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Assessment of the Number of Damaged Buildings from a Flood Event Using Remote Sensing Technique

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Abstract**—**The heavy rainfall from 3rd to 22th January 2017 had swamped much area of Ranot district in southern Thailand. Due to heavy rainfall, the district was flooded which had a lot of effects on economy and social loss. The major objective of this study is to detect flooding extent using Sentinel-1A data and identify a number of damaged buildings over there. The data were collected in two stages as pre-flooding and during flood event. Calibration, speckle filtering, geometric correction, and histogram thresholding were performed with the data, based on intensity spectral values to classify thematic maps. The maps were used to identify flooding extent using change detection, along with the buildings digitized and collected on JOSM desktop. The numbers of damaged buildings were counted within the flooding extent with respect to building data. The total flooded areas were observed as 181.45 sq.km. These areas were mostly occurred at Ban khao, Ranot, Takhria, and Phang Yang sub-districts, respectively. The Ban khao sub-district had more occurrence than the others because this area is located at lower altitude and close to Thale Noi and Thale Luang lakes than others. The numbers of damaged buildings were high in Khlong Daen (726 features), Tha Bon (645 features), and Ranot sub-district (604 features), respectively. The final flood extent map might be very useful for the plan, prevention and management of flood occurrence area. The map of building damage can be used for the quick response, recovery and mitigation to the affected areas for different concern organization.

Keywords**—**Flooding extent, Sentinel-1A data, JOSM desktop, damaged buildings.

I. Introduction

FLOODING is one of the main events of natural disaster, and they have a lot of effects to the country's economy, industrial sector, and social loss [11], [16], [15], [3]. Most of the countries suffer from flooding and they implement lots of protection works too. However, the floods have been increasing the negative impact on daily life with lots of damages [6]. Especially in Thailand, as per the long history of flood cycles, flooding occurs in every year in Southern and Centre regions. From 1989-2016, the number of occurrences is more than 40,000 times, and casualties are more than 2,000 people [22]. Because of lots of damage, flood is listed as a high prioritized natural hazard in Thailand. Although, Meteorological Department of Thailand can forecast rainfall and track the storm path, they are unable to perform the protection of damages from flood event [19].

Recently, heavy rainfall swamped much of southern Thailand many days from 3rd – 22nd January 2017. As a result, widespread flooding occurred across 11 provinces, and over 330,300 households were affected [4]. The Ranot district in Sokhal province is one of the main events from flood event along with much damage of infrastructures over there [1], [20]. The Ranot district was much affected because it is close to Thale Noi and Thale Luang lakes with flat surfaces. Thus, a wetland can lead to flood easily [14], [21].

Remotely sensed data are widely acquired by sensor of both active and passive systems from satellite [27], [24]. The active remote sensing can give data as radar images, and it is an active source of remote sensing data which acquires data via instruments that emit radar signal towards the surface of interest and measure the reflected energy from the earth's surface. The radar or SAR data have high potential for natural hazards observation because these can penetrate cloud cover and can be acquired any time [13], [5]. Several researchers used SAR data for flood monitoring, and many methods have been performed to extract the flooding extent using SAR image data. These techniques for identifying the flooded areas are as statistical active control model, multi-temporal image differencing, histogram thresholding, image rotation, change detection, Object Based Image Analysis segmentation and pixel-based segmentation [8], [10], [26].

The study was conducted to detect flooding extent by Sentinel-1 data and identify the number of damaged buildings over flooded areas. The image data were collected at pre-flooding stage and during flood event. Calibration, speckle filtering, geometric correction, and image thresholding were performed with the data. Then, both pre-and post-images were used to identify flooding extent using change detection method. The buildings were digitized and collected from base image on JOSM desktop. The damaged buildings were identified and counted over the flooding extent with respect to building data. The results provide flooding extent map and the number of damaged buildings, and these results have many benefits for concern community and organization to manage flood occurrence in the future.

II. Study Area

Southern Thailand was badly affected by the flood event from 3rd – 22 nd January 2017, along with the lots of damages on facilities in many areas. Thus, this study selected Ranot district in Songhla province, which covers an area of 441.71 sq.km. The Ranot district was much more affected from the flood event than others area in the Songhla province. The study area is shown in Fig. 1.

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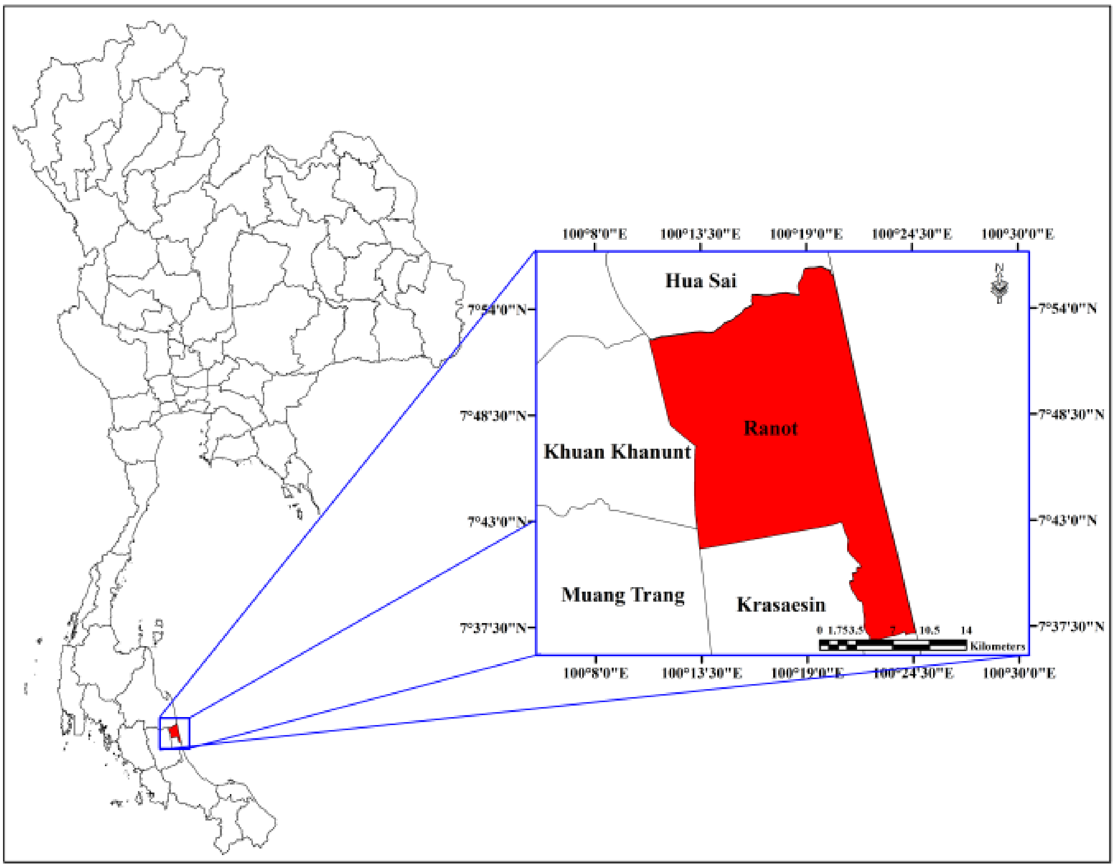

Fig. 1 Study area

III. Data Used

The study primarily used Sentinel 1 data to identify the flooded areas. The data were collected on 28th December 2016 before the flood event, and 9th January 2017 during the flooding over the Ranot district [1], [20], [16]. Sentinel 1 satellite image is free data for users and carries C-band synthetic aperture radar (SAR), provided from the European space agency (ESA) through Sentinels Scientific Data Hub [5]. The data provided by Sentinel 1A are mostly suitable for flood monitoring because of no cloud coverage [7], [25], [10]. The data were acquired in the Interferometric Wide (IW) swath mode, polarization (VV+VH), and Ground Range Detected (GRD) processing level. The spatial resolution is 5x20 square meters which is more suitable for this study [23], [5]. Buildings' data were collected by digitizing from OpenStreetMap Community through OpenstreetMap website online to provide information [12]. The online platform of OSM is an initiative to create and provide free spatial data, which is most convenient to use [15].

IV. Methodology

In this study, remote sensing techniques were applied to identify flooded areas and the damaged buildings. The workflow of this study is shown in Fig. 2.

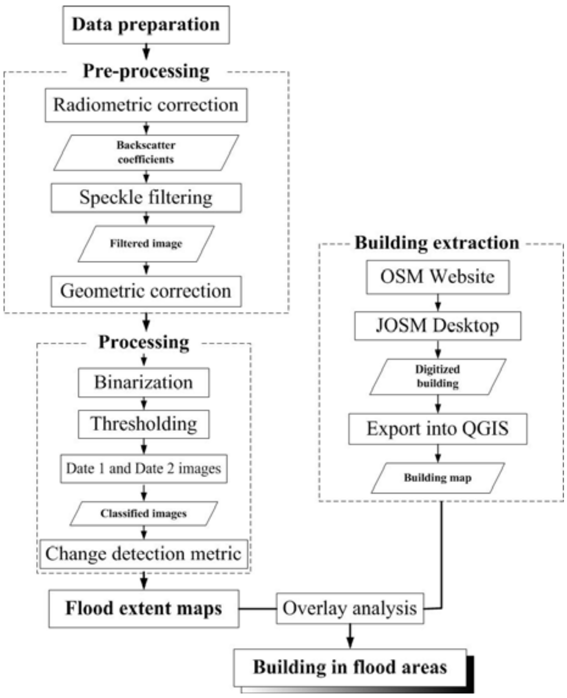

Fig. 2 Methodology

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Firstly, the pre-processing stage included calibration, speckle filtering, and geometric correction. These methods were conducted on the Application Platform (SNAP) version 4.0 software, and it is free software to process Sentinel data as well. The antenna pattern of the data was corrected to create new products with calibrated values of the backscatter of coefficient. Then, the improvements of new products were performed by Lee filter with widow 7x7 based on speckle filtering. The geometric correction was used to re-project coordinated system (Geography projection), and the image data were re-sampled to 8 m x 8 m (Fig. 3) [7], [5].

Secondly, the raw image data in different times (pre-flooding and during flood event) were used to identify flooded areas. In this study, the flooded areas were identified based on the Signma0_VV spectral values of image data with image threshold technique. This technique was used to extract flooded areas because it is effective in detecting water using spectral values [2], [17]. In the image tresholding, an image P(x, y) contains the objects on a dark background. An image was performed and then these objects are extracted by threshold technique. The formulation is as [18]:

$$P(x, y) = P(x, y) > T1 and P(x, y) \le T2 \quad (1)$$

$T1$ is defined a value as 1, $T2$ is defined a value as 0

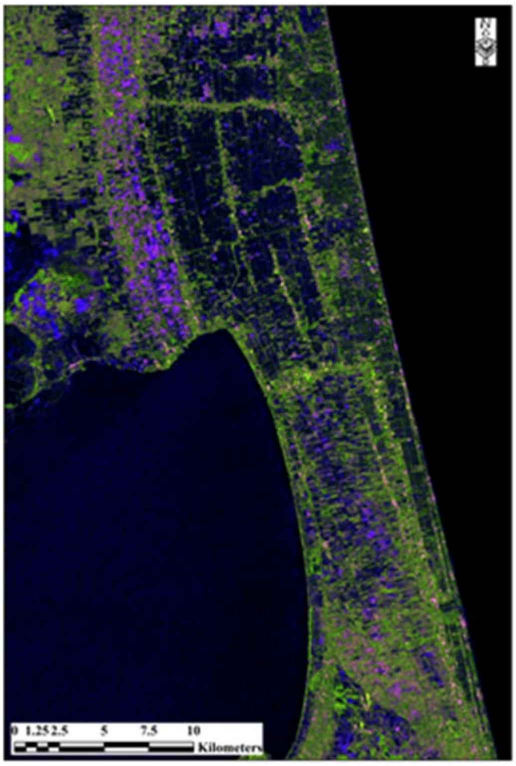
where $T1$ and $T1$ are the threshold values which are generated by analyst. All the pixel values of land area's objects (change) are defined as 1, and the pixel values of water's objects (no change) are defined as 0. The data were identified and classified with two classes as land and water areas, and these were useful for flood monitoring. The classification maps were compared with Sentinel-1A data as shown in Fig. 4.

Thirdly, the maps at different times (Date1 and Date2) were demonstrated to classify the pixel values. Then, the maps were overlayed together to identify land change using change detection method. This method can create decision change matrix presenting all the land change between dates across the flooded areas [9]. Thus, the flooded areas were extracted by pixel values of changing from land to water areas.

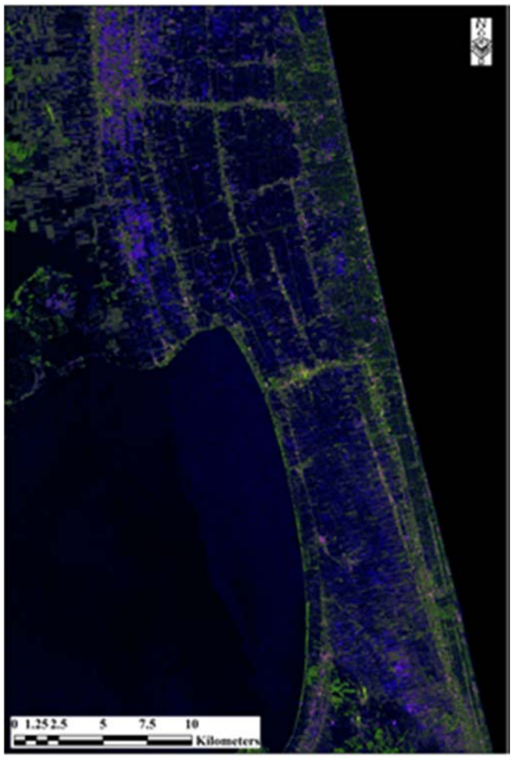
Finally, buildings were created from OSM website online and JOSM desktop. These are free open source software that most researchers can use to develop the project efficiently. This study digitized all buildings in Ranot district. Then, building data were exported to spatial data by QuickOSM plugins on QGIS software. Lastly, buildings (spatial data) were used to identify damages from flood event. This study identified damaged buildings by overlaying between all buildings with flooding extent and used Select by Location tool to select buildings over the flooded areas.

V. Result

The counting number of damaged building from flood even on 9th January 2017 showed the results below.



(a) Pre-flooding



(b) during flood event

Fig. 3 (a) pre-flood is no flooded situation, and (b) during flood event is occurring

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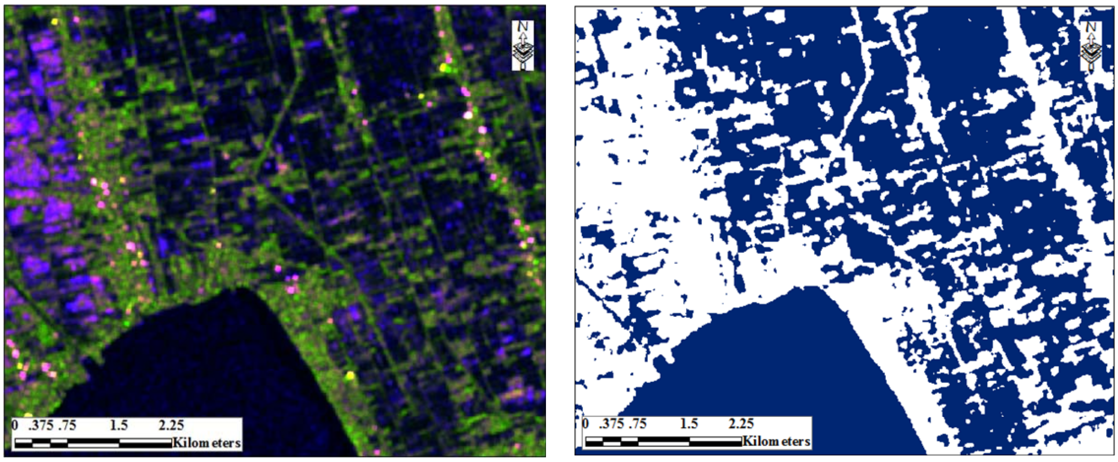
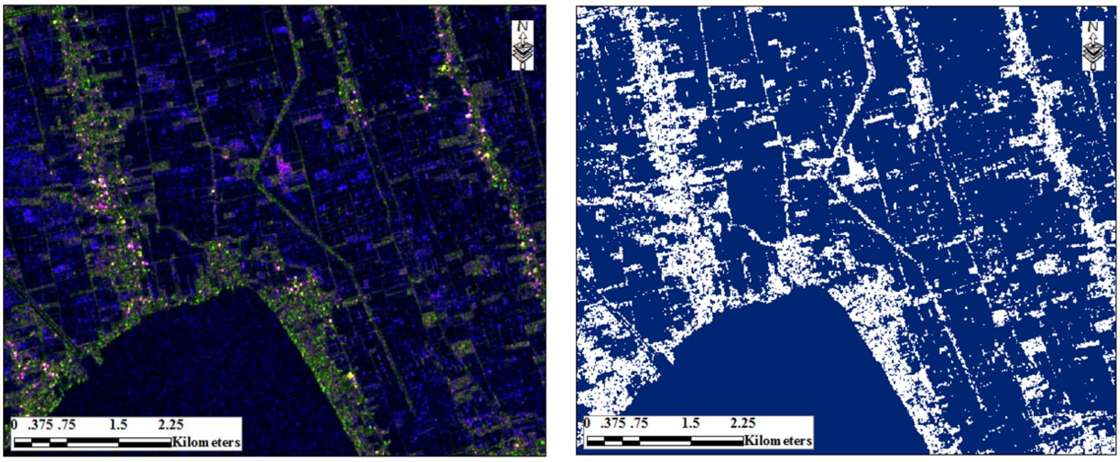
The SAR-C data were classified by spectral values based on histogram thresholding. The results showed that the 1st image (28th December 2016) had 0-0.065 (water area) and 0.066 - 21.78 (land area), and 2nd image (9th January 2017) had 0-0.0762 (water area) and 0.0762 -10.5 (land area). The thematic maps were compared using Sentinel-1A data as shown in Fig. 2 and these classification maps are used to identify flooding extent (Fig 4).



SAR-C image Thresholding image

(a) Pre-flooding (28th December 2016)



SAR-C image Thresholding image

(b) Flooded occurrence (9th January 2017)

Fig. 4 Classification maps

The classification maps were used to overlay for flood monitoring by change detection metric. This result had shown that flooded areas are 181.45 sq.km. over Ranot district. These areas mostly occurred at Ban khao (30.83 sq.km.), Ranot (29.13 sq.km.), and Takhria (22.37 sq.km.), Phang Yang (20.83 sq.km.), Wat Son (20.79 sq.km.), Bo Tru (20.28 sq.km.), Tha Bon (11.99 sq.km.), Ban Mai (10.68 sq.km.), Pak Trae (3.87 sq.km.), Khlong Daen (3.81sq.km.), Daen Sa-nguan (3.44sq.km.), and Rawa sub-district (3.34sq.km.), respectively. The Ban khao sub-district had more occurrence than the others because this area is located at lower elevation than others. The area is close to Thale Noi lake and Thale Luang lakes too. Moreover, the topography is mostly like wetland zone. The Daen Sa-nguan sub-district had less effect than the others because the place is located in higher elevation than others. The map displayed flooded areas is given in Fig. 5.

Buildings were digitized using OSM and JOSM desktop, and 15,661 numbers of buildings were recorded. These were used to carry out damage assessment over the flooded areas, and all the people who would like to use benefits that they can download the building data in OSM website. The digitization of buildings is represented in Fig. 6.

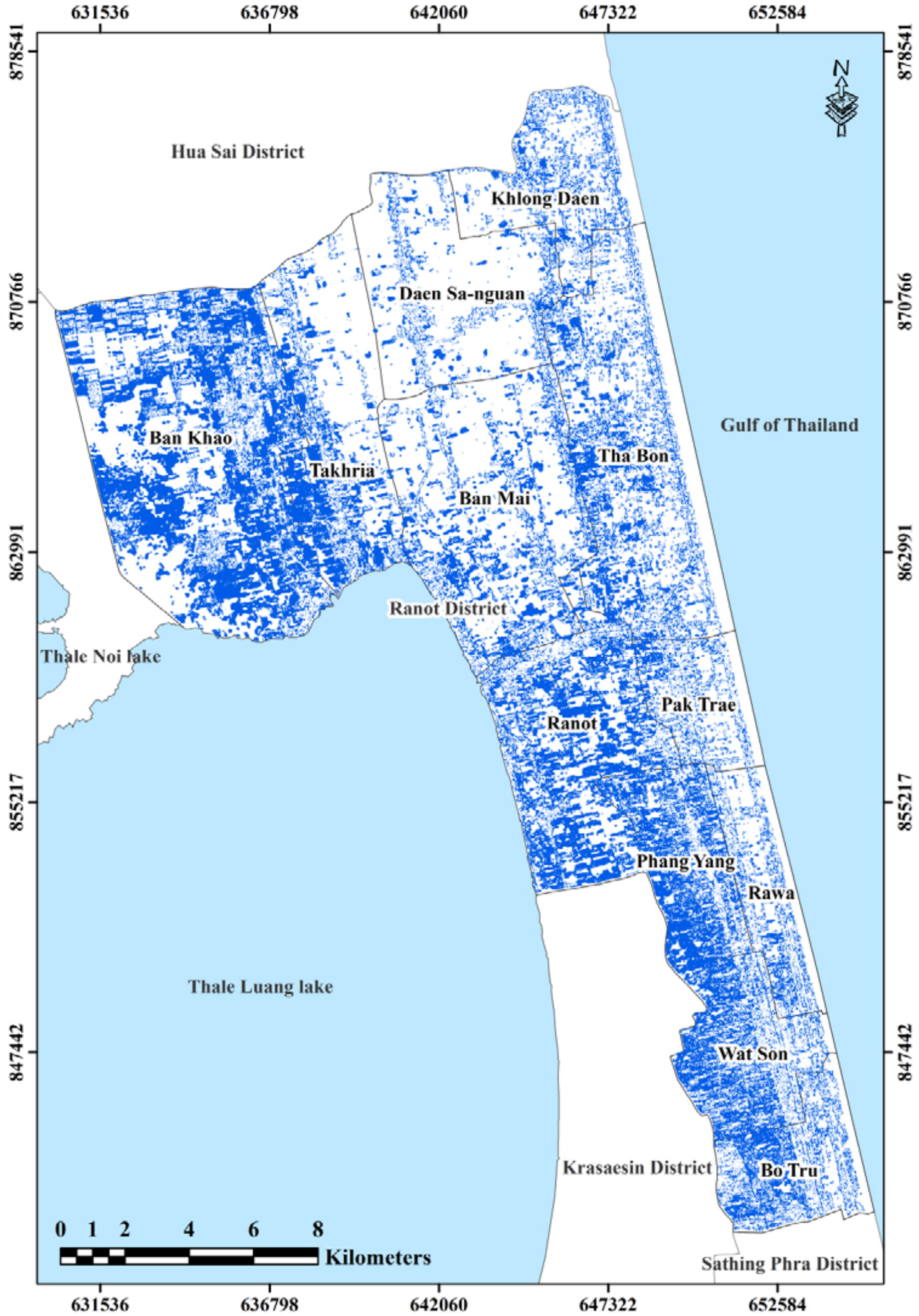
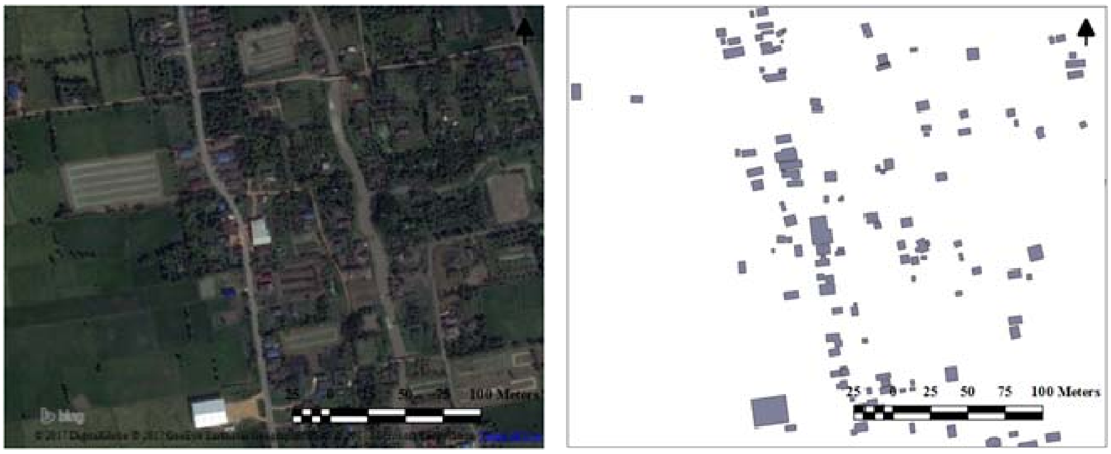


Fig. 5 Flooding extent in Ranot district

The number of damaged buildings was identified using flooding extent, and the result disclosed 3,973 buildings. High numbers of damaged buildings were found in Khlong Daen (726 features), and similarly Tha Bon (645 features), Ranot (604 features), Ban Khao (393 features), Ban Mai (371 features), Takhria (233 features), Wat Son (266 features), Pak Trae (218 features), Daen Sa-nguan (209 features), Bo Tru (156 features), Rawa (118 features), and Phang Yang sub-district (74 features), respectively. The Khlong Daen sub-district had higher effects than others because of high dense settlement near Khlong Daen river and sea. However, some places in Ranot district had less effect from flood event too. Phang Yang was one of the places in which buildings were less damaged because it was less populated. And all of buildings were located at higher elevation, close to roads not lake and sea. The number of damaged buildings was displayed in Fig. 7.



(a) Satellite image (b) Building data

Fig. 6 The buildings were digitized based on the based image in JOSM desktop

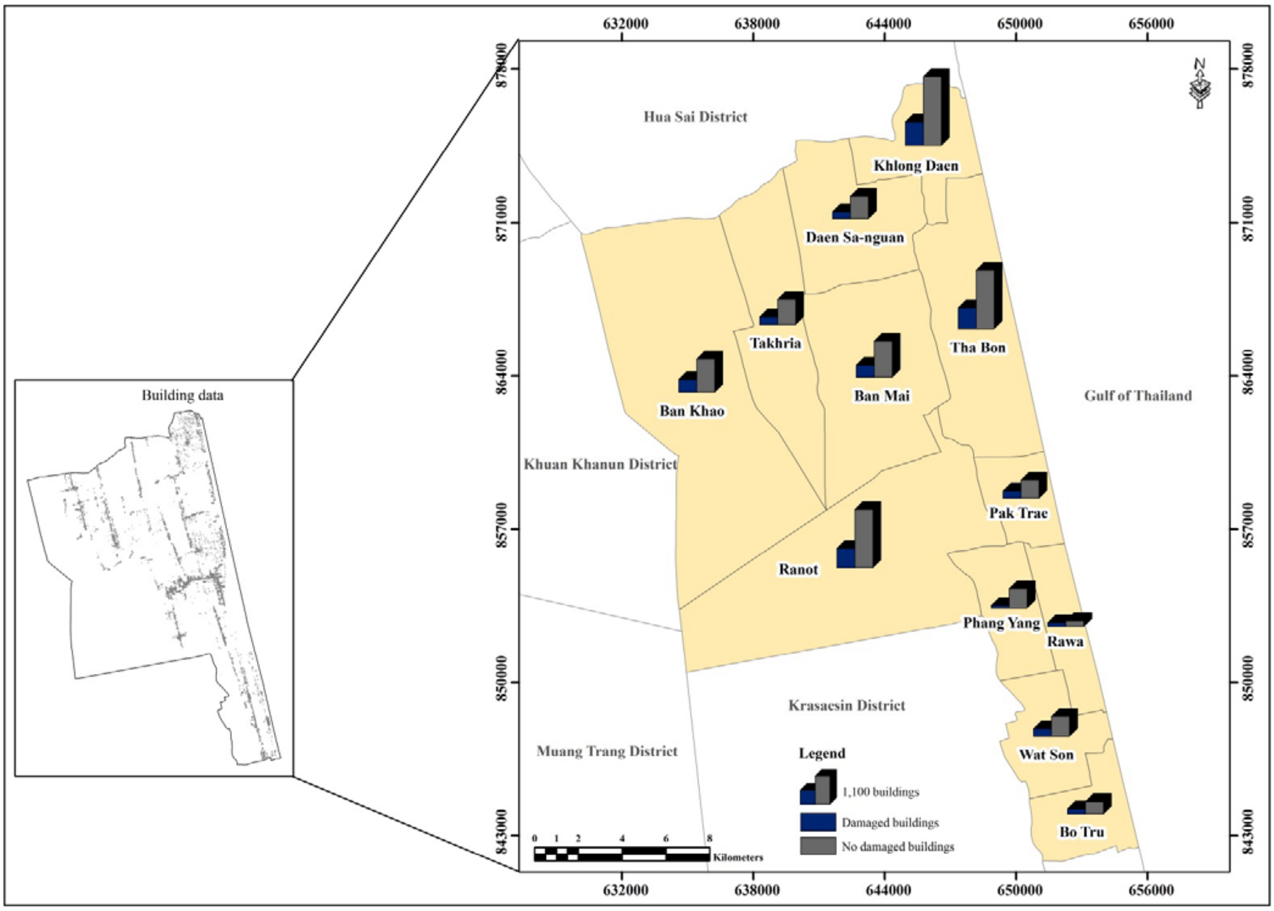


Fig. 7 The number of damaged buildings map

VI. Conclusion and Discussion

Flood monitoring by remote sensing technique is most important to carry out the damages from flood event. The study was conducted to detect flooding extent and identify the number of damaged buildings. The methodology was performed using Sentinel-1A data as pre-flooding and during flood event. Pre-processing, such as calibration, speckle filtering, and geometric correction was done. Flooding extent was identified using image data with histogram thresholding and change detection metric based on remote sensing technique. On the other side, the buildings were created from JOSM desktop. The building data and flooding extent were used to find out the number of damaged buildings.

The Sentinel-1A data are good products to develop research. These products provide high accuracy to classify thematic maps because of very high resolution data and no cloud coverage which are more suitable for this study. Moreover, histogram thresholding is highly efficient to obtain the highest accuracy. The flooding extent map also demonstrated reliability when we compared it with a very high resolution image. The building databases were digitized and collected, and the databases are uploaded in OSM website. Anyone can use building databases on OSM website to develop their researches as well. A number of damaged buildings had shown the good result because these are located as wetland zone and closed to Thale Noi Lake and Thale Luang Lakes. In future, field survey of buildings should be done for accuracy assessment, and digitizing of the buildings should use cloud free satellite image. In digitization, there are few mistakes because of the base image in JOSM desktop had slight cloud coverage in some places and zooming limitation. However, the map can be used to prevent occurrence of flood in the future. And the Thai governments can make planning and management strategies as per the flood map of Ranot district. The number of damaged buildings can be used to response, recovery, and mitigation to the concerned organizations. It might be very helpful to identify most affected places.

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