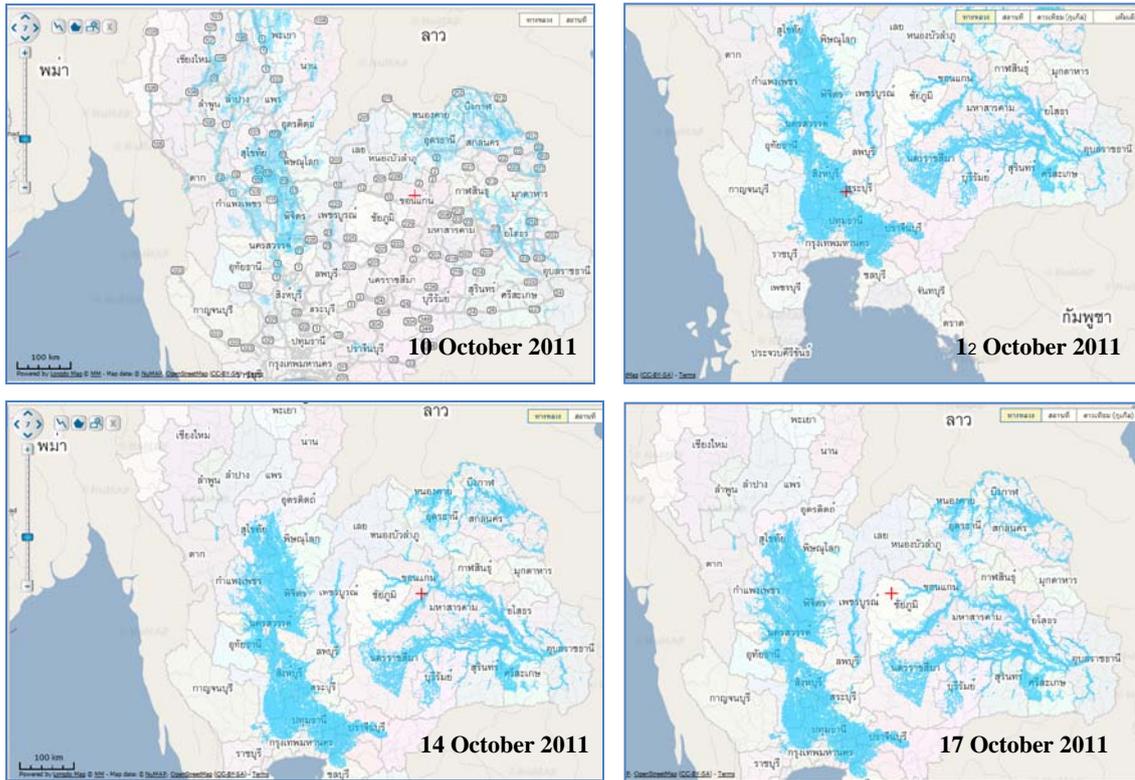


Figure 8 Thailand mega floods 2011⁹



Figure 9 Satellite photographs of flooded area in Ayutthaya and Pathum Thani Provinces¹⁰

⁹ ระบบบริหารจัดการงานอุทกภัยของกรมทางหลวงชนบท, กรมทางหลวงชนบท (Department of Rural Road): <http://fms2.drr.go.th/>, Date taken 7 October 2011

¹⁰ “2011 Thailand floods” File:2011 flooding in Ayutthaya Province-EO-1 merged.jpg : http://en.wikipedia.org/wiki/2011_Thailand_floods

Key challenges to CC adaptation in agriculture and environment

Thailand's adaptation strategies

As reported by Aree Wattana Tummakird (2006)¹¹, Thailand's adaptation strategies cover 5 major areas. These include: (1) Forests and Biodiversity (2) Coastal Areas (3) Agriculture (4) Water Resources and (5) Health

Forests and Biodiversity

- Promote capacity building on forest vulnerability and adaptation analysis
- Encourage reforestation with drought and heat tolerant species
- Prioritize protected areas for conservation
- Establish gene banks and collection of various plant cultures

Coastal Areas

- Develop guidelines on management and development of coastal areas
- Improve drainage and flood control facilities
- Improve cropping systems suitable to changing environment e.g. by using organic matter to improve salinity conditions
- Improve crop cultural practices

Agriculture

- Promote conservation of local drought-resistant varieties of paddy rice
- Improve drought-tolerant crop varieties
- Improve cropping practices to minimize water use
- Adopt risk-averse cropping systems
- Analyze potential crop substitution in different regions
- Promote crop diversification programs

Water Resources

- Promote integrated watershed management
- Support community-based water resource management
- Encourage water conservation and crop diversification in agriculture

Health

- Support R&D of health impacts from climate change
- Explore alternatives to cope with outbreak and disease resurgence

In summary, climate change impacts poses significant risks and burdens to development and the environment in Thailand through its expected impacts on temperature, seasonal rainfall patterns and extreme events. Significant impacts are anticipated in many domains. Ecosystems and biodiversity are often already under severe pressure from human activities.

Agriculture is crucial to both Thailand economic development and guarantee for food security. Its stability and vulnerability is subjected to both water availability and right temperature. Many of the risks from erratic weather patterns are likely to be worsen by water insecurities, which in a monsoonal climate can mean both too much and too little depending on the time of year, with impacts on both rural and urban livelihoods.

¹¹ Aree Wattana Tummakird (2006) "Climate Change Impacts & Adaptation in Thailand", Workshop on Mainstreaming Policies and Investment in Low Carbon: Opportunities for New Approaches to Investment and Flexible Mechanisms 31 August 2006 United Nations Conference Centre – Bangkok, Thailand

Conclusion

Scientific knowledge about the risks posed by climate changes in Thailand has expanded substantially in the past decade but major gaps persist and many adaptation options still need to be further explored. Most research has focused on understanding potential impacts, vulnerabilities and sensitivities. Much more work is needed to be achieved in the near future, for example adaptation options and building adaptive capacities.

Examples of improvement issues that need to be achieved in the approaching years include the following:

- Review of institutional arrangement/Law enforcement
- Prediction/Projection
- Warning System
- Disaster management systemization
(Pre-stage, Rescue-stage, Post-stage, Evaluation)
- Capacity building (every sector)
- Research and Development
- Building Capacity

Considering Flood Mitigation and Management during 2011 floods, there are many agencies involved in this action such as Thai Meteorological Department (TMD), Department of Water Resource (DWR), Royal Irrigation Department (RID), Department of Disaster Prevention and Mitigation (DDPM) Bangkok Metropolitan Authority (BMA), Electricity Generating Authority of Thailand (EGAT), Department of Public Works and Town and Country Planning (DPWP), Land Development Department (LDD), and other supporting agents such as HAIL, GISTDA etc. This has shown complexities and difficulties, in views of both institutional arrangement and law enforcement, for government to tackle the problems during the crisis.

Focusing on flood mitigation measures, it is necessary to consider both structural- and non-Structural Measures

Structural Measures:

- Multi-purpose reservoir
- Reservoir chainage
- Floodwalls/Dikes/Embankments/Improve drainage channels
- Flood retention basins/Retardation area
- Polder, drainage regulators and pumping system
- Diversion channel/Flood way
- By Passing canals
- Shift paradigm : From “Fail safe” to “Safe fail”

Non-Structural Measures:

- Improvement of reservoir operation
- Review “Rule Curves”
- Management of floodwater / flood retardation area
- Land use control
- Flood forecasting and flood warning system
- Flood relief/compensation
- Assurance for flood hazard management
- Shift paradigm : “Living with flood”

References

- [1] “List of countries by carbon dioxide emissions” The United States Department of Energy's Carbon Dioxide Information Analysis Centre (CDIAC), http://en.wikipedia.org/wiki/C90_List_of_countries_producing_90%25_of_carbon
- [2] “Country data : Thailand” CO₂ Scorecard, <http://www.co2scorecard.org/countrydata/> date taken 1st May 2012
- [3] Wijarn Simachaya (2010) “Climate Change Impacts to the Water Environment: Thailand” for The 2nd International Workshop (Climate change and the Water Environment) WEPA International Workshop, 23 February 2010, Shiba-Park Hotel, Tokyo, Japan
- [4] Tubtim Limsoontorn (2010) “National Strategy of Climate Change Management : Modeling and Data Application”, Data Democracy Workshop on Climate Change Geo-Informatics and Space Technology Development Agency 7-10 June, 2010 Bangkok Thailand
- [5] Viriya Laung-Aram, Chalermrat Sangmanee , Jutatip Thanakitmetavut (2008) “Simulating future climate scenarios for Thailand and surrounding countries” , Thailand Research Fund (TRF)
- [6] “รายงานสรุปสถานการณ์อุทกภัย วาตภัย และดินโคลนถล่ม ฉบับที่ 129 วันที่ 17 มกราคม 2555” (Flood, storm and landslide situation report)" (in Thai). 24/7 Emergency Operation Centre for Flood, Storm and Landslide. 17 January 2012. Retrieved 25 January 2012.
- [7] The World Bank Supports Thailand's Post-Floods Recovery Effort". World Bank. 13 December 2011. Retrieved 25 January 2012.
- [8] Thailand Flood Monitoring : <http://flood.gistda.or.th/>, Date taken 7 October 2011
- [9] ระบบบริหารจัดการงานอุทกภัยของกรมทางหลวงชนบท , กรมทางหลวงชนบท (Department of Rural Road): <http://fms2.drr.go.th/>, Date taken 7 October 2011
- [10] “2011 Thailand floods” File:2011 flooding in Ayutthaya Province-EO-1 merged.jpg: http://en.wikipedia.org/wiki/2011_Thailand_floods
- [11] Aree Wattana Tummakird (2006) “Climate Change Impacts & Adaptation in Thailand”, Workshop on Mainstreaming Policies and Investment in Low Carbon: Opportunities for New Approaches to Investment and Flexible Mechanisms 31 August 2006 United Nations Conference Centre – Bangkok, Thailand