SPATIO – TEMPORAL MAPPING OF FLOOD INUNDATION IN CHAO PHRAYA RIVER BASIN, THAILAND USING MODIS FLOOD PRODUCT

Wahaj Habib[1] and Sarawut Ninsawat[2]

[1]Remote Sensing and Geographic Information Systems, Department of Information and Communications Technology, School of Engineering and Technology, Asian Institute of Technology, Thailand
Email: whjktk@gmail.com
[2]Remote Sensing and Geographic Information Systems, Department of Information and Communications Technology, School of Engineering and Technology, Asian Institute of Technology, Thailand
Email: sarawutn@ait.ac.th

ABSTRACT

Floods, much like other natural disasters have an influence on human society from time immemorial. Impairment from flooding has been amassed, and floods are becoming a frequent phenomenon. The main aim of this study was to identify and analyze the spatial distribution and temporal pattern of flooding in Chao Phraya river basin, Thailand using satellite remote sensing observation. Moderate resolution satellite remote sensing data like MODIS provides observation on a daily basis. The efficient use of this data for disasters like floods for real-time situation analysis cannot be denied. Moreover, the archive of MODIS data is also very useful in studying past flood patterns in a region like the Chao Phraya river basin.

The basin is affected by flood almost every year. This study focuses on performing time series analysis of frequent flood events using daily Near-Real-Time (NRT) MODIS Global Flood Mapping product for the year 2005 to 2015. The result of the analysis shows the most frequent flooded places in Chao Phraya River Basin for the time span of eleven years. Moreover, further analysis shows that in terms of area, the province of Nakhon Sawan has been the most affected, with flood inundation of approximately 2000 square kilometers. Moreover, for the period of eleven years, the Uttaradit and Nakhon Sawan has the highest number of flood days, and are about 22 provinces in the basin that has been affected by flood every year. In conclusion, the study helps to identify the flood-prone areas in the basin providing maps for the spatial distribution of flood. Henceforth, the result can further help in understanding the behavior of floods in the study area and it can also help to manage and plan better for the future events.

1. INTRODUCTION

Floods, much like other disasters have an influence on human society from time immemorial. Impairments that are caused by flood has been amassed, and they are becoming a frequent phenomenon. It is usually a consequence of continued heavy rain, which is related to the passageway of a monsoonal depression or a tropical cyclone usually (Supharatid et al., 2015). Nevertheless, these disasters are also growing because of deficient land drainage, budding urbanization and agriculture, etc. (WMO, 2013). These events can stimulate an amplified degree of runoff and consequently a higher flood peak. This is study is based on analyzing the spatial and temporal trends of flood in the Chao Phraya River Basin using MODIS (Moderate Resolution Imaging Spectroradiometer(derived flood product. In the field of flood management, remote sensing has played an important role since the past two decades. There has been extensive use of remote sensing to identify flood affected area. Therefore this study focuses on identifying and analyzing the most flood-affected areas over time. The CPRB has been affected by some major floods over the past decade. Moreover, there are some areas in the basin that has been affected by flood almost every year. Most of the flood management organization covers the damages caused by major flood event, and there is a need to properly inventorize these frequent flood events. In order to identify these frequent flood-affected areas and study the flood dynamics, a consistent archive of satellite remote sensing observation over time is of utmost important.

The use of the optical based medium resolution data (for example MODIS), for the flood inundation monitoring and mapping, has been shown in a number of studies over the past decade. The Office of Applied Sciences, Goddard at NASA developed a service that builds upon this work and provides daily maps providing the surface water and floods all over the world. The presence of clouds instantaneously during and after a flood event limits the use of satellite imagery that is based on the optical sensor. Moreover, some optical based instruments (such as, MSG-2, ENVISAT and MODIS) have, low temporal resolution that can range from few hours up to few 10's of minutes, and can have lower (few kilometers to few hundred meters) spatial resolution, these specifications are high enough, that they can guarantee to generate the updated situational reports that are frequent and timely (Ireland et al., 2015). In order to reduce the limitation introduced by the cloud covers and separates water from shadows. Certain methods are proposed when water is data via EO (Ticehurst et al., 2014). This kind of methods has depicted promising results. Further, they have the capability of improving the accuracies supplied by the optical sensor based imageries in this situation in a significant manner)Ireland et al., 2015(. The internationally available and free rapid response data from NASA's two MODIS sensors have considerable potential for operational applications in applied hydrology, including 1(flood detection, characterization, and warning, 2(flood disaster response and damage assessment, and 3(flood disaster prevention or mitigation. Each requires different strategies for operational implementation. The MODIS NRT global flood product, detection of water is performed via threshold, and the area is derived empirically from the bands 1, 2 and 7 of MODIS (pan-sharpened at 250 m spatial resolution). Cloud shadows in this product sometimes initially are flagged as water because of the spectral similarity of cloud shadow and water in these bands. In order to overcome this restraint and to present a product that is less cloud cover affected, daily observation of two to three days are composited. When water is sensed consistently over each observation, the pixel then is flagged as water. The Acquisition of this multiple observation limits false positive for water detection greatly. The evaluation report of the product also showed the really good result in capturing flood as well as permanent water bodies (Nigro et al., 2014). Hence the main objective of this study constituted identifying and analyzing the spatial distribution and temporal pattern of flooding in the Chao Phraya river basin using MODIS based satellite remote sensing observation and utilize the potential of this archive in basin like CPRB where it is affected every year by flood.

2. METHODOLOGY

The methodology was based on flood inundation extraction using MODIS data. Since it provides daily based satellite products. NASA in this regard maintains a flood map repository which is updated on a daily basis. MODIS derived flood maps were downloaded as raster datasets via the NASA NRT daily flood map portal. Since there is no automated process available yet for download and data can be downloaded for every given single day manually. However, for this study a script was developed for cURL (Client Uniform Resource Locator) to download a huge number of files in an automated manner. For this repository, MODIS data were analyzed to generate NRT (Near Real Time) Global flood maps. This product was used to obtain daily flood maps. Firstly, the flood maps for the whole of Chao Phraya river basin were obtained for the year 2005 – 2015 for the months spanning from April - October. This product was used to examine the spatial distribution and temporal pattern of the flooding for the specified period. The spatial distribution showed the maximum flood inundated area. Adding to that, from the temporal pattern the high-frequency flood area were identified for the study area. The flow of data preparation is shown in the Figure 1.

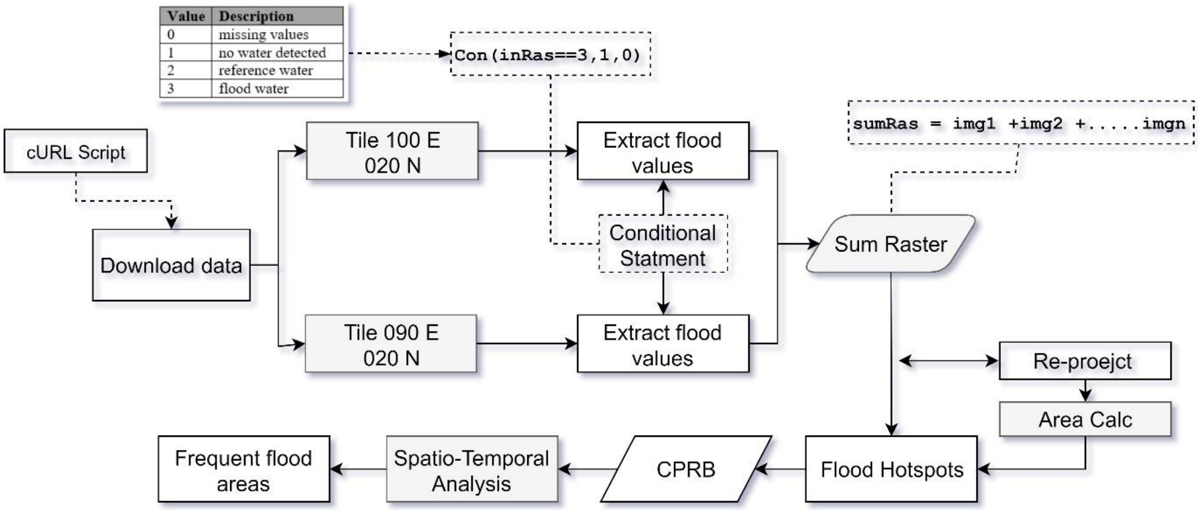

Figure 1. Flow of data processing

2.1 Study area

The CPRB (Chao Phraya River Basin) as depicted in the map (figure 2) is a geographical unit of Thailand, which is most vital regarding water and land resource development. It covers about 35 percent out of the total area of the country, and it is situated in the regions of north and south of the country. About 30 % of the total population (around 20 million people), inhabits the basin, the population of farmers make a total of 70 percent of this huge number. For both of the irrigated and the rainfed regions of the basin, rice is the main crop. The average annual rainfall (average) ranges between 1,000 to 1,400 mm in the basin. The Southwest monsoon dominates the climate, which happens between May and October. This period also constitutes about 90 percent of annual rainfall, which is the main cause of the heavy flood. Between November and April, there is a little amount of precipitation due to which the agricultural conditions are not favorable in this season.

The Chao Phraya river begins at the meeting point of Nan river and the Ping river and flows towards the south, into the Gulf of Thailand through the central plains and Bangkok, draining an area of 160,400 Square Kilometer. The middle of the basin covers most of the agrarian area)latitude: about 14°–17.5°(. While the upper basin, most of the area is covered by either forest or the bare soil)latitude: 17.5°–20°(. In the lower end of the basin)latitude: 13.5°–14°(, mainly urban and agricultural lands are present. Tropical monsoon makes the climate of this region. The season of monsoon spans between May to October, about 90 percent of the rainfall annually happen within this time span. During the monsoon season, floods were more common happenings in the past, between May to October, which is the monsoon season as mentioned before. Moreover, the responding policy to these floods in the past was also oriented towards engineering or structural, that is, storing the water in the upper stream areas during the wet season and eventually release the water for usage in the dry season. Three large size dams, were constructed for a flood management strategy. These dams were able to provide enough storage capability on completion, to decrease the impact of flooding in the city of Bangkok and the central plains. However, the agricultural and rural areas surrounding the Chao Phraya River are still frequently flooded.

3. RESULTS

The spatial distribution obtained from MODIS NRT Flood observations shows the areas that are affected by flood CPRB. The map below (figure 2) was obtained by combining more than two thousand layers. The resultant map represents the hotspots of the flood. Moreover, from the analysis, we can see that the provinces have been affected by flood every year. From the map, we can see that in Upper CPRB the province of Phitsanulok, Pichit, and Sukhothai are affected. These provinces cover two major river basins, Nan and Yom and both of these rivers cause flood almost every year. Further, in Lower Chao Phraya river basin, the province of Nakhon Sawan, Phetchabun, Ayuthaya and Lopburi shows the highest frequency of flood for the period of 2005 – 2015 in the months from April – October.

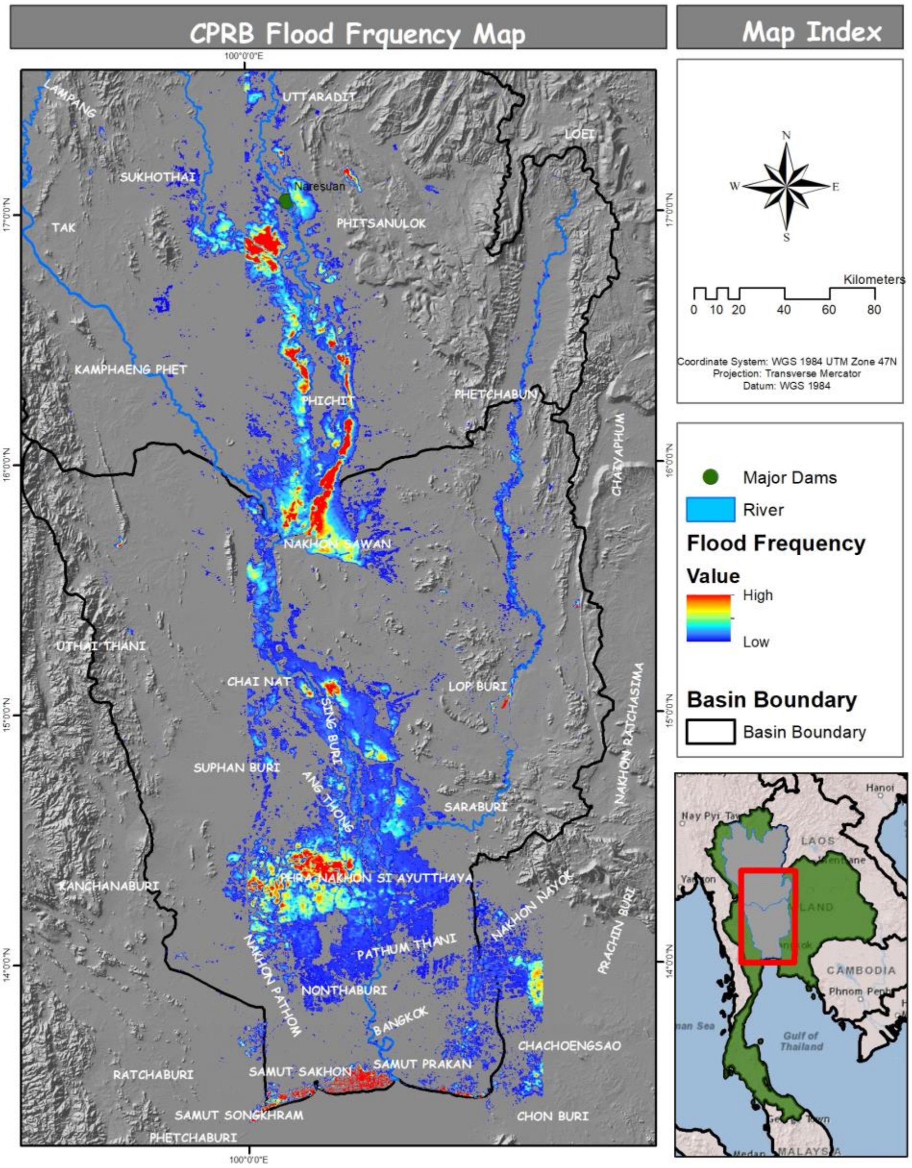

Figure 2. Spatio-temporal distribution of flood in CPRB

In terms of total area affected in all these provinces with a high frequency of flood (hotspots). From the following graph (figure 3), it can be seen that Nakhon Sawan is highly affected by flood in eleven years in terms of area. Adding to that the Ayuthaya province is the second province in terms of flood-affected area. Both these Province have a flood-affected area more than 2000 Square kilometers. All the four major rivers in the upstream of CPRB has a confluence point at Nakhon Sawan.

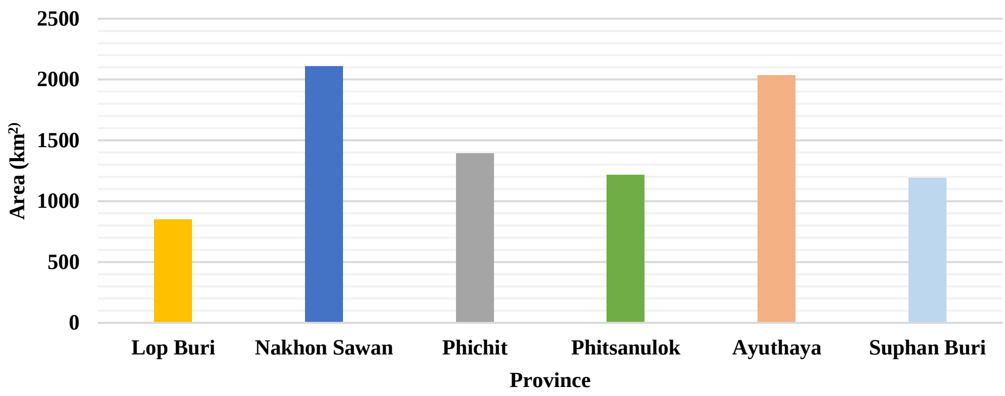

Figure 3. Flood affected area by Province (2005 - 2015)

Furthermore, for each province, the number of flood days, for the period of the year 2011 – 2015 were calculated using the flood frequency map. The map (figure 4 (a)) shows that for upper CPRB the Province of Uttaradit and Phitsanulok flood has been detected for the highest number of days. While the province of Phrae, Nan, and Phayao have been least affected by flood in terms of a number of days.

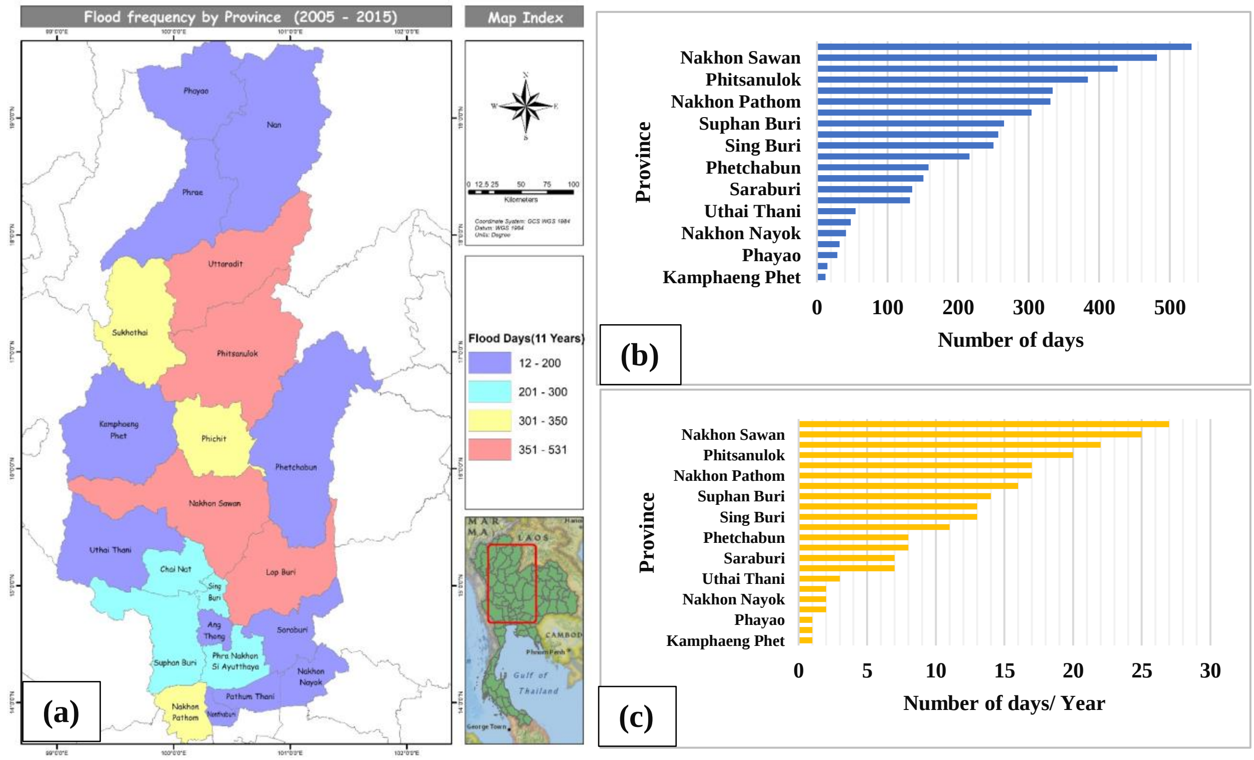

Figure 4. Flood frequency by province and days

Furthermore, Sukothai and Pichit are moderately affected. The province of Nakhon Sawan, which is situated in between upper and lower basin and the confluence point for the upper basin rivers, has also the highest number of flood-affected days. On the other hand, Lop Buri is the only province in the lower CPRB that has been highly affected. Adding to that Chai Nat, Sing Buri, Suphan Buri, and Ayuthaya has the second highest number for flood-affected days. The rest of the province is least affected in the lower basin area.

The graph (figure 4 (c) and (b)) shows the average amount of flood days per year in each year for the eleven-year time and total flood days in each year for eleven years respectively. It can be seen that Uttaradit and Nakhon Sawan are affected by flood each for almost a month it is also important to mention that for each year the months from April to October were considered which are the months that account for the most of the rainfall in the CPRB. Moreover, we can also see that from the middle beyond the province of Phetchabun the rest of the province were affected for less than ten days each year. In brief, spatial distribution of flood for the provinces that are present in upper and lower CPRB help us to understand the flood frequency in detail with respect to the province.

4. CONCLUSION

Based on the results, some notable characteristics were obtained about flood frequency in terms of spatial distribution and temporal pattern. In terms of spatial distribution, with respect to big river basin, flood frequency was the highest in the Yom, Nan, Chao Phraya and Pasak river basins. Most of the flood events that were detected were in the months of August, September, and October, which also correlates, with the heavy rainfall in these months. In the upper CPRB, the Yom and Nan river basin has been most affected and since there is the presence of two major dams; Sirikit and Naresuan, in the Nan river basin, there are few small dams in the Yom river basin. The additional significant thing to be considered is that there are low lying areas in both of this basin which was part of the water retention plan from RID. Therefore, in the big flood years, the water was also stored in those areas as well. In terms of temporal patterns of the flood in the Yom river basin, the month of October has flooded for a whole month in almost every year, except the big flood year of 2006 and 2011, where the flood is detected throughout June to October.

5. REFERENCES

Ireland, G., Volpi, M., & Petropoulos, G. P. (2015). Examining the capability of supervised machine learning classifiers in extracting flooded areas from landsat tm imagery: A case study from a mediterranean flood. *Remote Sensing*, *7*(3), 3372–3399.

Nigro, J., Slayback, D., Policelli, F., & Brakenridge, G. R. (2014). NASA/DFO MODIS Near Real-Time (NRT) Global Flood Mapping Product Evaluation of Flood and Permanent Water Detection. *Evaluation, Greenbelt, MD*, 27.

Supharatid, S., Aribarg, T., & Supratid, S. (2015). Assessing potential flood vulnerability to climate change by CMIP3 and CMIP5 models: case study of the 2011 Thailand great flood. *Journal of Water and Climate Change*, jwc2015116.

Ticehurst, C., Guerschman, J. P., & Chen, Y. (2014). The strengths and limitations in using the daily MODIS open water likelihood algorithm for identifying flood events. *Remote Sensing*, *6*(12), 11791–11809.

WMO. (2013). Flood Mapping. *Integrated Flood Management Tools Series*, (20), 88. Retrieved from www.apfm.info