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ESASGD 2016

GIS-IDEAS (2016)

Conference Title: International Conference on GeoInformatics for Spatial-Infrastructure Development in Earth & Allied Sciences (GIS-IDEAS)

Climate change and impact to tourism in Thailand: flood and heat stress-risk scenarios

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Abstract

Climate scientists have been working hard to track climate change by monitoring the change of global climate system continuously since the middle of 19th century. Climate anomalous signals, e.g. increasing temperature and precipitation, appear in forms of aberrant events e.g. longer and frequent flood and drought, harder and unpredictable tropical storm, and more serious heat stress and so on. These events can affect directly to human or indirectly to other human activities. The tourism is one of dominant activities that need to be prioritized since it gains very high income to Thailand. This paper intends to represent two climate-related scenarios including flood and heat stress and how these affect to tourist attractions in Thailand. The rising temperature and precipitation scenarios used in this paper were synthesized from a climate change model package, SimCLIM, which is based on the Fifth Assessment Report (AR5). In case of flood scenario model, this paper used flood data in year 2011 collected from GISTDA's Thailand Flood Monitoring System. Constrained Cellular Automata (Constrained CA) model was applied to simulate flood risk area constrained by the intensity of precipitation in each watershed. On the other hand, the heat index (HI) which is computed using average temperature and relative humidity was used to recognize the heat stress risk zone in Thailand. Finally, the categorized tourist attractions were mapped and superimposed to the risk zone to identify the impact. The heat stress risk of tourism sites in the upper north and the lower south will rise; they will increasingly expose to the heat. Flood simulation reflected higher impact for tourism sites in central, north and northeast parts of Thailand. The results from this paper are useful for associated organizations who need to plan for prevention, protection and adaptation, which is crucial issue in the future schemes.
Keywords: Climate change impacts, Tourism, Cellular Automata, Flood, Heat index

1. Introduction

Climate scientists from around the world have been working on tracking climate change by monitoring change of global climate system since the middle of 19th century. Climate change models were continuously developed from numerous climate laboratories around the world. Those models were used in order to monitor and predict possible atypical situations and their impacts to major sectors in the future. Almost of them represent unusual climate patterns which some of them would appear abruptly and some would happen gradually. Climate anomalous signals, e.g. increasing temperature and precipitation, appear in forms of aberrant events e.g. longer and frequent flood and drought, harder and unpredictable tropical storm, and more serious heat stress and so on.

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These events can affect directly to human or indirectly to other human activities such as agriculture, industry and service sectors.

Tourism is one of dominant activities that need to be prioritized since it gains very high income to Thailand. In year 2015, there are about 29 million international tourists come to visit Thailand, which bring in approximately 2.2 billion Baht (Ministry of Tourism and Sports, Thailand). There are vast amount of tourism sites in every part of Thailand which attract both domestic and international tourists to visit each year. Some of these tourism sites have high possibility to expose to climate change consequences in the future. Therefore, this impact would exceedingly affect to tourism situation in Thailand unavoidably.

This study investigated two climate-related scenarios including flood and heat stress and how these consequences affect to tourist sites in Thailand. The future climate change information was synthesized using SimCLIM software, which is based on the IPCC's Fifth Assessment Report (AR5) (Allen et.al., 2014). Several GIS techniques and spatial modeling were used to integrate climate change data with other information to map the potential risk of flood and heat stress of Thailand. The results from this study are useful for tourism planning in the future, which needs to strengthen adaptive capacity to build adaptable tourism in the future.

2. Objective

1. To model heat stress and flood risk in Thailand using projected climate change information.
2. To assess the impact from climate change consequences including flood and heat stress to tourism sites in Thailand.

3. Framework and methodology

Figure 1 represents the framework of this study. The details of each component are described below:
1. SimCLIM software was used to generate climate information of RCP8.5 scenario. Temperature, relative humidity and precipitation information in raster format of the year 2015 and 2055 were generated.
2. The precipitation data were summarized into watershed area using zonal statistic function.
3. The temperature and relative humidity data were used to calculate heat index maps using heat index equation (Rothfusz and Headquarters 1990).
4. To explore the change of precipitation and heat index, local function was used to calculate the difference between year 2015 and 2055.
5. The precipitation change was used as constraint in cellular automata model to simulate possible flood area in the future based on flood area detected from satellite image in year 2011.
6. Overlaying tourism locations to both heat index risk and flood risk maps to determine the impacts.
7. Summarizing the impact of both risks to tourism sites in Thailand.

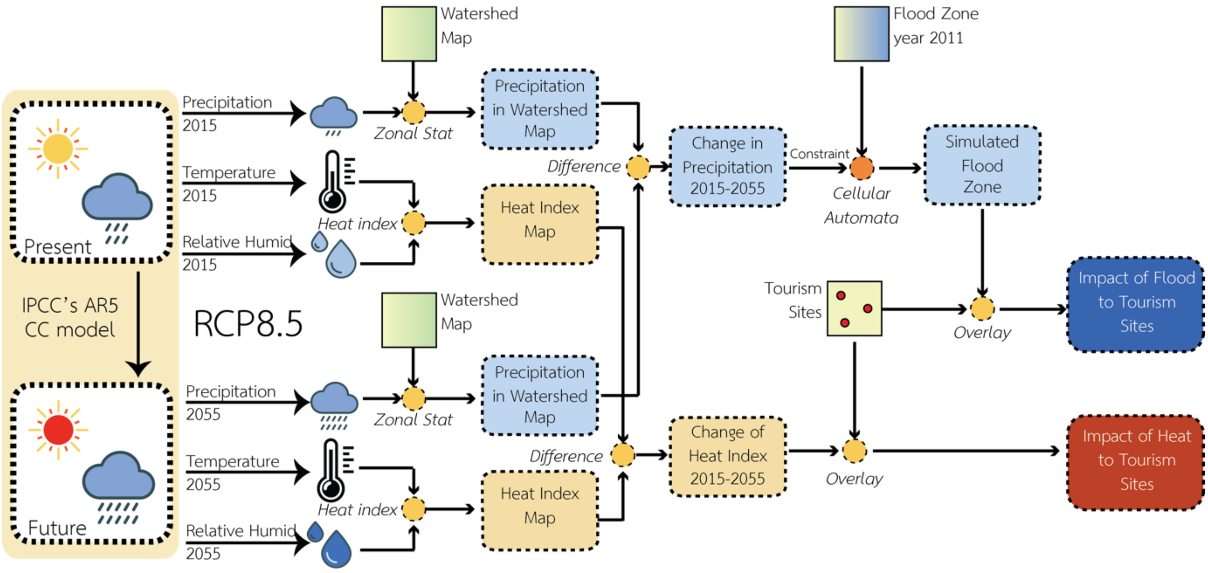


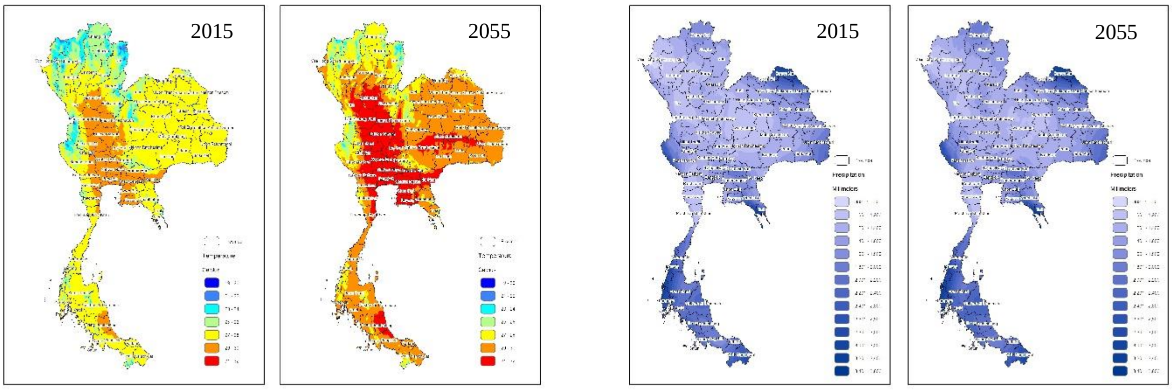
Fig. 1 Conceptual framework

3. Results

3.1 Temperature and precipitation changes based on RCP8.5

The fifth assessment report (AR5) from IPCC represented four climate scenarios according to the concentration of CO_2, called Representative Concentration Path (RCP) including; RCP2.6, RCP4.5, RCP6.0 and RCP8.5. The most severity is RCP8.5 which the projected temperature would rise up to 4.8°C in year 2100. This study used this scenario to model the impact of climate change to tourism sites in Thailand.

According to RCP8.5 scenario, the temperature will rise 1.8°C for the next 4 decades—averagely 0.22°C for every 5 years. The temperature will continuously rise until the year 2100, and then will begin to decline (Rachavong et.al., 2016). Fig.2 represents projected temperature and precipitation maps in the years 2015 and 2055 from downscaling climate data. It is clear that the temperature in the central part of Thailand is rising up. Pattern of projected precipitation is quite the same as the present; there are high intensity of rain in the north eastern, east and south of Thailand.



Temperature Precipitation

Fig. 2 Projected average temperature and precipitation in year 2015 and 2055 (RCP8.5)

3.2 Change of heat index of Thailand

Heat index is an index that represent 'real' temperature that human may feel since it includes the humidity which indicate how human skin can evaporate of sweat. To calculate heat index, the heat index equation was applied using two variables including temperature and relative humidity. The equation (1) is shown below:

$$HI = -42.379 + 2.04901523T + 10.14333127R - 0.22475541TR - 6.83783 \times 10^{-3}T^2 - 5.481717 \times 10^{-2}R^2 + 1.22874 \times 10^{-2}R^2 + 1.22874 \times 10^{-3}T^2R + 8.5282 \times 10^{-4}TR^2 - 1.99 \times 10^{-6}T^2R^2 \quad (1)$$

Where:

HI – Heat Index (Fahrenheit)
T – Temperature (Fahrenheit)
R – Relative Humidity (percentage)

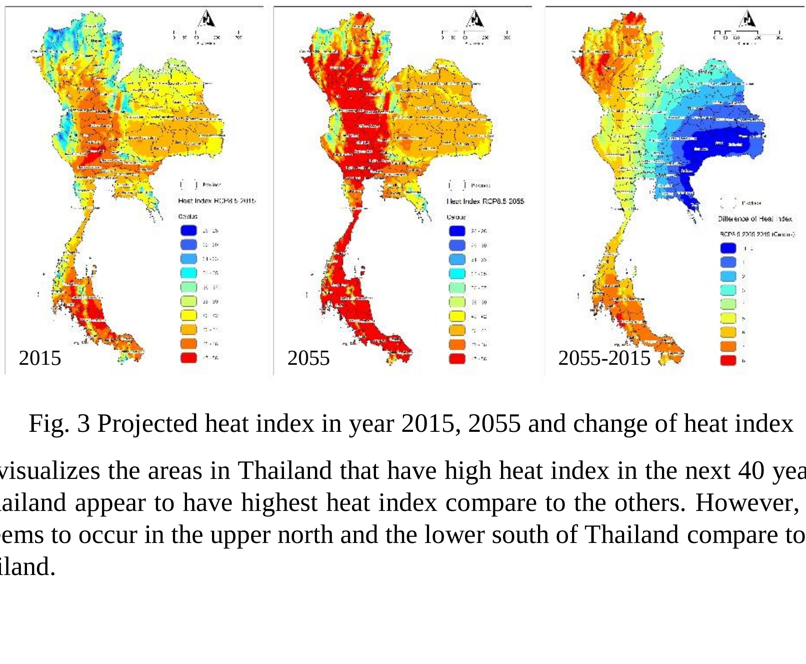


Fig. 3 Projected heat index in year 2015, 2055 and change of heat index

Fig. 3 visualizes the areas in Thailand that have high heat index in the next 40 years. The central, north and south of Thailand appear to have highest heat index compare to the others. However, change of heat index over 40 years seems to occur in the upper north and the lower south of Thailand compare to the northeast and the east part of Thailand.

3.3 Cellular automata and flood simulation

Cellular automata (CA) model is one of the most popular cell-based simulation model which can be applied to several spatial simulation applications, e.g. urbanization, land use change model, wildfire simulation etc. The main concept of CA model is to proceed the target cell (basically central cell) with a set of simple rules applied to the neighborhood cells in each time step. The CA model can be integrated to other spatial model and GIS to create more complex simulation model (Piyathamrongchai and Batty, 2007, Yeh and Li, 2001, Dottori and Todini, 2010).

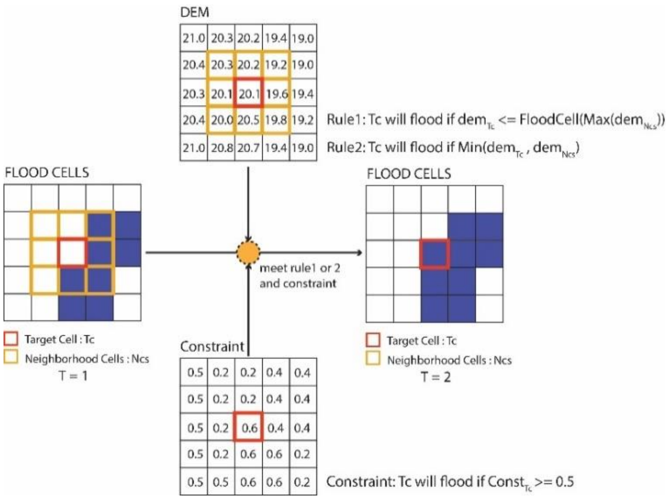
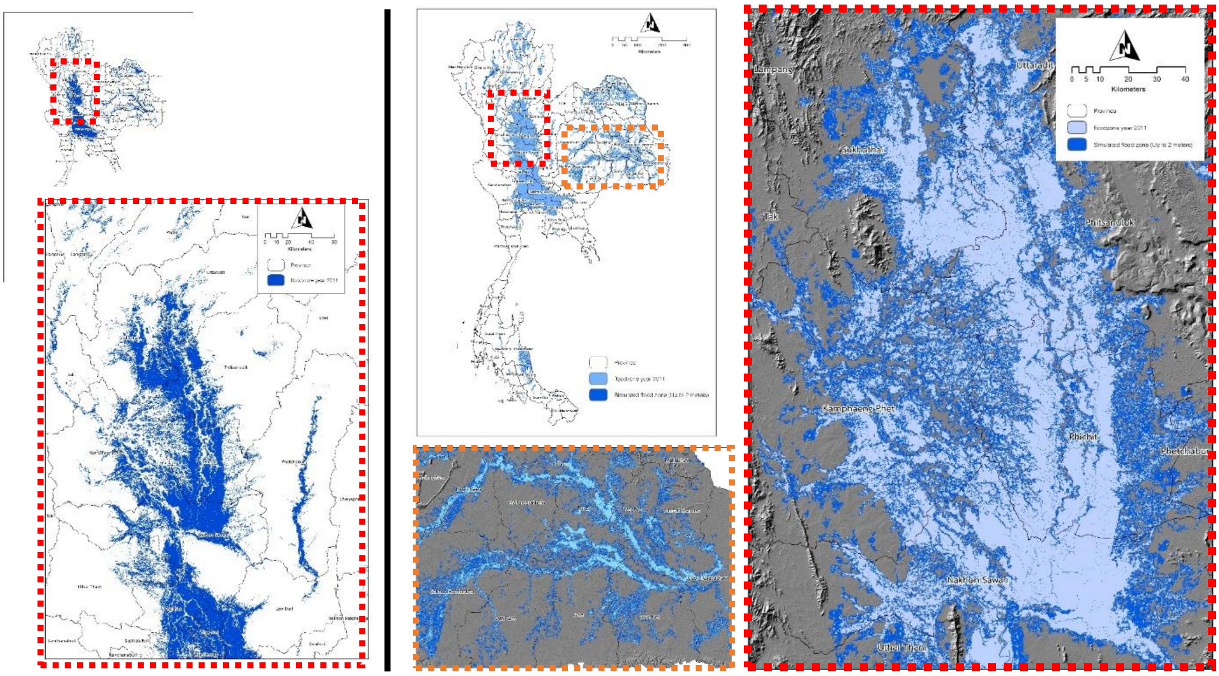


Fig. 4 Concept of cellular automata to simulate flood area



A) Flood in 2011: initial state

B) Simulated flood

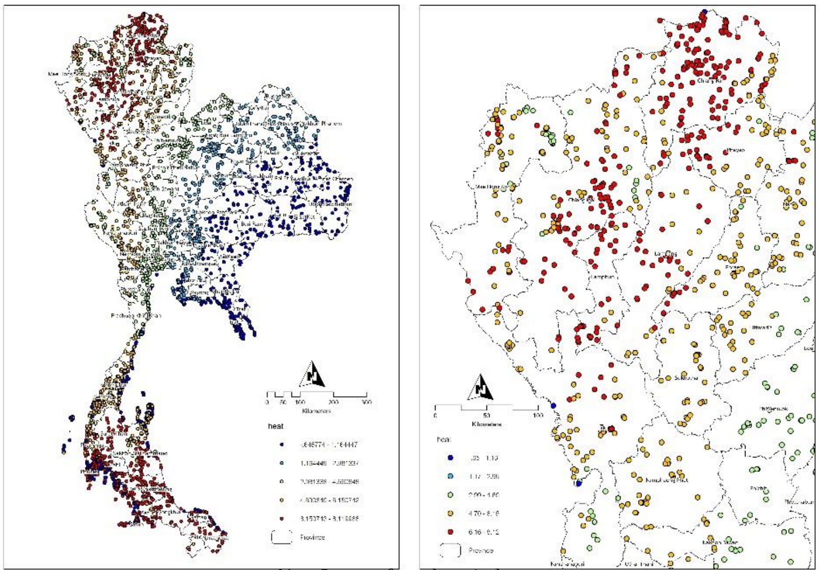
Fig. 5 Simulated flood area in up to 2 meters compare to year 2011

This study applied constrained CA model to simulate flood risk zone in the future. Flood area in year 2011 (the big flood of Thailand) collected from Geo-Informatics and Space Technology Development Agency of Thailand (GISTDA) was used as initial state. Projected precipitation data in each watershed was applied as constraint to generate new flood cells in CA model. The concept behind the flood CA simulation model is described in Fig. 4. The target cell at the first state (T =1) is non-flood cell that connects to at least one neighboring flood cell. During the CA processes, eight neighborhood cells are evaluated using 2 rules: 1) the target cell will be filled up when height value of the target cell (extracted from DEM) is lower than highest neighborhood cells; and 2) the target cell will be filled up when height value of the target cell is lowest value compare to neighborhood cells in T =1. Moreover, the target cell is constrained by potential value evaluated from precipitation that changing over the time. Fig. 4 gives some example that constrained cell matching the target cell is set as 0.6.

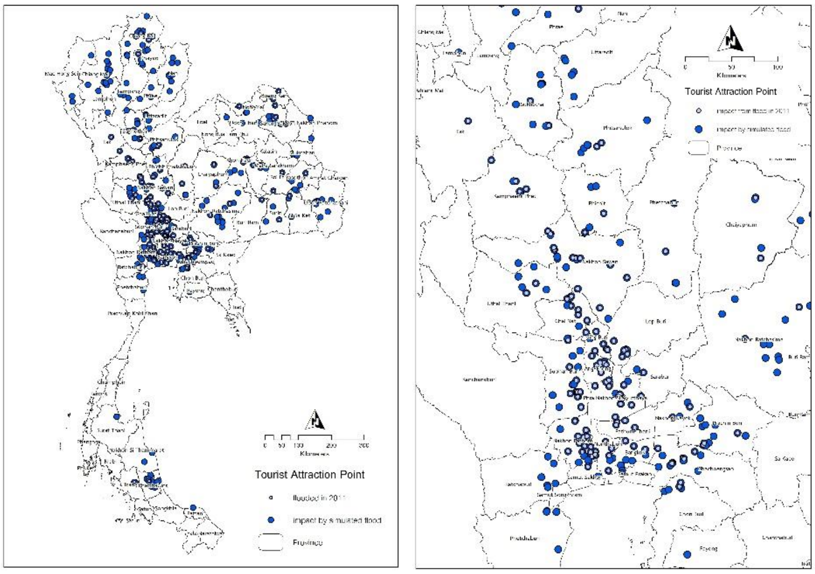
Fig. 5A) represents flood zone at the beginning state of simulation. The most damaged flood event occurred from the lower north part of Thailand to the great plain of Chao Phraya river basin to the gulf of Thailand. The CA model was therefore applied according to the rule described in Fig. 4 in order to observe the flood risk area based on the topography and projected precipitation as shown in Fig. 5B) (flood area in 2011 shown in light blue color and simulated flood visualized in darker blue). The maps show that flood areas expand to surrounding areas with different intensity according to the topography and the constraint. The lower northern, upper central and lower and upper northeastern parts of Thailand are potentially be affected by flooding in the future.

3.4 Impacts to tourism sites in Thailand

This paper represents increasing impact of flood and heat stress to tourism sites in the future based on climate change model. In this study, 3,552 tourism sites were collected from secondary sources and stored in the geo-database. Those were categorized as natural, cultural and historical and national park in order to explore the potential impact. Fig. 6A) represents the tourism sites which are possibly affected by heat stress in the future. The maps clearly show that the tourism sites in Northern Thailand in, e.g. Chiangmai, Chiangrai and Lampang, and the lower Southern Thailand in, e.g. Suratthani, Krabi, Trang and Songkhla, are in high heat stress risk.



A) Impact from heat index



B) Impact from simulated flood

Fig. 6 Impact of heat stress and simulated flood to tourism sites

Fig. 6B) visualizes impact of flood area simulated from CA model compare to flood in year 2011. Mostly, tourism sites in the Central Thailand have higher impact than other regions in year 2011. However, flood simulation model provides expansion of flood risk zone in every regions in Thailand. This causes impact to more tourism sites in each region. The number of tourism sites affected from flood risk increase up to 238 sites (from 151 to 389). Chiangmai, Chiangrai and Nakornratchasrima are the provinces which have most change in number of tourism sites. Mostly, the heat stress risk affects to natural tourism sites and in provincial level (see Fig. 7A) and B)).

Fig. 7C) and D) shows the impact of simulated flood to tourism sites according to tourism classes and types. All classes of tourism sites are affected by flood risk area. There are 26 more popular international tourism sites possibly locate in flood risk zone in the future. The result represents most of affected tourism sites are in provincial and local classes (see Fig.7C)). In case of tourism type, cultural and historical tourism sites have higher impact from flood risk compare to natural tourism sites and national parks.

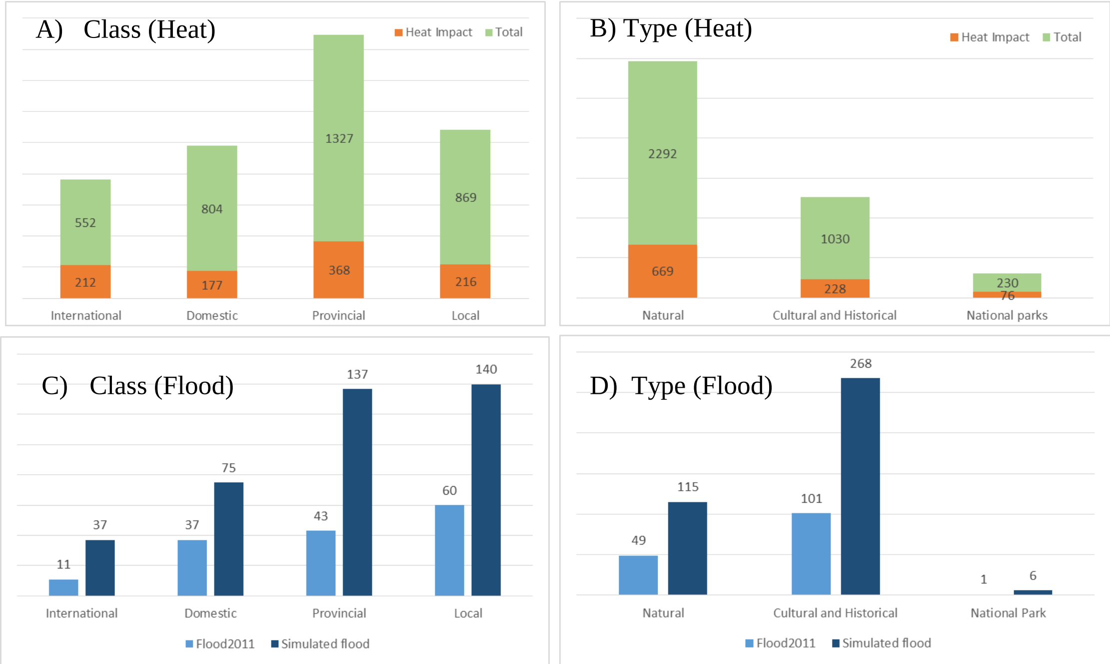


Fig. 7 Impact of simulated flood to tourism sites

4. Summary and recommendation

Climate change is a hot issue that many countries pay attention to investigate consequences and impacts to major sectors since more and more evidences from around the world have emerged. Climate change could cause many irregular events, which could consequently affect directly and indirectly to human and human activities. This study chose two possible climate change consequences including heat stress via heat index and flood risk using CA model to simulate. Both were superimposed to 3,552 tourism sites to inspect the impact. For the heat stress, tourist places in the north and south of Thailand are affected by increasing of heat index. Natural tourism sites have higher risk than the others. In case of simulated flood risk, the result shows that the tourist attraction sites are at risk in every regions—mostly in the north, northeast and central parts of Thailand. Cultural and historical tourism sites are the most flood risk compare to the others. This paper patently represents climate change risks to tourism sites, which can be used to prepare for climate change adaptation plan in the future. For instance, local government agencies can plan ahead to protect their important local tourism sites in risk zone; tourism business sectors in risk zones can offer some good deals to attract tourists; and government might promote other tourism places where locate outside the risk zone.

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