Building Damage Mapping of the 2006 Central Java, Indonesia Earthquake Using High-Resolution Satellite Images

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ABSTRACT

In order for emergency response and early recovery assessment in large-scale disaster, it is important to rapidly comprehend the extent and severity of the building damage. In the 2006 Central Java, Indonesia earthquake (M6.3), severe building damage was observed in and around Yogyakarta city. Many satellite images have captured the damaged areas since the occurrence of the earthquake. In this study, the supervised image classification technique is applied to the QuickBird (QB) images to identify the damaged areas. First, the pre- and post-earthquake QB images are compared with the ground photographs to examine the characteristics of the damaged buildings. The damaged areas in the post-earthquake image are discolored to white due to the exposure of the debris such as the wall brick. In order for building damage mapping, supervised maximum likelihood classification is applied to the post-earthquake QB image by selecting the training pixels. The result shows severely damaged buildings are mostly identified. However, the extracted pixels are induced not only from heavily damaged buildings but also bare grounds and dusty roads.

INTRODUCTION

Rapidly quantifying the extent and severity of building damage is a high priority in the aftermath of extreme earthquake. In the Central Java, Indonesia earthquake of May 27, 2006 (M6.3), severe building damage was observed at the densely populated urban and rural areas in and around Yogyakarta city. According to the damage report (BAKORNAS 2006), the latest casualty figures stand at about 5,700 killed and 38,000 injured. An estimated 140,000 houses were completely collapsed, and 280,000 suffered partially damage in the earthquake. After the earthquake, some research institutes have released the damage distribution map on their website (e.g., UNOSAT 2006 and RESPOND 2006). The maps were delineated based on the visual detection of high-resolution satellite images such as QuickBird (QB) images. However, automated or semi-automated damage detection technique is required for more rapidly damage assessment. In this study, supervised image classification technique is applied to QB images observed in the central Java area for building damage mapping.

FIELD SURVEY FOR THE 2006 CENTRAL JAVA, INDONESIA EARTHQUAKE

Figure 1 shows the location of the Central Java, Indonesia and the damage distribution estimated in UNOSAT (2006). The damage was interpreted from QB images observed after the earthquake in the UNOSAT map. The map shows that heavily damaged areas are concentrated in the northwest of the fault. The authors

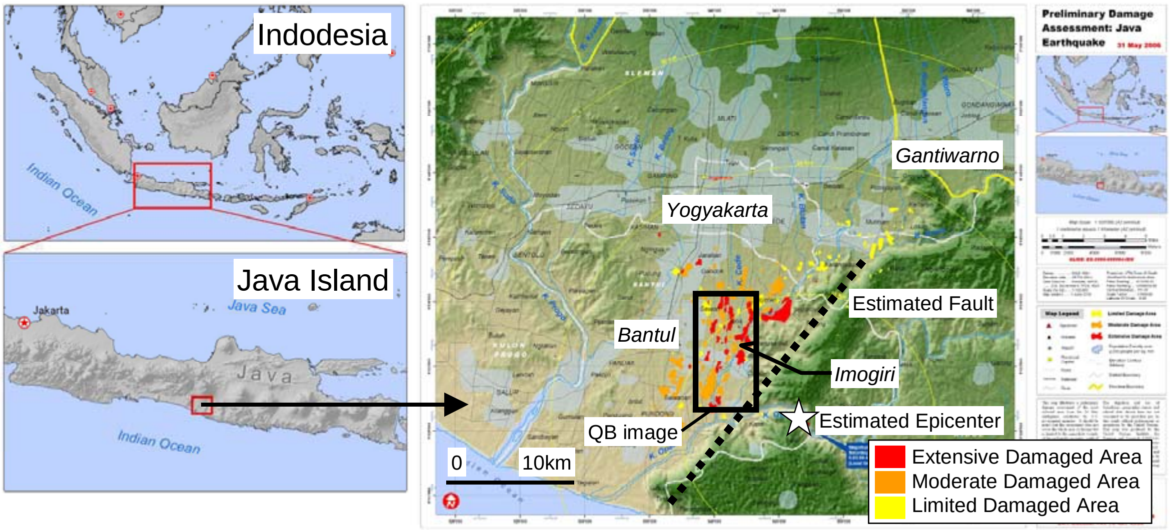


Fig. 1 Location of Central Java, Indonesia and damage distribution estimated by UNOSAT(2006)

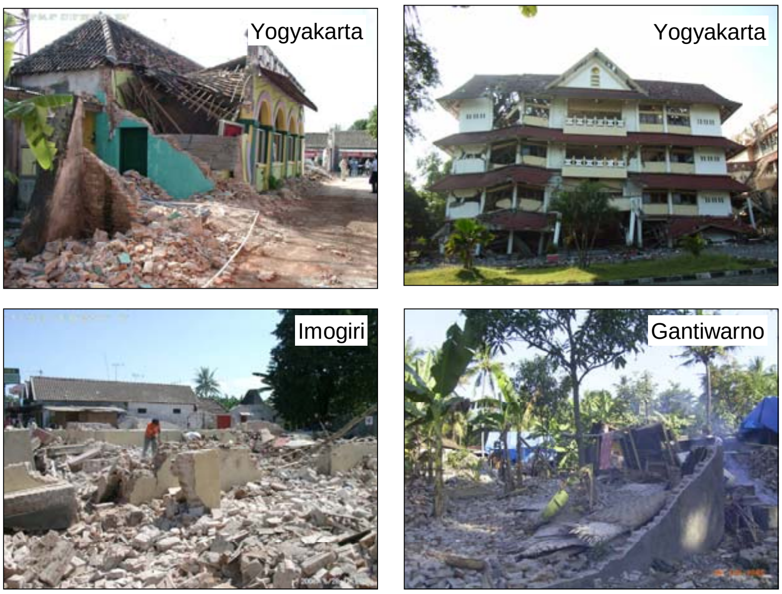


Fig. 2 Ground photographs in the damaged area in Yogyakarta, Imogiri and Gantiwarno

visited the affected area from June 26 to July 1 to gather ground truth data of the building damage and reflectance characteristics of surface materials. Figure 2 shows the ground photographs taken at Yogyakarta, Imogiri, and Gantiwarno. The typical structure of the houses is unreinforced adobe construction with wooden frame and roof tiles. As shown in the photos, not only the adobe houses but also RC-framed buildings are also damaged in Yogyakarta city. In the rural area, numbers of the houses are completely collapsed. The field survey reveals that the heavily damaged area is distributed not only in the south rural area such as Bantul and Imogiri but also in the east rural area such as Gantiwarno, that is located in the northeast of the fault. The UNOSAT map does not contain the damage in Gantiwarno because the QB images used in the interpretation didn't cover the area. According to the report by Murakami (2006), the complete collapse ratios in Imogiri and Gantiwarno are more than 30%.

In order to gather the ground truth data of satellite optical images, measurements of spectral reflectance of

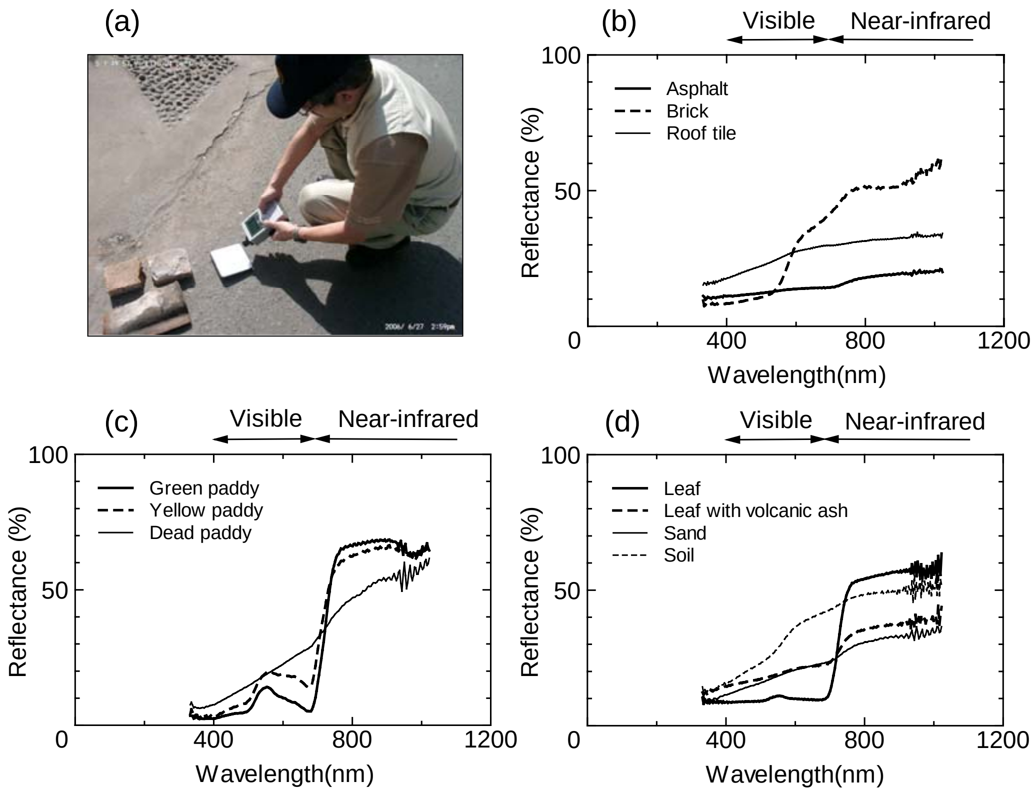


Fig. 3(a) Condition of reflectance measurement,
(b)-(d) Reflectance of surface materials

surface materials were conducted in the field survey using a hand-held spectrometer, MS-720 made by Eko Instruments Co., Ltd., Japan. Figure 3(a) shows the condition of the observation and Figure 3(b)-(d) illustrates the reflectance of the materials. Horizontal axis indicates wavelength in nanometer while vertical axis shows reflectance in percentage. As shown in Fig. 3(b), the reflectance of brick that is a material of wall in a collapsed building is much higher in near infrared band while it is lower than those of roof tile and asphalt in visible band. A clear difference is observed among the three reflectance curves of vegetation as shown in Fig. 3(c). A rapid increase in reflectance between visible band and near infrared band is observed for the green healthy paddy, while this characteristic is reduced for the yellow unhealthy paddy, and it is lost for the dead paddy. This trend is also observed for between healthy leaf and volcanic ash-covered leaf as shown in Fig. 3(d).

VISUAL DETECTION OF BUILDING DAMAGE FROM QB IMAGES

The QB images that cover the severely damaged area as shown by the square in Fig. 1 are used for building damage mapping. The post-earthquake image observed in June 13, 2006 and the pre-earthquake image observed in July 11, 2003 are used in this paper. The pan-sharpened image whose resolution is 0.6 m is constructed from the panchromatic image and the multispectral image by using the Brovey transformation. In order to examine the characteristics of the affected areas in the QB images, visual detection of the building damage is applied. The building damage is interpreted by comparing the pre- and post-earthquake images and classified into some categories based on the European Macroseismic Scale (European Seismological Commission 1998). Figure 4 illustrates the classification of damage to masonry buildings. Because it is difficult to classify damage equal to or less than Grade 2 from QB images, negligibly to slightly damaged

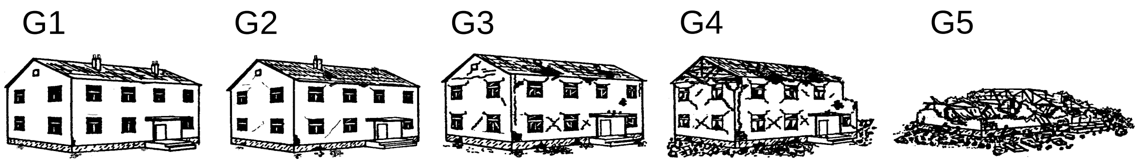


Fig. 4　Classification of damage to masonry buildings (EMS 1998)

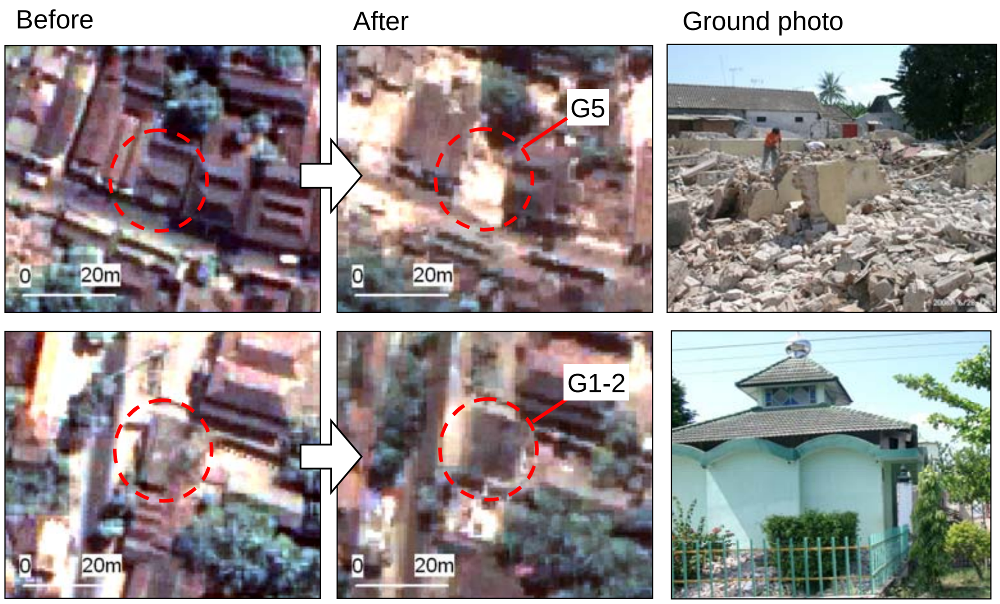


Fig. 5　Comparison of pre- and post-earthquake QB images with ground photographs

Table 1　Result of interpretation of QB images compared with actual damage

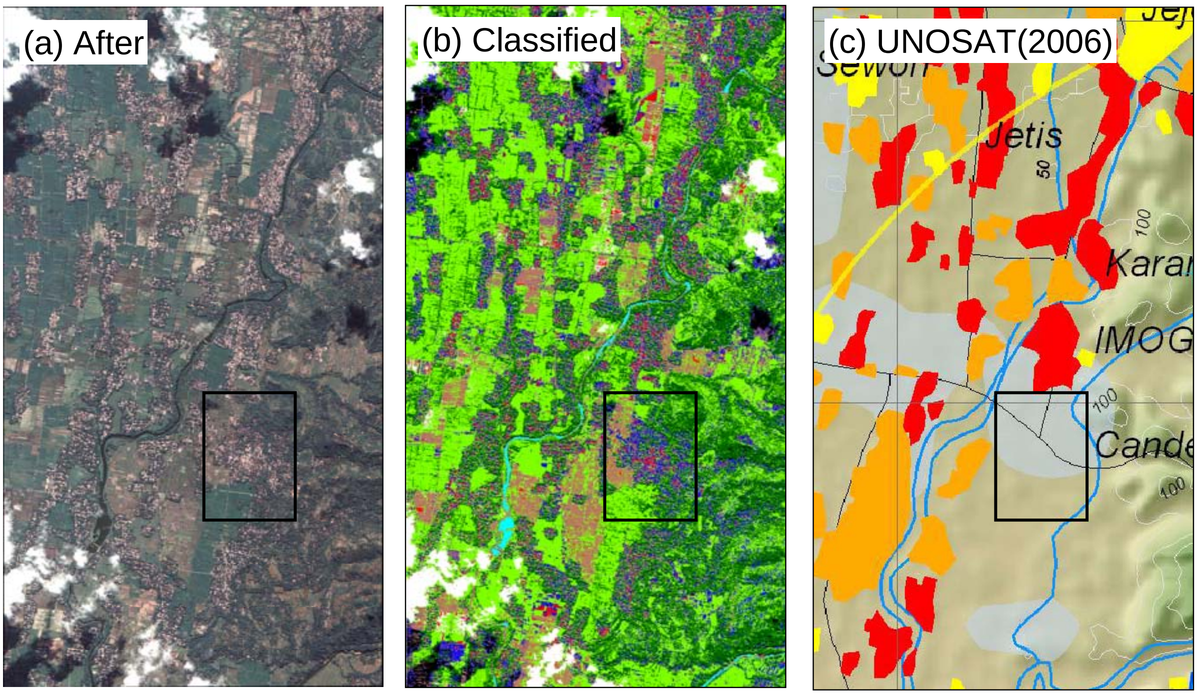
		Damage classified from ground photographs					
		G1	G2	G3	G4	G5	Total
Damage interpreted from QB images	G1-2	27	8	4	4	0	43
	G3	1	0	1	0	1	3
	G4	1	2	0	4	2	9
	G5	0	0	0	2	33	35
	Total	29	10	5	10	36	90

buildings are classified into Grade 1 or 2 (G1-2) in this study.

Figure 5 shows the comparison of a building between pre- and post-earthquake images. The building surrounded by dotted circle in the upper figures is classified into Grade 5 (G5), completely collapsed damage, since it is whitened and textured in the post-earthquake image. On the contrary, the building in the bottom figures is classified into G1-2, because significant difference is not observed between the images. The right figures show the ground photographs of the buildings, indicating that the classification of the visual detection agrees with the actual damage level. Totally damage levels for 90 buildings in and around Imogiri village are interpreted and compared with the actual damage level classified from the ground photos. Table 1 shows the comparison of the classifications. Most of the buildings are classified into G5 or G1-2. It indicates that the number of moderately damaged building such as G3 is small in the heavily damaged area. According to the table, negligibly damaged buildings and completely damaged buildings are well detected from the QB images. These results show the damaged buildings could be easily extracted from the image because the characteristics of the damaged buildings are totally different from undamaged ones.

IMAGE CLASSIFICATION FOR BUILDING DAMAGE MAPPING

The visual detection requires great demand of time and labor, although it can provide the distribution of the reliable building damage. In order for preliminary stage of automated identification of the damaged areas, supervised image classification technique is applied to the post-earthquake QB image. As shown in Fig. 5, bricks and debris are exposed on the surface in the damaged area due to the collapse of the buildings, while the undamaged buildings are covered with roof tiles in the image. Considering that the reflectance of brick is different from that of roof tile as shown in Fig. 3, the areas covered with bricks are classified into the damaged buildings, while the areas covered with roof tiles are classified into the undamaged buildings. Bricks, roof tiles, vegetation (tree and paddy), bare ground, water, cloud, and shadow are selected as the class for the image



■ : Damaged building (Brick), ■ : Non-damaged building (Roof),
■ : Tree, ■ : Paddy, ■ : Bare ground, ■ : Water, ■ : Shadow, □ : Clouds

Fig. 6 (a) Post-earthquake image, (b) Result of image classification, and (c) UNOSAT map

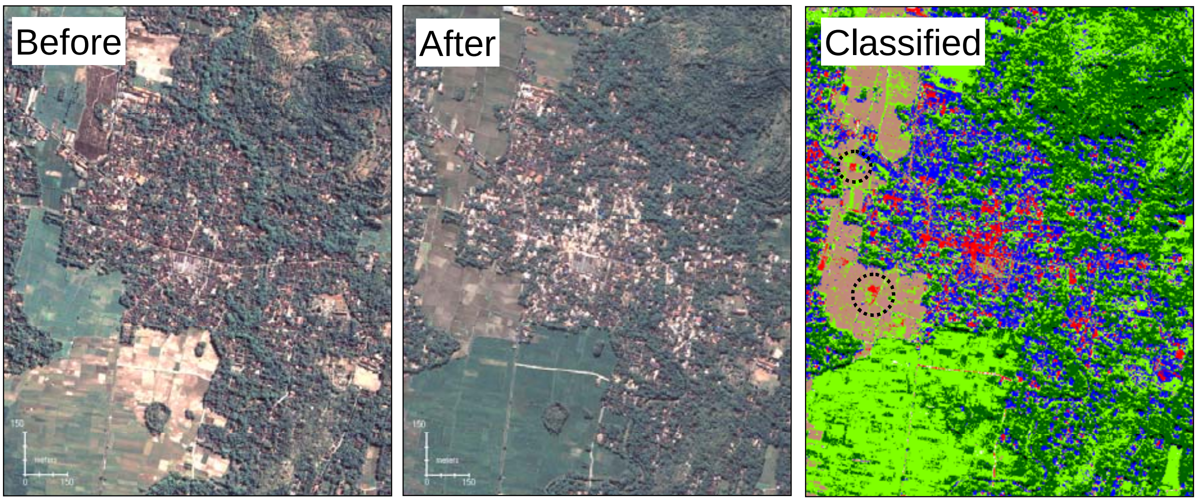


Fig. 7 Close-up of severely damaged area with pre-earthquake image

classification. About 10,000 pixels of the training data for each class are collected from the image.

Figure 6(a) shows the original image and Figure 6(b) shows the result of the supervised maximum likelihood classification. Red colored pixels indicate bricks and blue colored pixels represent roof tiles. The settlements are dotted in the area, while most of the image is covered with the paddy and the trees. The UNOSAT map is also shown in Fig. 6(c) compared with the classification map. The damage in the area shown by square in the figure is not mapped in the UNOSAT map since the area is covered with clouds in the QB image. The close-up of the square in Fig. 6 is shown in Fig. 7. The pre-earthquake image is also shown in the figure. The comparison between the pre- and post-earthquake indicates that heavily damage is clearly observed in the central part of the image since the color of the buildings is discolored to white. In the classification map, the red pixels are concentrated in the apparently damaged area and the blue pixels are distributed in the settled area. It suggests that the severely damaged areas are well identified by the image classification. However, the red pixels are distributed also in the bare ground area and the road as shown by dotted circles in the figure. They are mis-classified because the color of the ground is similar with the exposed bricks. The number of the mis-classification would be reduced by including the result of the land cover classification of the pre-earthquake image in the analysis.

CONCLUDING REMARKS

The field survey was conducted in the affected areas in the 2006 Central Java, Indonesia earthquake to gather the ground truth data of the building damage and the reflectance characteristics of the surface materials. The brick houses in the rural area are severely damaged due to the strong ground shaking. The characteristics of the pre- and post-earthquake QB images are examined. The result of the visual detection reveals that the completely collapsed buildings are easily interpreted because the wall bricks of the houses are apparently exposed on the surface. The supervised image classification technique is applied to the post-earthquake QB image for the identification of the damaged area. The result shows that the severely damaged areas are well detected, while mis-classification in the ground area is also observed.

ACKNOWLEDGMENTS

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REFERENCES

European Seismological Commission: *European Macroseismic Scale*, 1998.

Indonesian National Disaster Management Coordinating Board (BAKORNAS): *Report of Damages and Relief Conditions*, http://www.bakornaspbp.go.id/html/buletindijjateng.htm, 2006.

Murakami, H.: *Preliminary Damage Report of the 2006 Central Java, Indonesia Earthquake* (2006/7/28 Ver.), 2006 (Private communication in Japanese).

RESPOND*: Earthquake May 27, 2006 - Damage Assessment*, http://www.respond-int.org/Respond/, 2006.

UNOSAT: *Indonesia Maps*, http://unosat.web.cern.ch/unosat/asp/, 2006.