EXTRACTION OF FLOODED AREAS IN THE 2011 THAILAND FLOOD FROM RADARSAT-2 AND THAICHOTE IMAGES

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ABSTRACT

This paper examines an extraction method of widespread flooded areas in the Chao Phraya River basin of the central Thailand during the 2011 monsoon season. RADARSAT-2 imagery data were mainly used to extract affected areas while ThaiChote imagery data were aslo used as optical supporting data by the Thai government. In this study, the same data were used by a somewhat different method in more detail. The extracted results were validated by GeoEye-1, a high-resolution optical satellite image, water height data from gaging stations and a digital surface model (DEM) from LiDAR.

***Index Terms*—** 2011 Thailand flood, RADARSAT-2, THAICHOTE, SAR

1. INTRODUCTION

Floods happen almost every year in Thailand and have brought dissatisfied situations. Severe flooding occurred during the 2011 monsoon season. It spread throughout the northern, northeastern and central provinces of the country. It caused heavy economic impacts by disturbing industrial production activities of the affected areas and the supply chains of world's industries.

In this study, satellite imagery data, the most effective ways for extracting information of large-scale disasters, are introduced. RADARSAT-2 (RS2), a Canadian SAR satellite with the C-band at a wavelength of 5.6 cm, had been mainly used for flood monitoring in Thailand since 2008 [1]. It can operate in the daytime/nighttime and under all weather conditions, and thus is considered to be very effective in flooded area extraction because water surfaces always show low backscatter [2]. ThaiChote (TH1), the Thai first satellite, was used as optical supporting since 2004. The NDVI values obtained from TH1 images could recognize flooded areas in the open space under a clear sky condition. After the flood situation had ended, a Digital Elevation Model (DEM) from LiDAR was brought into use for the first time in Thailand in early 2012, which would be very helpful to improve the accuracy of flooded areas extraction. These data sets are used in this paper for flood situation monitoring in Thailand.

2. STUDY AREA AND IMAGERY DATA

This paper focuses on the central part of Ayutthaya, which includes Ayutthaya Historical Park, Rojana and Hi-Tech Industrial Estates, about 16.5 km in width and 21.0 km in length shown in **Figure 1**. To detect floods in a large-scale area, ScanSAR mode HH (single) polarization had been used in the most cases by the Thai Government. An in-flood image observed on November 11, 2011 was in SCNA (W1+W2) beam types shown in **Figure 2 1A** while a post-event image observed on February 23, 2012 was in SCNB (W2+S5+S6) beam types shown in **Figure 2 2A**. Both of them were observed from the descending path approximately in the duration of one minute, respectively at 6:07 and 6:12 in the local time of Thailand.

A GeoEye-1(GE1) image taken during the flood event on November 22, 2011 was also used in this study. A pansharpened GE1 image has 4 multispectral bands with 1-m resolution shown in TH1 and RS2 images were used to extract water body due to **Figure 3 1A**. TH1 multispectral image with 15-m resolution taken in the flood event on November 25, 2011 is shown in **Figure 3 2A** and another in the dry season before the flood on December 12, 2009 in **Figure 3 3A**.

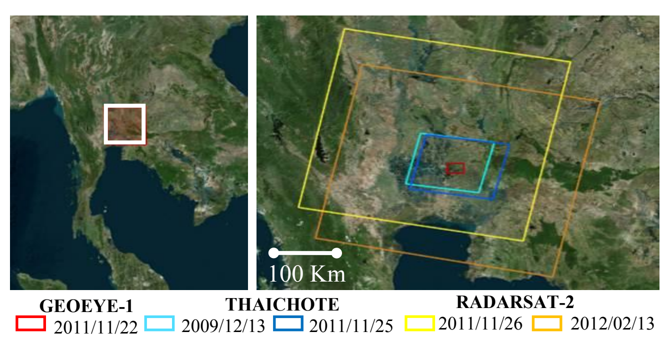


Figure 1. The Chao Phraya River basin and the areas covered by satellite images used in this study.

3. EXRACTION OF FLOODED AREAS FROM GEOEYE-1 IMAGE

In this image interpretation, rivers and ponds were also extracted as flooded areas because nearly the whole study area were covered by water. In order to extract flooded areas from the GE1 image, the Normalize Different Vegetation Index [NDVI= (NIR–R)/(NIR+R)] was calculated using the near-infrared (NIR) and Red (R) band values.

Water bodies have low reflectance in the R and NIR spectral bands, and thus it leads to very low positive or even slightly negative NDVI values and water can be classified easily [2, 3] as shown in **Figure 3 1B**. The threshold of NDVI for water body during the flood period was determined by visual interpretation as NDVI $\leq$ -0.11 or 73.8% of the image area shown in **Figure 5 1A** and **1B**.

4. EXTRACTION OF FLOODED AREAS FROM THAICHOTE AND RADARSAT-2 IMAGES

RS2 and TH1 are the main satellites to be used by the Thai government in case of flood disasters. Normally the threshold values of the backscattering coefficient and NDVI have been used to extract flooded areas, comparing visually with optical images. In this study, those threshold values were determined from the NDVI from the GE1 image in the previous section.

The comparison between two (the truth data and the estimation) two-class spatial images, water body areas (W) or non-water body areas (N), results in 4 combinations: W-W, N-N, W-N, and N-W. When the threshold for a client image is set up to the minimum value, all of its results will be non-water body areas (N). Some of them are N-N, which represents the same N values as those from the master image (GE1), while the others are W-N which represents underestimated areas, omission errors in water body extraction. When the threshold moves to higher values, some of the client image will be extracted as water body areas (W). Some of them are W-W which represents the same W values, while the others are N-W which represents overestimated areas, exaggeration in water body extraction. The best threshold value is the point that the summation of W-W and N-N areas becomes largest. At this point, the most similar result with that from the GE1 image can be obtained.

Similar as GE1, TH1 has an optical sensor with 4 bands and each band has the quite similar spectral range, but its spatial resolution is much lower. Before calculating NDVI values, TH1 images in **Figure 3 2A** were registered to the GE1 image. Then we compared their NDVIs in **Figure 3 2B** with those from the GE1 image. It can be seen that the best NDVI threshold for water was 0.20, which corresponds to estimated water body of 73.15% (W-W and N-W) in **Figure 5 2A** and **2B**. Among these extracted areas, 83.24% were similar to those from the GE1 (W-W and N-N), 8.33% were omission (W-N) and 8.43% were exaggeration (N-W) in **Figure 4 A**. By applying this NDVI threshold to the TH1's pre-flood image in **Figure 3 3B**, the water-covered ratio for this area was 14.53%.

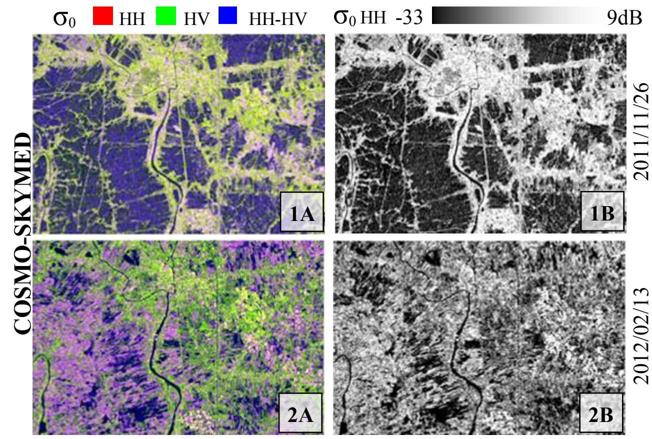


Figure 2. Comparison of RS2's dual polarization composite (HH+HV) (1A, 2A) and backscattering coefficient (σ_0) HH (1B, 2B) for the post-flood and in-flood.

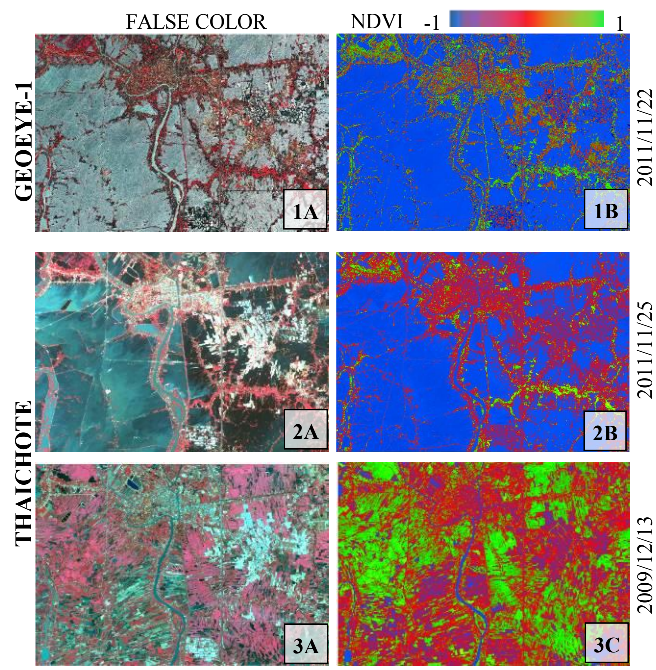


Figure 3. False color composites and NDVI values from GE1 for the in-flood time (1A, 1B) and from TH1 for the in-flood and pre-flood times for the study area (2A-3C).

Although RS2 has a different sensor from GE1 and TH1, the most standard image processing method to extract water body is the same technique, thresholding. The backscattering coefficient or Sigma Naught value (σ_0) is usually used instead of NDVI for optical sensors. The smoothness of water surface usually represents a low σ_0 value. Before using RS2 products acquired in the ScanSAR Narrow mode, they were processed in three steps. Firstly, calibration, an essential process for the quantitative use of SAR data, was applied to the images. Then, orthorectification was applied to derive precise geolocation information by using the SRTM DEM 30 s reference. Finally, the Lee filter with 3x3 window size was used to the images for reducing speckle noise. After the RS2 images had been processed, it was compared with the result from GE1. Although the color compositions of dual polarization in **Figure 2 1A** and **2 A** could identify board-leaved trees as green, narrow-leaved plants or paddy fields as purple and water body as blue, just only HH polarization images were be used for flood extraction. The best threshold of σ_0 HH can be obtained at -10.0 dB, which corresponded to the estimated water body 62.31% (W-W and N-W) in **Figure 5 3A** and **3B**. Among these extracted water body areas, 78.22% were similar to the results of GE1 (W-W and N-N), 16.33% were omission (W-N) and 5.46% were exaggeration (N-W) in **Figure 4 B**. By using this σ_0 HH threshold to the RS2 post-flood image, the water-covered ratio was 27.60%

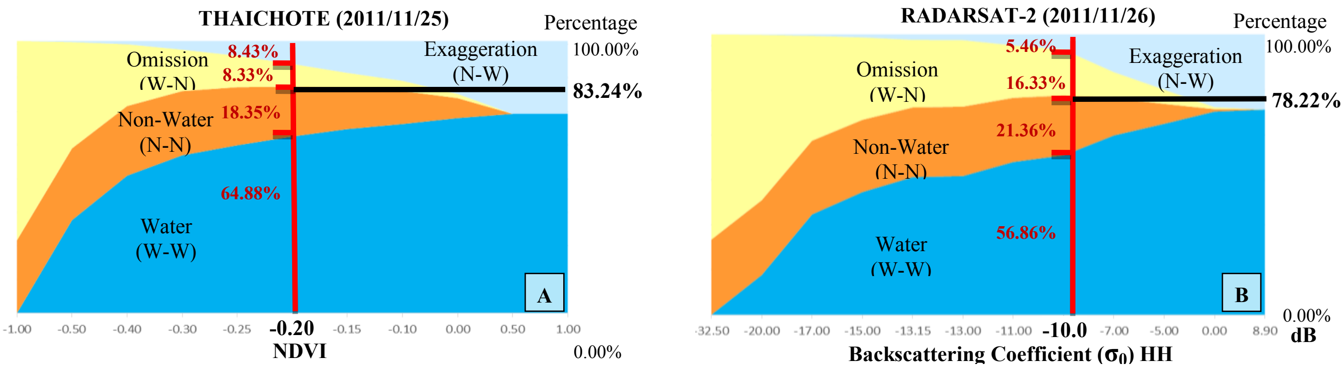


Figure 4. Relationship between the threshold and accuracy of water body extraction from the TH1's NDVI (A) and RS2's σ_0 (B).

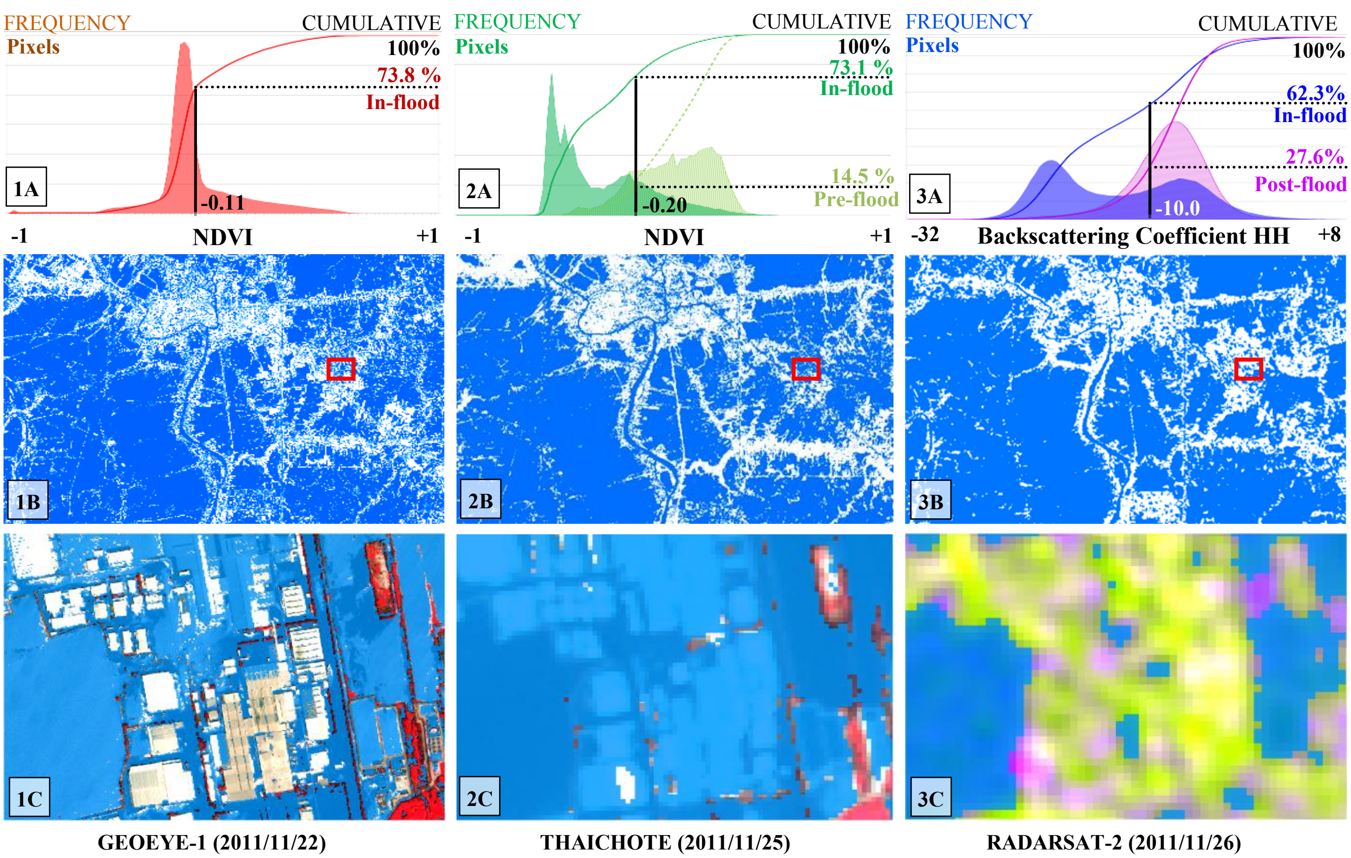
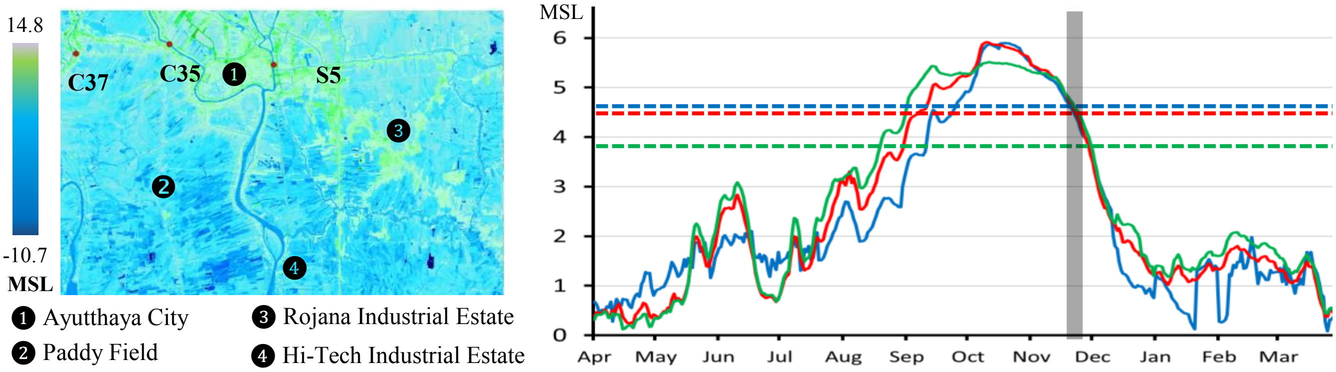


Figure 5. Histogram and cumulative probability plot and extracted flooded areas during the flood in the study area with close up images at Honda Automobile (Thailand) in Rojana Industrial Estate from GE1 (1A-1C), TH1 (2A-2C), and RS2 (3A-3C) overlaid on their color composite images.



Station	Levee (MSL)
S5	------ 4.70
C35	------ 4.58
C37	------ 3.80

Satellite Images	Acquired Date	Water Height (MSL)			Water Depth (Meter)		
		S5	C35	C37	S5	C35	C37
GeoEype-1	22/11/2011	4.48	4.56	4.62	-0.22	-0.02	0.82
THAICHOTE	25/11/2011	4.17	4.25	4.41	-0.53	-0.33	0.61
RADARSAT-2	26/11/2011	4.05	4.15	4.32	-0.65	-0.43	0.52

Figure 6. LiDAR DEM and telemetry gaging stations with their levee and water height above the MSL.

5. WATER HEIGHT

Because the satellite images were not taken from the same sensors and cannot be acquired on the same date when the water height is assumed to be equal, it is difficult to explain the reason why evaluated water areas were different. Not only the difference of sensor type and spatial-resolution, but also the change of the water height may reflect the fact that the evaluated water areas from TH1 and RS2 are smaller than that from GE1. The height of flood-water was difficult to project because water flows down without stopping although rather slowly in this area. To understand the flood situation, the daily average water height above the mean sea level (MSL), collected from 3 nearest telemetry gaging stations (C35, C37 and S5), were be considered as truth data [4] as shown in **Figure 6**.

The line graph demonstrates the water height at the 3 telemetry gaging over one year period from April, 2011 to March, 2012. The period that the satellite images were acquired was at the end of the flood situation when the water level dramatically decreased. Although the water height was slightly different on November 22, 2011, they significantly dropped more than 30 cm in 3 days on November 25, 2011, and nearly 10 cm in 1 day on November 26, 2011.

Since Ayutthaya is situated on a plane area, a little height of water may spread in a wide area. At that time, just only water height at station C37 was higher than the levee, resulted that the water at this station spread outside the river. Although the water heights of the others stations (S5 and C35) were under the levee and there was no water spread outside, the water was still remained on the ground and kept running to lower parts. This fact might cause the extracted areas in this study were a little bit different.

6. CONCLUTIONS

TH1 and RS2 images were used to extract water body due to the 2011 Chao Phraya River basin flood in Thailand. Those images could extract flooded areas easily by introducing thresholds to the NDVI value and backscattering coefficient. The extraction results were very similar to the visual inspection result from a GE1 image around 80%. However, it could not detect flooded urban areas easily due to the limitation of their spatial resolutions. The results from the TH1 image had more similarity to GE1 image because the NDVI value for water kept low even buildings was surrounded by water or not. On the other hand, the results form RS2 was lower than GE1 because the backscattering coefficient had a little bit change when buildings were surrounded by water. Another reason why the extracted water areas were less than that from GE1 was due to decreasing of water height at the end of the flood situation.

7. REFERENCES

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