EXTRACTION OF FLOODED AREAS DUE TO THE 2011 CENTRAL THAILAND FLOOD USING ASTER AND TERRASAR-X DATA

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ABSTRACT

In this study, the flooded areas following the 2011 central Thailand flood were extracted using VNIR and TIR images of ASTER and ScanSAR-mode images of TerraSAR-X. The existence of water body was easily recognized for open spaces without trees and buildings from the NDVI value. The surface temperature was also found to be effective in detecting floods in a wide open space although it is limited by its coarse spatial resolution. The SAR intensity images were the most effective because water surfaces showed weak backscatter and they can be acquired at nighttime and under cloud-cover conditions. The extracted results were validated by a high-resolution optical satellite image.

Index Terms— Floods, synthetic aperture radar, optical sensors, thermal sensors

1. INTRODUCTION

In the autumn of 2011, a large scale flood occurred along the Chao Phraya River in central Thailand [1]. A large amount of water flowed down to wide areas and many associated failures occurred in civil infrastructures and lifeline networks, and hence the flood brought serious effects for a long period. Approximately 9% of the whole nation's area in 44 prefectures out of 77 prefectures in Thailand suffered from the flood. Many industrial estates were affected, and it caused the disruption of the supply chains of world's industries, such as automobile and electronics.

In order to grasp the extents of large-scale disasters at an early stage, the use of satellite remote sensing is effective. In this study, visible near-infrared (VNIR) and thermal-infrared (TIR) imagery of Terra/ASTER and ScanSAR-mode imagery of TerraSAR-X were employed to grasp the extent of the affected area due to the 2011 central Thailand flood. The extracted results were examined by a high-resolution Ikonos image and field survey data [2].

2. THE STUDY AREA AND ASTER IMAGERY

This paper studies on a part of Chao Phraya River basin, about 30 km in width and 110 km in length ("ASTER" in Fig. 1) from the north of Ayutthaya to the Gulf of Thailand through the capital city Bangkok. This region is the heart of Indochina as well as the most important one for the Kingdom of Thailand since it contains the center of administration and economy (Bangkok), cultural heritage (Ayutthaya), international and domestic air transportation hubs (Suvarnabhumi and Don Mueang airports) and also a number of industrial parks operated by Industrial Estate Authority of Thailand.

Since the flooded areas were large, ASTER sensor onboard Terra satellite were employed. ASTER has 3 bands in Visible and Near-Infrared (VNIR) radiometer with 15 m resolution, 6 bands in Short-Wavelength Infrared (SWIR) radiometer with 30 m resolution (currently out of order), and 5 bands in Thermal-Infrared (TIR) radiometer with 90

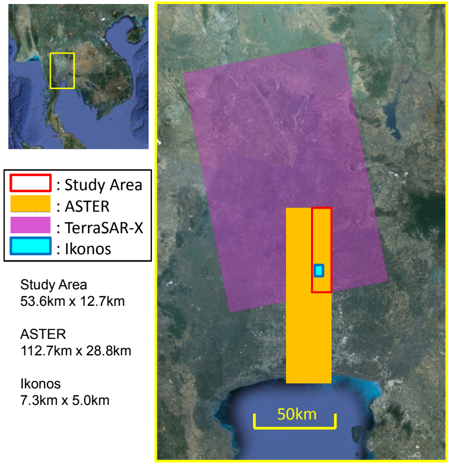


Fig. 1 The Chao Phraya River basin and the areas covered by satellite images used in this study

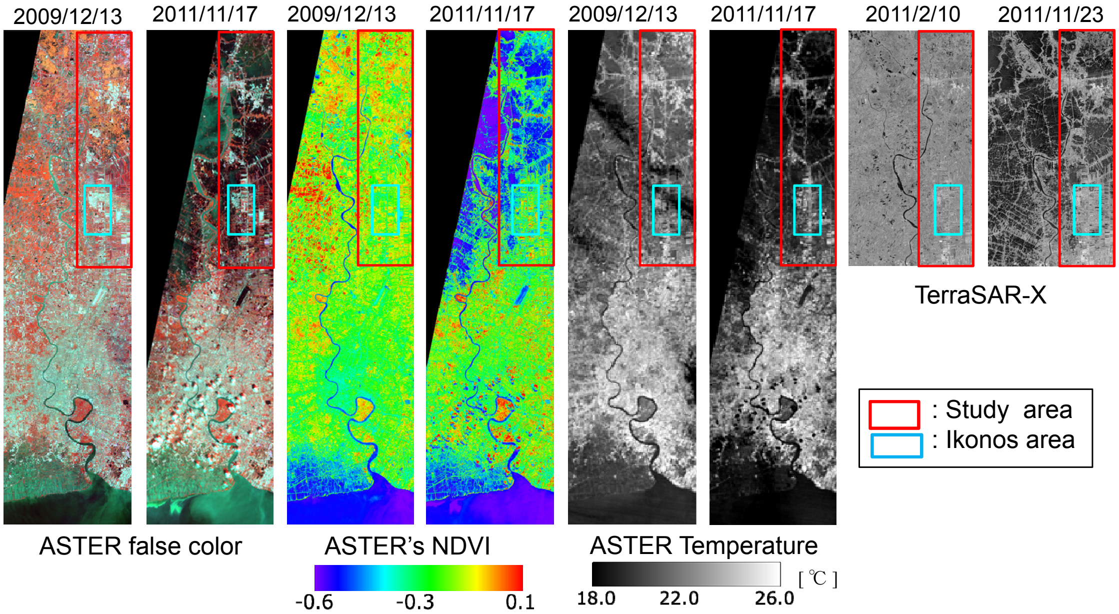


Fig. 2 Comparison of false color composite, NDVI, and surface-temperature obtained from ASTER's VNIR and TIR bands and the backscattering coefficient σ_0 from TerraSAR-X for the pre-flood and in-flood periods.

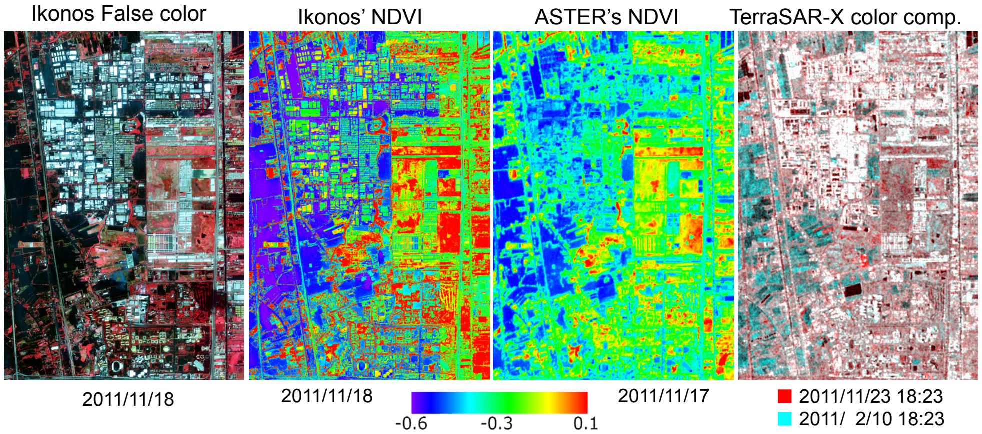


Fig. 3 In-flood Ikonos image including Navanakorn Industrial Estate, AIT and Thammasat University, and its NDVI compared with ASTER's NDVI and TerraSAR-X color composite images

m resolution, 14 observation channels in total [3]. Out of these channels of ASTER, band 10 in TIR, bands 1 (G), 2 (R), and 3 (NIR) in VNIR were used in this study.

A pre-event VNIR image observed on December 13, 2009, and a VNIR image during the flood observed on November 17, 2011, were employed to observe the flood situation of the study area (red rectangle: 54 km x 13 km) shown in Fig. 2. TIR images were also acquired on these two dates and they were used to access the capability of TIR images in flood monitoring. Both the VNIR and TIR images were observed from 10:48 to 11:10 in the local time of Thailand (3:48 to 4:10 in UTC).

From the VNIR bands, the Normalized Difference Vegetation Index (NDVI) was calculated because it is known to show small values for water body.

$$NDVI = (NIR-R)/(NIR+R) \qquad (1)$$

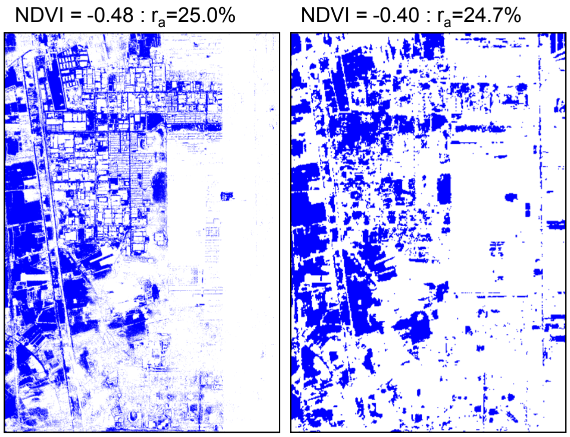
where NIR is the reflectance of the NIR band and R is that of the red band. Figure 2 also shows the NDVI from the ASTER's VNIR images, in which flooded areas are easily observed by low NDVI values.

3. EXTRACTION OF FLOODED AREAS FROM VNIR IMAGES OF IKONOS AND ASTER

Flooded areas can be estimated by setting thresholds for NDVI and surface temperature from the ASTER images. In order to determine these thresholds, a high-resolution Ikonos image, which includes Navanakorn Industrial Estate, Asian Institute of Technology (AIT), and Thammasat University's Rang-sit Campus, acquired at 11:04 (local time), November 18, 2011, was introduced as shown in Fig. 3.

Ikonos has a panchromatic band with 1-m resolution and multispectral (B, G, R, NIR) bands with 4-m resolution. After pan-sharpening, a multispectral image with 1-m resolution was obtained. Using this flood-time image, the NDVI threshold for water body was determined by visual inspection. Fig. 4 (a) shows the extracted flooded areas for the Ikonos image. Based on the observation for different NDVI values, the water body ratio was determined as about 25 % of the image area, which corresponds to the pixels with NDVI ≤ -0.48 in the Ikonos image.

The NDVI values were also calculated for the ASTER images to have the same flood area ratio (25 %) as shown in Fig. 4 (b). Comparison of the cumulative distributions of NDVI for the Ikonos's image area, plotted in Fig. 5, exhibited different NDVI values between the Ikonos and ASTER images. This difference is mostly due to the difference in their spatial resolutions (Ikonos: 1 m, ASTER: 15 m). Hence the threshold of water body for the ASTER images was determined as NDVI ≤ -0.40, which gave the same ratio of water body (25 %) in the Ikonos's image area.



(a) Ikonos (b) ASTER

Fig. 4 Estimated flooded areas from the Ikonos (a) and ASTER (b) images

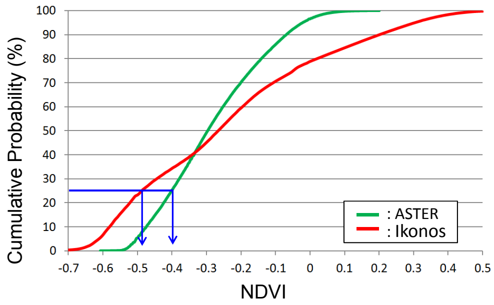


Fig. 5 Comparison of Ikonos' and ASTER's NDVI cumulative probability plots for the Ikonos's image area

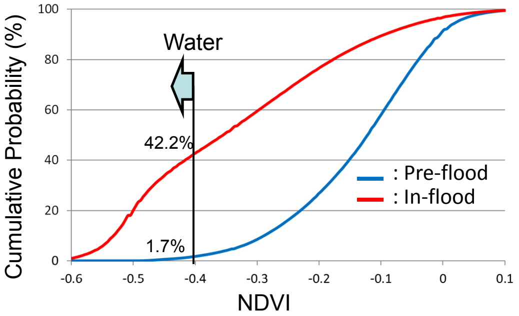


Fig. 6 Comparison of pre-flood and in-flood ASTER' NDVI cumulative probability plots for the study area

Figure 6 shows the distributions of NDVI in the study area (the red rectangle in Fig. 2) by the ASTER images. Using the NDVI threshold for ASTER, the water-covered ratio for this area is about 42 % during the flood and about 2 % before the flood.

4. EXTRACTION OF FLOODED AREAS FROM THERMAL-INFRARED IMAGES OF ASTER

Thermal sensors can observe the earth surface both at daytime and nighttime. Hence they have more chances to observe perishable scenes such as flooding by tsunami [4] and are considered to be useful to detect widely spread affected areas, especially at nighttime. The spatial resolution of TIR bands is, in general, much lower than that of VNIR bands, and hence the use of TIR bands at daytime is not so meaningful in case VNIR images are available. We used ASTER's TIR band, however, in order to examine its capability to extract flooded areas in the Thailand flood.

The surface temperature was obtained by converting the digital number of the TIR's band 10. Figure 2 also shows the surface temperatures in the pre-flood and in-flood days. Since the heat capacity of water is larger than other surface materials, the daytime surface temperature for a flooded area is lower than that in the normal (no flood) daytime. From the figure, the surface temperature of flooded areas is seen to be lower than that of dry grounds. Since those TIR images were taken at daytime in a tropical region, water surface may be extracted by a temperature threshold. From the cumulative distributions of the two-temporal TIR images shown in Fig. 7, 19 °C was selected as the threshold

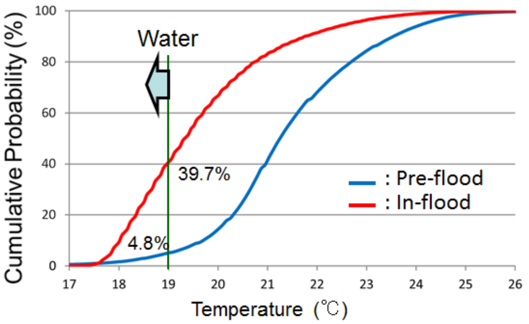


Fig. 7 Comparison of pre-flood and in-flood ASTER' temperature cumulative probabilities for the study area

value of water surface in this in-flood image. Note that in this surface-temperature threshold, the ratio of water body is about 40 %, the same ratio in the case of NDVI $\le$ -0.40 for the ASTER's VNIR images.

5. EXTRACTION OF FLOODED AREAS FROM TERRASAR-X IMAGERY

Two temporal TerraSAR-X (TSX) images (Fig. 2) taken before and during the 2011 Thailand flood were used in this study. The pre-flood image was taken at 11:23 on February 11, 2010 (UTC) while the in-flood one at 11:23 on November 23, 2011. The incidence angle was 36.23° at the center of the images. The two images were captured with HH polarization from an ascending path. The images were acquired in the ScanSAR mode and had been processed as orthorectified multi-look corrected (EEC) products with a square pixel size of 16 m.

Two preprocessing steps were applied to the images before flood extraction. First, the two TSX images were transformed to the backscattering coefficient represented as a Sigma Naught (σ_0) value, which represents the radar reflectivity per unit area in the ground range. After applying Lee filter with 3 x 3 window size, the flooded areas were estimated from the backscattering coefficient value because water surfaces show a very small value for X-band SAR.

Figure 3 also shows a color composite of the pre-flood (Blue + Green) and the in-flood (Red) TSX images. Cyan colored areas indicate that the backscattering coefficients were reduced in the in-flood TSX image due to flood water. The cumulative distributions of the backscattering coefficient on the two dates are plotted in Fig. 8 for the study area. The coefficient (-13 dB) corresponding to about 40 % cumulative probability was determine as the threshold of water body for the X-band SAR.

6. CONCLUSIONS

The flooded areas following the 2011 central Thailand flood were extracted using ASTER's VNIR and TIR images and TerraSAR-X images. First, a high-resolution Ikonos image was introduced to extract water body visually for a selected area. Then the threshold value of NDVI for water body was determined by comparing the ASTER and Ikonos images. The existence of water body was easily recognized for open spaces without trees and buildings from the NDVI value. The surface temperature was also found to be effective in detecting water body in a wide open space although it is limited by its coarse spatial resolution. The SAR intensity images were also effective because water surface shows weak backscatter and they can be acquired at nighttime and under cloud-cover conditions.

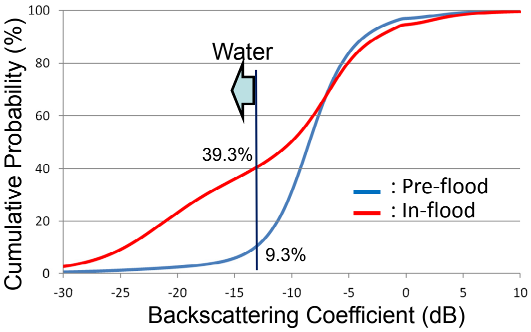


Fig. 8 Comparison of pre-flood and in-flood TerraSAR-X's σ_0 cumulative probabilities for the study area

7. ACKNOWLEDGMENT

ASTER images used in this study were provided by Global Earth Observation Grid (Geo Grid), National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan.

8. REFERENCES

[1] Geo-Informatics and Space Technology Development Agency (GISTDA), Thailand Flood Monitoring System, 2011.
URL: *http://flood.gistda.or.th/*

[2] J. Shimakage, and F. Yamazaki, Detection of flooded areas following the 2011 Thailand floods using ASTER images, *Proc. 33rd Asian Conference on Remote Sensing*, Pattaya Beach, CD-ROM, 8p, 2012.

[3] Jet Propulsion Laboratory (JPL), ASTER - Advanced Spaceborne Thermal Emission and Reflection Radiometer.
URL: *http://asterweb.jpl.nasa.gov/instrument.asp*

[4] D. Hanada, and F. Yamazaki, "Detection of the Flooded Area by the 2011 Tohoku Earthquake/Tsunami using ASTER Thermal Infrared Images," *9th International Conference on Urban Earthquake Engineering,* Tokyo Institute of Technology, 235-239, 2012.