APPLICATIONS OF SENTINEL-1 SYNTHETIC APERTURE RADAR IMAGERY FOR FLOODS DAMAGE ASSESSMENT: A CASE STUDY OF NAKHON SI THAMMARAT, THAILAND

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ABSTRACT:

Flooding is one of the major disasters occurring in various parts of the world. Estimation of economic loss due to flood often becomes necessary for flood damage mitigation. This present practice to carry out post flood survey to estimate damage, which is a laborious and time-consuming task. This paper presents a framework of rapid estimation of flood damage using SAR earth observation satellite data.

In Nakhon Si Thammarat, a southern province in Thailand, flooding is a recurrent event affecting the entire province, especially the urban area. Every year, it causes lives and damages to infrastructure, agricultural production and severely affects local economic development. In order to monitor and estimate flood damages in near-real time, numerous techniques can be used, from a simply digitizing on maps, to using detailed surveys or remote sensing techniques. However, when using the last-mentioned technique, the results are conditioned by the time of data acquisition (day or night) as well as by weather conditions. Although, these impediments can be surpassed by using RADAR satellite imagery. The aim of this study is to delineate the land surface of Chian Yai, Pak Phanang and Hua Sai districts of that was affected by floods in December 2018 and January 2019. For this case study, Sentinel-1 C-Band SAR data provided by ESA (European Space Agency) were used. The data sets were taken before and after the flood took place, all within 1 days and were processed using Sentinel Toolbox. Cropland mapping has been carried out to assess the agricultural loss in study area using Sentinel-1 SAR data. The thematic accuracy has been assessed for cropland classification for test site shows encouraging overall accuracy as 82.63 % and kappa coefficients (κ) as 0.78.

1. INTRODUCTION

1.1 Background

In recent years, the number of weather and hydrological calamities has been steadily increased, at the global level being affected hundreds of millions of people every year, especially in south Asian countries. Seasonal flooding is a regular feature of the Monsoon climate and flood plain landscapes of Thailand (Duan et al., 2009). Floods represent the most generous natural disaster that may occur at different levels, having an impact on environment, ecology, agriculture and infrastructure. Damage and loss assessment are significant for flood management, but it is always challenging task in context with its complexity in dealing with big data, damage types, spatial and temporal scales i.e. depth of analysis (Menoni et al., 2016; Dingtao et al., 2015). Usually due to the hassle and availability of facts and information, simple methods are used. Damage evaluation depends on an assumption like spatial and temporal boundary selection and financial contrast like depreciated values or alternative cost, classification of the thing at risk, quantification of the uncovered asset values and tactics for describing susceptibility (Merz et al., 2010). Cost of distinctive sorts of natural disasters consists of direct cost, indirect cost, intangible effect and value of mitigation (Meyer et al., 2012).

Remote sensing and especially synthetic aperture radar (SAR) sensors are appropriate for cloudy condition during flood and fast assessment and long-term monitoring of the flooded areas. SAR sensors is sensitive to moisture due to specular reflection and are capable to acquiring imagery both day and night. These capabilities mapping surface water and changes using SAR data which is more feasible then optical data. Speedy generation of flood extent maps from SAR data provide access to valuable data in rapid disaster response planning and management. Monitoring of affected area by flooding and damage to agriculture and infrastructure assessment, represents an important task in managing disaster situations. Number of studies has been carried out to carry out loss and damage assessment and flood extent mapping of flood affected area using sentinel-1 SAR data (Plank S, 2014; Twele et al., 2016; Tavus et al., 2018; Olen and Bookhegen, 2018; Ahmed and Kranthi, 2018). Here, we are presenting an approach with a case study of damage assessment using sentinel-1 SAR data for “Pabuk” typhoon affected town of southern Thailand. This will contribute help local policymakers in disaster response planning in such type of typhoon cases in future. Moreover, the flood maps from the presented approach can be used for the cross-validation of existing study carried out for flood extant mapping and damage assessment using Sentinel-1 data (Chung et al., 2015; Twele et al., 2016; Ahmed and Kranthi, 2018).

2. METHODOLOGY

One of the major benefits of using SAR imagery, apart from its all-weather ability, lies in its capability to discriminate water

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from other classes. Water features act as a mirror reflecting surface, their response is low (low backscatter coefficient in SAR images) and thus appears like a dark area. The land mass, for its part, gives a much higher amount of radar energy due to the surface roughness and this generates the high contrast between surfaces: soil and water (Vilches, 2013). Different flood mapping techniques such as threshold, random forest and deep learning approaches using backscatter intensity are available for accurate flood extant mapping. In this study threshold technique is used. Similarly, for land cover classification many algorithms are available such as random forest, KNN, KD-tree KNN, maximum likelihood and minimum distance to mean. In this study random forest algorithm is used for supervised classification of study area. The satellite images were acquired sequentially by satellite Sentinel 1A, before and after the flood took place. The images were pre-processed and analysed using SNAP software, Sentinel-1 Toolbox (S1TBX) module developed by ESA. It is followed by generation of histogram of backscatter coefficient, and it was used to fix a value which most accurately reflects the threshold between water features and non-water features. Finally, the resulting binary raster data were converted into a vector file for analysis. These vector datasets are overlaid on land cover map for damage estimation.

Monitoring the areas affected by flooding and damage to property assessment, represents an important step in managing crisis situations. In order to monitor and estimate rapid, fair and accurate flood damages, framework is presented in this study.
To analyse flood damage, all Sentinel-1A images are first pre-processed with orbit correction, thermal noise removal, calibration to sigma naught, Range Doppler terrain correction and de-speckling (Lee 7x7 speckle filter) using the SNAP software as shown in figure 2.

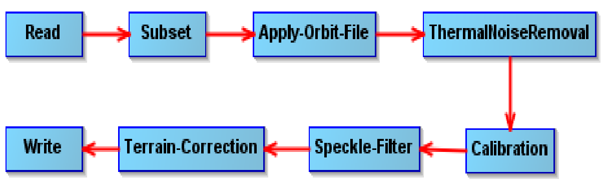

Figure 2. Image pre-processing steps

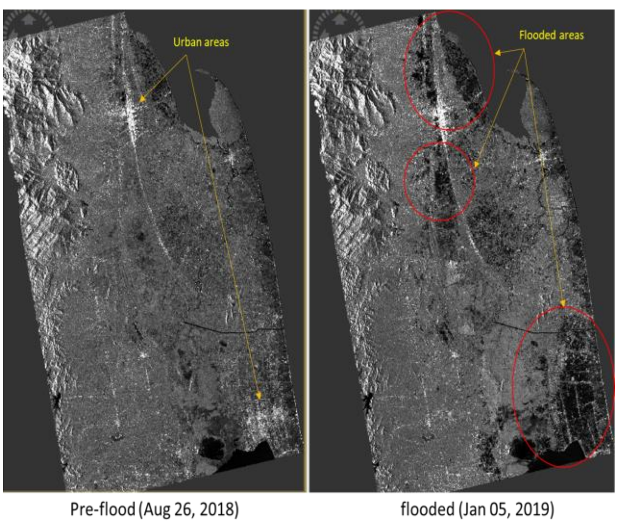

Figure 3. Pre-processed Sentineil-1 data in VV polarization

Pre-processing is followed by backscatter thresholding by binarization. This will help in generating flood inundation map over study area. After this, land use and land cover classification into built-up and cropland was carried out using random forest classification. At last, area affected was identified by overlay flood inundated map over land cover map. The flowchart used this study is presented in figure 4.

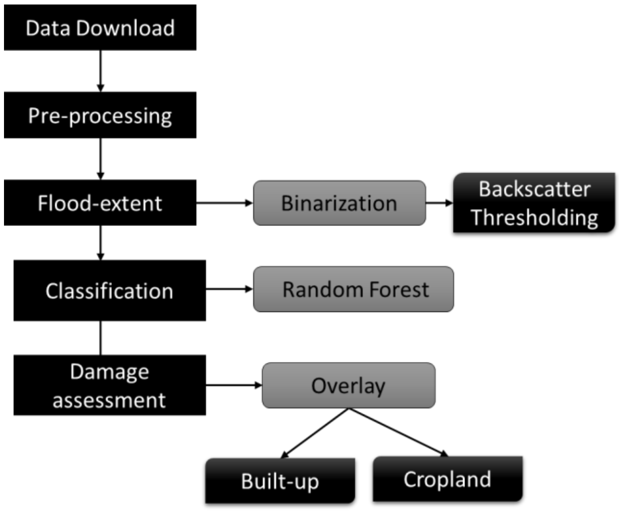

Figure 4. Flowchart of study

3. EXPERIMENT

3.1 Study area

The study area chosen for this study is coastal region of Nakhon Si Thammarat, a southern province in Thailand as shown in figure 1. This area faces recurrent and intensive flooding which affects the rural and urban population of entire province. Every year, it makes huge loss and damages to human life and infrastructure, agricultural production and ultimately affects local economic development. Deforestation in study area also fostered the impact due to flood. In this paper, four coastal districts namely Pak Phanang, Chalermphrakiet, Chian Yai and Hua Sai are taken into consideration. Local authorities and Insurance companies need access to accurate, reliable, timely flood-related information and timely warnings to assist them respond to flood events.

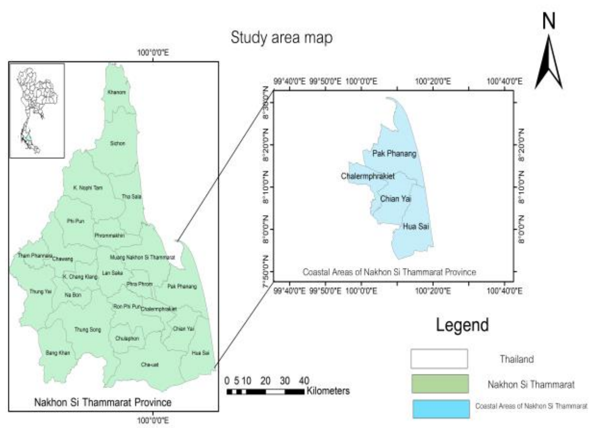

Figure 1. Study area map

3.2 Data and scope

The Sentinel-1 constellation includes two polar-orbiting C band SAR satellites (Sentinel-1A and Sentinel-1B). Sentinel- 1A data, used in this study, are interferometric wide swath (250 km); Level-1 Ground Range Detected (GRD) products and dual polarization (VV and HH). Pre-flood imagery acquired on August 26, 2018 and post-flood imagery acquired on January 5, 2019 were used to identify changes in inundation over study area. Sentinel 1 data have a short revisit time with all data available for download within 24 hours of acquisition.

Dataset	Sentinel-1A		
Product	GRD	GRD	SLC
Purpose	Crisis	Pre-flood	LU/LC
Acquisition Date	5 Jan. 19	26 Aug. 18	14 Aug. 18
Beam mode	IW	IW	IW
Polarization	HH/VV	HH/VV	HH/VV
Pass	Ascending	Ascending	Ascending

Table 1. Detail of dataset

The data is processed in open source Sentinel Application Platform (SNAP) toolbox, which can be downloaded from the Copernicus Services Access Hub https://scihub.copernicus.eu/

4. RESULTS AND DISCUSSION

4.1 Flood area and extant mapping

In order to distinguish flood mapping, three Sentinel-1 images of pre-event and post-event were acquired (Table 1). After pre-processing of both images, Water features are identified from other features by performing. In this task, histogram thresholding is selected to filter out backscatter coefficient. The histogram shows backscattering (Sigma nought) distribution of pixel values of features available on image in form of peak. Higher values of backscatter indicate the non-water class and lower values indicate water class (Iurist et al., 2017).

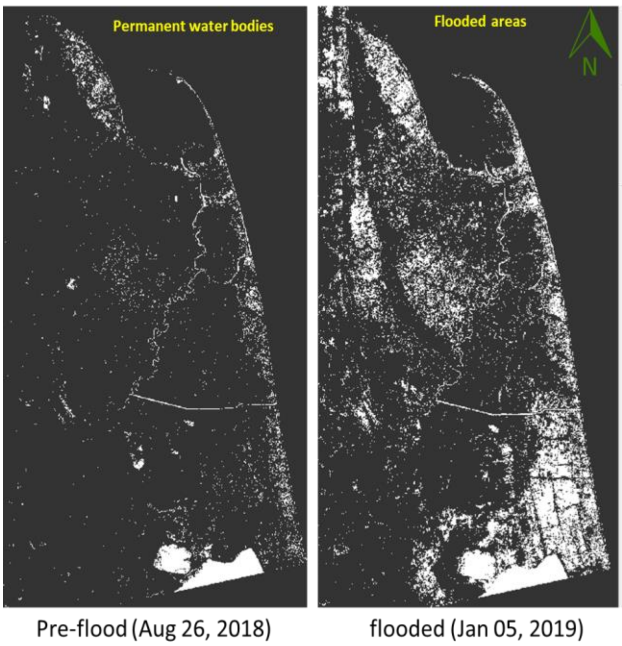

Figure 5. Results of change detection using thresholding

Once the thresholding is done, water class of the study area generated. The threshold value of backscattering coefficient or sigma naught obtained for flooded area and water bodies detection was 0.05. When the edge is connected, water class of the investigation region created. Water features for pre-flood image is mapped to identify permanent water bodies existing in study area. Similarly, water features of flooding day were also mapped, and its results are compared with permanent water bodies to identify extent of flooding due to cyclone. Figure 5 shows permanent water bodies and flooded area. Accuracy assessment analysis was carried out for flood extant mapping using thresholding. For the accuracy analysis 200 pixels are distributed randomly on SAR images and accuracies are estimated. The results of statistics and accuracy assessment are shown in table 2.

Dataset	Aug 26, 2018	Jan 05, 2019
Water (km2)	352	1052
Other (Km2)	2573	1889
Overall accuracy	92.6	93.4
Kappa coefficient	91.3	92.1

Table 2. Detail of dataset

The Random Forest Classification (RFC) method provides a unique predictive validity and model interpretability within known machine learning methods. RFC method provides better generalizations because of the random sampling and the improved properties of the techniques in community methods. For this reason, there are valid estimates (Horning, 2010). The RFC which has performed for land cover classification using Radar image before the flood occurs. Features can be identified from the scatter from the target and the texture differs with different targets. This classification is performed on GRD data and it was validated using land cover classification performed on SLC data. Accuracy is assessed by creating an error matrix. The Google Earth image and generated land cover map is presented in figure 6. Land area is classified into four classes viz. crop land, bare soil, built-up and water-body.

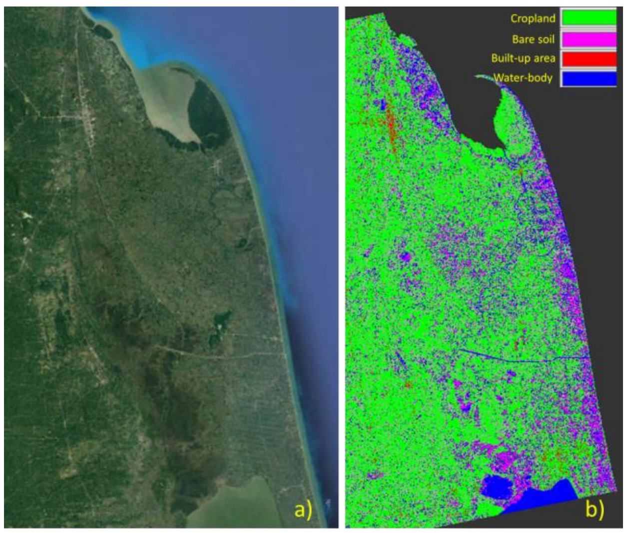

Figure 5. a) Google Earth image of study area b) Results of land cover classification

Cropland area was calculated 2422 sq. km (242200 hectares) which were 53.3% of the total area. This depicts that the major livelihood of this area is agriculture. Similarly, built up area was very less, which was only about 4 %. From accuracy assessment overall accuracy is obtained as 82.63 and kappa coefficient obtained is 78.54. error matrix of land cover classification is shown in table 3.

	Cropland	Bare soil	Built-up	Water body	Row
Cropland	54	2	3	2	61
Bare soil	3	19	2	1	25
Built-up	1	4	9	0	14
Waterbody	0	1	0	9	10
Column	58	26	14	12	110

Table 3. error matrix of land cover classification.

The damage analysis was carried out by overlying flood inundation map over land cover map and inundated pixels was calculated for each type of class. It has been observed that majority of area affected was agricultural and bare field. Results of damage assessment are show in table 4.

Land cover type	**Total area (hectares)**	**Inundated (hectares)**	**% Total Inundated**
Cropland	242200	55700	23.9
Bare soil	31990	25144	78.6
Built-up	18280	1681	9.2

Table 4. Detail of area affected

News coverage of this storm also validate that “Pabuk” tropical storm heavily affected this area. Parts of Nakhon Si Thammarat have suffered heavy damage from tropical storm Pabuk but officials expect to downgrade the storm to a tropical depression” (Bangkok Post, 2019). “Fallen trees blocked roads as wind speeds reached 70 kilometres per hour. More than 6,100 people in four provinces were evacuated ahead of the storm, and there were no immediate reports of casualties on land.” (Euronews, 2019). The fisheries sector is estimated to have lost more than 1.2 billion baht over the five days affected by the storm, while the cost to agriculture could rise to 2 billion (khaosodenglish, 2019).

This result of this study may be improved by carrying out crop type and fishery type discrimination to examine the loss occurred for specific type of crop and seafood product. These results may be overestimated due to overlap of flooded area with paddy field, so efforts need to be applied to discriminate paddy field with flooded area. There is ample amount of scope in utilizing different algorithms for flood extent mapping and land cover mapping. The approach presented in this study can be useful for preliminary planning for disaster response using freely available radar data and open source software.

The flood events of January 2019, in Nakhon si Thammara, should induct the commencement of a new example for improving the affected area through a zone-based scheme by considering on the land use type, extent, and depths of flood water levels at various locations.

5. CONCLUSIONS

In January 2019, Tropical Storm “Pabuk” knocked coastal villages on Southern Thailand’s east coast (TMD, 2019), which caused extensive damage to man and materials. For effective response management in such kind of disasters, the information about approximate damage will be helpful for high government authorities and even non-life insurance agencies. This study presents a framework for detection of flood affected areas using freely available SAR data and open source tools, which is a cost and time effective solution for near real time monitoring of flood. This study shows effectiveness of Sentinel-1 C-band SAR for flood inundation mapping and land cover classification and cross validate the previous studies which proved effectiveness of Sentinel-1 data. In this study GRD data is used to examine flood extant. Flood extant mapping was carried out using thresholding technique. The threshold value of backscattering coefficient or sigma naught obtained for flooded area and water bodies detection was 0.05. From accuracy assessment of flood extant map, overall accuracy and kappa coefficient obtained was more than 90%. The agricultural area was classified using random forest classifier and it was also showed accurate results. It has been observed that major affected community is fishery and agricultural. This approach can be utilized by policy makers and disaster response agencies for disaster risk management. In addition, further research needs to be carried out by assessing loss to specific crop and aquaculture.

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