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UTILIZATION OF GEOTAGGED PHOTOGRAPH, REMOTE SENSING, AND GIS FOR POST-DISASTER DAMAGE ASSESSMENT

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ABSTRACT

Merapi eruption in 2010 causing major damage impact on that region. Post-disaster damage assessment that has been done by the government have not been supported with a good spatial data so that validation is relatively weak. Method of post-disaster damage assessment, particularly assessment of building damage using geotagged photos, remote sensing and GIS is expected to improve the method of damage assessment by the government of Indonesia. Geojot Applications for Android Smartphone/Tablet allows the assessment of building damage to be included in the photo attribute. Interpretation of satellite imagery of building damage is done by using three indications: building visibility, building collapse, and building roof. Geotagged photograph can complement the needs of building damage assessment from satellite images because it can describe the structural and non-structural damage to buildings clearly. Geotagged photograph with GPS Lock-Off mode requiring information on the direction and distance of the object being photographed. Geotagged photograph with the QR code is the most profitable because the identity of the building is already known and can be matched with an existing database.

Keywords : geotagged photograph, damage assessment, remote sensing, GIS

ABSTRAK

Erupsi Merapi 2010 mengakibatkan dampak yang besar pada wilayah di sekitarnya. Meskipun demikian, pendugaan dampak pasca bencana yang telah dilaksanakan pemerintah tidak didukung oleh ketersediaan data spasial yang baik sehingga validasi yang dilakukan memiliki konfidensi yang rendah. Metode pendugaan dampak pasca bencana, terutama kerusakan bangunan menggunakan foto geotagging, penginderaan jauh, dan sistem informasi geografis (SIG) diharapkan mampu meningkatkan pendugaan dampak yang dilakukan oleh pemerintah. Aplikasi Geojot pada Smartphone/Tablet berbasis Android dapat digunakan dalam pendugaan dampak, yang dapat dimasukkan dalam atribut foto. Interpretasi citea satelit untuk pendugaan kerusakan bangunan dilakukan melalui tiga indikator, meliputi; visibilitas bangunan, runtuhan bangunan, dan atap bangunan. Foto geotagging dapat digunakan untuk melengkapi pendugaan kerusakan bangunan dari citra satelit karena dapat digunakan untuk mendeskripsikan bangunan, baik kerusakan secara struktural maupun non-struktural. Foto geotagging dengan mode GPS Lock-off digunakan untuk memperoleh informasi mengenai arah dan jarak dari objek pada foto. Foto geotagging dengan QR code sangat bermanfaat untuk merekam identitas bangunan untuk dicocokkan dengan data yang tersimpan pada database.

Kata kunci: foto *geotagging*, pendugaan dampak, penginderaan jauh, GIS

INTRODUCTION

Cangkringan sub-district, Sleman, Yogyakarta is one of the region severely affected by the eruption of Merapi volcano in 2010. Based on *BNPB* data, Sleman district suffered heavy damage in Cangkringan and Ngemplak with the number of heavy damaged houses of 2339 units [*BNPB*, 2011a]. Cangkringan sub-district consists of 5 villages namely Umbulharjo, Kepuharjo, Glagaharjo, Wukirsari and Argomulyo. This sub-district is one of the sub-districts in the Sleman regency located on the southern slope of Merapi volcano. The area was greatly affected by the eruption of Merapi Volcano in 2010.

In 2011, Indonesian government issued a regulation of *BNPB* Nr. 15/2011 as a standard guideline for post-disaster assessment. Based on this regulation, there are standards for the assessment of damage due to disasters. There are no more specific instructions for the type of volcanic disaster. Based on the criteria used, remote sensing can not fulfill all the required data for the assessment of damages due to the disaster. Post-disaster damage assessment in Indonesia conducted by disaster management agency of Indonesia. Improvements to the method that has been used by disaster management agency of Indonesia is very necessary to improve the results obtained.

The aim of this research is to develop and to test method for volcanic post-disaster damage assessment from geotagged ground photograph in combination with remote sensing and *GIS* in Indonesia, especially for building damage assessment. The development of geotagged photograph and Geographic Information System can make more possibilities for utilization in disaster management. According to Welsh *et. al.,* [2012], *"geotagging is easy to undertake and is potentially cost effective"*. Geotagged photos can be generated directly through the *GPS* equipment and digital cameras [*Yaegashi et. al.,* 2009]. With the current technological developments, the smartphone is also equipped with geotagging facility. The use of smartphone allows to use of certain applications for geotagging.

One of the applications on the Android-based smartphone for geotagging is GeoJot that produces geotag photos with *GPS* coordinates and can be used also to add the attribute data associated with geotag photos such as *name, condition, value, etc* [*Geospatial Experts*, 2012]. This allows the interpretation of geotag photos for post-disaster damage assessment purpose. Photograph of the entire building and the details that are taken will be useful as data for verification and analysis of matters that are not included in the list of field survey format [*Crandell et. al*, 2005]. 3D photograph may have a role in post-disaster damage assessment. *Tsai et. al.* [2011] explain that a photographer who is on site observations can generate 3D anaglyph photograph by photographing the object from different angles. He explained that the main difference of the images of 3D and 2D is a 3D anaglyph photograph can "*provide a greater field depth contrast, the distances are extremely realistic, and the disaster sites (under 1 km^2) can be better observed".* He stressed also that by using 3D anaglyph photographs, photos user is not necessary to be at the location of the photo to see the site conditions.

THE METHODS

Geo Eye imagery 2009 is used as primary satellite imagery before Merapi volcano eruption. For areas in Geo Eye imagery that is covered by cloud, Quickbird imagery 2006 is used. Geo Eye imagery of Cangkringan Sub-District is recorded in May 2009, while Quickbird imagery is recorded in September 2006. World View 2010 of Merapi region recorded in November 2010 is used as an imagery that describes the condition of post-eruption of Merapi 2010. This imagery illustrates the impact of pyroclastic flows and surges that hit parts of the southern slope of Merapi. Geo Eye imagery of Cangkringan sub-district recorded in June 2011 is used to illustrate the impact of Merapi's lahars. Satellite imagery that used in this research is shown in the Figure 1.

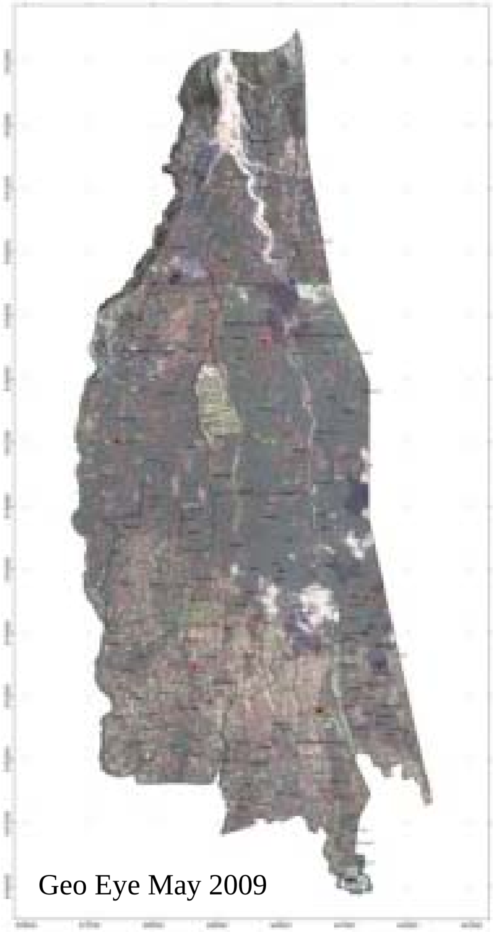

Figure 1. Satellite Imagery of Cangkringan Sub-District Before and After Merapi Eruption 2010

Secondary maps and data are used as initial data for this research in the form of administrative map, hazard map, and photograph. Secondary data of geotagged photographs that related to the research purpose will be used to obtain preliminary information on the impact of disasters recorded in the study area.

Landcover map is produced from visual interpretation of multitemporal high resolution imagery. Further, multitemporal landcover map can analyze kinds of landcover that has been changed. Damage information from selected object can be obtained from high resolution imagery according to damage criteria. Disaster affected areas can be identified from the analysis of changes in land cover and condition of the objects visually seen from the imagery. Disaster affected area map, landcover map with damage information and others map then used as the basis for sampling in the field. Sampling technique that will be used is purposive sampling. Building damage isthe focust element in this research. Area that is affected by disaster will be used as sampling location.

Damages on building is the focus in this research. The building damage criteria were adopted and modified from *Baxter* [2005] and *BNPB* [2011b]. This analysis is conducted to adjust the type of disaster damage to volcanic and general criteria used by the government of Indonesia. The criteria of building damage due to pyroclastic flows/surges are shown in the Table 1.

Table 1. Criteria for Building Damage

No	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	Buildings collapsed or damage on most of the components	• Total/large collapse of buildings, partialy collapse • Large part damage on most of the main structure of buildings • Lifted off/missing on roof • Most of the walls broken/cracked/removed • Imploded and frame missing for windows • Fence push over • Totally damaged on supporting component • Harm / have risk if it will be functioned • Physically damage percentage of > 70%
2	Medium Damage (RS)	The building still stands, damage on a small component of the structure, and damage on supporting component	• The building still stands • Small part damage on main structure • Partialy burned/lifted on roof • Crack in plaster walls • Windows blown out but frame intact/burnt • Fence partially collapse/bent • Many damaged on supporting component • Relatively can be functioned • Physically damage percentage of 30% -70%
3	Slightly Damaged (RR)	The building still stands, partly cracked on structural components (structure can still be functioned)	• The building still stands • Minor damage on main structure • Minor damage on roof • Minor cracks in plaster walls • Small part broken/burnt on windows • Fencing intact and unbent • Small part damage on supporting component • Can still function • Physically damage percentage of <30%

Source: Adopted and modified from *Baxter* [2005] and *BNPB* [2011b]

QR code (Quick Response Code) for identification of the building using Geojot combine with *QR* code scanner software for Android is designed as a scenario for combination of spatial data from satellite image interpretation and attribute of geotagged photos (Figure 2). *QR* code is designed with a format like this fromat below:

Sub-district name\Village name\Sub-Village name\Building owner\Building Identity Number

Example : **Cangkringan\Argomulyo\Bakalan\Sosro Supriyono\19**

A laser distance meter is used to measure the distance from the camera to the object being photographed. It aims to compare the role of 2D & 3D images in visual observations for post-disaster damage assessment. In fact, within this scenario, there is a condition in which the photographer may not be able to achieve the object to be photographed at close range because of some conditions such as the soil is still hot and other dangerous conditions. Comparison between 2D and 3D geotagged photographs for building damage assessment is done by comparing the visual appearance of each scenario distance. Distance variation scenario of 2D and 3D geotagged photograph is shown in Figure 3.

Figure2. *QR* Code Sample for Building Identification

RESULT AND DISCUSSION

Damage Interpretation using High Resolution Satellite Imagery

Identification of damage from multi-temporal satellite imagery is conducted by looking for areas that have land cover change. Image before and after the disaster is very useful for this purpose. An area with land cover changes with certain characteristics is one possible indication of a disaster that happened in that area. On-screen visual interpretation on a digital imagery using ArcGIS can be done to delineate land cover. Land cover before Merapi volcanic disaster 2010 is divided into six classes, namely bare soil (dry), compacted clay surface (building), concrete surface, non-woody broadleaves, woody broadleaves and water bodies. Woody broadleaves dominate the land cover in the Cangkringan sub-district of about 2983.61 Ha (65.25 %). Compacted clay surface (building) has a relatively large coverage of 256.42 Ha (5.6 %).

Interpretation of land cover after Merapi volcanic disaster 2010 produces land cover types such as bar dry soil (interleaved by building), burned vegetation, compacted clay surface (building), concrete surface, non-woody broadleaves, water bodies and woody broadleaves. Landcover of bar dry soil covers 1564.72 Ha (34.22 %), almost similar with woody broadleaves area. Bare dry soil is the most extensive in the three villages closest to the peak of Merapi, that villages are Glagaharjo, Kepuharjo and Umbulharjo.

Overlay analysis of the land cover maps before and after the Merapi volcanic eruption by using GIS To determine the area affected by the disaster. The types of landcover changes in Cangkringan sub-district are compacted clay surface became bare soil (dry), concrete surface became bare soil (dry), non-woody broadleaves became bare soil (dry), non-woody broadleaves became burned vegetation, woody broadleaves became bare soil (dry) and woody broadleaves became burned vegetation (Figure 4; Table 2). Most of the area changed after the eruption of Merapi is the area with the type of land cover woody broadleaves (77.71 % into bare soil and 9.57 % into burned vegetation). Another major change is the landcover type of non woody broadleaves that turns into a bare soil (9.13 %). Compacted clay surface also experienced considerable changes in land cover that turns into bare soil (3.48 %).

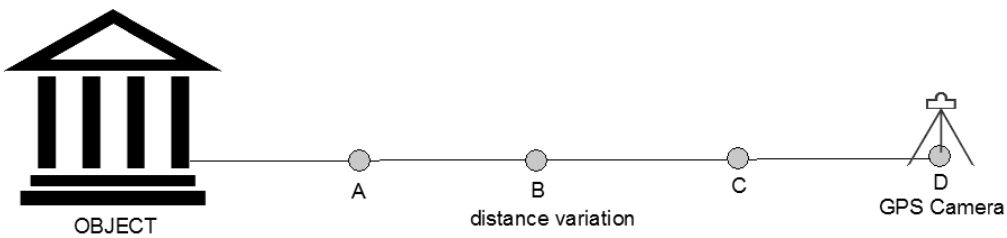

Figure 3. Distance Variation Scenario of 2D and 3D Geotagged Photograph

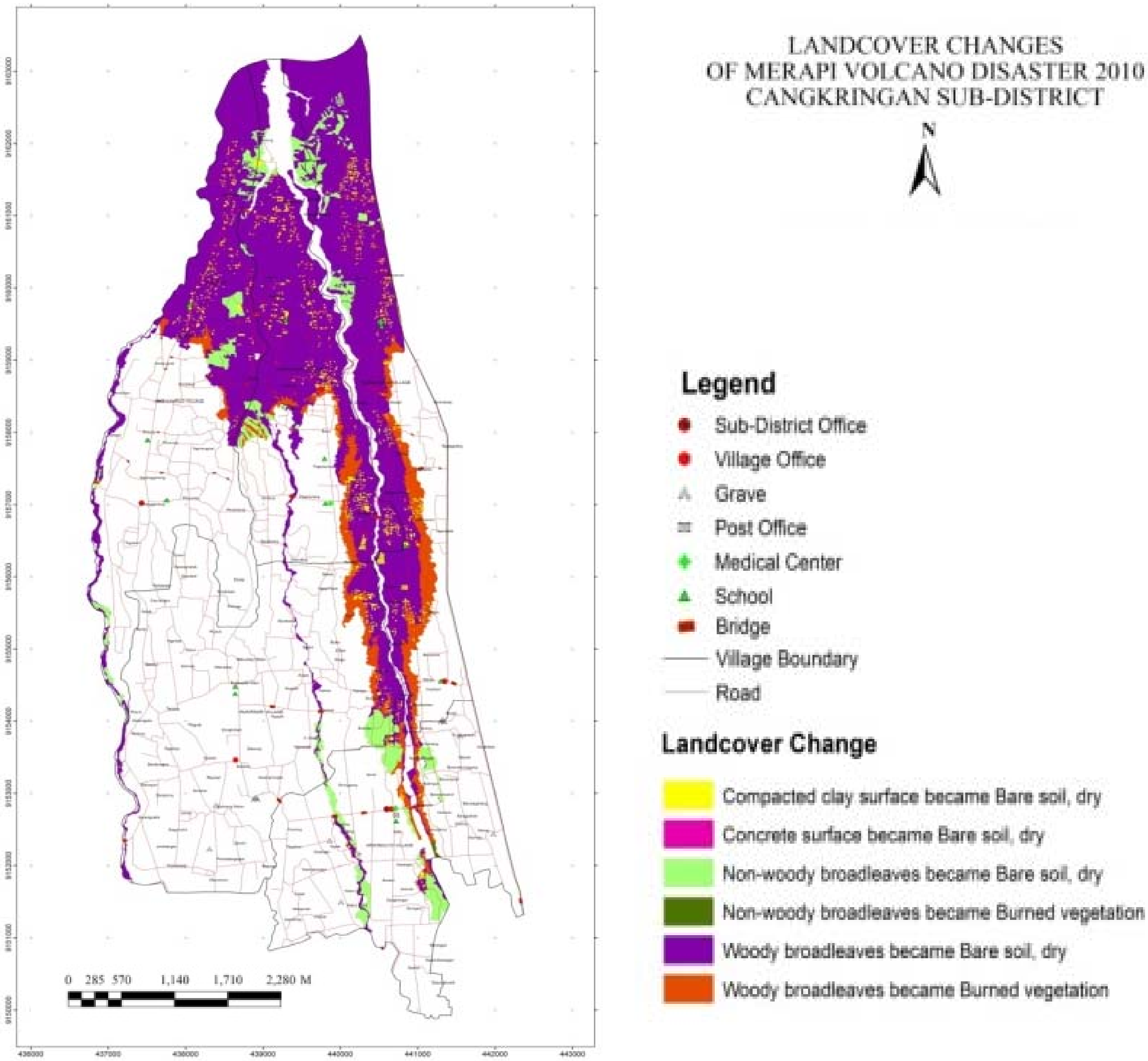

Figure 4. Landcover Changes Map after Merapi volcanic disaster 2010

Table 2. Landcover changes area after Merapi volcanic disaster 2010

Nr	Landcover	Width area in Village (Ha)					
		Argomulyo	Glagahharjo	Kepuharjo	Umbulharjo	Wukirsari	Total
1	Compacted clay surface turned into Bare soil, dry	3.62	16.61	20.51	9.87	4.53	55.15
2	Concrete surface turned into Bare soil, dry	0.08	0.25	0.27	-	-	0.64
3	Non-woody broadleaves turned into Bare soil, dry	43.03	27.31	26.33	29.47	-	144.54
4	Non-woody broadleaves turned into Burned vegetation	1.08	-	-	-	-	1.08
5	Woody broadleaves turned into Bare soil, dry	24.00	440.79	402.98	300.79	-	1230.07
6	Woody broadleaves turned into Burned vegetation	18.01	67.24	32.61	9.28	24.35	151.49
	Total	89.82	552.21	482.71	349.40	108.82	1582.96

Source: Data processing, 2013

There are 3 types of hazards that can be analyzed in the event Merapi eruption in 2010, these types are pyroclastic flows, pyroclastic surges and lahars. Settlement widely affected by pyroclastic surges are situated in the Glagaharjo, Umbulharjo and Kepuharjo village respectively 11 Ha, 9.21 Ha, and 7.67 Ha, while the largest area of settlement affected by pyroclastic flows is located in the Glagaharjo and Kepuharjo village respectively 12 Ha and 5.22 Ha. Settlement for the widest area affected by lahars is located in the Argomulyo village with total area of 1.44 Ha.

Interpretation of the damage is focused on damage to building. Interpretation of building damage from high-resolution satellite imagery is done by using the criteria from *Ogawa* [2000] that has been modified. Three criteria are used namely building visibility, building collapse and building roof condition. Interpretation is done by using on screen visual interpretation in ArcGIS by overlaying building layer and satellite imagery after the 2010 eruption of Merapi. The buildings that vanish/not visible, totaly collapse, and lifted off/missing roof have the highest number of 938 units (58.37 %), while the smallest (0.37 %) is building with clearly visible/building still stands, no collapse and lifted off/missing roof (Table 3).

Damage Interpretation from geotagged photograph

Geotagged photos depict the condition of the photographed object. Interpretation of building damage based on these components on geotagged photos isfacilitated by using a device for geotagging photos called Geojot. Geojot is an application for geotagging photos on the Android operating system. This application gives the users flexibility to design their own attributes of the photos. In this case, the design attributes that made is the design attributes for damage assessment due to volcanic disaster. Attributes of building damage to the main structural elements such as the foundation, columns, floor and beam is made into single point that is the main structure of the building.

Figure 5 (left) is an example of the interpretation of damage to buildings in the Bakalan sub-village, Argomulyo village, Cangkringan by using Geojot and *GPS* Photo Link application. Geojot is used to generate geotagged photograph and to fill the attributes of geotagged photograph, while the *GPS* Photo Link is used to create reports and spatial data based on photographs from Geojot with attributes that have been filled. It can be seen that the large building collapse occurred, large part damage on main structure, most broken/ cracked/removed, partialy lifted on roof, blown out on windows but frame intact, totally damage on supporting component, and harm to be functionalized. Based on the above photo and the attributes, *GPS* Photo Link can be assembled into watermark photo as report that shows the building damage attribute information. The geotagged photograph as shown in Figure 5 (right) was taken with *GPS* Lock-Off mode so that the coordinates listed are the coordinates of camera positions. Figures 290° *WNW* is the direction of the shooting (the camera towards the object to be photographed). *GPS* accuracy that can be obtained when shooting with geotagging Android devices are ± 5-10 meters. Desired minimum accuracy limit for the *GPS* when photographing can be determined on Geojot settings.

Combination of geotagged photograph attribute, interpretation from remotely sensed data by mean of *GIS*

Automatically geotagged photos with geotagging device primarily record the position of the camera when taking pictures, not the position of the object being photographed. By using Geojot, coordinates recorded photos depends on the options selected. *GPS* Lock-Off option produces coordinates of camera position, while the *GPS* Lock-On option can produces coordinate of the object photographed. To generate the coordinates of the object that be photographed, the photographer should be toward the object to be photographed and locked the coordinate of the object. Furthermore, all resulting photos have the same coordinate that is the coordinates of the photographed object. There are three methods to be applied for combining geotagged photos and attributes with the results of imagery interpretation, ie geotagged photos with *GPS* Lock-Off scenario, *GPS* Lock-On scenario and *QR* Code scenario.

Table 3. Building damage interpretation from satellite imagery

Nr	Building damage from high resolution satellite imagery interpretation (Building Visibility, Buillding collapse, Building Roof)	Total (Unit)
1	Building clearly visible/Building still stands, No collapse, Lifted off/missing	6
2	Building clearly visible/Building still stands, No collapse, Minor damage on roof tile	145
3	Building clearly visible/Building still stands, No collapse, No damage on roof	202
4	Building clearly visible/Building still stands, No collapse, Partialy lifted off or major damage on roof tile	86
5	Building clearly visible/Building still stands, No collapse, Lifted off/ missing	84
6	Building clearly visible/Building still stands, No collapse, Partialy lifted off or major damage on roof tile	70
7	Building unclearly visible/building can still be identified, Totally colappse, Lifted off/missing	76
8	Vanish/not visible, Totally colappse. Lifted off/missing	938
	Total (Unit)	1607

Source: Data processing, 2013

Figure 5. Building damage interpretation in Geojot (left) and its interpretation report from Geojot to *GPS* Photo Link (right).

GPS Lock-Off scenario
In this scenario, shooting direction becomes a very important factor for the combination with spatial data from remote sensing imagery. With an Android device that has an electronic compass and Geojot software, shooting direction can be recorded on the attributes of the photo. Distance data between the camera and the object being photographed is also important. Relatively accurate distance measurements can be performed using a laser distance meter. In this study, Laser Ace 300 is used to calculate distance between camera and the object being photographed which can measure distances up to 300 meters.

If there is no distance information, the direction of the shooting information and camera position is used as the basis for determining which objects are photographed on remote sensing imagery. By the direction and distance information, panning (offset) camera coordinates into object coordinates can be done. Right or not the result of the coordinates shifting will be affected by the *GPS* accuracy when shooting and the accuracy of distance measurement to the object.

The offset distance variation to determine the position of the object that has been photographed (Figure 6). From the above results can be analyzed that the greater of the shooting distance (for the same *GPS* accuracy), the offset becomes less accurate. That is because the precision of shooting direction became very influential. Change of a few degrees over long distances will cause the offset position shifted further and further.

The incorporation of spatial data structure in which contained the interpretation results and damage attribute to buildings from geotagged photos can be done by using spatial join technique if the photos coordinate is in the building objects. If the results of offset are not in the building boundary, then the provision of common identity between building objects and the point location of the photo on the attribute is another way that can be done to combine attributes. The result of attribute combination is shown in Figure 7.

GPS Lock-On Scenario
The second scenario is to lock the coordinates of geotagged photos with the coordinates of the object to be photographed on Geojot. Photographer came to the location of the object photographed building and wait until the *GPS* accuracy reaches a maximum. This method will produce photographs with the same coordinates. The downside of this method is the photographer may not be able to enter the building at the building that can not be approached/entered because of certain conditions. The results shown in the Figure 8.

QR Code Scenario
QR Code/barcode is a unique code that can be used for identity building. *QR* code can be read by using the camera on the Android Barcode Scanner software. Barcode scanner software has been integrated with Geojot so that it reads *QR* code that can be stored in the attribute of geotagged photos. *QR* code scenario and the read and entry of Building *QR* Code in Geojot is shown in the Figure 9. *QR* code has the advantage to merging geotagged photos attribute and other spatial data that also have the same *QR* Code. Another advantage of the *QR* Code is the material used can be selected which are resistant to heat up to 600°C. If the area affected by volcanic disaster extremely hot temperatures, the *QR* Code which has been attached in certain parts of the building will have a resistance that can still be read by a *QR* Code scanner for rapid disaster response purposes such as post-disaster damage assessment.

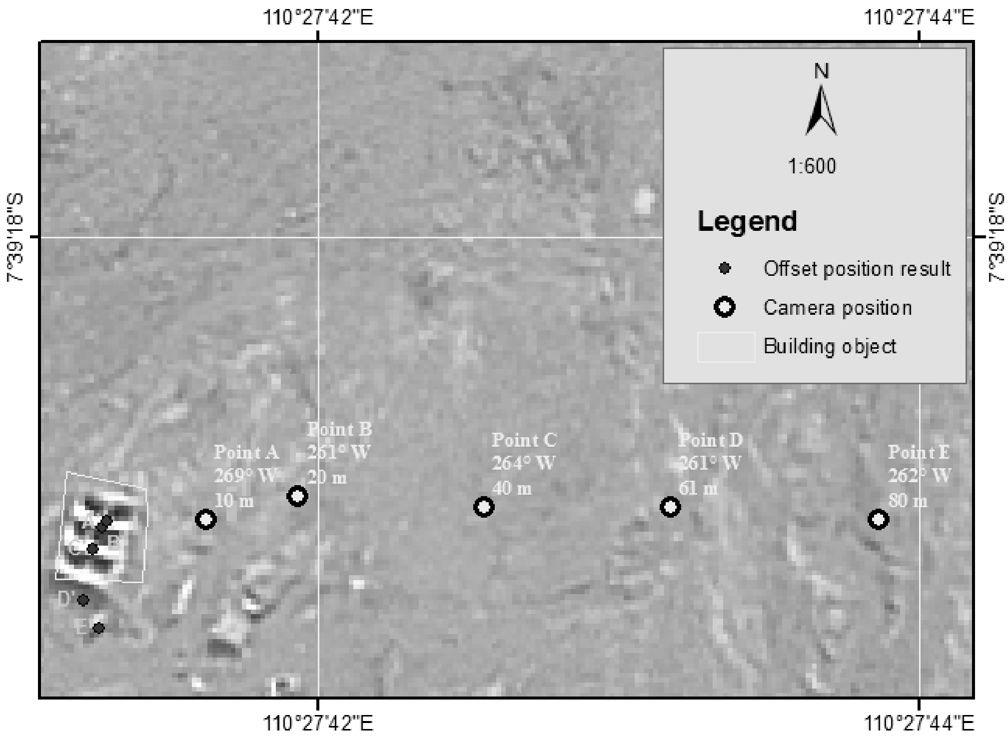

Figure 6. Offset position result from different variation of distance

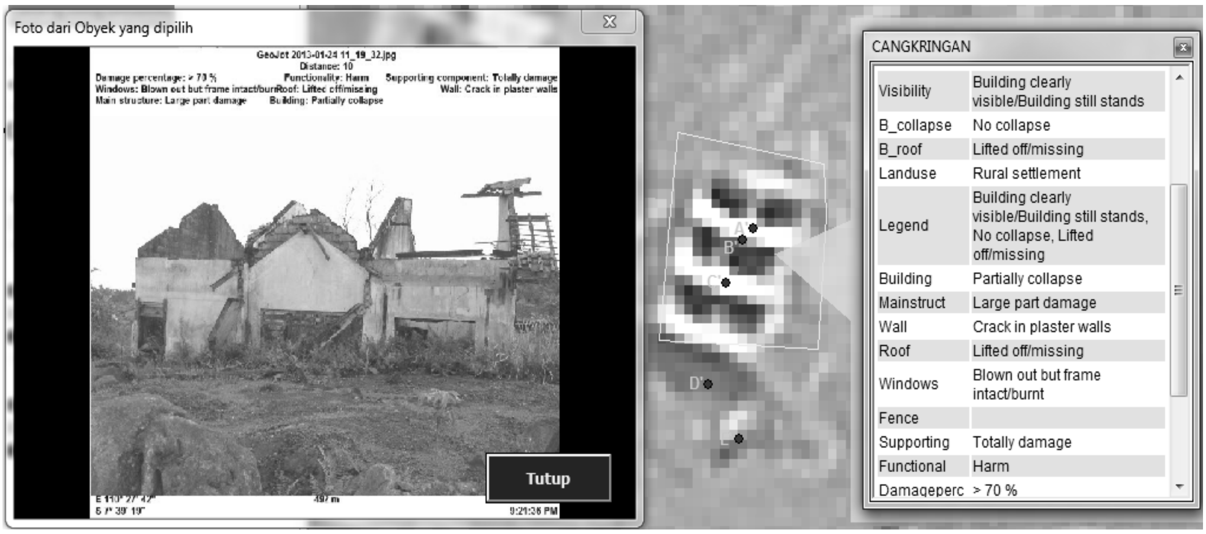

Figure 7. Combined geotagged photograph attribute and imagery interpretation attribute using GIS (spatial join process)

Data collection and assessment of building damage using geotagged photos combined with a *QR* Code is very beneficial because the attribute of photos can be combined directly with the spatial data of building through a join operation table with GIS. By using *QR* Code, building that will be recorded is building that has slighty to moderate level of damage or heavy damage by the condition of the remains of the building that is attached QR Code is still there. If the boundary of the disaster affected area are known, based on the join table of geotagged photos attribute and building spatial data, the building that was not recorded using *QR* Code in the field can be identified. The buildings that are not registered can be assumed to have heavy/ total damage. Thus the priority of building damage data collection with *QR* Code is a building with slightly to moderate damage.

QR Code test conducted in the Bakalan sub-village, Argomulyo village, Cangkringan sub-district. Building object in the Bakalan sub-village before Merapi eruption 2010 can be mapped into 62 building unit as shown in Figure 10. The total number of buildings before the disaster and then surveyed by using *QR* Code Scenario with Geojot for conditions after Merapi eruption 2010 (with *GPS* Lock-Off or GPS Lock-On). The number of buildings with a *QR* Code that can still be recorded is 17 building unit. The rest is a 45 unit building with a *QR* Code that can not be recorded can be assumed that these buildings were heavy damaged by the condition of buried or completely destroyed.

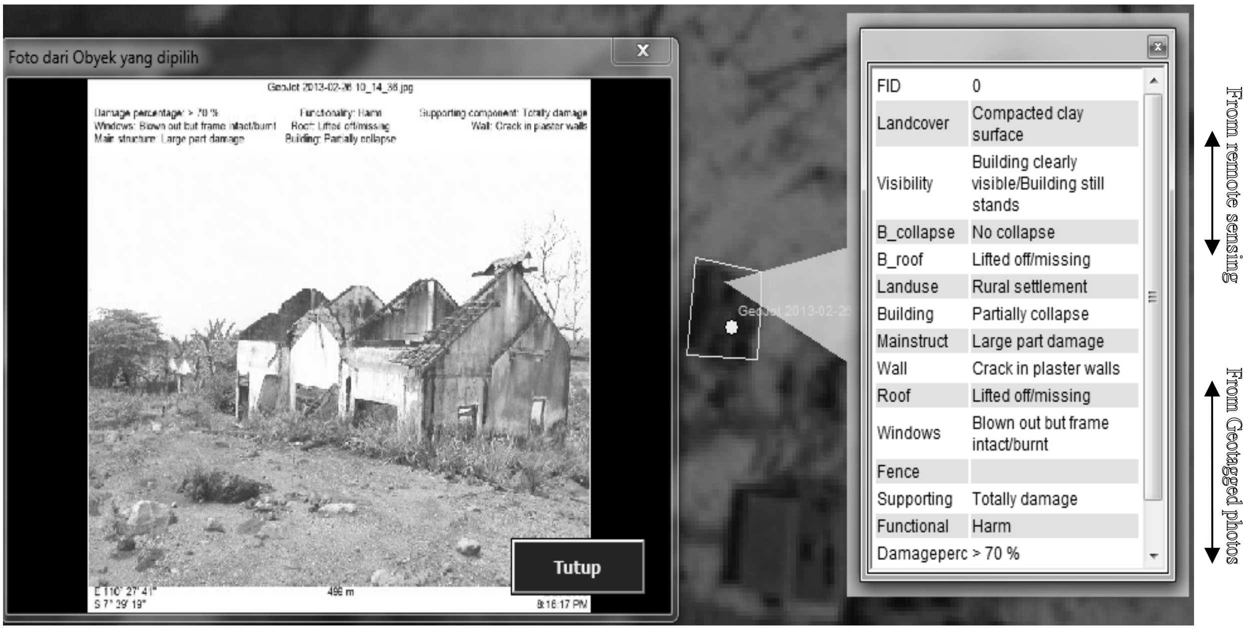

Figure 8. Combination of geotagged photograph attribute and imagery interpretation by *GPS* Lock-On scenario

Figure 9. *QR* Code scenario on building and the ‘read and entry’ in Geojot

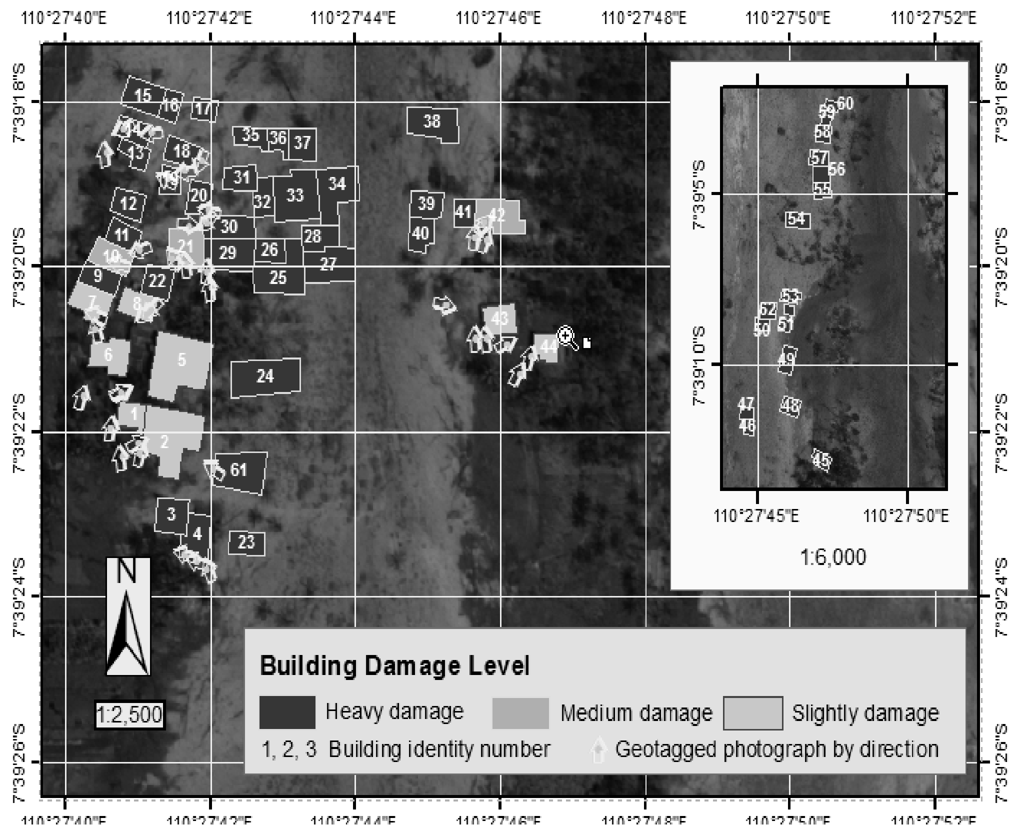

Figure 10. Building damage level in Bakalan sub-village

Not all buildings were sampled due to conditions on the ground is a lot different because the process of reconstruction and mining (field work is 2 years after the eruption of Merapi in 2010). Interpretation result of building damage from remote sensing imagery is combined with geo-tagged photograph attributes by using the join operation in ArcGIS. Building damage level assessed by performing a query based on the building damage criteria that are used. Spatial distribution of the building damage level in the Cangkringan sub-district and the number of buildings damaged by the types of hazard are shown in Figure 11.

Each type of disaster either pyroclastic flows, pyroclastic surges and lahars can cause different levels of damage that are slightly damaged, moderate damaged and heavy damaged. According to *Baxter* [2005] who assess the dynamic pressure experienced by the building due to Pyroclastic Density Currents (*PDCs*), heavy damage buildings are buildings that undergo dynamic pressure > 4 kPa, while the moderate damaged buildings are buildings that undergo dynamic pressure of 2-6 kPa and slightly damage buildings are building experienced with dynamic pressure of 1-3 kPa. Based on *Jenkins et. al.*, [2013] who made the contour map of the estimated dynamic pressure experienced by the buildings on the southern slopes of Merapi volcano, dynamic pressure experienced by buildings ranging from 0-15 kPa where the higher value areas closer to the peak of Merapi volcano. This is in accordance with the position of the buildings in the villages, in which the location closest to the peak of Merapi (Kepuharjo and Glagaharjo village) are the most heavy damaged buildings that can be found.

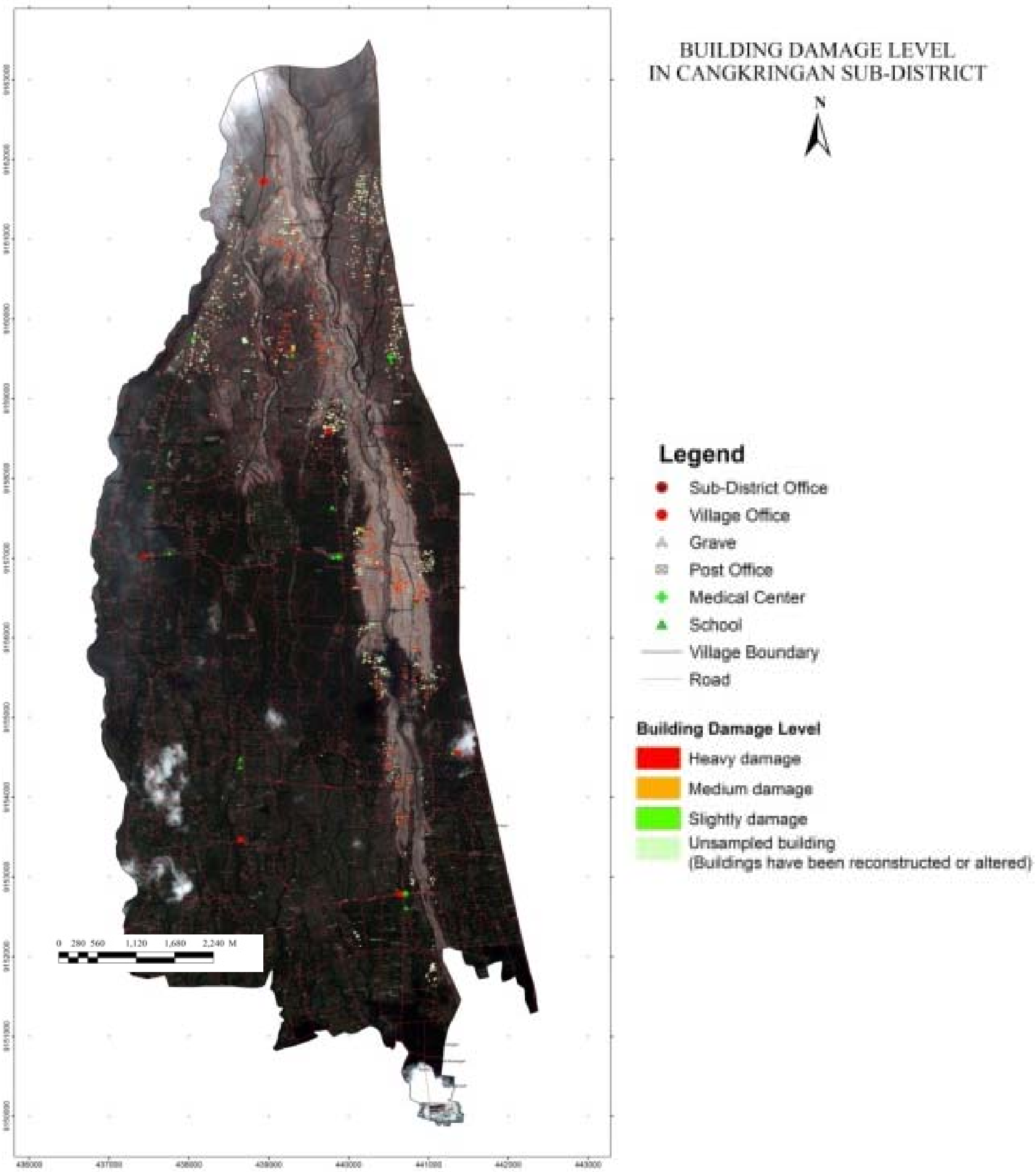

Figure 11. Building damage level for sampled buildings in Cangkringan sub-district.

Comparation of 2D and 3D Geotagged Photograph

Comparison between 2D and 3D geotagged photos is conducted by testing for a variety of distances to the object of the assessed building damage. In this case, it is done by comparing the level of clarity of property damage that can be recorded from 2D and 3D photos. Measuring the distance to the object of the building is done using laser distance meter. Variation distance is used depends on the conditions on the ground. The maximum distance that can be measured by the Laser Ace 300 about 300 meters on the ground but in reality the maximum distance that can be measured is 250 meters because without using special reflectors. 3D Anaglyph photograph is created from a pair of 2D geotagged photograph treated with Anaglyph Maker that can be observed by using 3D glasses to observe the visual appearance of an object in three dimensions. The distribution of the distance scenario to the building object that was sampled in the Glagaharjo village with seven variations of distance, from 150.4 m, 125 m, 106.5 m, 75.1 m, 50.2 m, 25.2 m and 10.2 m (Figure 12; Table 4).

Comparison of visual appearance appearance 2D and 3D geotagged photos depicting damage to buildings based on variations in the distance is shown in Figure 25. Based on the figure, 3D Anaglyph geotagged photograph can illustrate more clearly of building damages such as damage to structures in the form of a column structure that collapsed on one side and severe cracking in the column on the other pole as shown by yellow arrow. In addition, the damage to the roof tiles and the windows is very visible and more clearly with 3D Anaglyph photograph than 2D geotagged photograph. The closer distance from the shooting position of geotagged photograph with the object to be photographed, then the more obvious 3-dimensional effects of the building structure so it can make the clearer observations of building damage that occurs.

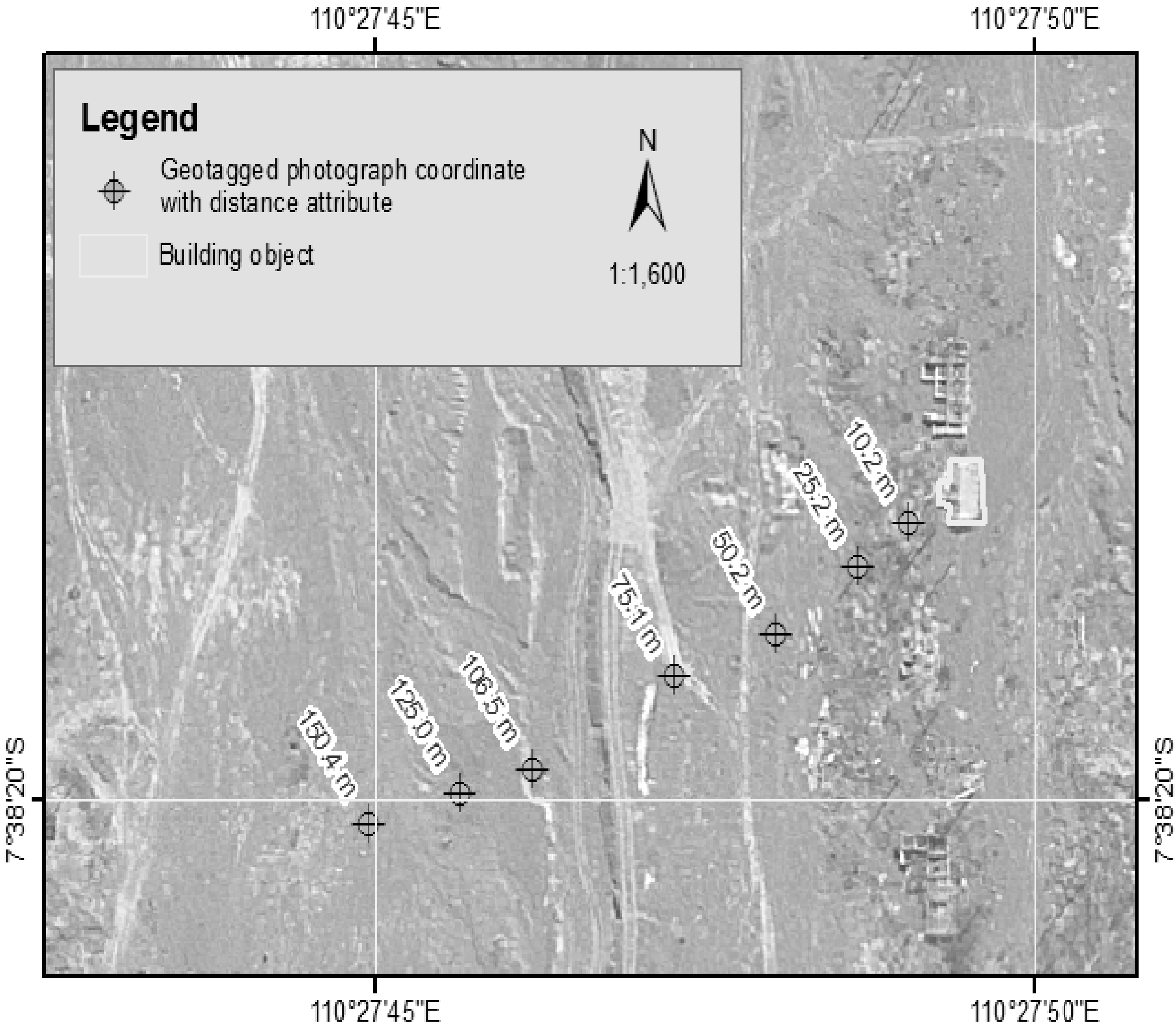

Figure 12. Distribution of geotagged photograph for distance variation

Table 4. 2D and 3D geotagged photograph visual comparison based on distance variation on Building sample 3.

Distance to building (m)	2D geotagged photograph	3D Anaglyph geotagged photograph
150.4		
125		
106.5		
75.1		
50.2		

Table 4 (cont.). 2D and 3D geotagged photograph visual comparison based on distance variation on Building sample 3

Distance to building (m)	2D geotagged photograph	3D Anaglyph geotagged photograph
25.2		
10.2		

Source: field obsevation, 2013

CONCLUSION AND RECOMMENDATION

To perform a combination of geotagged photograph, remote sensing and *GIS* can be done with three methods of geotagged photograph shooting in the field, ie geotagged photograph with *GPS* Lock-Off, *GPS* Lock-On and *QR* Code. Each can be applied and the accuracy of *GPS* is essential. The most minimal error method is geotagged photograph combined with *QR* Code for identification of the building that can be done quickly, having the lowest error, and the incorporation of the spatial data of high-resolution satellite imagery interpretation is easy to do with combining/joining tables with *GIS*.

The use of 3D geotagged photograph is better than using 2D geotagged photograph in terms of the clarity of building damage that occurred, particularly for structural damage. The closer distance to the object that is photographed, it can produce geotagged photograph with the more obvious effect of three-dimensional and the clearer of the damage observed.

Maps of land cover and land use on detail scale and building spatial data in level of building owner needs to be made because the data is not yet available by the Indonesian government. By having these databases, remote sensing imagery can serve as updating data so that post-disaster damage assessment process could be faster than current condition. QR Code can be used for data collection of building identity that can be read by the surveyors for the purpose of post-disaster damage assessment.

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