EXTRACTION FLOOD INUNDATION BY UTILIZING ALOS/PALSAR IMAGE

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ABSTRACT: The climate change leads the disaster occurring in everywhere. Remote Sensing as useful technology can detect the disaster quickly even though in a remote area and bad weather condition. The extreme rainfall occurred on 28-29th August 2008 around Chugoku, Shikoku, Tokai, Kanto in Japan that leading the flood. The most impacted area is Okazaki City and Anjo City. According to Japan Meteorology Agency data, the rainfall was 146.5 mm in one hour. In this research, we utilized pre-disaster and post-disaster images of the ALOS/PALSAR satellite to extract the inundation of flood in Okazaki City and Anjo City. By extracting the backscattering value of each object from a pre-disaster and post-disaster image, then decided the threshold of the backscattering, we extracted the inundation area. The result was validated by using flood report from Okazaki and Anjo City. This method can be used as a quick response to flood disaster.

KEYWORDS: ALOS/PALSAR, Backscattering, Flood.

1. INTRODUCTION

In recent years, natural disasters have frequently occurred in many parts of the world. Early detection of damage situation is important. Therefore, it is possible to recognize early damage status by using the satellite of remote sensing technology that can grasp disasters phenomenon. Remote sensing technology can be utilized in the various phases of disaster management such as prevention, preparedness, relief and reconstruction (Westen, 2000).

The heavy rain occurred on 29th August 2008 in Okazaki City and Anjo City. In this study, we tried to extract flooded areas of the city due to the heavy rain disaster using satellite remote sensing. ALOS/PALSAR image was applied to achieve this study. We use ALOS/PALSAR data because ALOS/PALSAR satellite can record in all weathers condition (JAXA, 2003). ALOS/PALSAR image was used to observe the flood inundation areas, flood extent mapping using SAR images is widely applied because water appears dark with very low backscattering compared to other objects (Smith, 1997). Even though SAR image is difficult to be processed and interpreted due to foreshortening, layover, shadow effect, relief displacement and also speckle noise.

A single radar image is normally exposed to a gray scale image. The backscatter of the each pixel is influenced by types, sizes, shapes and direction of the scatters in the objective area; moisture content of the target area; the radar pulses frequency and polarization; as well as the incident angles of the radar beam. The pixel intensity values are often converted to a physical quantity namely the backscattering coefficient or normalized radar cross-section calculated in decibel (dB) units, the range value of the backscattering is from +5 dB for over bright objects to -40 dB for very dark surfaces (CRISP, 2001). SAR backscattering coefficient is controlled by Dielectric constant, surface roughness, terrain slope (and radar look angle), scattering mechanisms, polarization, and radar wave. According to the backscattering coefficient, the flooded area will be extracted. The extraction of flooded area compares to field survey.

By thresholding the flood backscattering, we extracted the value of flooded area. Thus, phases of disaster management namely relief the disaster can be achieved. This research can be used as the quick response of the flood disaster.

2. METHODOLOGY

2.1. Data and study area

This study utilized ALOS/PALSAR data that provided by JAXA (Table 1) and building data of Okazaki City that provided by GSI. The building data was recorded on 5th November 2008 (GSI, 2014).

Table 1. ALOS/PALSAR Specification

Date	Image	Observation direction	Off-nadir angle	Polarization	Resolution
2008/8/30	Pre- disaster	Ascending	21.5°	HH	6.25m
2007/8/21	Post-disaster	Ascending	34.3°	HH+HV	12.5m

The research area is in Okazaki City, Aichi Prefecture, Japan as shown in Figure 1 below. The flood inundation in August 2008 reached up to 1.05 m (Japan Meteorology Agency, 2008).

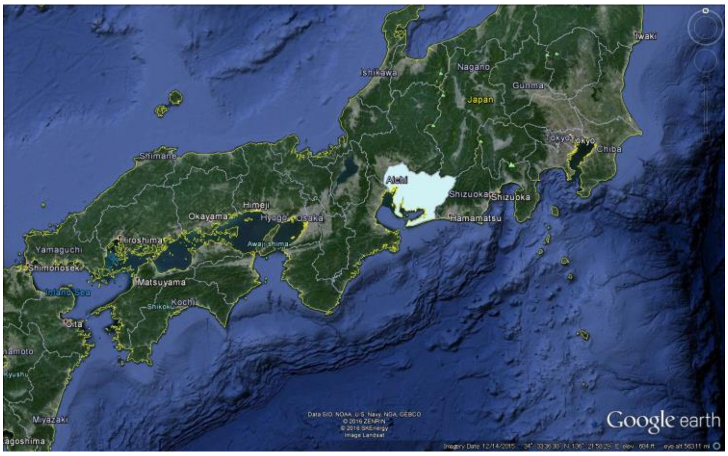


Figure 1 Research Location (Googleearth, 2014).

2.2. Pre-processing of ALOS/PALSAR

Advanced Land Observing Satellite (ALOS) PALSAR were utilized in this research. The ALOS system was launched by Japan Aerospace Exploration Agency (JAXA) on January 24th, 2006. PALSAR installed in ALOS is a fully polarimetric instrument. ALOS/PALSAR has 10m resolution. Those satellites have L-band wavelength. It can be easy to detect a water surface because of its wavelength is L-band which could penetrate the canopy of vegetation (JAXA, 2016). The first step of processing the ALOS/PALSAR data is converting from the digital number (DN) to the backscattering coefficient (sigma-naught) denote as dB. It can be done by the following equations (JAXA, 2016).

$$\sigma^0_{Q16} = 10 \cdot \log_{10}\left\langle DN^2 \right\rangle + CF_1 \quad \text{(for L1.5, 2.1)} \qquad \text{Equation 1}$$

$$\sigma^0_{slc} = 10 \cdot \log_{10}\left\langle I^2 + Q^2 \right\rangle + CF_1 - A \quad \text{(for L1.1)} \qquad \text{Equation 2}$$

where CF and A are listed in Table 2.

Table 2. Value of CF and A for ALOS/PALSAR

CF	**mean (dB)**	**std (dB)**
CF_1	-83.0	0.406
A	32.0	-

2.3. Binarization

Image binarization is one of the fundamental techniques of image processing. Image binarization is a method to separate the pixel values into two groups namely white as the background and black as foreground (Si Qi & Lei, 2002). Thresholding has an important role in binarization process. Because the suitable threshold value is the beginning of the next process operation, for example, feature extraction, segmentation, target recognition and so on (Zhang & Dou, 2014).

The threshold method proposed by Otsu is a global adaptive binarization technique, which is the best representative of global adaptive thresholding, and tries to find a single threshold value for the whole image (Otsu, 1979). Image thresholding is a simple arrangement of image segmentation. It is a way to create a binary image from a grayscale or full-color image (ENVI, 2004).

2.4. Closing and Opening

Opening and closing are two significant operators from mathematical morphology. They are both derived from the fundamental operations of erosion and dilation. They are normally applied to binary images, although there are also gray level versions. The basic effect of an opening is somewhat like erosion in that it tends to remove some of the bright pixels (foreground) from the boundaries of regions of foreground pixels. However, it is less destructive than erosion in general (HIPR2, 2004).

Similar to other morphological operators, the faithful operation is determined by a structuring element. The effect of the operator is to preserve *foreground* regions for opening process and background region for closing process that have a similar shape to this structuring element, or that can completely contain the structuring element while removing all other regions of foreground pixels for opening and background pixels for closing (HIPR2, 2004).

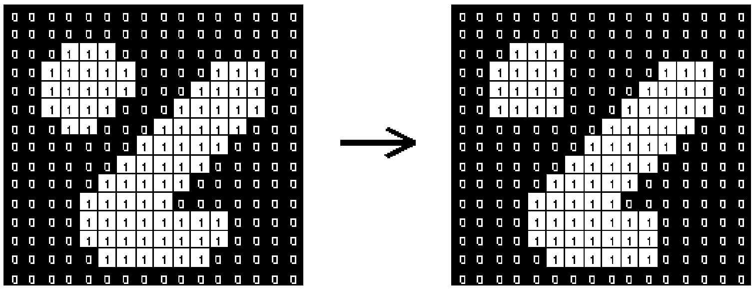


Figure 2 Effect of opening using a 3x3 square structuring element

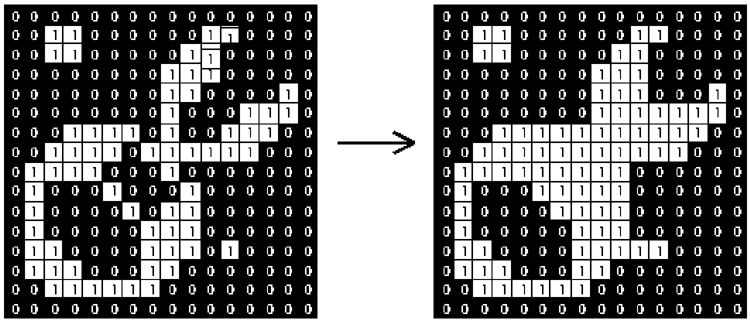


Figure 3 Effect of closing using a 3x3 square structuring element

2.5. Flowchart

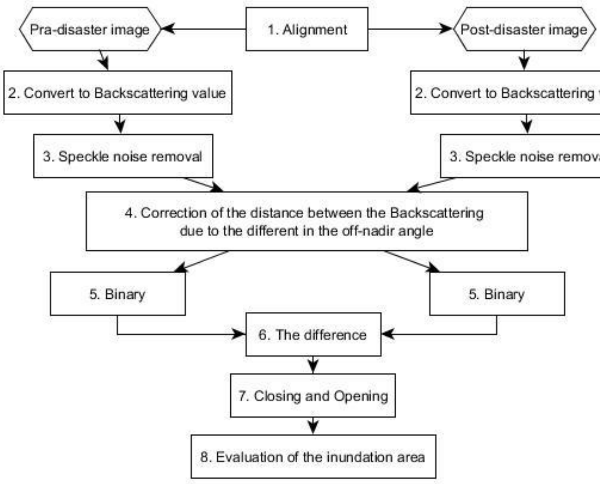


Figure 4 The flow chart

1. Alignment the image into the same position
2. Converting the Digital Number (DN) to Backscattering value
3. Filtering the image to remove the speckle noise
4. Correcting the different of backscattering coefficient of before and after image due to the different of the off-nadir angle
5. Binarization processing of before and after disaster image to extract the object
6. Extracting the different of before and after image from the binarization result
7. Closing and opening process to remove the small region of selected area
8. Extracting the flooded area

3. RESULT

3.1. Correction of the difference between the backscattering coefficients due to the difference in the off-nadir angle

We utilized two images of ALOS/PALSAR pre-disaster and post-disaster. Those images have difference off-nadir angle that caused the difference of backscattering coefficient. We selected the city object that has same characteristic and location on both images. By using ROI tools (Region of Interest) in ENVI software (ENVI, 2004), we selected the object in the pre-disaster image and post-disaster image as shown in Figure 5. The red color is the ROI of the city area that has high backscattering of building. When to select the ROI of the city, we make sure that the areas are free from flood.

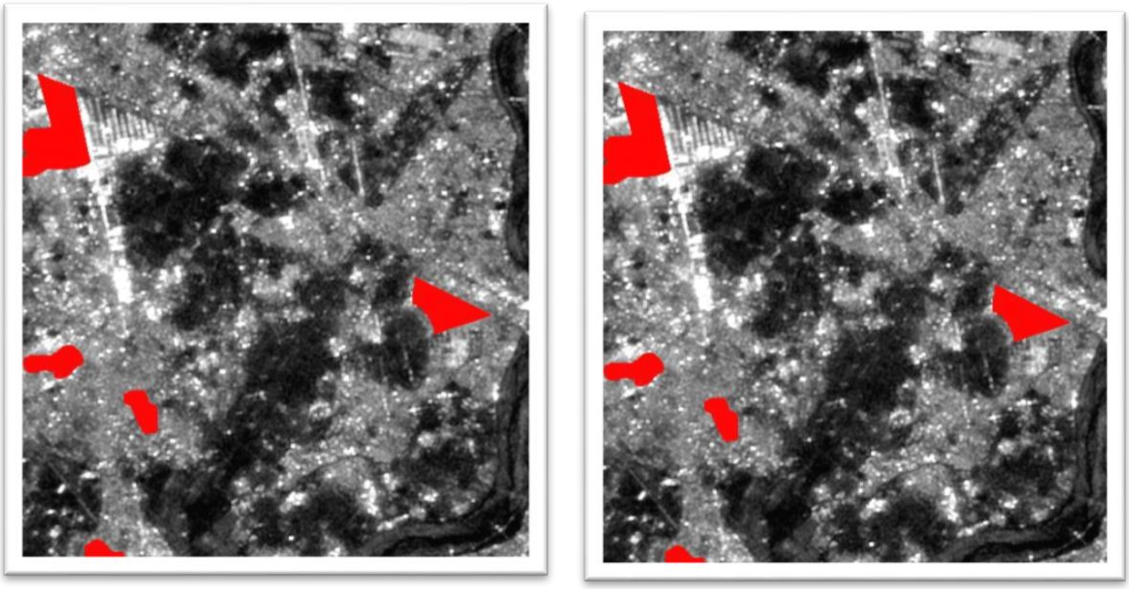


Figure 5 ROI of before the flood (left) and ROI after the flood (right)

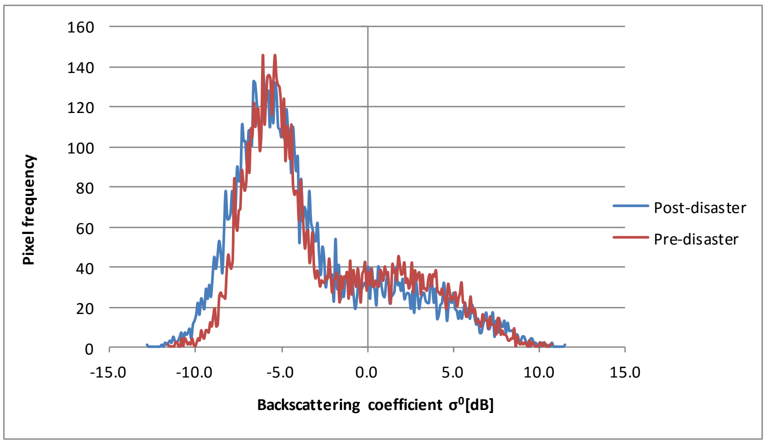


Figure 6 Histogram of selected ROI

Figure 6 shows the backscattering coefficient difference of pre-disaster and post-disaster. It caused by the different of the off-nadir angle. The off-nadir angle is any point not directly beneath a scanner's detectors, but rather off at an angle (ESRI, 2016). We could observe the difference in low backscattering value. The difference of backscattering of them is around -0.9[dB]. This value used as the correction value of post-disaster images.

3.2. Binarization

We extracted the interested area by applying ROI tools. The selected objects are the city (building), rice field and open area for the pre-disaster and post-disaster image. The histogram of each ROI was generated and also accumulated as shown in Fig.7 and Fig.8. According to those histograms, we generated the threshold of the backscattering value. There are two methods to decide the threshold; (a) Mode method and (b) Laplacian histogram method. Mode method decides the threshold according to bimodal (2 peaks) histogram that means two dominant modes characterize the image histogram (Raju & Neelima, 2012) and it takes the threshold from the low value of the valley. This method is suitable when we have a clear valley. The Laplacian is the two-dimensional equivalent of the second derivative. As general, in this research we composed of a dark object on a light background, the difference between dark and light is the contour of an object that means increasing absolute value of the Laplacian (Shapiro & Stockman, 2001). Hence, the absolute value of the Laplacian is calculated for each pixel.

Figure 7 shows the bimodal histogram; it is the backscattering value histogram of the pre-disaster image. Figure 8 shows the histogram after the disaster. It has only one peak. Thus, the threshold the edge should be used the Laplacian histogram.

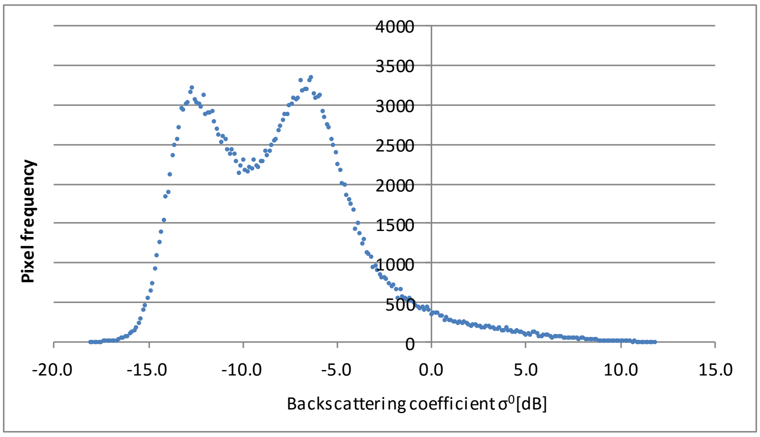


Figure 7 Histogram of the pre-disaster image.

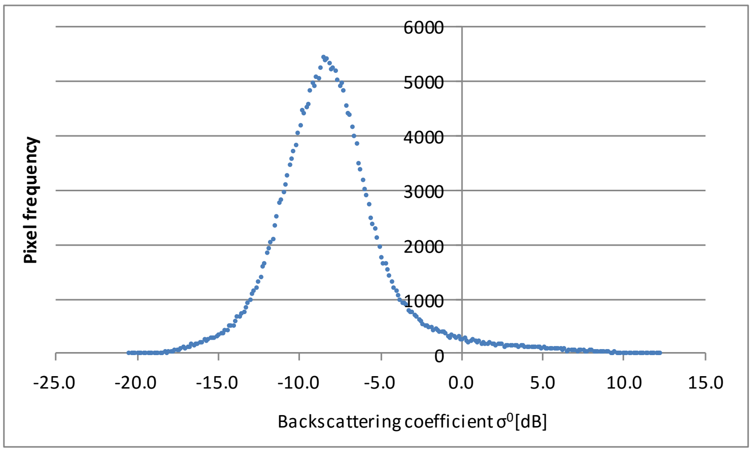
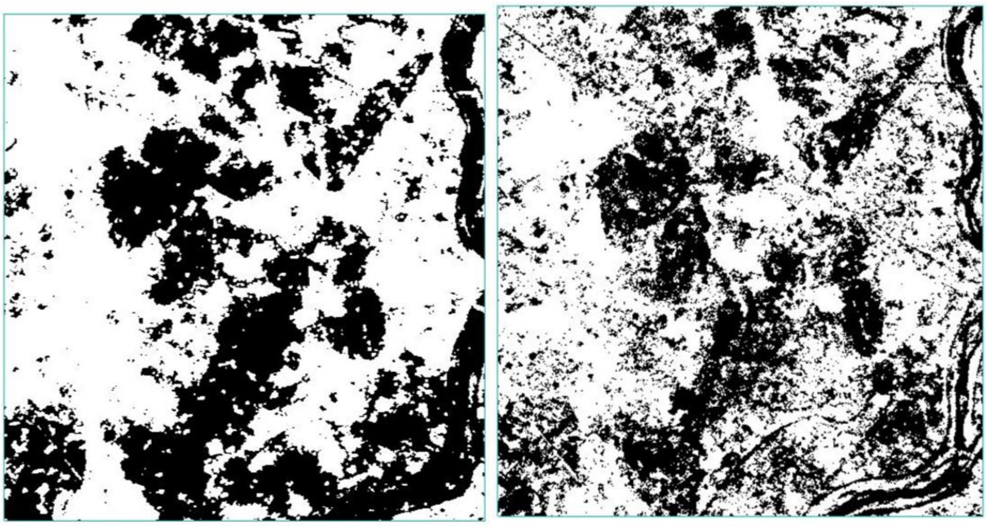


Figure 8 Histogram for post-disaster



(a) (b)

Fig. 9 (a) Binary image of pre-disaster with threshold -9.8; and (b) Binary image post-disaster threshold -9.1.

Figure 9 shows the binary images of pre-disaster and post-disaster, those images derived from the histogram of binarization as shown in Fig. 7 and Fig.8. Before producing the Fig.8, we should reduce the backscattering value with -0.9 dB due to the difference of the off-nadir. The threshold of binary image for pre-disaster is 9.8 dB and for post-disaster is -9.1 dB.

3.3. Closing and Opening

Figure 10a shows the difference of pre-disaster and post-disaster. It was generated from Fig.9 where Fig. 9a was reduced by the area of Fig. 9b. The white areas are the difference between before and after, that definite as flood area. Figure 10b shows the result of closing and opening the image. It was produced from Fig.10a. In order to remove the noise and interpolate the flood area, we carried out the closing and opening.

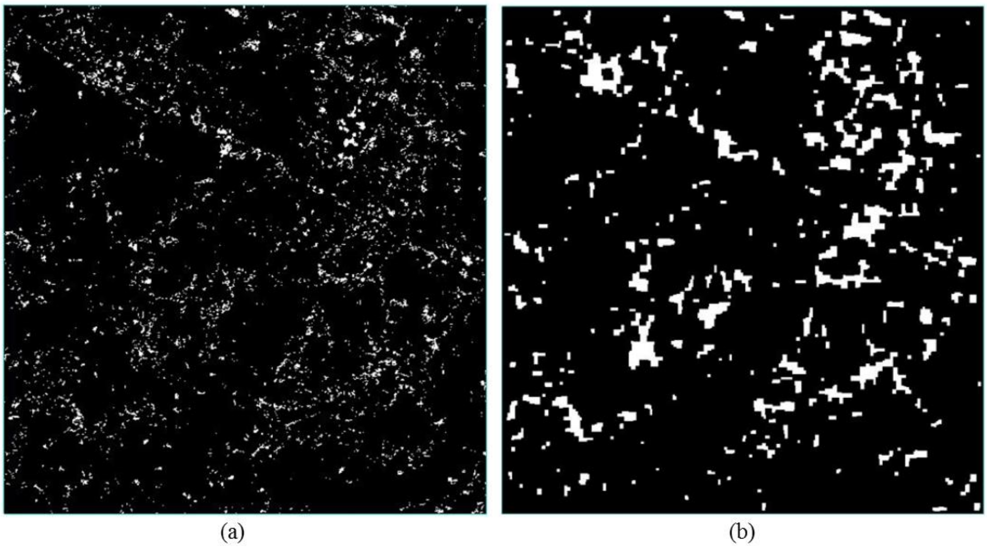


Figure 10 (a) The difference of pre-disaster and post-disaster image, (b) After closing the opening processing of the pre-disaster and post-disaster image.

3.4 Evaluation of the inundation area

Figure 12a is the flooded area in Okazaki City; the blue part is the inundated areas, it a field survey data that conducted by Okazaki City. 12b is the location of flooded area as shown in the google earth that areas are mostly rice field area or farming area. It is a Google Earth image.

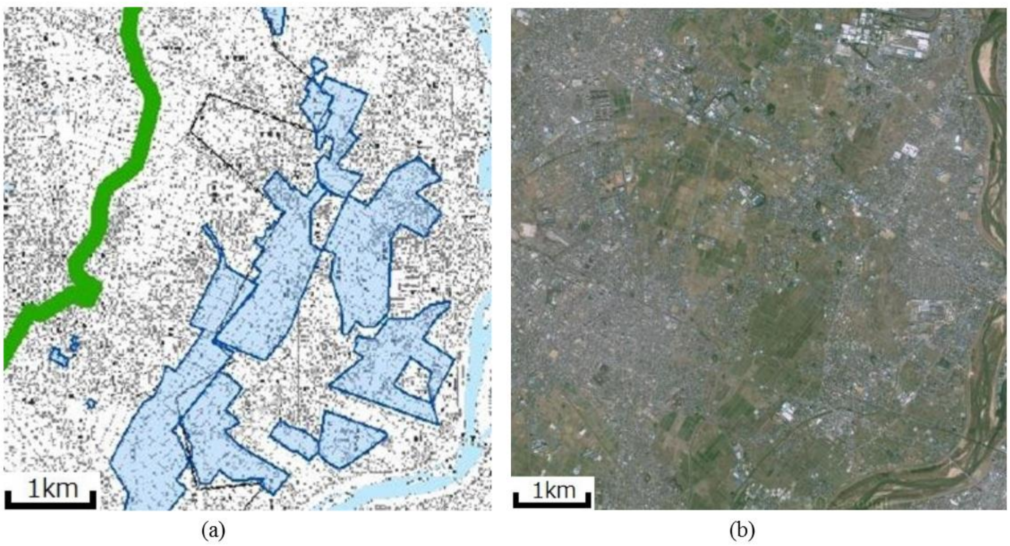


Figure 12 (a) Flooded area by field survey (Okazakishi, 2013) & (b) Google map non-inundated by flood (Googleearth, 2014).

Figure 13(a) shows the area building area that flooded in Okazaki City. The blue part is the buildings. Figure 13b shows the area of flooded by the field survey and difference of the binarization from before and after disaster image. The flooded area in Fig. 13b is the white part. This result is too narrow comparing to the field survey. We need to expand the threshold result. Hence, the value of flooded area is ±1 from the flood threshold.

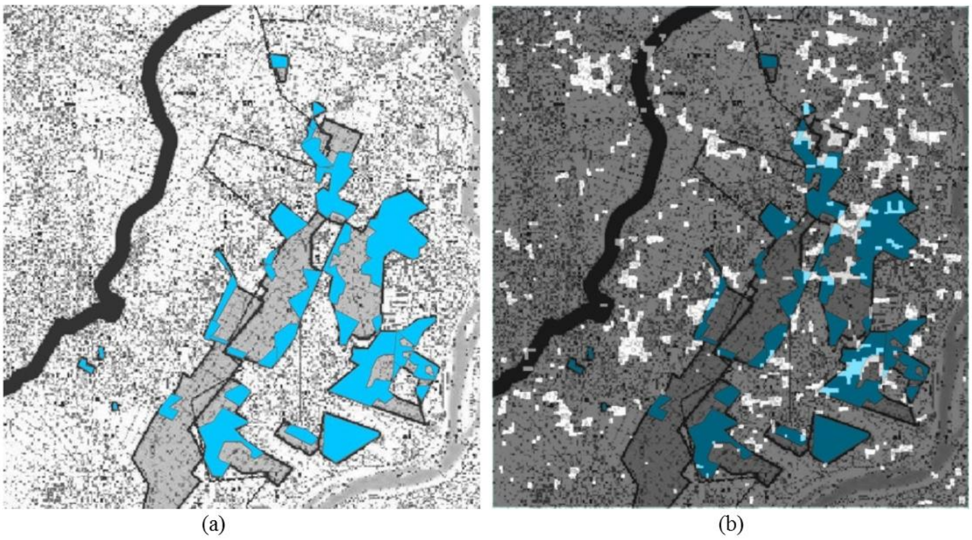


Figure 13 (a) The blue area is the building area that flooded (GSI, 2014)and (b) Overlaid the Fig.9a and Fig. 11a

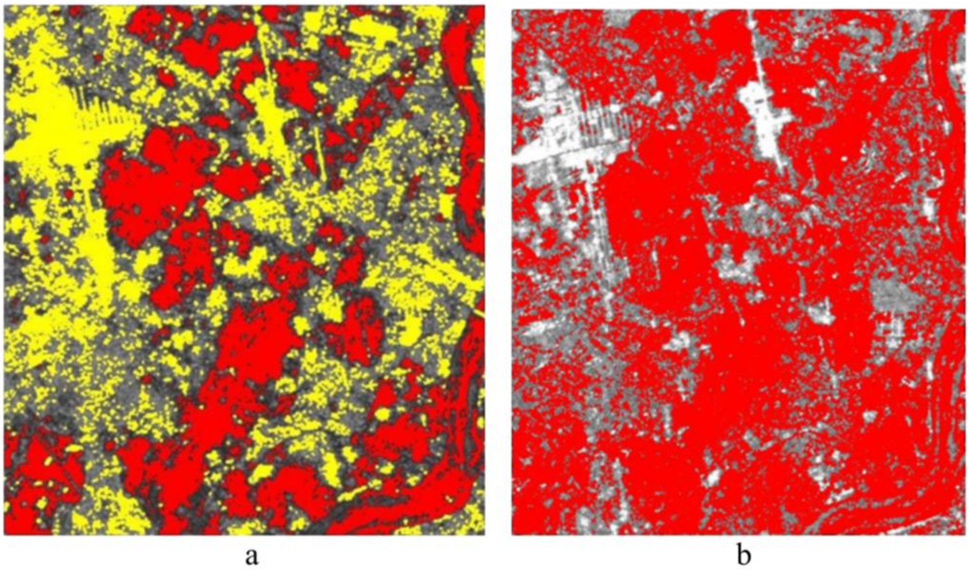


Figure 14 (a) Binarization result of pre-disaster image and (b) post-disaster image with value ±1 of threshold

Figure 14 shows the binarization before the flood in the left and after the flood in the right. Figure 14 has two colors because its histogram has two peaks. The red color is the water, and the yellow is the building. As shown in Fig. 14b, the red color expanded and it is cover some building area.

4. DISCUSSION

The typhoon brought heavy rainfall to Japan on August 28-29th, 2008. The highest impacted area was in Aichi Prefecture. Total rainfall amounts on these two days were 304.5 mm at Okazaki City in Aichi Prefecture (NagoyaUniversity, 2016). The amount of hourly rainfall is approximately 146.5 mm at Okazaki from 01 to 02 (JST) on August 29 (Japan Meteorology Agency, 2008).

In this research, we tried to extract the flood area by using the threshold method. The threshold of objects was defined for the pre-disaster and post-disaster image. According to the threshold, we make the binary of the image and then extracting the flood area by subtraction the pre-disaster image and the post-disaster image. Hence, the difference area pre-disaster and post-disaster could be extracted.

The difference between the positions of the off-nadir angle has an impact on the backscattering value. The off-nadir angle is vary depending upon the location of the target from the instrument flight. The off-nadir as known as elevation angle, when it is looking straight down that means its angle 0° or nadir. The off-nadir pre-disaster image is 34.3°, and the post-disaster image is 21.5°. Hence, these images generated -0.9 dB of the difference of backscattering value. This value was used to correct the backscattering value of the post-disaster image. For example, if the pixel had value -

20.5dB and deducted by -0.9 dB, hence the new pixel value would be -19.6 dB.

The threshold of the object has an important role in this research. In this research, we tried to threshold by using the histogram. The fruitfulness of the segmentation depends on the threshold value. We generated threshold value -9.8 dB for pre-disaster image and -9.1 dB for post-disaster images. We utilized this value to produce the flooded area; this range value seems to narrow. Thus, we were unable to generate a good classification. By expanded the range value to ±1, we were able to generate wide area. Hence, the range for flood area -8.1dB – 10.1dB.

This research can be used as a quick response to flood disaster. This method has some weakness due to this case mostly rice field was flooded. Thus, we assumed that the rice field around this area in the post-disaster image was flooded. The image that used in this research is one day after the peak of rainfall, hence the area of flood different with the field survey. Even though the water has low backscattering value, thus easier to recognize to water from the other object. However, some difficulty in extracting the flood area. Some areas were overestimated because some areas in the range -8.1dB – 10.1dB might be not flooded area. Thus, other data should be used to compile the flooded area.

This is simple analysis to generate the flooded area. ALOS2/PALSAR2 is capable of recording the area during the disaster occurs (JAXA, 2016). Hence, this method can be applied to flood areas as first evacuation step to help the victims of natural disaster.

5. CONCLUSIONS

This is a quick method to respond the flash flood. By analyzing the histogram, we generated that the flood backscatter value is -8.1dB – 10.1dB. The future task, we need to improve the method such as adding some other data. Thus we can get the range of flooded area. This method can be applied to ALOS2/PALSAR2 as the first step of evacuation process because this satellite can record the disaster area during disaster occurring.

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