

## The Impacts of Long-term Climate and Forest Ecosystem Changes over the 1951-2009 Period in Thailand

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### ABSTRACT

*It is important to understand the aspects of climate system and forest ecosystem changes over the short- and long-term. This study explored climate and forest areas change in Thailand using rainfall data, temperature data, forest area change and discussed the likely impacts of these changes on occurrence of natural disasters. GIS-based techniques were used to do mapping of the ecosystem changes with accessible data. Land use/land cover changes were evaluated by using the overlaying technique. The study was based on forest cover data of 1988, 1998, and 2008. From 1988-1998, forest areas in Thailand decreased by 1,408,100 ha or 0.83% per year. However, from 1998-2008, forest areas increased 4,246,328 ha or 2.5% per year. The results indicate that in the latter half of 1951-2009 periods, the annual mean temperature, annual mean maximum temperature and annual mean minimum temperature all showed a clear trend of increasing. The potential impacts of climate and forest area changes on forest management and the occurrence of natural disasters were discussed. The rising temperature will effect the growth and compositions of forest ecosystems and cause the occurrence of more frequent and severe forest fires. Forest fires can destroy a high percentage of forests in a watershed. Significant reduction in forest covers in turn will cause erosion, landslides and floods.*

**Key words:** Climate change, Forest change, Thailand

### INTRODUCTION

Climate and forest ecosystem changes represent two important components of global changes. Climate change is a very complex phenomenon involving the coupled physical, chemical, and biological processes affecting the atmosphere, land and fresh water surfaces, and the oceans (McNulty and Aber, 2000; NRC, 2010). However, observations and long-term studies indicate that the potential impacts of a changing climate on society and the environment will be significant (Walck, 2009; CEQ, 2010). These changes can be considered at regional levels or types of ecosystem condition in the different levels.

Tropical forest ecosystems around the globe, particularly the ones on which the livelihoods of people from several regions of the world depend, are the most vulnerable ecosystems to climate change variability and long term changes in temperature and rainfall (Juday et al., 1998; CIFOR, 2007). The changes in rainfall, runoff, and temperature will affect the distribution and range of ecosystems and species respectively. These changes will also affect the viability, persistence and resilience of ecosystems on land and in water (Kelly and Adger, 2000; Füssel and Klein, 2006; Solomon et al., 2007). Changes in ecosystems will in turn affect the delivery of ecosystem services, thereby affecting human wellbeing and resilience.

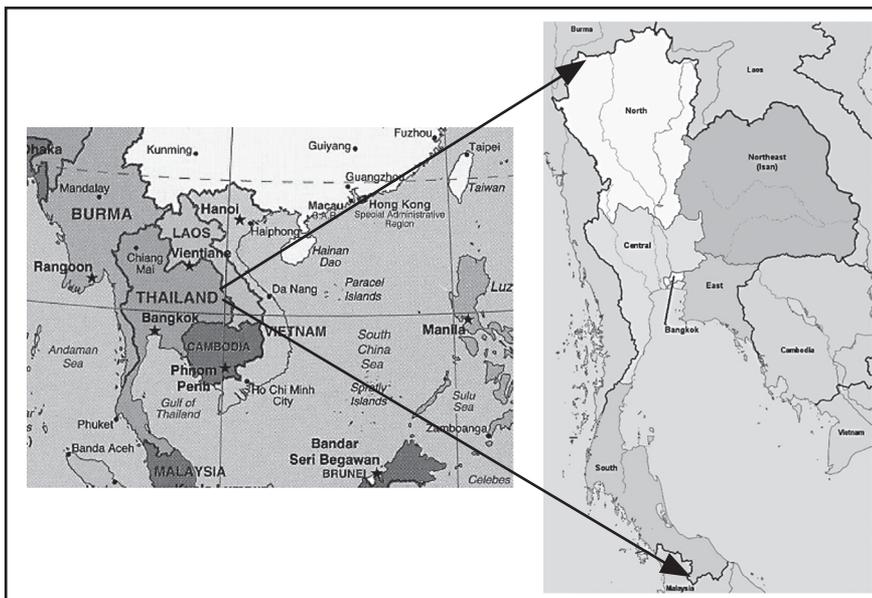
The objectives of this study were to 1) explore climate and forest areas changes in Thailand using rainfall data, temperature data, forest area change and 2) discuss impacts of these changes on growth and compositions of forest ecosystems and the occurrence of natural disasters. GIS-based techniques were used to do mapping of the ecosystem change with accessible data.

## MATERIALS AND METHODS

### Study description

Thailand is located in Southeast Asia, adjoining Laos and Burma (Myanmar) to the north, Cambodia and the Gulf of Thailand to the east, Burma and the Andaman Sea to the west, and Malaysia to the south (Figure 1). Its total area, which is about twice the size of Wyoming, measures 513,115.02 square kilometers. Thailand is located between latitudes 5° 37'N to 20° 27'N and longitudes 97° 22'E to 105° 37'E. The length of its coastline measures 3,219 kilometers (2,000 miles). Thailand is composed of four main regions that are North, North East, Central, and South.

The tropical evergreen forests are found in all areas of Thailand. A common characteristic of tropical evergreen forest is the appearance of lush green vegetation all year round. The forest is home to hundreds of species of flora that grow in close proximity, all of which do not lose their leaves. The north and northeast is drier than other areas thus the forest has slightly different vegetation. The weather in Thailand is tropical and the climate is generally hot and humid. The hot and dry season is from March to June and April is the hottest month across the country. From July to October is the monsoon season when most of Thailand's annual rainfall is accumulated. From November to February the northeast monsoon blows cool, dry air which serves as a respite from the heat. During this cool season, the temperature ranges from 18 to 32 degrees centigrade.



**Figure 1.** Thailand-the study area.

Source: <http://thailandforvisitors.com/general/regions.html>

### Data collection

This study was carried out in land use categorization/classification and mapping of the study sites according to past and present, and the baseline data in period: 1961-2009. It highlights the climate change scenarios selected, approaches to temperature, and precipitation. Some of the information of land use maps such as forest change, land cover and the impact of climate and forest change are also used in disaster risk management. The impacts of climate change, including higher surface temperatures, floods, and droughts (Kisner, 2008) uncertainties and errors involved in different steps of the analysis are also discussed (Boonprakrob and Hattirat, 2006).

The data set obtained from the Meteorological Department of Thailand consists of monthly averaged mean, maximum, minimum temperatures. A relatively stable network of stations and consistency in operational procedures ensure that the quality of surface weather observations in Thailand, for climate studies, is somewhat good (Ouprasitwong, 2002; Brishavana and Ouprasitwong, 2002).

The study covered change on the capacity of climate, forests ecosystem changes and impacts of climate changes. The following goods and services were studied

- i) Climate changes
- ii) Forest ecosystem changes
- iii) The impacts of climate changes.

## RESULTS AND DISCUSSION

### Climate changes

#### Temperature

According to the Thai Meteorological Department (TMD), there has integrated climate group and climate academic group forming to the National Climate Center of Thailand (NCCT). NCCT is the unique center of the country to provide climate information, climate research and application, climate change and strength cooperation to international climate service and research. The average temperature in Thailand during the 1950-2007 period is presented in Figure 2. The results clearly to show that the annual mean temperature in Thailand during the past 58 years is increasing steadily at rapidly rate.

The average maximum temperature in Thailand during the 1951-2009 period indicates an increasing trend starting in the year of 1970 (Figure 3). On the other hand, the average minimum temperature graph (Figure 4) suggests an increasing trend since 1955. The characteristic of increasing annual mean minimum and maximum temperature has increased rapid rate. It has the effect of temperature in all regions in Thailand significantly higher at the average rate of 1.35°C within 50 years (Limsakul, 2004). Those are consistent results of this study about the increase in average temperature.

Figure 5 showed the distribution of maximum temperatures in North and North-east Thailand during 1978-2007 period. The maximum temperature is 44°C at Tak province in Northern Thailand on 25 April 2007. By 2010, increases in temperature and the length of the hot season would have been large enough and of long enough duration to heat significant areas in Thailand.

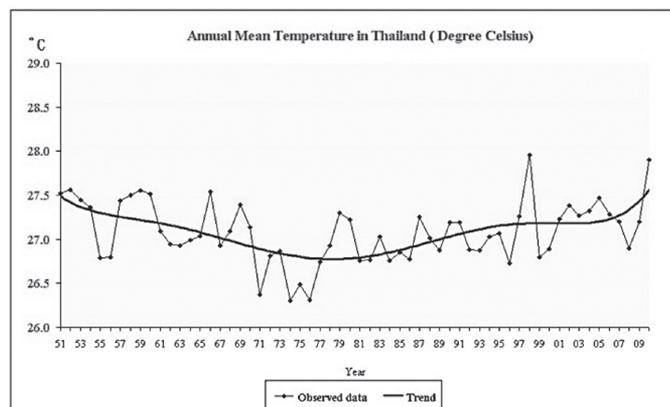


Figure 2. Annual mean temperature in Thailand during 1951-2009 (TMD, 2010).

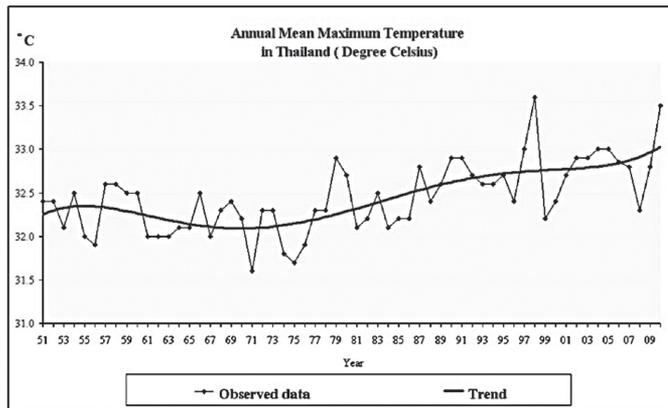


Figure 3. Annual mean maximum temperatures in Thailand, 1951-2009 (TMD, 2010).

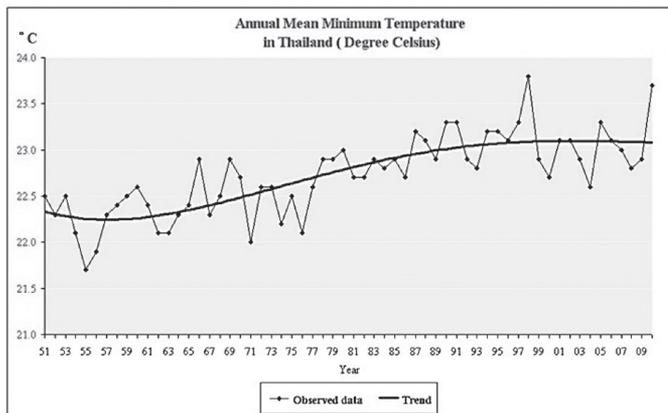


Figure 4. Annual mean minimum temperatures in Thailand, 1951-2009 (TMD, 2010).

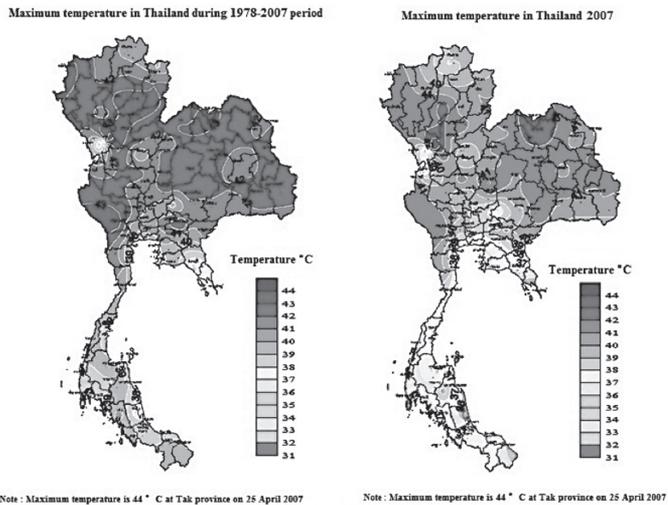


Figure 5. Maximum temperature in Thailand (a) 1978-2007, (b) 2007 (TMD, 2010).

### Precipitation

Thai Meteorological Department (TMD) has reported the variability in annual rainfall. This data is used to examine the characteristics of rainfall at different times and space scales as shown in Figure 6 for the period 1951-2009. The graph shows an increasing in frequency and magnitude of rainfall. Annual precipitation first shows a decreasing trend followed by increasing after 1989. Chitradon et al. (2009) provided the annual rainfall data in Thailand, as an average annual rainfall of over 1,300 mm. Table 1 has show annual rainfall, rain-days and relative humidity, selected by location and by region during 2006-2010 period. The South region has the highest quantity of all types. There are only two seasons in the south region, rainy and summer. Conversely, in the north, northeast, central, and east regions, there are three seasons, winter, summer, and rainy. Hydro and Agro Informatics Institute in Thailand has reported mean annual rainfall in Thailand data as illustrate in Figure 7.

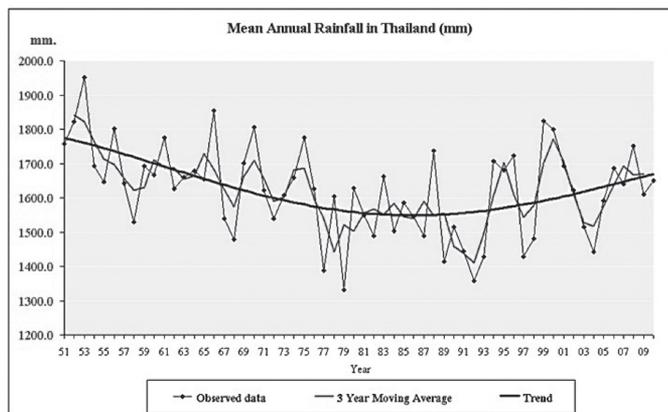


Figure 6. Mean annual rainfall in Thailand 1951-2009 (mm) (TMD, 2010).

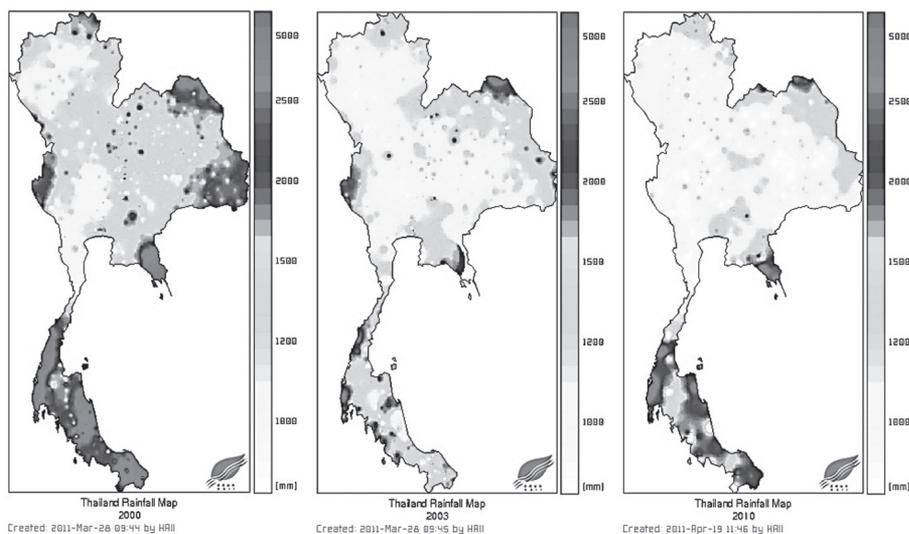


Figure 7. Mean annual rainfall in Thailand (a) 2000, (b) 2003, (c) 2010 (Hydro and Agro Informatics Institute, 2011).

**Table 1.** Annual rainfall, rain-day and relative humidity: selected location by region during 2006- 2010 period (Hydro and Agro Informatics Institute, 2011).

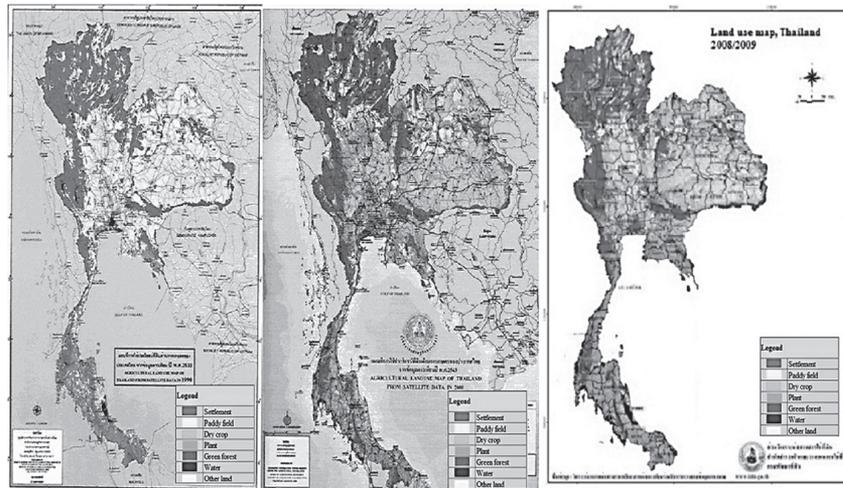
| Region     | 2006          |             |                     | 2007          |             |                     | 2008          |             |                     | 2009          |             |                     | 2010          |             |                     |
|------------|---------------|-------------|---------------------|---------------|-------------|---------------------|---------------|-------------|---------------------|---------------|-------------|---------------------|---------------|-------------|---------------------|
|            | Rainfall (mm) | Rainday day | Relative humidity % | Rainfall (mm) | Rainday day | Relative humidity % | Rainfall (mm) | Rainday day | Relative humidity % | Rainfall (mm) | Rainday day | Relative humidity % | Rainfall (mm) | Rainday day | Relative humidity % |
| North      | 1,478         | 125         | 75                  | 1,241         | 115         | 72                  | 1,333         | 139         | 74                  | 1,108         | 113         | 73                  | 1,310         | 114         | 72                  |
| North-east | 1,435         | 115         | 72                  | 1,520         | 114         | 71                  | 1,727         | 134         | 73                  | 1,514         | 115         | 72                  | 1,492         | 121         | 72                  |
| Central    | 1,165         | 112         | 74                  | 1,163         | 110         | 72                  | 1,243         | 127         | 73                  | 1,188         | 111         | 73                  | 1,204         | 107         | 75                  |
| East       | 1,958         | 135         | 76                  | 1,825         | 136         | 74                  | 1,903         | 142         | 75                  | 1,836         | 137         | 75                  | 1,894         | 135         | 76                  |
| South      | 2,234         | 177         | 82                  | 2,340         | 173         | 79                  | 2,545         | 166         | 80                  | 2,339         | 168         | 79                  | 2,407         | 172         | 80                  |

**Table 2.** Forest areas in Thailand 1988, 1998, and 2008 (Royal Forest Department, 2010).

| Year<br>Region | Total area of Thailand |            | 1988       |            | 1998       |            | 2008       |            | Change of forest area |            |           |            |           |            |
|----------------|------------------------|------------|------------|------------|------------|------------|------------|------------|-----------------------|------------|-----------|------------|-----------|------------|
|                | (ha)                   | % of total | (ha)       | % of total | (ha)       | % of total | (ha)       | % of total | 1988-1998             |            | 1998-2008 |            | 1988-2008 |            |
|                |                        |            |            |            |            |            |            |            | (ha)                  | % per year | (ha)      | % per year | (ha)      | % per year |
| North          | 16,964,429             | 47.39      | 8,040,200  | 43.06      | 7,305,700  | 55.31      | 9,515,434  | 32.89      | -734,500              | -0.43      | 2,209,734 | 1.30       | 1,475,212 | 0.43       |
| North - East   | 16,885,440             | 14.03      | 2,369,300  | 12.43      | 2,098,400  | 16.51      | 2,770,174  | 27.43      | -270,900              | -0.16      | 671,774   | 0.40       | 401,244   | 0.12       |
| East           | 3,650,250              | 25.59      | 1,724,400  | 23.81      | 1,604,900  | 21.97      | 806,214    | 33.44      | -119,500              | -0.07      | -798,686  | -0.47      | -918,183  | -0.27      |
| Central        | 6,739,870              | 20.69      | 1,724,400  | 23.81      | 1,604,900  | 32.89      | 2,000,907  | 27.43      | -119,500              | -0.07      | 396,007   | 0.23       | 488,111   | 0.14       |
| South          | 7,071,519              | 28.03      | 1,463,000  | 17.15      | 1,212,500  | 25.28      | 2,125,799  | 25.28      | -250,500              | -0.15      | 913,299   | 0.54       | 450,745   | 0.13       |
| Whole Kingdom  | 51,311,502             |            | 14,380,300 |            | 12,972,200 |            | 17,218,528 |            | -1,408,100            | -0.83      | 4246328   | 2.50       | 2,838,129 | 0.84       |

### Forest ecosystem changes

The information on extent of forest areas in Thailand is shown in Table 2. By 1988 the Royal Forestry Department of Thailand (RFD) reported that there was just over  $14 \times 10^6$  ha (or 28% of total area of Thailand) of forest remaining. This loss of forest in the period 1988-1998 corresponds to an annual clearing rate of over  $0.14 \times 10^6$  ha (or 0.83% per year). However in 2008 Thailand had a forest area  $17 \times 10^6$  ha (or 33.44%). This was an increase of total forest area to over  $2.8 \times 10^6$  ha (or 0.84% per year) in the period 1988-2008. During that time Northern Thailand had the highest rate of increase in forest area of  $9 \times 10^6$  ha. It also has the highest percentage increasing rate in the region; approximately 0.43% of the forest area in 1988 had been increase by 2008. Most of the deforestation in Thailand took place in the northern mountainous region around the province of Chiang Mai and in eastern Thailand along the Cambodian border where shifting cultivation, expansion of commercial agriculture and logging are very active. The total area of Northern Thailand is  $17 \times 10^6$  ha, with  $9.5 \times 10^6$  ha (or 55.3% of the total area) forest in 2008. The loss of forest largely occurred during the 1988-1998 period. Figure 8 shows the land use map during the year 1990-2008. The North-east and East region has lost many forest areas. But Table 2 shows whole Kingdom has increase forest area at 2008. The conversion of forest had mostly taken place in the Northern region of Thailand.



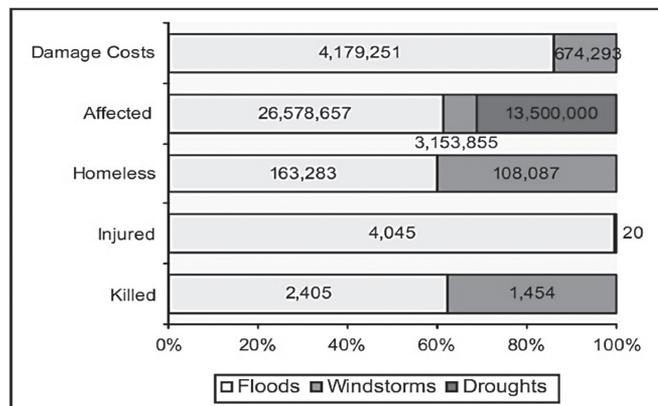
**Figure 8.** Land use map of Thailand (a) 1990, (b) 2000, (c) 2008 respectively (Tangtham, 2009a; Land Development Department, 2010).

### The impacts of climate changes

Forest fires can destroy a high percentage of forest in a watershed. Significant reduction in forest cover in turn will cause erosion landslides and floods. Therefore, increase in forested area by reforestation will be desirable from the viewpoint of disaster mitigation. Adaptation to these changes by modified forest management program will be required. Cheng (1980) reported that the Eden Fire in Canada increased water yield, peak flow magnitudes, soil erosion and stream sedimentation and advanced the timing of snowmelt runoff and annual peak flows.

Floods in Thailand are normally caused by tropical storms and depressions, rarely by typhoons. The tropical storm season starts from May to November. During the first two months and the last month of the season, the probability of storms occurring in the country is minimal. It rises during August to September where the probability is maximal (Tospornsampan and Thai National Mekong Committee, 2006).

Mekong Wetlands Biodiversity Conservation and Sustainable Use Programme (MWBP) (2005) suggested that floods do not often lead to deaths, considering that they make up almost all of the climate-related disaster events (Figure 9). However, they do cause a large amount of damage (86%) to housing, paddy fields, equipment, and other losses that can have longer-lasting impacts on household's well being. The cost of these events is likely underestimated since it is difficult to assign a monetary value to many household assets. The number of people affected in the numerous smaller disasters that are not reported in the international database. It also does not include secondary impacts such as health and sanitation problems in the weeks after a flood. It is also important to note that, although droughts show up only in the "affected" category of Figure 9, the impacts from these disasters has a great impact on communities.



**Figure 9.** Impacts of Climate-Related Hazards in Thailand (1966-2002) (MWBP, 2005).

Thailand has frequently suffered from flood and drought (Figure 10). Because of some parts of the country continue to suffer drought problems due to the uneven distribution of rainfall at 2006. Some particular areas experience both flooding and drought conditions in a single year, due to temporal and spatial uncertainties in the monthly rainfall or the poor management of the conveyance infrastructure. The common practice in Thailand is to manage the risks after considering which areas are likely to be vulnerable to either flood or drought. Thailand has several areas, especially in north-eastern, where both drought and flood occur in the same location (Sooksuwan, 2009). The higher temperatures, floods, droughts, severe storms and sea level rise were the likely effects of climate change. The damage to agriculture, coastal tourism, and the capital city as consequences of climate change will have enormous economic, cultural and environmental impacts.

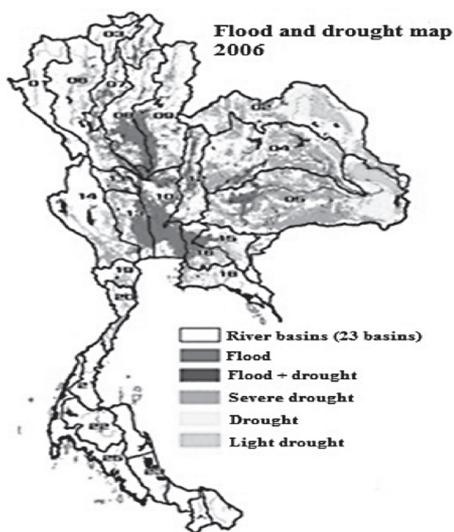


Figure 10. Flood and drought map 2006 (Chitradon et al., 2009).

The growths and conditions will be affected by the forest fires. Under the changing climate, the forest fire also substantially increased due to higher temperatures and long droughts, as well as because of the unstable of precipitation. Climate change will further impact forest fire dynamics. As temperature increases, forest fires may become the primary agent of vegetation change in the vulnerable areas of Thailand. Forest Fire Control Division, Department of National Park, Wildlife and Plant Conservation of Thailand have reported the regional forest areas burnt and frequency of forest fires during 1998-2010 periods (Figure 11 and 12). The impacts that will lead to further dynamic of climate in Thailand that will lead to more conducive conditions for fires of greater magnitude.

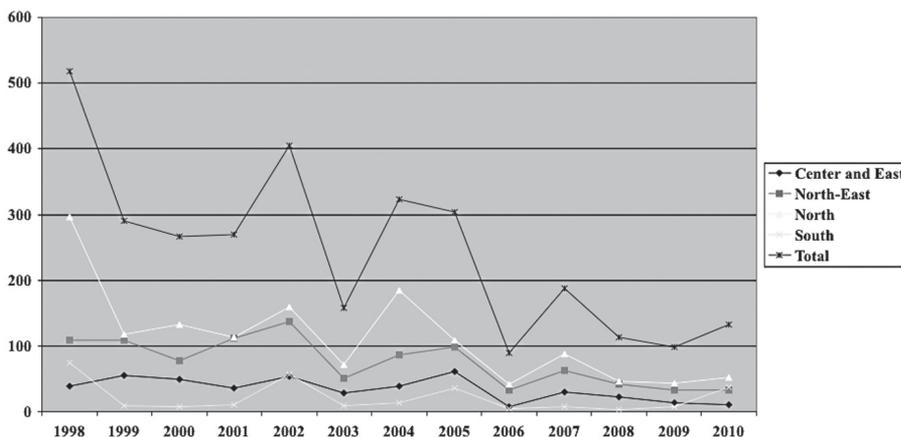
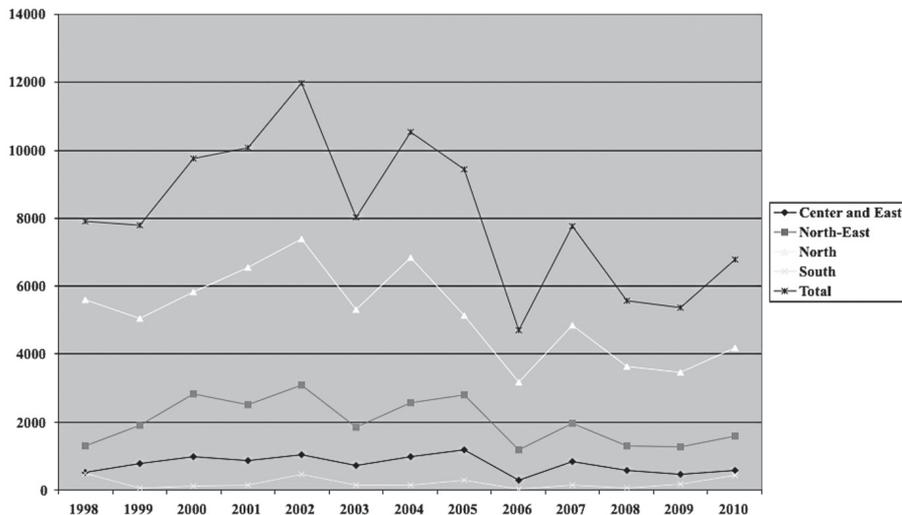


Figure 11. Regional forest areas burnt in Thailand at 9 Year (Year 1998 - 2010) (RFD, 2010).



**Figure 12.** The frequency of forest fires in Thailand at 9 years (Year 1998 - 2010) (RFD, 2010).

The climate changes may include effects the growth and composition of forests. As temperatures rise, the amount of moisture evaporated from land and water surface increased, droughts will become more frequent and more severe, with potentially devastating consequences for agriculture, water supply and human health. The impacts that will lead to further dynamic of climate in the Thailand to more conducive conditions for fires of greater magnitude. Significant changes in forests may be expected with climate change in the future as described in earlier sections. Changes in the distribution and abundance of several forest areas of Thailand in response to short-and-long term variations accompany global warming have been well particularly documented.

## CONCLUSION

Based on the data of 1988, 1998, 2008, from 1988-1998, forest areas in Thailand decreased by 1,408,100 ha or 0.83% per year. On the other hand, from 1998-2008, forest areas increased 4,246,328 ha or 2.5% per year. The results also indicate that in the latter half of 1951-2009 periods, the annual mean temperature, annual mean maximum temperature and annual mean minimum temperature all showed a clear trend of increasing.

Rising temperature may affect the growth and composition of forest ecosystems. It will also results in more frequent and severe occurrence of forest fires. Forest fires have the capability of causing a significant percentage of reduction in watershed forest cover, leading to severe disasters such as erosion, landslides and floods. Therefore, modified forest management programs based on climate change consideration are required.

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