THESIS

UTILIZATION OF GEOTAGGED PHOTOGRAPH, REMOTE SENSING AND GIS FOR POST-DISASTER DAMAGE ASSESSMENT IN CANGKRINGAN SUB-DISTRICT, SLEMAN, YOGYAKARTA AS VOLCANIC DISASTER-PRONE AREA

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DISCLAIMER

This document describes work undertaken as part of program of study at Double Degree International Program of Geo-Information for Spatial Planning and Disaster Risk Management, a Joint Education Program of Faculty of Geo-Information and Earth Observation University of Twente – The Netherlands and Gadjah Mada University – Indonesia. All views and opinions expressed there in the sole responsibility of the author and do not necessarily represent those of the institute.

I certifiy that although I may have conferred with others in preparing for this assignment, and drawn upon arrange of sources cited in this work, the content of this thesis report is my original work.

Signed ....

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ABSTRACT

Cangkringan is one of sub-districts in the southern slope of Merapi volcano. 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.

Geotagged photograph presenting visual information in the field conditions and coordinate saved in the photo attribute. Geojot Applications for Android Smartphone/Tablet allows the assessment of building damage to be included in the photo attribute. Attributes of geotagged photograph can be designed according to the needs of post-disaster damage assessment. High-resolution satellite imagery (Geo Eye, Worldview, and Quickbird of Cangkringan sub-district) before and after the disaster are used to know changes in land cover. Changes in land cover before and after disaster is an early indication of the area affected by the disaster. Interpretation of satellite imagery of building damage is done by using three indications: building visibility, building collapse, and building roof. The resulting data is used as the basis in the field to shoot buildings with Geotagged photograph using Geojot. 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. The use of 3D Anaglyph geotagged photograph is better than using 2D geotagged photograph in terms of the clarity of building damage that occurred, particularly for structural damage.

The combination of geotagged photograph to the results of image interpretation can be done in three ways geotagged photograph shoot: the object coordinates (GPS Lock-On), geotagged photograph with the camera coordinates (GPS Lock-Off) and geotagged photograph with QR Code. Geotagged photograph with GPS Lock-off and GPS Lock-On requires a good GPS accuracy. 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.

Post-disaster damage assessment method with geotagged photograph, remote sensing and GIS in general is not faster than the method of assessment of the damage that has been done by the government of Sleman regency in Merapi eruption 2010, but the results are more accurate and reliable. Special assessment of building damage with geotagged photograph on the field is faster than the verification process of building damage done by the government.

Conversion of the system used by the government towards the post-disaster damage assessment system with geotagged photograph, remote sensing and GIS requires a relatively large funds and require increased resources owned by the government.

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

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ABBREVIATIONS

BAPPEDA	Regional Board for Planning and Development
BPBD	Local Disaster Management Agency
BNPB	National Disaster Management Agency
BPN	National Land Agency
DPPD	Local Land Control Agency
DPU	Public Work Department
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GPS	Global Positioning System
IDR	Indonesian Rupiah
RBI	Topographic Map

Chapter 1. General Introduction

1.1. Background

Post-disaster needs assessment is the activities of effect assessment, impact analysis, and needs estimation as the basis for the preparation of the action plan of rehabilitation and reconstruction (BNPB, 2011b). Identification and assessment of the damage is a component used for analysis in the post-disaster needs assessment. Inventory, identification or verification of the damage done through the rapid assessment on emergency response and/or rehabilitation that undertaken by disaster management agency or other party coordinated by the disaster management agency (BNPB, 2008). Further, BNPB (2008) explains that method for estimating the location and extent of damage can be done quickly with participatory methods and/or using geoinformation technology through image interpretation and GIS assistance. Geotagged photograph and remote sensing imagery as geoinformation technology are evidence to describe the condition of the object after the disaster. Evidence-based approach is one of the basic principles in the post-disaster needs assessment (BNPB, 2011b).

Geotagged photograph is photograph that has metadata information in the form of coordinates and time of capture. Geotagged photograph technique exists after the development of integration photographic and Global Positioning System. According to Montoya (2003), "*global positioning systems (GPS) have great potential in disaster management*". Integration GPS facility in camera that produces geotagged photograph increased the potential for their use in disaster management.

Geo-tagged information in the photograph can be used for documentation purposes for assets such as building and infrastructure. Although the geotagged photos in general are only used to define the location and condition of assets, geotagged photograph on the GPS with geotagging facility can be used to assess the damage of property that caused by natural disaster quickly and accurately. In addition, this method is the most efficient way to collect data in order filing assistance to the government after the disaster and to minimize the fraudulent reimbursement claims against the assets damaged by the disaster (Corbley, 2012a). Disaster damage on assets defines as *total or partial destruction of physical assets existing in the affected area* (The World Bank, 2010).

Geographic information system (GIS) defined as "a computer system for managing spatial data" (Bonham, 1994). This system is useful for a variety of functions for input, manipulation, analysis, modeling and visualization. GIS has now evolved to take advantage of the internet media (Ingensand, 2007). According to Yamazaki (2001), GIS is often used in disaster management activities by developing GIS databases for the assessment of damages due to natural disasters. GIS combined with remote sensing and GPS provide more support for disaster management activities (Rezaeian, 2010). Remote sensing has the advantages in disaster management activities. As described by Filippi (2008), *"remote sensing is of great utility in synoptically assessing damage over wide geographic areas in a time- and cost-effective manner"*. Remote sensing also has another advantage of multitemporal aspect. By using multitemporal imagery then changes before and after the disaster can be identified. Although remote sensing has the advantages but it also has limitation. Rezaeian (2010) explains that in the absence of depth perception in high-resolution imagery, remote sensing can not detect collapsed flatly roof. Field work with GPS and photographic equipment for documentation will help overcome the lack of remote sensing techniques to generate the data required as input in the GIS analysis.

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 the use of certain applications for geotagging. One of the applications on the Android-based smartphone for geotagging is GeoJot. Geojot application 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, 2012a). The attributes data of geotag photos can be used as input for analysis in GIS as shown in figure 1 below:

Figure 1. GeoJot for geotagging that can be used for disaster damage assessment (Geospatial Experts, 2012b)

Yaegashi et al (2009) further explained that "*geotags have potential to improve performance of visual image recognition, since recognition targets are unevenly distributed in the real world"*. 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).

Merapi is one of the most active volcanoes in Indonesia. Major eruption in 2010 and caused a great impact. 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). The hazard map and affected area of Merapi eruption 2010 is shown in the figure 2 that Cangkringan sub-district has potential several volcanic hazard types such as pyroclastic flow, lava flow, lahars, avalanche etc.

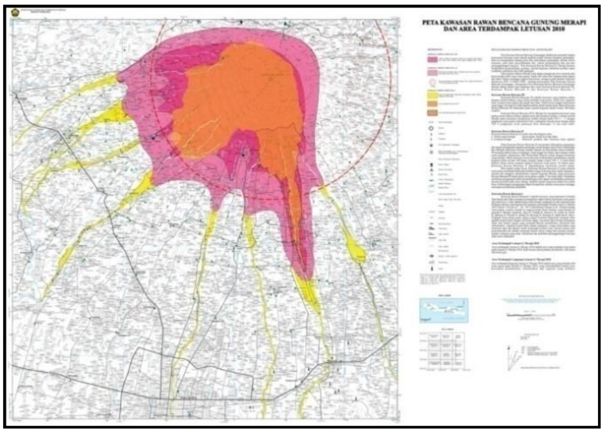


Figure 2. Hazard map of Merapi volcano (BPPTK–ESDM., 2010)

1.2. Research Problem

Yamazaki et al (2005) used multitemporal high-resolution imagery (Quickbird) to distinguish the condition of the building before and after the earthquake disaster to estimate the level of damage. With satellite imagery as a basemap and GPS as a tool, further building damage estimation results compared to field data. According to Ozisik (2004) that utilize remote sensing techniques to obtain information because of the earthquake damage, remote sensing data can not meet all the needs of damage assessment information. Remote sensing technique usually uses to analyze or identify the differences feature on imagery before and after the disaster. This assessment has limitations to get detail information about the damaged that happened because remote sensing is looking only from above. Several damage information of the building that can not be obtained from remote sensing will be possible obtained by using geotagged photograph. How to make interpretation from geotagged photograph due to damaged that happened need to be investigated.

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 a 3D anaglyph photographs, photos user is not necessary to be at the location of the photo to see the site conditions. Is the use of 3D geotagged photograph necessary for damage assessment compare to 2D geotagged photograph?

Remote Sensing, GIS and field work has been widely used for the purpose of assessing the damage from disasters. In every field work almost certainly always use the photographs as documentation and at this time geotagged photographs has become a technology that is very helpful for documentation in the field. This has been done by FEMA that make the list of data on the camera to be used in the field to capture structured data. Determination of the extent of damage done based on the criteria that have been used as the standard. After geotagged photographs shoot in the field, they are individually viewed in a GIS database where reports of damage can be seen along with the picture (Corbley, 2012b).

Indonesia as a country that prone to disaster in 2011 issued a regulation of BNPB Nr. 15/2011 as a standard guideline for post-disaster needs assessment in which there are standards for the assessment of damage due to disasters. This standard guideline is general instructions for all types of disasters in Indonesia. There are no more specific instructions for the type of volcanic disaster. Damage assessment using geoinformation technology is needed to be able to quickly meet the needs of the data for post-disaster needs assessment. Post-disaster damage assessment of Merapi volcanic disaster 2010 conducted by disaster management agency of Indonesia. An improvement to the method that has been used by disaster management agency of Indonesia is very necessary to improve the results obtained.

Based on the criteria used in standard guideline of post-disaster needs assessment of Indonesia, remote sensing can not fulfill all the required data for the assessment of damages due to the disaster. Field work by using geotagged photograph device has possibility to fulfill data that is interpreted as an attribute of photograph that can not be obtain by remote sensing. Damage assessment in the field with the help of geotagged photograph and GIS application that assist in the preparation of the database needs to be done because it can increase the effectiveness of field work and can meet the data that can not be obtained from remotely sensed data. How to assess the damage with these techniques in the field is needed to be investigated. Investigation will be conducted in volcanic area namely Cangkringan sub-district, Sleman, Yogyakarta that is one of the regions severely affected by the eruption of Merapi volcano in 2010 and has several volcanic hazards type.

1.3. Research Objectives

There are two main objectives in this research:

1. To develop method for volcanic post-disaster damage assessment from geotagged ground photograph in combination with remote sensing and GIS in Indonesia.
2. To test the volcanic post-disaster damage assessment method that use geotagged ground photograph in combination with remote sensing and GIS.

1.4. Research Question

The table 1 below shows several questions that can be structured to answer the research objectives.

Table 1. Research objective and research question

Nr	Research Objective	Research Questions
1	To develop method for volcanic post-disaster damage assessment from geotagged ground photograph in combination with remote sensing and GIS in Indonesia.	1. What is the current volcanic post-disaster damage assessment method by disaster management agency in Indonesia in case Merapi volcanic disaster 2010? 2. What kind of data that is needed for volcanic post-disaster damage assessment in Indonesia? 3. How to interprete geotagged ground photograph for volcanic post-disaster damage assessment? 4. What kind of volcanic post-disaster damage assessment data can be fulfilled from geotagged ground photograph? 5. What are the differences in visual appearance of damage for different type of volcanic hazards as seen from the geotagged ground photograph? 6. How to combine geotagged ground photograph, remote sensing and GIS for volcanic post-disaster damage assessment? 7. Is the use of 3D geotagged ground photograph is better for volcanic post-disaster damage assessment compare to 2D geotagged ground photograph?

Nr	Research Objective	Research Questions
2	To test the volcanic post-disaster damage assessment method that use geotagged ground photograph in combination with remote sensing and GIS.	1. Is the proposed post-disaster damage assessment method in fact faster and/or more reliable? 2. What is the test result of 3D geotagged ground photograph interpretation compare to 2D geotagged ground photograph for volcanic post-disaster damage assessment by disaster management agency? 3. How much total cost to convert current post-disaster damage assessment method with the proposed post-disaster damage assessment method?

1.5. Benefit of The Research

This study is useful for government agencies or organizations that deal with disaster. The use of geotagged photograph for damage assessment combined with data from remote sensing by mean of GIS can be apply to improve the effectiveness for government agencies or organizations to make the disaster management plans.

1.6. Expected Results

Expected results of this research are:

1. Landcover map and damage information based on visual interpretation remote sensing
2. 2D & 3D geotagged photograph databases and damage information from visual interpretation.
3. Post-disaster damage assessments result from data analysis of geotagged photograph, remote sensing and GIS.
4. Test result of post-disaster damaged assessment method using geotagged photograph.

Chapter 2. Literatur Review

2.1. Natural Disaster Management

According to Pampel (2008) "*A disaster can be defined as an unusual and dramatic event that, in a relatively short time span, causes enough death and destruction as to disrupt normal patterns of living in a community, region, or society*". Disaster caused by natural factor is called natural disaster. Natural factors that caused the disaster is volcanic eruption, landslides, floods, earthquake and so on. Handling of natural disasters requires disaster management activity. Disaster management is *"the effective organization, direction and utilization of available counter-disaster resources*" (ADPC, 2004). Figure 3 below shows the activities in the disaster management that post-disaster management activities include response, recovery and development.

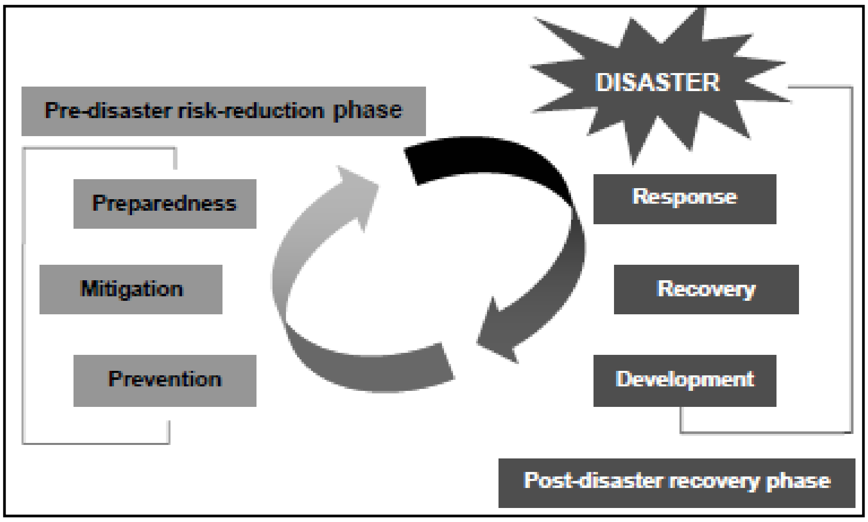


Figure 3. Disaster management activity (ADPC, 2004)

2.2. Natural Disaster Damage Assessment

Natural disaster management needs the process of disaster damage assessment. Damage assessment is defined as "*identification a qualitative and quantitative recording of the extent, severity and location of the effects of a destructive event*" (USAID, 2001). The level of building damage can be assessed qualitatively based on certain criteria. Montoya (2002) provide an explanation of classification of building damage for an earthquake based on criteria as shown in figure 4 which shows the level of damage to masonry building and reinforced concrete buildings. The extent of damage the building is divided into five classes, namely negligible to slight damage, medium damage, substantial to heavy damage, very heavy damage and destruction. Building damage criteria for each disaster is different because of the characteristics of the damage caused by a disaster can be different. Baxter (2005) explains building damage level for volcanic disaster especially building damage from pyroclastic flow. The level of building damage is divided into five classes, namely no damage, light damage, medium damage, heavy damage, partial devastation and total devastation as shown in the figure 5. Elements of the building which is used for the assessment is the condition of the roof, windows, walls, fences and structures.

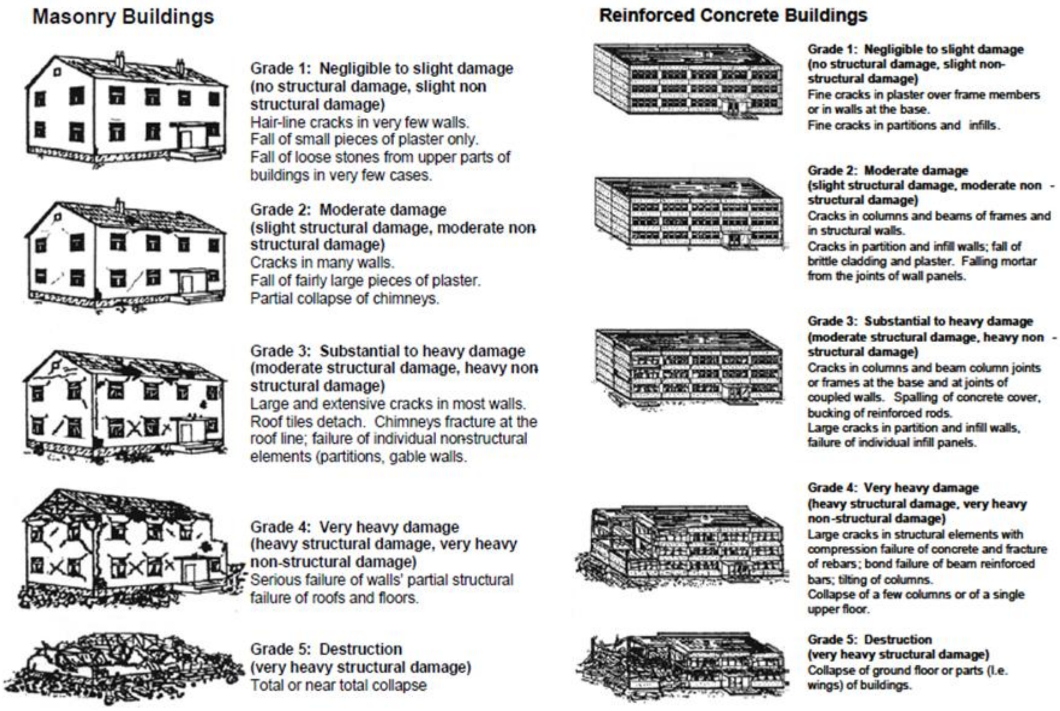


Figure 4. Building damage classification in earthquake disaster (Montoya 2002)

1 Level	2 Description	3 Effects: observed	4 Effects: estimated	5 Approx pressure range (kPa)
Level 0	No Damage	Windows and roof intact Minimal external burn damage to buildings, including even lightweight wooden houses. No evidence of pushed over fences or posts, but light charring of wooden posts and vegetation, including trees in places *No or minimal ash penetration. Infiltration of ash due to window catch or frame in bad condition.*	Little damage except to occasional window panes.	Less than 1
Level 1	Light Damage	One or two windows on side facing crater with windowpane broken. No, limited or even extensive fire damage to roof. Effects mainly due to intense heat, not dynamic pressure. Fencing and posts intact and unbent. PVC guttering melted *Thin layer of ash inside. Heat damage localised to impacted room or rooms, and even to within a corner of a room.*	PVC louvers melted, aluminium frame catches in bad condition break allowing ingress of ash. Window panes break.	1 to 3
Level 2	Moderate Damage	Old wood window and door frames imploded on side facing crater, exit windows or panes blown outwards, but window frames intact, or roof partially burned through in places from external heat of flow. In surrounding area visible effects of dynamic pressure and heat. Patchy sandblasting of walls facing volcano, scattered flow debris. All ordinary wooden houses consumed *Deep layer of ash in rooms where penetration has occurred, but fine layer only in remainder of building. Fire caused by combustion of furnishings by hot ash deposit. If no furnishings, roof stays intact but externally damaged by heat of flow. Complete combustion in rooms where fire occurs, part of roof burnt out from internal fire.*	Aluminium window and door frames damaged or destroyed.	2 to 6
Level 3	Heavy damage	All windows on side of volcano imploded, frames missing, and windows on opposite sides blown out or outwards, including frames, roofs lifted off. Evidence of flow missile damage. Missiles such as galvanised sheets and wood more abundant and gathered against walls facing crater. Tops of sturdy trees cut off, most trees and utility poles downed or pushed over. Fences and posts pushed over *Widespread internal fire with ash deposit throughout, roof burnt away by internal fires, radiant heat from deposit, or heat transfer from flow*	Some serious damage to masonry structures. Masonry in-fill panels of reinforced concrete (RC) structures fail in numerous buildings Many one- and two-storey weak non aseismic RC structures collapse; some multi storey strong non-aseismic and weak aseismic RC structures collapse.	4 to 10
Level 4	Partial devastation	As for Level 3, but loss of parts of external and/or internal walls. Large single or multiple small missile impacts to wall facing volcano, most or all of roof missing from fire or lifting off of non-RC roofs. No lightweight buildings left standing. Abundant missile debris.	All masonry in-fill panels collapse. Widespread serious damage to masonry buildings, most RC structures collapse except for strong aseismic RC structures	8 to 25
Level 5	Total devastation	Walls removed, only parts or none of the structure still standing. Multiple large missile impacts. Complete devastation from heat, dynamic pressure and missiles; ground scoured with little deposit or remaining debris.	All masonry and non-aseismic RC structures collapse. Only strong aseismic 1 and 2-storeys RC structures survive, but these are seriously damaged.	>25

Figure 5. Building damage classification in volcanic disaster (Baxter 2005)

Indonesia as disaster prone areas would have issued the regulation on standard guideline for post-disaster needs assessment through the regulation number 15/2011 that issued by the BNPB. Based BNPB (2011b), damage is defined as a change in the form of physical assets and infrastructure owned by governments, communities, families and business entities that cause disrupted function in partially or totally as a direct result of the disaster.

One of the scopes of the disaster management is rapid and appropriate assessment to the location, damage and resources (Republic of Indonesia, 2007). Based on Republic of Indonesia (2008) as government regulation number 21/2008, damage analysis is the basis for the action plan of rehabilitation. Inventory and identification of the disaster damage level is done by national disaster management agency of Indonesia (BNPB) and / or local disaster management agency (BPBD) and / or other elements coordinated by BNPB and / or BPBD (BNPB, 2008).

Based on BNPB (2011b) as BNPB regulation Nr. 15/2011 of Indonesia about standard guideline for post-disaster needs assessment, there are several damage criteria for disaster damage assessment. In this regulation, the damage criteria are divided into four sectors, namely:

1. The housing sector: building
2. Public infrastructure sector: roads and bridges, telecommunications networks, water and sanitation.
3. Productive economic sector: agriculture, infrastructure of agriculture, fisheries, small and medium industry, trade and market, tourism.
4. Cross-sector: environment, government facilities, finance and banking facilities, security facilities.

The damage is divided into three levels, namely heavy damage, medium damage and slightly damage. The table 2 to table 15 below shows the detail of damage assessment criteria for each sector:

1. The housing sector

According to the table 2, the building damage is divided into 3 levels, namely heavy damage, medium damage and slightly damage. The building by heavy damage category assessed based on criteria that buildings are collapsed or damage on most of the components. Building damaged by medium damage category being assessed based on criteria which building still stands, damage on a small component of the structure, and damage on supporting component, while building with slightly damage categories judged on criteria that building still stands, partly cracked on structural components (structure can still be functioned).

Table 2. Criteria for building damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	Buildings collapsed or damage on most of the components	• Physically damage of > 70% • Total collapse of buildings • Damage on most of the main structure of buildings • Most of the walls and floor of the building broken / cracked • Other supporting components totally damaged • Harm / have risk if it will be functioned • Repairs with reconstruction
2	Medium Damage (RS)	The building still stands, damage on a small component of the structure, and damage on supporting component	• Physically damage of 30% -70% • The building still stands • A small part of the main structure of buildings damaged • Most of the other supporting components damaged

Nr	Damage category	Damage criteria	Damage description
			• Relatively still functioning • Repairs with rehabilitation
3	Slightly Damaged (RR)	The building still stands, partly cracked on structural components (structure can still be functioned)	• Physically damage of <30% • The building still stands • A small part of building structures has minor damage • Cracks in plaster walls • A small part of other supporting components damaged • Can still function • Minor repairs

Source: BNPB (2011b)

2. Public infrastructure sector

Public infrastructures referred to in this assessment are divided into three sub-sectors, namely roads and bridge, telecommunication network, and water and sanitation. For road and bridge, heavy damage category is assessed by the criteria that the road / bridge building mostly destroyed. For medium damage category, criteria used is the existence of road / bridge building that still exist, damage on a small component of the structure, while the category of minor damage used criteria that road / bridge building is still existing, a small component (hardening layer) cracked and can still function. Table 3 below shows each category of damage to public infrastructure with a description of the damage.

Table 3. Criteria for road and bridge damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	The road / bridge building mostly destroyed	• Physically damage of > 70% • Damage on most of the main structure / roads body • Most of the asphalt layer broken / cracked • Harm / risk to traffic • Repairs with reconstruction
2	Medium Damage (RS)	The road / bridge building is still exist, a small component of the structure is damaged	• Physically damage of 30% -70% • The structure of the road is still exist • A small part of the primary structure is damaged (broken, cracked) • Relatively still functioning • Repairs with rehabilitation
3	Slightly Damaged (RR)	The road / bridge building is still exist, a small component (hardening layer) cracked (can still function)	• Physically damage of <30% • The building is still exist • A small part of the structure with minor damage • Cracks in the pavement layer • A small part of other supporting components damaged (drainage path) • Can still function • Minor repairs

Source: BNPB (2011b)

For telecommunication network, heavy damage category being assessed based on criteria that most of the major network infrastructure and telephone number unit damaged, medium damage category being assessed based on criteria which The main network infrastructure is still exist, damage on a small telephone number units, while slightly damage category being assessed based on criteria that the main fraction of network infrastructure components was damaged and the phone connection unit can still be functioned. Table 4 below presents the categories and criteria with a description of the damage to telecommunication network damage.

Table 4. Criteria for telecommunication network damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	Most of the major network infrastructure and telephone number unit damaged	• Physically damage of > 70% • Most of the major networks damaged • Most of the structure damaged • Can not function at all • Repairs with reconstruction
2	Medium Damage (RS)	The main network infrastructure is still exist, a small telephone number units damaged	• Physically damage of 30% -70% • The structure is still exist • A small part of the primary structure is damaged (broken, bent, cracked, etc.) • Relatively still functioning • Repairs with rehabilitation
3	Slightly Damaged (RR)	The main fraction of network infrastructure components damaged, the phone connection unit can still be functioned	• Physically damage of <30% • The structure is still exist • A small part of the structure has minor damage • A small part of other supporting components damaged • Can still function • Minor repairs

Source: BNPB (2011b)

For water and sanitation, heavy damage category is assessed by the criteria that the main building and most of pipeline was damaged. For medium damage category, damage can be seen by using criteria that the main building is still exist, the parent pipeline and a small component of the structure is damaged, while the category of minor damage used criteria that the main building and the existing networks is still exist, most of supporting building is damaged but still able to function. Table 5 below shows the damage explanation to water and sanitation.

Table 5. Criteria for water and sanitation damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	The main building and most of pipeline damaged	• Physically damage of > 70% • Damage on most of the main building and a pipeline system • Damage on most of the processing building and piping damaged • Can not function at all • Repairs with reconstruction
2	Medium Damage (RS)	The main building is still exist, the parent pipeline and a small component of the structure is damaged	• Physically damage of 30% -70% • Processing structures and networks still exist • A small part of the primary structure is damaged • Relatively still functioning • Repairs with rehabilitation
3	Slightly Damaged (RR)	The main building and the existing networks is still exist, most of supporting building is damaged but still able to function	• Physically damage of <30% • Building is still exist • A small part of the processing building and piping network has slightly damaged • A small part of other supporting components damaged • Can still function • Minor repairs

Source: BNPB (2011b)

3. Productive economic sector

The third sector is the productive economic sectors which are divided into sub-sectors of agriculture, agriculture infrastructure, fisheries, small and medium industry, trade and market and tourism. For agriculture damage, heavy damage category characterized by criteria most of field / farm / garden damaged. Medium damage category has criteria that a small part of the field / farm / garden plants damaged, whereas slightly damage category using criteria which a small part of the field / farm / garden plants damaged and can still be cultivated and harvested. Table 6 below shows the details description of the damage to agriculture.

Table 6. Criteria for agriculture damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	Most of field / farm / garden damaged	• Physically damage of > 70% • Most of the area of field / farm / garden damaged • Most of the plants were destroyed / lost • Harm / risk to traffic • Repairs with overall replanting
2	Medium Damage (RS)	A small part of field / farm / garden plants damaged	• Physically damage of 30% -70% • Structure of the area is still exist • Most of the small area of rice paddies / fields / orchards damaged • Relatively still be cultivated and harvested • Repairs with rehabilitation
3	Slightly Damaged (RR)	A small part of field / farm / garden plants damaged and can still be cultivated and harvested	• Physically damage of <30% • The building is still exist • A small part of the component areas of field / fields / orchards damaged with minor damage • A small part of the plant is damaged / missing • Could still be cultivated and harvested • Minor repairs

Source: BNPB (2011b)

The criteria for the assessment of agricultural infrastructure damage are based on the physical condition and function. For agriculture infrastructure that categorized as heavy damage has criteria such as the main agricultural infrastructure largely destroyed and can not be functioned. On the other hand, medium damage category has criteria that the main agricultural infrastructure still exists but some are not able to function. For slightly damage can be identified by criteria that major fraction of agricultural infrastructure components are damaged but can still function. Damage description for each criterion is shown in the table 7.

Table 7. Criteria for agriculture infrastructure damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	The main agricultural infrastructure largely destroyed and can not be functioned	• Physically damage of > 70% • Most of the major infrastructure damaged • Most of the irrigation networks damaged • Can not function at all • Repairs with reconstruction
2	Medium Damage (RS)	The main agricultural infrastructure is still exist, some are not able to function	• Physically damage of 30% -70% • Infrastructure is still exist • A small part of the irrigation network is damaged (broken, bent, cracked, etc.) • About 50% are still functioning • Repairs with rehabilitation
3	Slightly Damaged (RR)	Major fraction of agricultural	• Physically damage of <30%

Nr	Damage category	Damage criteria	Damage description
		infrastructure components are damaged, can still function	• Infrastructure is still exist • Most of the infrastructure has minor damage • A small part of the irrigation network components damaged • Can still be functionalized • Minor repairs

Source: BNPB (2011b)

Fisheries sub-sector damage is identified from physical damage of fish pond and water pipelines as well as their function. Heavy damage of fisheries has criteria susch as The main fishpond and pipeline network damaged, while medium damage has criteria that the main fishpond is still exist but the parent pipeline and some fish / aquaculture animals lost / died. Slightly damage in fisheries has criteria that the main fishpond and the pipeline network is still exist but a small part of fish / aquaculture of animals lost / died. Table 8 below describes criteria and detail description for fisheries damage.

Table 8. Criteria for fisheries damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	The main fishpond and pipeline network damaged	• Physically damage of > 70% • Most of the main fishpond and damaged a pipeline system • Most of the fish / aquaculture animals lost / died • Can not function at all • Repairs with reconstruction
2	Medium Damage (RS)	The main fishpond is still exist, the parent pipeline and some fish / aquaculture animals lost / died	• Physically damage of 30% -70% • A small part of the main fishpond and damaged pipelines • Fraction fishing / aquaculture animals lost / died • 50% are still functioning • Repairs with rehabilitation
3	Slightly Damaged (RR)	The main fishpond and the pipeline network is still exist, a small part of fish / aquaculture of animals lost / died	• Physically damage of <30% • The building is still exist • A small part of the main fishpond and piping network has slightly damaged • Fraction fishing / aquaculture animals lost / died • Can still function • Minor repairs

Source: BNPB (2011b)

Damage to small and medium industry is identified from industrial buildings, equipment and machines condition. Heavy damage category assessed based on criteria that industrial buildings, equipment and machines largely destroyed. On the other hands, medium damage assessed based on criteria that industrial buildings are still exist but damage on infrastructure, small equipment and machinery. Slightly damage can be assessed based on criteria that existing industrial buildings and infrastructure is still exist, equipment and machinery partially damaged but still able to function. Small and medium industry that has heavy damage can be repairs with reconstruction, while medium damage with rehabilitation. Slightly damage for small and medium industry only needs minor repairs. The detail of damage description for each criterion for small and medium industry can be shown in Table 9.

Table 9. Criteria for small and medium industry damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	Industrial buildings, equipment and machines largely destroyed	• Physically damage of > 70% • Most of the industrial buildings and infrastructure damaged • Most of the equipment and machinery damaged • Can not function at all • Repairs with reconstruction
2	Medium Damage (RS)	Industrial buildings are still exist, infrastructure and small equipment and machinery damaged	• Physically damage of 30% -70% • A small part of industrial buildings and infrastructure damaged • Fraction damaged on equipment and machinery • 50% are still functioning • Repairs with rehabilitation
3	Slightly Damaged (RR)	Existing industrial buildings and infrastructure is still exist, equipment and machinery partially damaged but still able to function	• Physically damage of <30% • The building is still exist • A small part of industrial buildings and infrastructure components has minor damage • Fraction damaged on equipment and machinery • Can still function • Minor repairs

Source: BNPB (2011b)

For trade and market sub-sector, the damage can be assessed based on physical condition of building and infrastructure and their function. Table 10 shows clearly about criteria and description of trade and market damage for each category.

Table 10. Criteria for trade and market damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	Market building and infrastructure largely destroyed	• Physically damage of > 70% • Most of the markets buildings and infrastructure damaged • Most of the kiosk / shops and supporting facility damaged • Can not function at all • Repairs with reconstruction
2	Medium Damage (RS)	Market building and infrastructure are still exist, a small kiosk / shop damaged	• Physically damage of 30% -70% • A small part of the market buildings and infrastructure damaged • A small part of kiosk / shop and supporting facility damaged • 50% are still functioning • Repairs with rehabilitation
3	Slightly Damaged (RR)	Market building and infrastructure is still exist, a part of kiosk / shop and supporting damaged but still able to function	• Physically damage of <30% • The building is still exist • A small part of the markets building and infrastructure has minor damage • A small part of kiosk / shop and supporting facility damaged • Can still function • Minor repairs

Source: BNPB (2011b)

The last sub-sector for productive economic sectors is tourism. Tourism damage can be assessed based on physical building dan tourism facilities as shown in table 11. Heavy damage category has criteria that main building and tourist facilities destroyed. For medium damage, the main building still exists but damage on the infrastructure and a small part of tourist facilities. Slightly damage category can be identified by criteria such as the main building is still exist and the infrastructure and a small part of tourist facilities damaged but still able to function.

Table 11. Criteria for tourism damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	The main building and tourist facilities destroyed	• Physically damage of > 70% • Most of the major buildings and infrastructure damaged • Most of tourist facilities damaged • Can not function at all • Repairs with reconstruction
2	Medium Damage (RS)	The main building is still exist, the infrastructure and a small part of tourist facilities damaged	• Physically damage of 30% -70% • A small part of the main buildings and infrastructure damaged • A small part of tourist facilities damaged • 50% are still functioning • Repairs with rehabilitation
3	Slightly Damaged (RR)	The main building is still exist, the infrastructure and a small part of tourist facilities damaged but still able to function	• Physically damage of <30% • The building is still exist • A small part of the main building and infrastructure has slightly damaged • A small part tourist facilities has slightly damaged • Can still function • Minor repairs

Source: BNPB (2011b)

4. Cross-sector

Cross sector damage assessment dibagi menjadi 4 sub-sektor yaitu environment, government facilities, finance/banking facilities and security facilities. For environment damage, the damage divides into three category of heavy damage, medium damage and slightly damage. Environment with heavy damage can be assessed by criteria as most of protected areas / forests / sanctuaries are damaged, while the medium damage can be assessed by criteria such as protected areas / forests / sanctuaries are damaged and some animals and plants die / disappear. For slightly damage can be identified by criteria that protected areas / forests / sanctuaries has minor damaged and a small part animals and plants die / disappear. Damage description for each criterion is shown in the table 12 below.

Table 12. Criteria for environment damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	Most of protected areas / forests / sanctuaries damaged	• Physically damage of > 70% • Most of the area of protected areas / forests / sanctuaries damaged • Majority animals and plants die / disappear • Repairs with overall replanting
2	Medium Damage (RS)	Protected areas / forests / sanctuaries damaged, some animals and plants die / disappear	• Physically damage of 30% -70% • The structure is still exist • Most of the small area of protected areas / forests / sanctuaries damaged • Approximately 50% of animals and plants die / disappear • Repairs with rehabilitation
3	Slightly Damaged (RR)	Protected areas / forests / sanctuaries has minor damaged, a small part animals and plants die / disappear	• Physically damage of <30% • The building is still exist • A small part of the component area of protected areas / forests / sanctuaries has minor damage • A small part of animals and plants die / disappear • Minor repairs

Source: BNPB (2011b)

Goverment facilities damaged can be identified from the office physically condition and the public service/function. Heavy damage category is assessed by the criteria that government offices and most public services damaged and can not be functioned. For medium damage category, criteria used is government offices and public services still exist but most are not able to function, while the category of minor damage used criteria that a small part of government offices and public services components is damaged but it can still function. Table 13 below shows each category of damage to government facilities with a description of the damage.

Table 13. Criteria for government facilities damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	Government offices and most public services damaged and can not be functioned	• Physically damage of > 70% • Most of the buildings of government and public services damaged • Can not function at all • Repairs with reconstruction
2	Medium Damage (RS)	Government offices and public services still exist, most are not able to function	• Physically damage of 30% -70% • A part of government buildings and public services damaged • About 50% are still functioning • Repairs with rehabilitation
3	Slightly Damaged (RR)	A small part of government offices and public services components is damaged, it can still function	• Physically damage of <30% • Infrastructure is still exist • A small part of government buildings and public services damaged • Can still function • Minor repairs

Source: BNPB (2011b)

In finance and banking facilities sub-sector, the damage can be assessed based on bank and financial means damage. Table 14 shows criteria and description of finance and banking facilities damage for heavy damage, medium damage and slightly damage category.

Table 14. Criteria for finance and banking facilities damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	Most of Banks and financial means damaged	• Physically damage of > 70% • Most of the banks and financial means damaged • Most of the automated teller machines (ATM) damaged • Can not function at all • Repairs with reconstruction
2	Medium Damage (RS)	Banks and financial means and partially automated teller machines (ATM) is damaged	• Physically damage of 30% -70% • A small part of banks and financial means damaged • A small part of automated teller machines (ATM) damaged • 50% are still functioning • Repairs with rehabilitation
3	Slightly Damaged (RR)	Banks and financial means, a minority of automated teller machines (ATMs) damaged	• Physically damage of <30% • The building is still exist • A small part banks and financial means of slightly damaged • A small part of automated teller machines (ATM) damaged • Can still function • Minor repairs

Source: BNPB (2011b)

Security facilities damage can be identified from physical condition of infrastructure, means or equipment. Heavy damage category assessed based on criteria that damage on means of the army and police, most of the equipment and vehicles. On the other hands, medium damage assessed based on criteria that means of the army and police are still exist and infrastructure and small part of equipment and also vehicles were damaged. Slightly damage can be assessed based on criteria that means of the army and police are still exist, some equipment and vehicles were damaged but still able to function. The damage description for each criterion for security facilities can be shown in table 15.

Table 15. Criteria for security facilities damage caused by disasters

Nr	Damage category	Damage criteria	Damage description
1	Heavy Damage (RB)	Means of the army and police, most of the equipment and vehicles damaged	• Physically damage of > 70% • Most of the the army and police facilities and infrastructure damaged • Most of the equipment and vehicles damaged • Can not function at all • Repairs with reconstruction
2	Medium Damage (RS)	Means of the army and police are still exist, infrastructure and small part of equipment and vehicles were damaged	• Physically damage of 30% -70% • A small part of TNI-police-owned facilities and infrastructure damaged • A small part of equipment and vehicles damaged • 50% are still functioning • Repairs with rehabilitation
3	Slightly Damaged (RR)	Means of the army and police are still exist, some equipment and vehicles were damaged but still able to function	• Physically damage of <30% • The building is still exist • A small part of TNI-police-owned facilities and infrastructure has minor damage • A small part of equipment and vehicles damaged • Can still function • Minor repairs

Source: BNPB (2011b)

2.3. Geotagged photograph

Geotagged photograph is defined as "*images having the latitude and longitude information"* (Singh, V. et al, 2010). Rost et al (2012) explain that photograph can be geotagged in two ways i.e from the user manually or from a camera that is used directly and automatically. With an automated way, the recorded location is the location where the camera takes a picture, while the manual way depending on how the user performs geotagging.

According to Welsh et al (2012), "*Geotagging photographs could be considered as an innovative field technique which brings together several existing fieldwork techniques*". Maiyo et al (2010) explains that by using geotagged photograph database system users can search for various specific information at specific locations and search location based on infrastructure damage due to disasters. Accurate information of damage caused by disasters is needed urgently by the government and insurance companies. Accurate data collection, geotagged photos and video documentation required for accurate reporting (RunMobile, 2012). Availability of geotagged photos is very important to help speed up the formal assessment of damages by the government after the disaster subsided. This has been done in Brown County, South Dacota where geotagged photos with location information and time of capture helps FEMA to assess damage of infrastructure due to flooding (Geospatial Experts, 2010a). Figure 6 shows geotagged photograph sample of the condition of the area before and after the disaster.

Figure 6. Disaster damage seen from geotagged photograph (Fontugne et al, 2011)

Geographic coordinate information that is available in photograph can be displayed in private collections and can also be displayed in the web (Joshi et al. 2012) as shown in the figure 7 below.

Figure 7. Geotagged photograph visualisation on website (Joshi et al. 2012)

"Anaglyphs are one of the simple and economical methods for 3D visualization" (Ideses et al, 2005). Dietz, H. G. (2012) explains that anaglyph is an image that creates the impression of three-dimensional depth when viewed using glasses with a particular filter. According to Doneus M, Hanke K. (1999), *"The detectability of depth differences decreases with the squared distance from the observer to the object. Its capacity is very high with the object close to the observer"*. Geotagged photographs can be processed into Anaglyph image using certain software. Example Anaglyph photo which depicted the condition of the building affected by disaster is as shown in figure 8 below.

Figure 8. Anaglyph 3D Photograph of flooded house (Fotothing, 2007)

2.4. Geographic Information System (GIS)

Geographic Information System is "*a collection of computer, hardware, software, and geographic data for capturing, storing, updating, manipulating, analyzing, and displaying all forms of geographically referenced information"* (Kennedy, 2001). Geographic Information System (GIS) consists of several parts as shown in the figure 9 below.

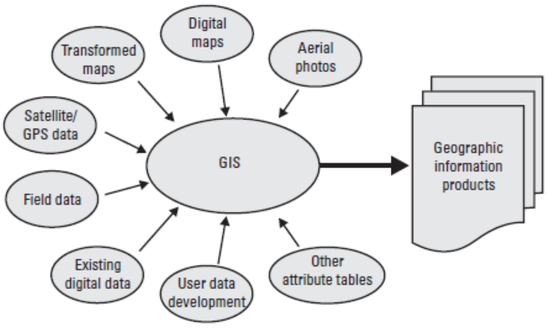


Figure 9. Geographic Information System path (Galati, 2006).

Natural disaster is one field that can apply Geographic Information System. Cavvara et al (2011) examined the role of GIS for volcanic risk mitigation and the importance of GIS to assist in decision making. Volcanic eruption has caused damage to buildings and assets. In that event, the roles of GIS are to compile risk map, to analyze the risk, to determine the evacuation plan, to determine the strategy of the future eruption and to make the database of the building, economic resources and the population.

2.5. Remote Sensing for Damage Assessment

Filippi (2008) states that, "*Remotely sensed images for disaster-monitoring can be manually/visually interpreted or analyzed via computer algorithms*". High spatial resolution imagery has a better role in the damage assessment. This is confirmed by Adam et al (2007) in Filippi (2008) that *"high-spatial resolution imagery is very useful for detecting damage to individual structures*". Yamazaki et al (2005) conducted a visual interpretation of high spatial resolution imagery (Quickbird imagery) before and after the earthquake and compared to determine the level of damage. He further stated that it is easier to detect the extent of damage to Grade 5 and *"almost impossible to detect damage equal to or less than Grade 2".* Comparation of images and damage level from visual interpretation is shown in the figure 10 below.

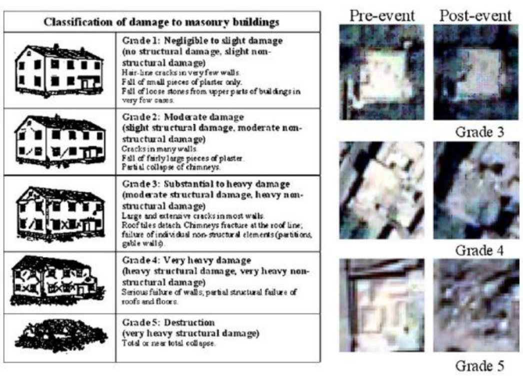


Figure 10. Comparison of images before and after the disaster and the level of damage (Yamazaki et al, 2005)

Ogawa (2000) used aerial photographs to identify damage to buildings due to the earthquake. Interpretation is done visually, either monoskopis and stereoscopic. The result of the interpretation of building damage is compared with reality damage to buildings on the ground. Criteria for visual interpretation are shown in the figure 11 below.

Single photo-interpretation		Stereoscopic photo-interpretation	
Damage classification	**Standard of interpretation**	**Damage classification**	**Standard of interpretation**
Collapse	Collapsed, deformed, or severely leaning buildings	**Collapse**	Totally collapsed, buildings which reduced to rubble
		Partial collapse	Partially collapsed, deformed, or severely leaning buildings
Falling of roof tiles	Falling of roof tiles, damaged buildings other than those in the above category		
No damage	Buildings without visible damage or buildings whose damage state is difficult to identify from aerial photographs		

Figure 11. Criteria for visual interpretation of building damage (Ogawa, 2000)

Further, Ogawa (2000) divides the building into two categories : wooden building and non-wooden building. For wooden building, the criteria used for building damage are shown below in the figure 12.

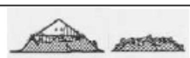
Building damage criteria by AIJ & CPIJ group			**Destructive patterns for wooden building by Takai et al. [1997]**		
Damage classification	**Criteria of damage classification**	**Examples of damage for wooden buildings**	**Damage classification**		**Destructive pattern**
Severe damage	Unusable buildings or buildings with very low possibility of reuse.	Totally collapsed, layer-collapse, severely leaning, or severe damage to foundation, columns and walls	**Collapse**	**D5+**	
				D5-	
			Severe damage	**D4**	
Moderate damage	Buildings may be reused after substantial repair.	Partially collapsed, extensive cracks on walls	**Moderate damage**	**D3**	
Slight damage	Usable buildings with slight damage or buildings with possibility of use after little repair.	Falling of some roof tiles, or small cracks/peeling on walls	**Slight damage**	**D2 D1**	
No damage	No damage in appearance		**No damage**	**D0**	

Figure 12. Criteria of wooden building damage (Ogawa, 2000)

The results of visual interpretation must be compared with field surveys to determine the level of accuracy assessment of the damage as figure 13.

Red : Grade 5
Yellow : Grade 4
Green : Grade 3
Blue : Grade 2 & 1

correct
omission error
commission error

Field survey / QuickBird	G 1	G 2	G 3	G 4	G 5	sum
G 1 & G 2	0	0	0	0	0	0
G 3	0	2	2	1	4	9
G 4	0	1	2	1	5	9
G 5	0	0	3	2	27	32
sum	0	3	7	4	36	50

Figure 13. Accuracy assessment of the damage interpretation
(Hisada et al (2005) in Yamazaki et al, 2005)

2.6. Photograph for Damage Asessment

The location information is "*the most important attribute of information"* that can be managed with GIS and elements required "*in disaster management and response"* (Kevany, 2005). Further, Kevany (2005) explains that an application to enter data in the field that is integrated with a digital camera that records the disaster conditions is useful for the assessment of damages. Figure 14 & 15 below shows geotagged photograph integrated with field data entry to describe the disaster event and damage assessment from photograph for flood disaster.

Figure 14. Geotagged photograph integrated with field data entry (Geospatial Experts, 2010c).

Figure 15. Damage assessment from photograph (Broward, n.d.)

2.7. Geojot and GPS Photo Link

Geojot is mobile-based software for GIS field data collection via geotagged photos that can be used on Android and Apple devices. Geotagged photos produced by a standard device for geotagging generally only produce according to standard EXIF information (position and time of capture) without any specific attributes. On the other hand, "*Geojot allows users to collect geotagged photos and capture descriptive attribute information for each photo*. *Organizations then map the results in ArcGIS or Google Earth, import the* data *into a backend database*, *or create reports showing the photo, the location on a map, and the attribute information"* (Geospatial Experts, 2012b).

Users can design attributes as appropriate photo survey. The attributes of the image is stored in the EXIF metadata format and encrypted by the software so that it can only be read using the GPS Photo Link / Geojot Core. Figure 16 below shows Geojot facilities and attribute entry ability.

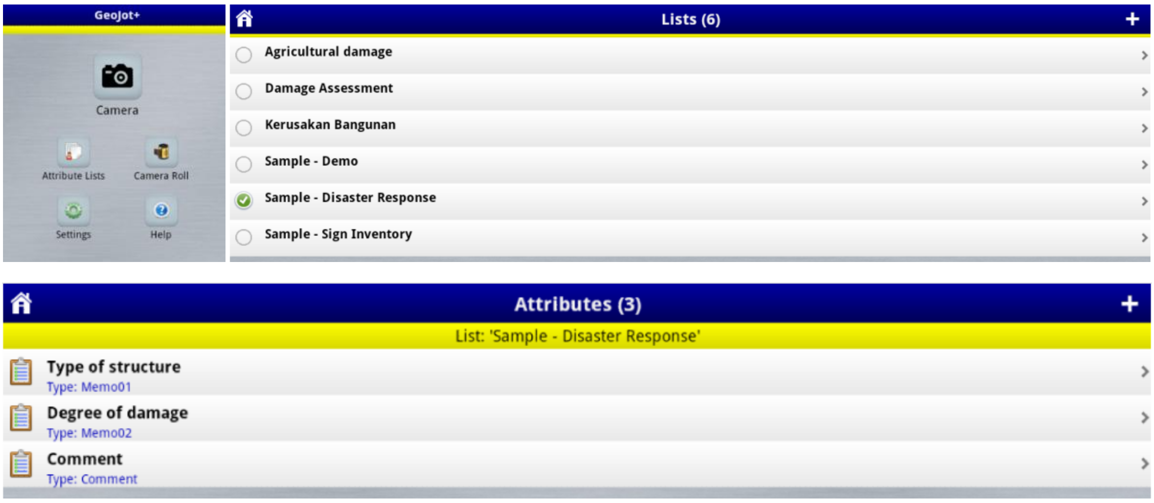


Figure 16. Geojot facilities and Attribute entry ability

Geojot provide GPS-Lock, Laser distance device connection and Barcode/QR code. GPS-Lock feature works if the user wants to lock the coordinates of the new object and then to shoot the object. Laser distance device with bluetooth connection serves to get the distance between the capture position and the photographed object. Barcode/QR code has the function to read the code in a way to scan the barcode available. Data from the barcode/QR code can be matched with an existing database.

" GPS-Photo Link is the software for geotagging and photo mapping and able to map photographs and accompanying attribute information captured with a GPS camera, smartphone, tablet, or any digital camera used in conjunction with any GPS unit " (Geospatial Experts, 2010b). Attributes that has been filled in Geojot readable and can be processed using the GPS-Photo Link. GPS-Photo Link or Geojot Core that is part of the GPS-Photo Link can produce "*4 different types of customizable reports, watermarked photos, and photo maps in both ArcGIS (shapefiles and Geodatabases) and Google Earth"* (Geospatial Experts, 2010b). Figure 17 shows the attributes of geotagged photograph from Geojot and sheet report from GPS Photo Link.

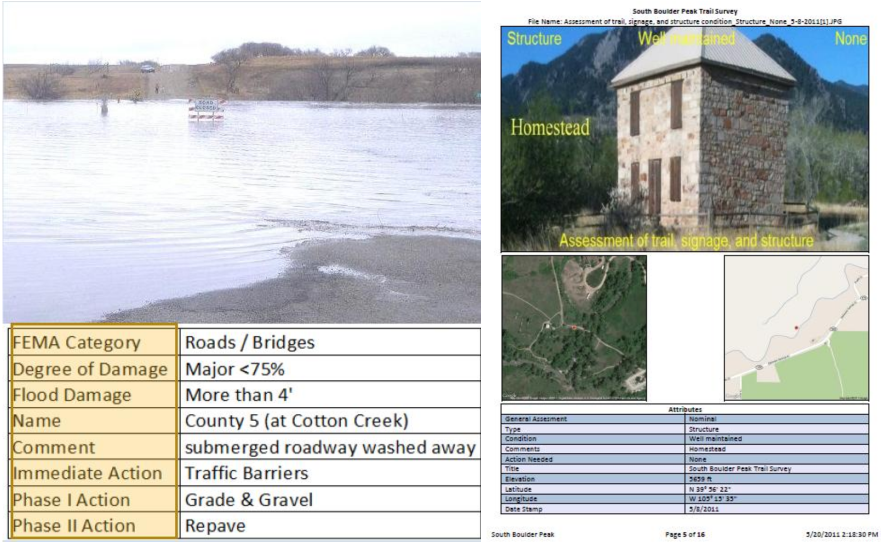


Figure 17. Photo attributes from Geojot and Report (Geospatial Experts, 2011a & 2011b)

Chapter 3. Study Area

3.1. General Information of Cangkringan Sub-District

Cangkringan sub-district is one of the sub-districts in the Sleman regency located on the southern slope of Merapi volcano. The geographic coordinates of Cangkringan sub-district is 110º 25' 34" – 110º 28' 38" E and 7º 34' 2" – 7º 41' 25" S. Cangkringan sub-district consists of 5 villages namely Umbulharjo, Kepuharjo, Glagaharjo, Wukirsari and Argomulyo as shown in the figure 18 below.

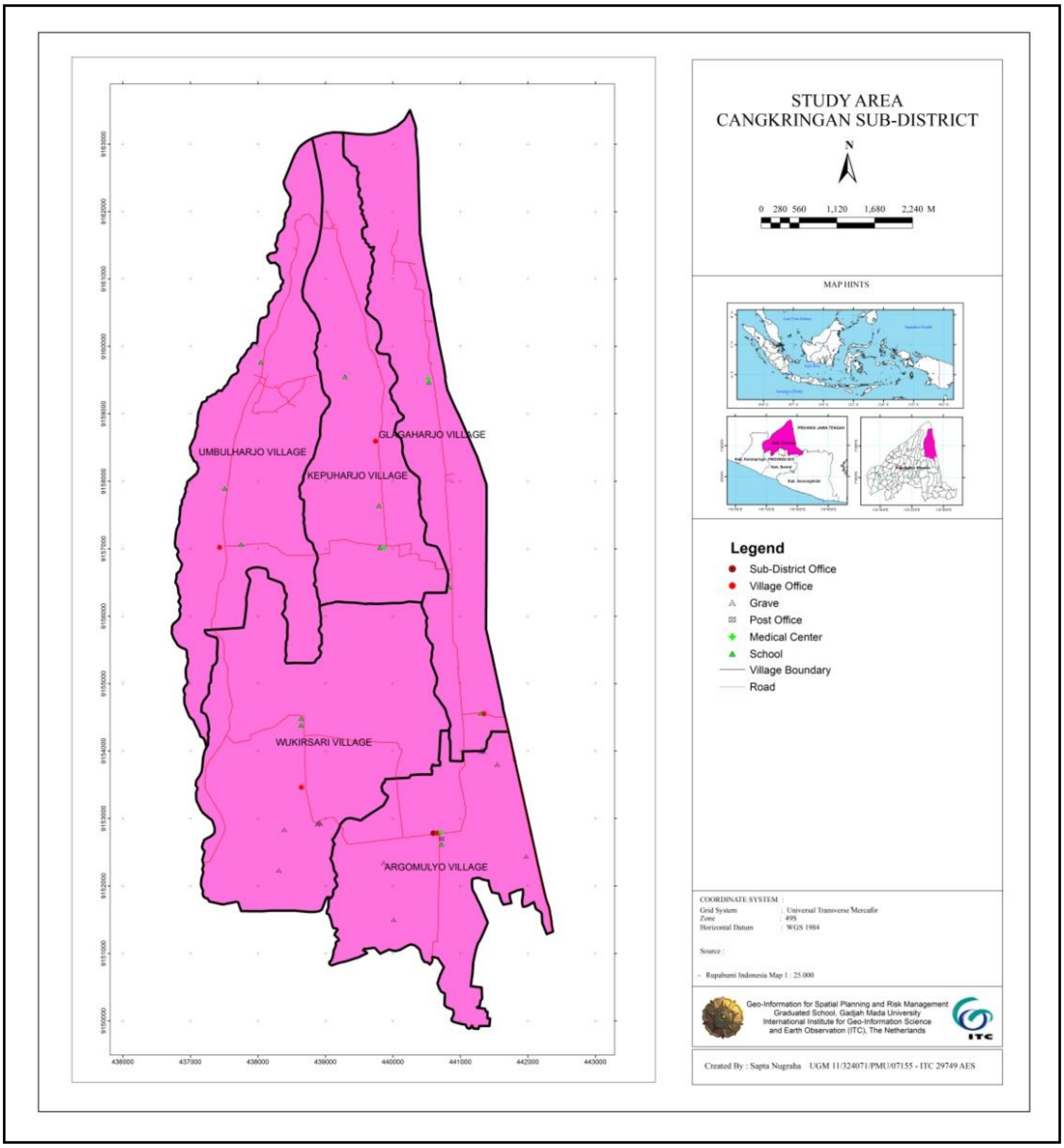


Figure 18. Cangkringan sub-district as study area

Cangkringan sub-district was chosen as representative location for this research because greatly affected by the eruption of Merapi Volcano in 2010.

3.2 Description of Merapi Eruption 2010

At the end of 2010, large eruption of Merapi volcano had higher intensity than the 2006 eruption. An area affected by the eruption is a region in the southern slope of Merapi volcano, Sleman. In general, the chronology of the eruption of Merapi volcano can be described as the table 16 below.

Table 16. The chronology of the eruption of Merapi volcano 2010

Nr	Date	Information
1.	20 September 2010	Status of Merapi volcano increased from Level I (normal) to be Level II
2.	21 October 2010	Merapi status to Level III
3.	25 October 2010	Merapi status to Level IV (Highest level)
4	26 October 2010	Merapi volcano erupted. A total of 40 people were killed. Residents who lived at the disaster prone areas were evacuated to refugee barracks.
5	3 November 2010	Large heat clouds occurred for 1.5 hours. It was reported that the pyroclastic flow reached 9 km in Gendol River. Safe area outside a radius of 15 km from the peak of Merapi.
6	5 November 2010	Mount Merapi eruption. 222 people died. Safe areas for refugees changed from outside a radius of 15 km, to be beyond the radius of 20 km from the peak of Merapi
7	19 November 2010	Starting on 19 November 2010 at 12:00 pm, the area is safe for refugees to sleman district is in the east of the river Boyong beyond 15 km.
8	3 December 2010	Status of Merapi volcano has been reduced to Level III

Source: Bappeda Sleman (2011)

Further, piles of material that is the result of the eruption of Merapi caused lahars flood. The period when the eruption occurred was the rainy season so that the lahars flood swept through the region around the rivers that disgorge on Merapi Volcano. The chronology of the lahars flood of Merapi volcano can be described as the table 17.

Table 17. The chronology of the lahar floods of Merapi volcano 2010

Nr.	Date	Information
1	29 November 2010	Lahar flood in Boyong- Code river
2	4 December 2010	Lahar flood in Opak river. Access roads connecting Umbulharjo and Kepuharjo village buried by material on Pagerjurang bridge.
3	14 December 2010	Lahar flood in Gendol river. The military office in the Cangkringan sub-district affected by lahar flood
4	23 December 2010	Lahar flood in Opak river. Pagerjurang bridge was damaged.
5	3 January 20100	Lahars flood in Opak river. The police station in the Cangkringan sub-district affected by lahar flood
6	8 January 2011	Lahar flood in Gendol river. Two houses were damaged.
7	19 March 2011	Lahar flood in Opak and Gendol river.
8	22 March 2011	Lahar flood in Opak and Gendol river
9	22 April 2011	Lahar flood in Opak and Gendol river
10	1 May 2011	Lahar flood in Opak and Gendol river
11	28 May 2011	Lahar flood in Opak and Gendol river swept Jaranan and Teplok hamlet
12	31 May 2011	Lahar flood in Opak and Gendol river swept Plumbon and Tambakan hamlet
13	05 June 2011	Lahar flood in Gendol river swept Ngerdi hamlet

Source : Bappeda Sleman (2011)

Chapter 4. Research Methodology

4.1. Materials

Materials needed for this research include high-resolution satellite images before and after the disaster, geotagged photographs and other spatial database which is needed in the analysis. The table 18 below shows the required material in this research.

Table 18. Materials needed for this research

Nr.	Data	Data source
1	Geotagged photograph	Field Work (Using Smartphone/Tablet with Geojot Application) and Secondary data
2	High resolution Satellite Imagery	
	- Pre volcanic disaster 2010	Quickbird 2006 from BPN Geo-Eye 2009 from UGM
	- Post volcanic disaster 2010	WorldView 2010 from UGM Geo-Eye 2011 from UGM
3	Landcover Map	Satellite Imagery Interpretation
4	Administration Map	RBI Map
5	Volcanic Hazard Map	BNPB of Indonesia

4.2. Equipment and Software

There are some equipment and software required in this research. The table 19 shows the required equipment and software in this research.

Table 19. Equipment and software

Nr.	Equipment and Software	Utility
1	Motorolla Xoom 3G Android Tablet with Geojot Application	Geotagged photograph capture device and application
2	Anaglyph Maker V1.08	Create 3D-Anaglyph photograph from 2D photograph
3	GPS Photo Link software (Trial)	Read geotagged photograph attribute taken by Geojot and manual geotagging utility
4	Zint Barcode Studio	To create QR Code for building identity scenario
5	Android QRCode/Barcode Scanner software	To read QR Code of Building from camera
6	Laser distance meter (Laser Ace 300)	To calculate distance from camera position to captured object
7	3D-Glasses	To see 3D-Anaglyph photograph
8	ArcGIS	To combine attribute of damage interpretation from remotely sensed data and geotagged photograph
9	Notebook	Processing device

4.3. Methods

Pre-Field Work

After the Merapi volcanic disaster event 2010, disaster management agency of Indonesia has done post-disaster damage assessment with a particular method. Furthermore, the method has been evaluated and will be improved with the use of geo-information technology in the form of post-disaster damage assessment method using geotagged photograph interpretation, satellite imagery interpretation and GIS. This stage includes the preparation of data that will be used such as hazard map, administrative map, high resolution satellite imagery (before and after disaster) and secondary data of geotagged photographs. High resolution imagery that recorded before and after the disaster can describe the condition before and after the disaster occurred. On this imagery is done the on screen visual interpretation of landcover and damage information that can be observed with comparing high resolution imagery before and after the disaster. Secondary data of geotagged photographs that related to the purpose of research 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 what 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 because the condition in field work in 2012-2013 maybe very different with condition after disaster 2010, for example because reconstruction activity, mining and other activities. Only building object will be conducted in this research because some limitations. Building damage will be the focust element in this research. Area that is affected by disaster will be used as sampling location.

Further, the attributes design of the geotagged photograph is drawn on the Geojot application. This design is adapted to the post-disaster damage assessment criteria of disaster management agency of Indonesia and other source. Figure 19 below show the example of attribute design of geotagged photograph in Geojot.

Figure 19. Attribute design of geotagged photograph in Geojot (Geospatial Experts, 2012d)

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. QR code designed and printed using Zint Barcode Studio and attached directly to the building that were sampled in the scenario. QR code is designed with a format like this fromat:

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

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

Figure 20 below shows the QR code sample for building identification as text above.

Figure 20. QR code sample for building identification

In addition, the GPS scenario Lock-Off mode and GPS Lock-On mode when shooting object will also be conducted to determine their role in the combination of attributes photo and satellite image interpretation results as shown in the figure 21 below.

GPS Lock-On Mode GPS Lock-Off Mode

Figure 21. GPS Lock-Off/On Mode for geotagged photograph in Geojot

Field Work

The field work is conducted by using maps that have been prepared to guide the determination of the location survey. Geotagged photographs are taken by using a smartphone/tablet to produce 2D geotagged photograph with Geojot application facility. In Geojot application, the data attributes of the object is designed to meet the needs for building damage assessment. The number of attribute of each geotagged photograph in Geojot Application has limitation up to 24 attributes. To creating 3D photograph using a single camera, this "*would need to shoot two images of the same subject from slightly different positions. For the first image, just shoot an image of the subject from a distance. Then slide the camera to the right or left by 3 to 4 inches and click the second image*" (Francis D'Sa, 2010). Figure 22 below describe the way to create 3D photograph using a single camera.

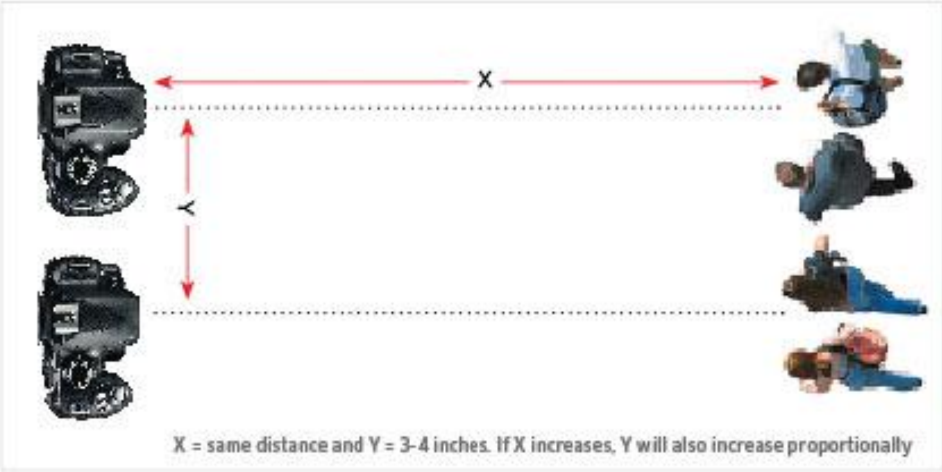


Figure 22. Creating 3D photograph using a single camera (Francis D'Sa, 2010)

For some samples of 2D & 3D geotagged photograph, shooting scenario will be made based on the distance to the object. It aims to compare the role of 2D & 3D images in visual observations for post-disaster damage assessment. In fact, within this scenario is a condition where 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. The figure 23 below explains distance variation scenario of 2D and 3D geotagged photograph.

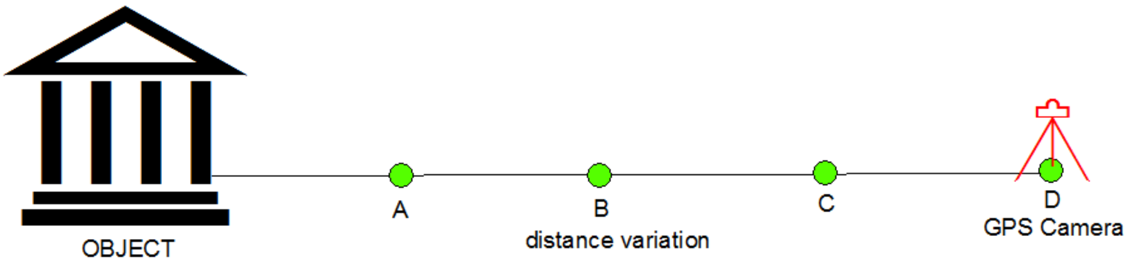


Figure 23. Distance variation scenario of 2D and 3D geotagged photograph

Geotagged photograph must meet the needs for disaster damage assessment. For instance, building should describe the component that be used for damage assessment such as wall damage condition, roof etc. On screen visual interpretation in Geojot will do to observe objects and describe the damage occurred which appear from geotagged photograph.

Some buildings will also be chosen for testing to be performed by the local disaster management agencies. Officers from the agencies previously trained to be able to apply the method of the combination of geotagged photographs, remote sensing and GIS for post-disaster damage assessment. The test is performed to test the advantages of that method in terms of time required, the results obtained and cost.

Post-Field Work

In the post-field work phase, both pairs of 2D photograph that were taken from filed work is processed by using Anaglyph Maker V1.08 software to be single 3D photograph file which from this photograph can be seen the impression of three dimensions through 3D-glasses. Damage which appears from geotagged photograph and their spatial distribution then analyzed along with hazard maps to determine the type of damage based on the hazard. Because of the study area is a volcanic area, the damage type that will be observed from geotagged photograph can be identified based on the type of hazard such as pyroclastic flows/surge and lahar.

Farther, geotagged photograph databases and interpretation result from remote sensing are combined into spatial databases. Attribut from geotagged photograph will be joined with spatial database from remote sensing interpretation. Disaster damage assessment will do by query analysis of attribut from geotagged photograph and remote sensing interpretation. Comparison between 2D and 3D geotagged photographs for building damage assessment is done by comparing the visual appearance of each scenario distance.

Post-disaster damage assessment method with a combination of geotagged photographs, remote sensing and GIS will be evaluated involving local disaster management agencies. What is the total cost to be able to use this method as compared with previous methods are discussed. Conclusions can be formulated after this evaluation of the usefulness of geotagged photograph, remote sensing and GIS for disaster damage assessment. In addition, recommendations will be prepared based on the results and conclusions obtained. Research framework which shows activity in the pre field work, field work and post field work is shown in figure 34.

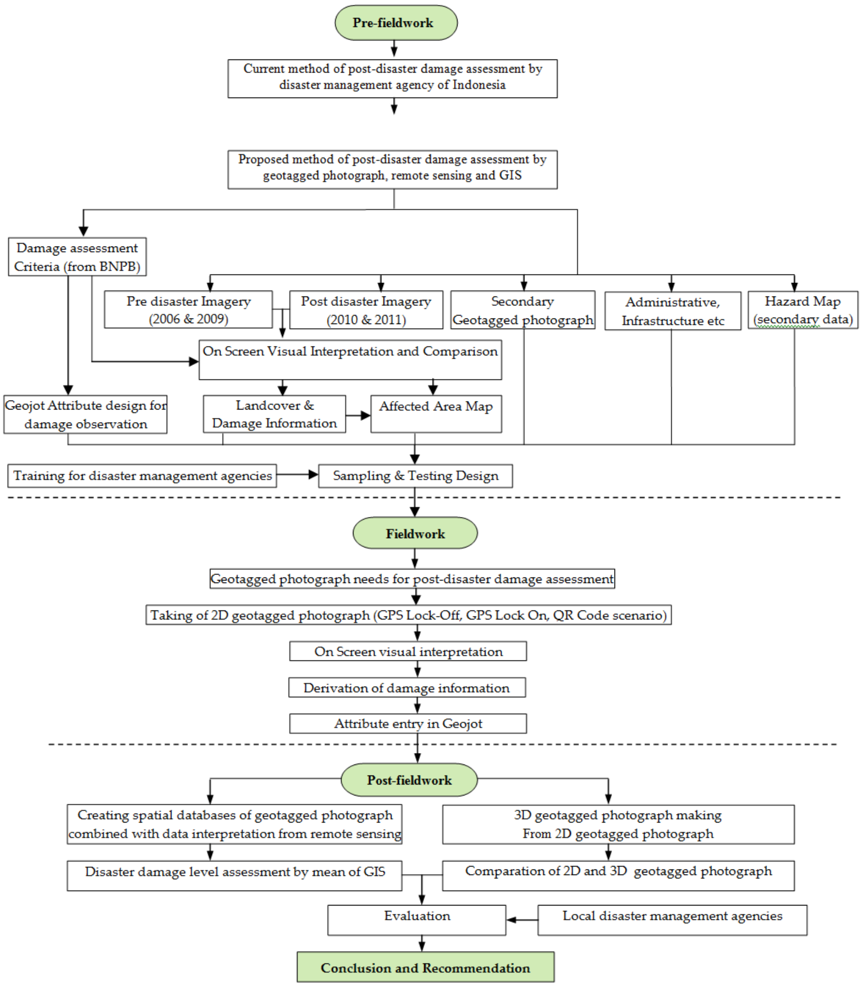


Figure 24. Research Framework

4.4. Data collecting and Preparation

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. Figure 25 shown satellite imagery before Merapi eruption 2010 that used in this research.

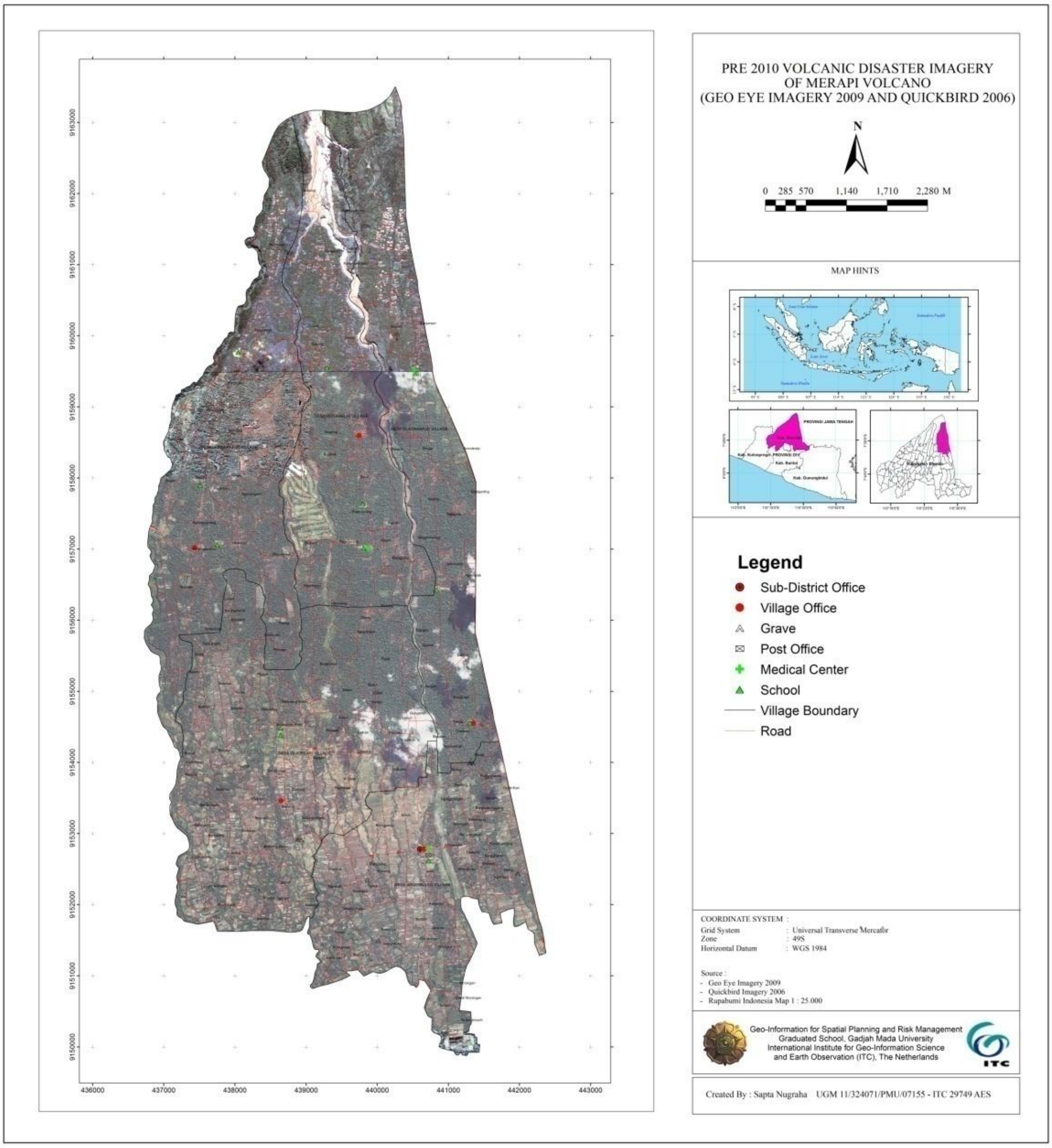


Figure 25. Satellite imagery before Merapi eruption 2010

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. It is shown as figure 26.

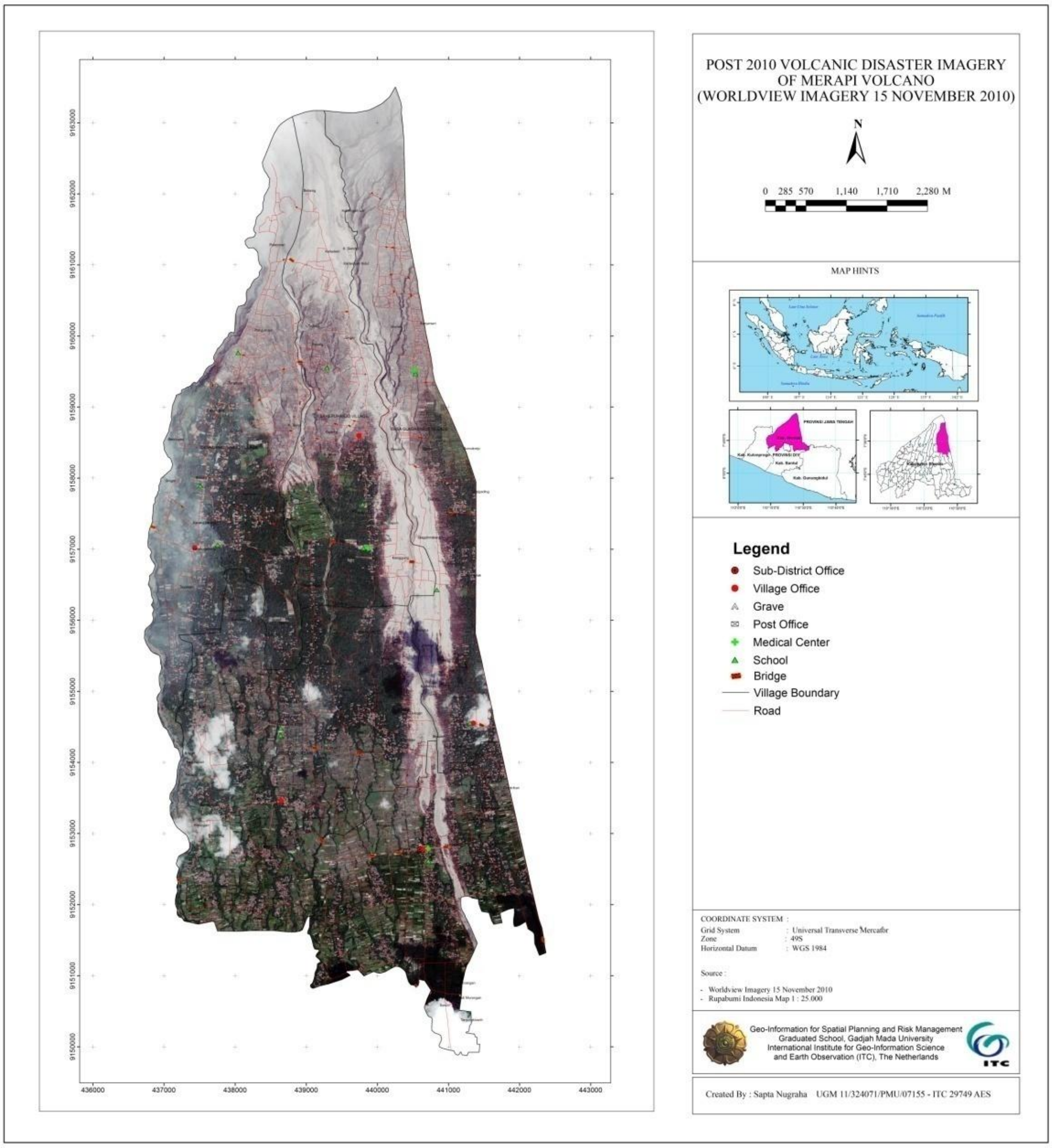


Figure 26. Satellite imagery after Merapi eruption 2010 (November 2010)

Geo Eye imagery of Cangkringan sub-district recorded in June 2011 is used to illustrate the impact of Merapi's lahars. Figure 27 shows Geo Eye imagery as satellite imagery after Merapi eruption 2010 that describe condition in 2011.

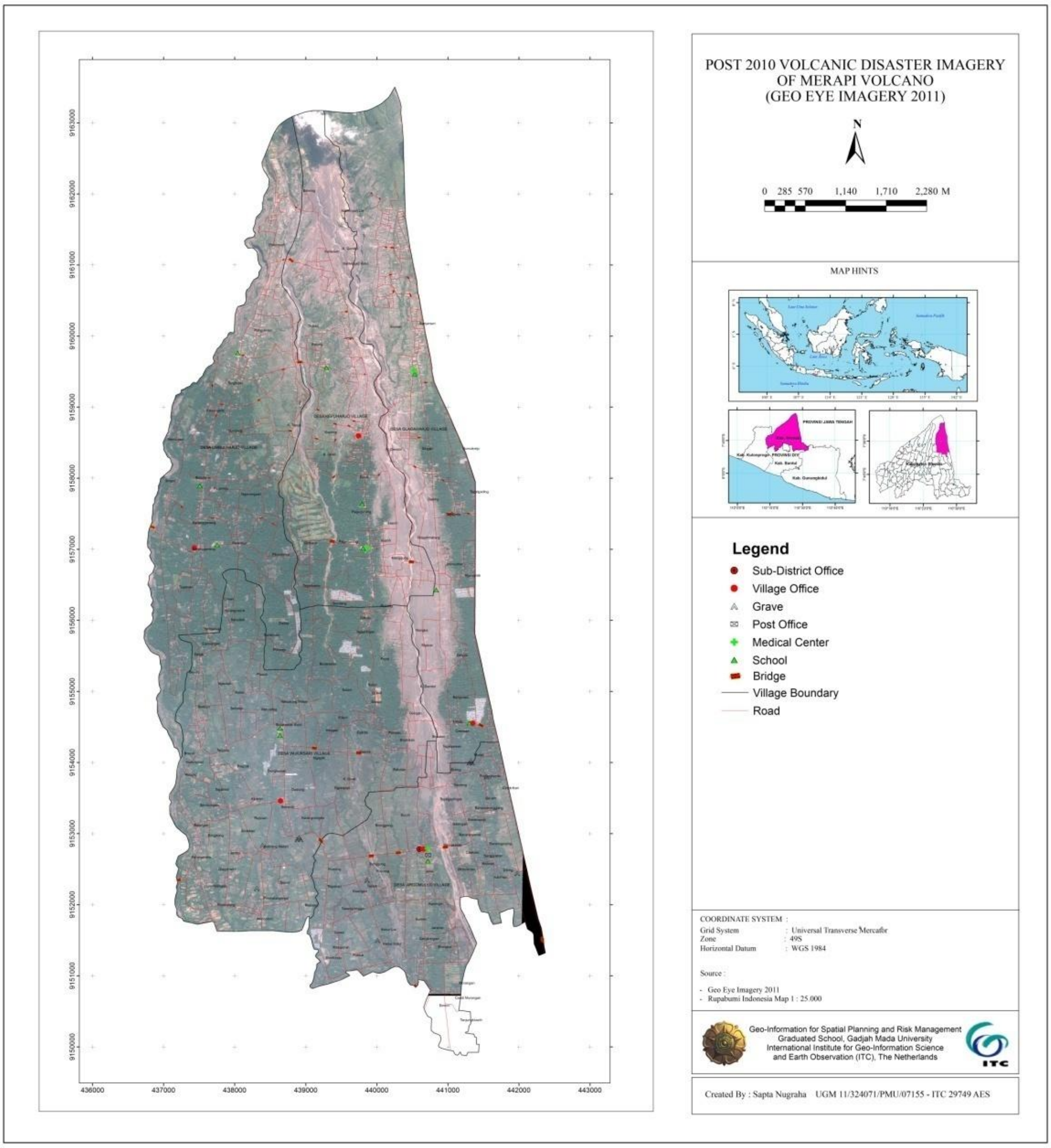


Figure 27. Satellite imagery after Merapi eruption 2010 (June 2011)

Secondary maps are used as initial data for this research in the form of administrative map of and hazard map. These maps are used to assist in sampling and analysis. According to hazard map of Merapi 2010 from BNPB, Cangkringan sub-district is divide into three hazard zone, namely KRB III (Hazard zone III), KRB II (Hazard zone II) and KRB I (Hazard zone I). Hazard Zone III often affected by pyroclastic flow, lava flows, incandescent rock avalanches, toxic gases and incandescent stones throw to a radius of 2 km. Hazard Zone II is area that potentially devastated by pyroclastic flows, toxic gases, incandescent rock avalanches and lahar. Area that potentially affected by lahar and potentially affected by the expansion of pyroclastic flow and lava flows is area namely Hazard Zone I. Figure 28 shows Hazard Map of Merapi Volcano 2010.

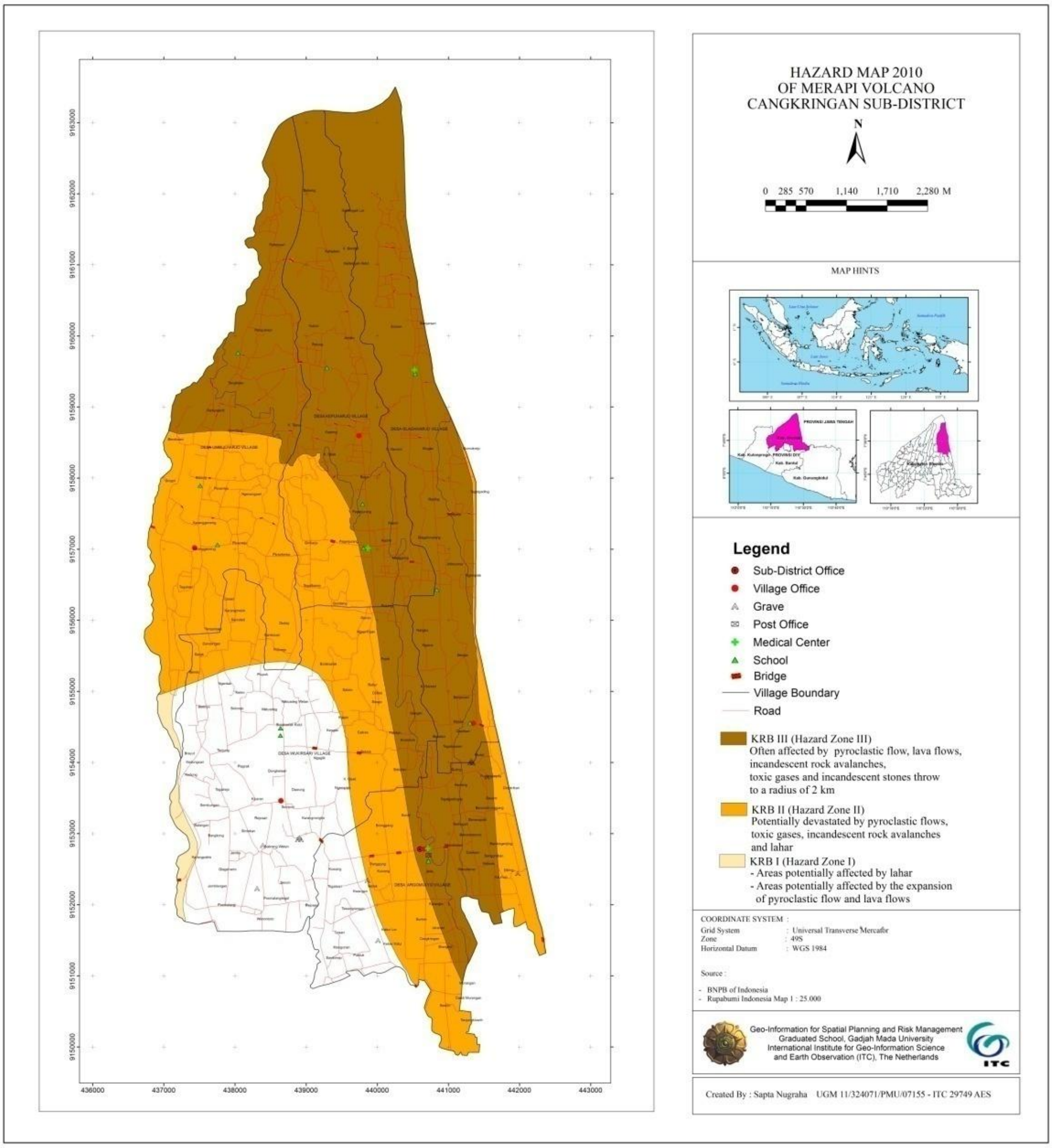


Figure 28. Merapi Volcano Hazard Map 2010 (BPPTK–ESDM, 2010)

Chapter 5. Result and Discussion

5.1. Current system of Disaster Damage Assessment of Merapi Eruption 2010

Post-disaster damage assessment methodology used in Indonesia is the adoption of the methodology developed by the UN Economic Commission for Latin America and the Caribbean (ECLAC). This methodology produces preliminary estimatation of the impact of the physical assets that must be repaired, replaced, and the streams that will not be produced until repaired and constructed assets.

Assessment of damage caused by the eruption of Merapi volcano is done start from 22 November 2010. Because of at that time Merapi is still in the highest level of warning (Level IV), the results of damage asessment continuously changes and must be continuously update. Further, government locked the damage assessment data on 9 December 2010 because on 3 December 2010 Merapi status was decreased to Level III.

Documenting the disaster damage is done by the disaster management agency along with the relevant government agencies. Lowest level of government involvement is beneficial because the bottom level of government (villages and sub-villages) is the least understood area. Sub-village chiefs in the disaster affected areas were included in the data collection of building damage. The involvement of the sub-village chiefs is very beneficial because he is the most understand the location of each house people living in the village. Therefore, the resulting damage data is based on the name of the owner of the home / family. Reports of damage from the village is the main input used in addition to the data taken by the designated officer. Table 20 is an example of the result of damage asessment data to building by the government.

Table 20. Damage asessment calculation result example of building by government

Nr.	Village name	Sub-village name	Building damage (unit) on 28 Nov 2010
1	Glagaharjo	Ngancar	146
		Glagah Malang	84
		Banjarsari	6
		Besalen	46
		Singlar	126
		Srunen	131
		Kalitengah Kidul	107
		Kalitengah Lor	156
2	Argomulyo	Banaran	63
		Suruh	30
		Bakalan	89
		Gadingan	64
		Karanglo	2
		Jaranan	1
		Jetis	9

Source: Public Works Department of Sleman Sub-District

Detail of damage level by building owner name as the report from village in Cangkringan sub-district to Public Works Department of Sleman sub-district is shown in the table 21 below.

Table 21. Damage asessment result example of building by government

Nr	Building Owner Name	Address	Damage Classification		
			Slightly Damaged (RR)	Medium Damage (RS)	Heavy Damage (RB)
1	Cipto Hanolo	Bakalan			RB
2	Sumanto	Bakalan			RB
3	Sunarto	Bakalan			RB
4	Wiryanti	Bakalan			RB
5	Agus Susilo	Bakalan			RB

Source: Public Works Department of Sleman Sub-District

Although the government has a pretty good tabulation of data, even the names of people whose building/home that affected by disaster, but the data are poorly supported by spatial data and good documentation. Data validation is still needed because it comes from a variety of sources. The Government validate the damage directly in the field at the end of 2011 to ensure the data for the person who will receive permanent housing assistance provided by the government.

Classification used by the government to assess the damage due to the Merapi eruption and lahars is a modification of the standard criteria for building damage due to earthquakes that have been used by Indonesian government. Modified criteria for building damage caused by the eruption of Merapi in 2010 by the government are shown in the table 22 below.

Table 22. Building damage asessment criteria in Merapi 2010 case by government

No	Damage category	Building damage description
1	Heavy Damage (RB)	Vanish/lost, washed away, collapsed buildings, damaged column, collapsed roof, assets can not be used anymore
2	Medium Damage (RS)	Significant damage to the structure of the roof, wall, and floor, but but no significant damage to the structure of the column
3	Slightly Damaged (RR)	Minor damage to the roof structure, walls, beams, and floor; column structure is not damaged and the asset can still be used

Source: Public Works Department of Sleman Sub-District

5.2. Damage Interpretation using High Resolution Satellite Imagery

Identification of damage from multitemporal satellite imagery can begin 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 in ArcGIS is one way that can be done to delineate land cover. Land cover before the eruption of Merapi in 2010 resulted from the on screen visual interpretation Geo Eye 2009 and Quickbird imagery 2006. Quickbird imagery recorded in 2006 is used to cover the area on the Geo Eye imagery of the 2009 covered by clouds. 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 as shown in the figure 29 and table 23 that woody broadleaves type dominate the land cover in the Cangkringan sub-district of 2983.61 Ha (65.25 %). Compacted clay surface (building) has a relatively large coverage of 256.42 Ha (5.6 %).

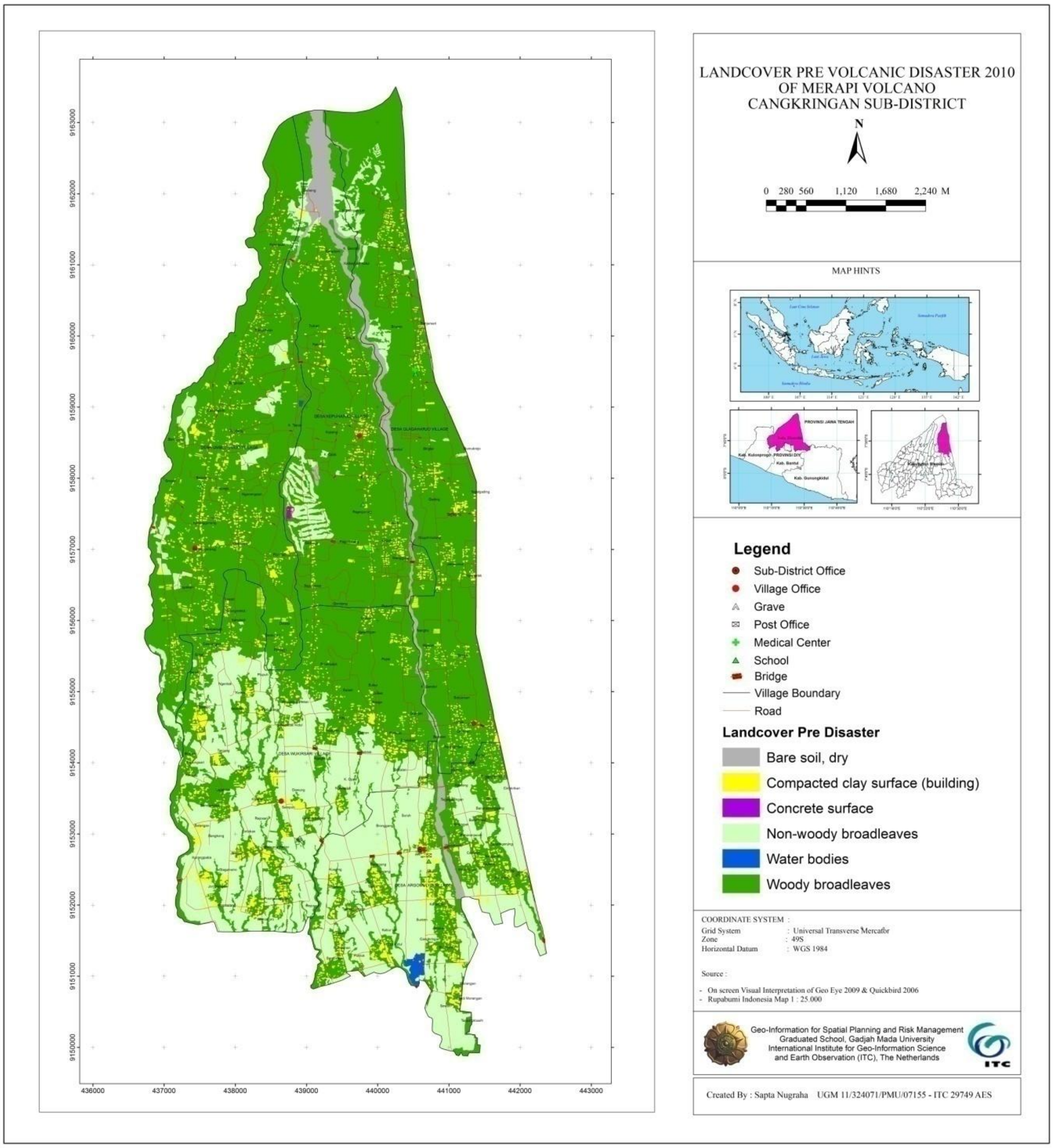


Figure 29. Landcover Map before Merapi volcanic disaster 2010

Table 23. Landcover area before Merapi volcanic disaster 2010

Nr	Landcover	Width area in Village (Ha)					
		Argomulyo	Glagaharjo	Kepuharjo	Umbulharjo	Wukirsari	Total
1	Bare soil, dry	16.63	41.91	73.27		2.51	134.32
2	Compacted clay surface (building)	60.06	30.26	28.83	56.14	81.12	256.42
3	Concrete surface	0.08	0.25	1.54		0.04	1.91
4	Non-woody broadleaves	455.74	28.38	53.09	64.40	586.21	1187.82
5	Water bodies	7.79			0.47		8.26
6	Woody broadleaves	238.30	708.64	632.06	829.79	574.82	2983.61
	Total	778.60	809.44	788.79	950.80	1244.70	4572.34

Source: Data analysis (2013)

From the landcover map prior to the eruption of Merapi and analysis with other data and field checks can be generated to landuse map prior to the disaster. There are 16 types of landuse in Cangkringan sub-district, ie dam, dryfield with cashcrops, education/school, forest, freshwater fishpond, golf course, golf facility, golf parking area, government office, inundated rice field (sawah), lahar field, military facilities, mixgarden, police office, reservoir, rural settlement. Spatial distribution of landuse in Cangkringan sub-district before Merapi disaster 2010 is shown in the figure 30.

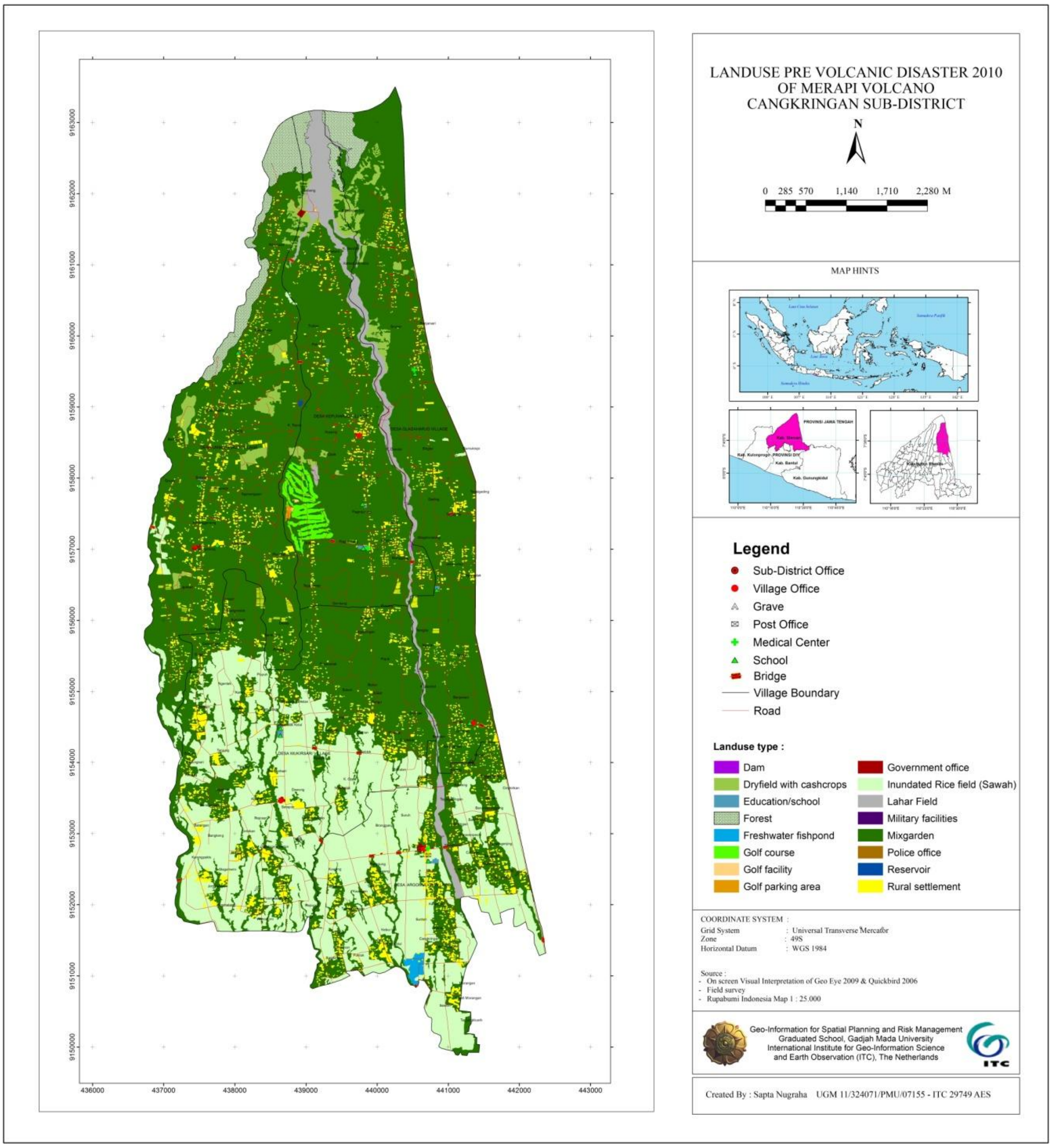


Figure 30. Landuse Map before Merapi volcanic disaster 2010

Mixed garden, Inundated rice fields (sawah) and rural settlement are the landuse type that dominates in Cangkringan sub-district. Rural settlement has the smaller total area in the villages closest to the peak of Merapi, except Umbulharjo village. The table 24 shows the area of each land use type in the Cangkringan sub-district prior to the eruption of Merapi Cangkringan 2010.

Table 24. Landuse area before Merapi volcanic disaster 2010

Nr	Landuse	Width area in Village (Ha)					
		Argomulyo	Glagaharjo	Kepuharjo	Umbulharjo	Wukirsari	Total
1	Dam	0.08	0.25	0.27		0.04	0.64
2	Dryfield with cashcrops		27.31	19.50	41.16		87.98
3	Education/school	0.91	0.48	1.20	0.35	0.97	3.91
4	Forest		25.29	21.45	69.86		116.60
5	Freshwater fishpond	7.79					7.79
6	Golf course			33.42			33.42
7	Golf facility			0.43			0.43
8	Golf parking area			1.27			1.27
9	Government office	0.96	0.10	0.60	0.56	0.50	2.72
10	Inundated Rice field (Sawah)	455.74	1.07	0.17	23.24	586.21	1066.43
11	Lahar Field	16.63	41.91	73.27		2.51	134.32
12	Military facilities	0.09					0.09
13	Mixgarden	238.30	683.34	610.61	759.93	574.82	2867.01
14	Police office	0.03					0.03
15	Reservoir				0.47		0.47
16	Rural settlement	58.07	29.69	26.60	55.23	79.65	249.23
	Total	**778.60**	**809.44**	**788.79**	**950.80**	**1244.70**	**4572.34**

Source: Data analysis (2013)

To determine the condition of land cover after the eruptions in 2010, Worldview image recorded in November 2010 is used for the interpretation of land cover. Interpretation of land cover from that imagery produces land cover types such as bar soil dry (interleaved by building), burned vegetation, compacted clay surface (building), concrete surface, non-woody broadleaves, water bodies and woody broadleaves. Landcover of bar soil dry (interleaved by building) is the area that very wide of 1564.72 Ha (34.22 %), almost the same as woody broadleaves area. Bare soil dry (interleaved by building) is the most extensive in the three villages closest to the peak of Merapi, that villages are Glagaharjo, Kepuharjo and Umbulharjo as shown in the table 25 below.

Table 25. Landcover area after Merapi volcanic disaster 2010

Nr	Landcover	Width area in Village (Ha)					
		Argomulyo	Glagaharjo	Kepuharjo	Umbulharjo	Wukirsari	Total
1	Bare soil, dry (interleaved by building)	87.36	526.88	523.37	340.13	86.98	1564.72
2	Burned vegetation	19.08	67.24	32.61	9.28	24.35	152.56
3	Compacted clay surface (building)	56.44	13.65	8.32	46.27	76.59	201.27
4	Concrete surface			1.27			1.27
5	Non-woody broadleaves	411.64	1.07	26.76	34.93	567.81	1042.20
6	Water bodies	7.79			0.47		8.26
7	Woody broadleaves	196.30	200.60	196.47	519.72	488.97	1602.06
	Total	778.60	809.44	788.79	950.80	1244.70	4572.34

Source: Data analysis (2013)

The figure 31 shows landcover after the 2010 eruption of Merapi that is the result of World View 2010 and Geo Eye 2011 imagery by on sreen visual interpretation. Upper Cangkringan sub-district after Merapi Eruption in 2010 entirely of bar soil dry (interleaved by building) shown in the map with a gray color. Patterns of land cover in the form of burned vegetation seemed to be on the outer circumference of the bar soil dry (interleaved by building).

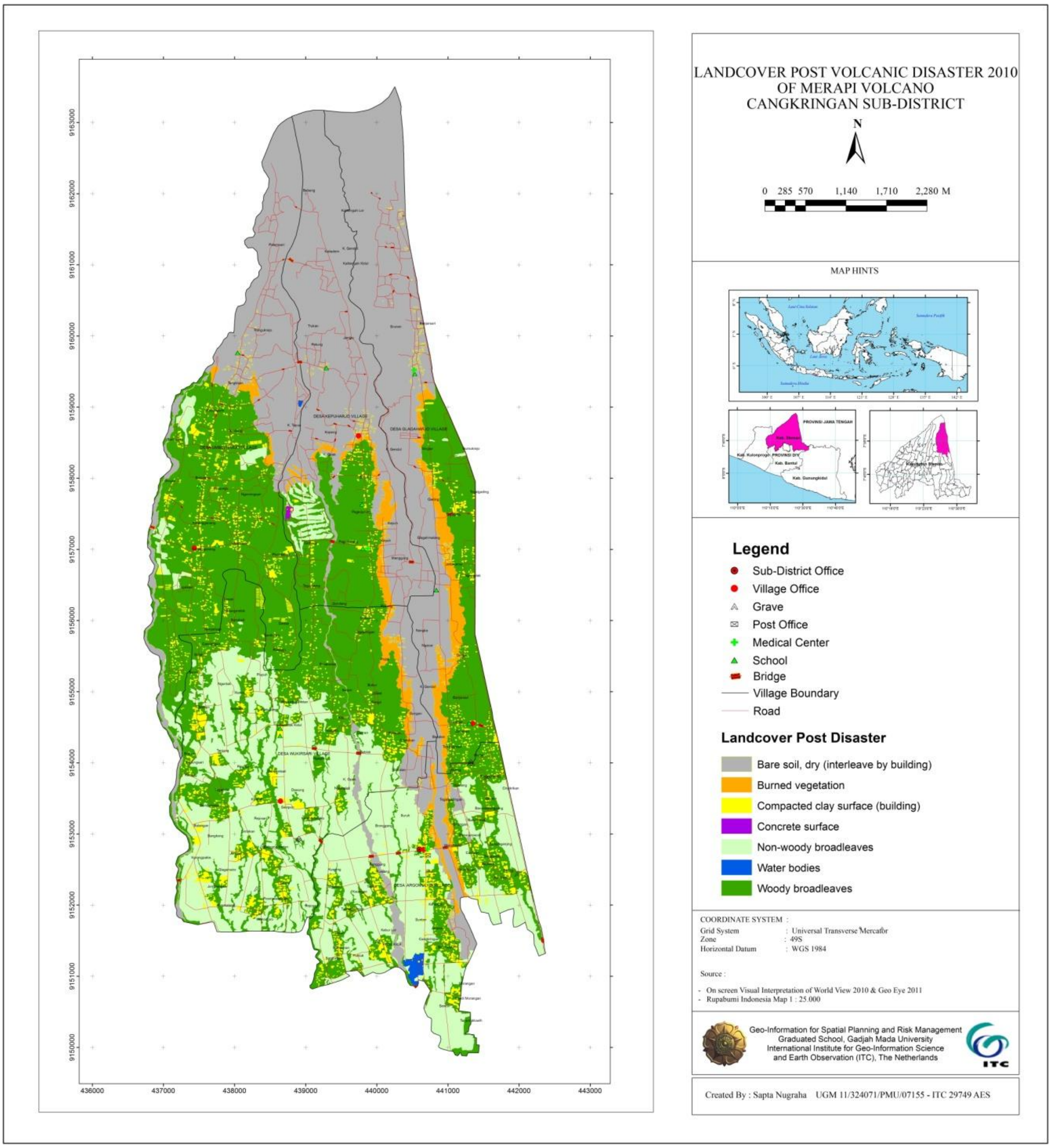


Figure 31. Landcover Map after Merapi volcanic disaster 2010

To determine the area affected by the disaster then is overlaid maps and analysis of the land cover maps before and after the Merapi volcanic eruption by using GIS. The figure 32 shows landcover changes after Merapi volcanic eruption in 2010 that can be used as disaster impact area indication. 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.

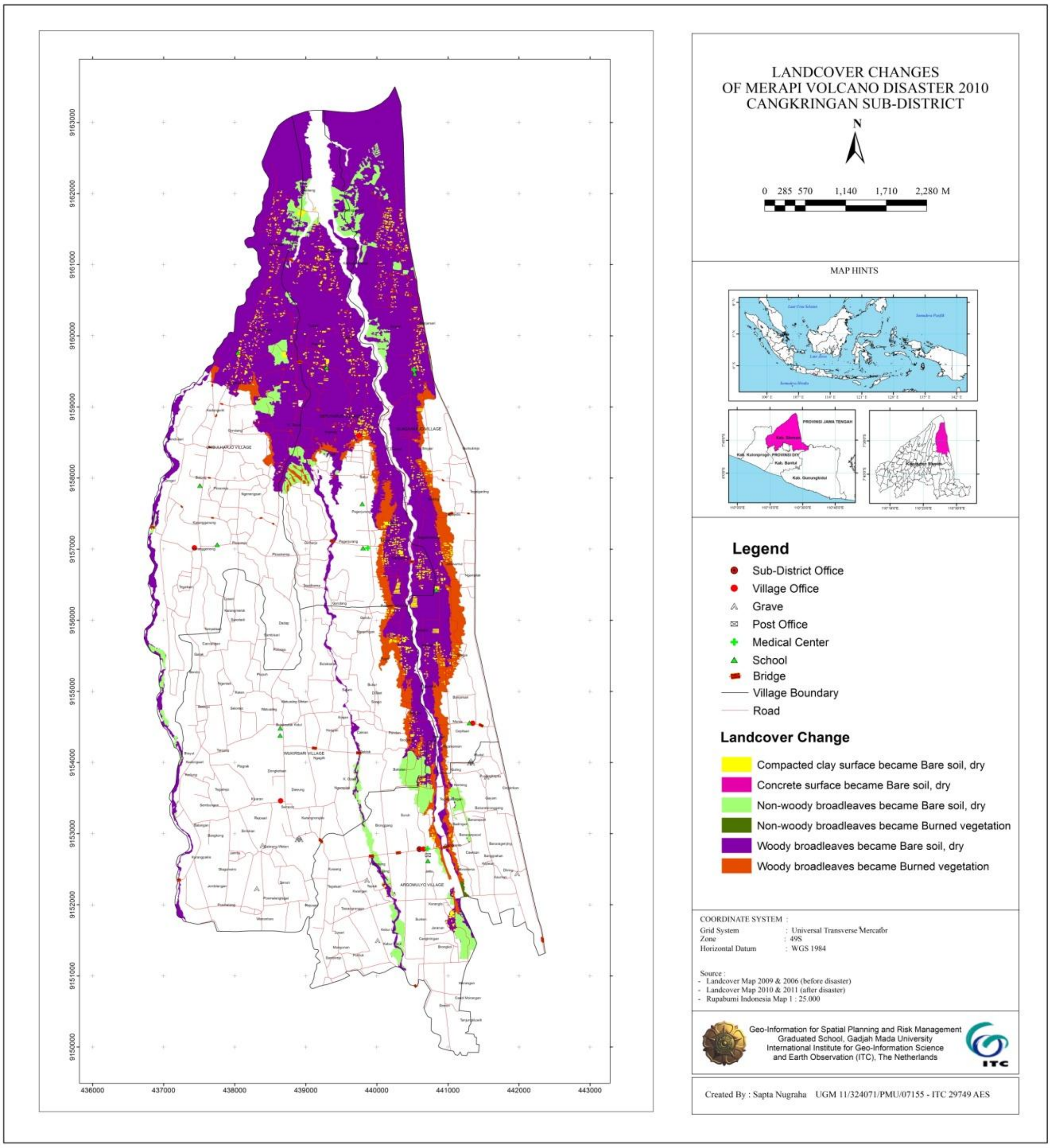


Figure 32. Landcover Changes Map after Merapi volcanic disaster 2010

The table 26 below shows the area of each land cover changes after Merapi volcanic eruption.

Table 26. Landcover changes area after Merapi volcanic disaster 2010

Nr	Landcover	Width area in Village (Ha)					
		Argomulyo	Glagaharjo	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		0.04	0.64
3	Non-woody broadleaves turned into Bare soil, dry	43.03	27.31	26.33	29.47	18.40	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	61.50	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 analysis (2013)

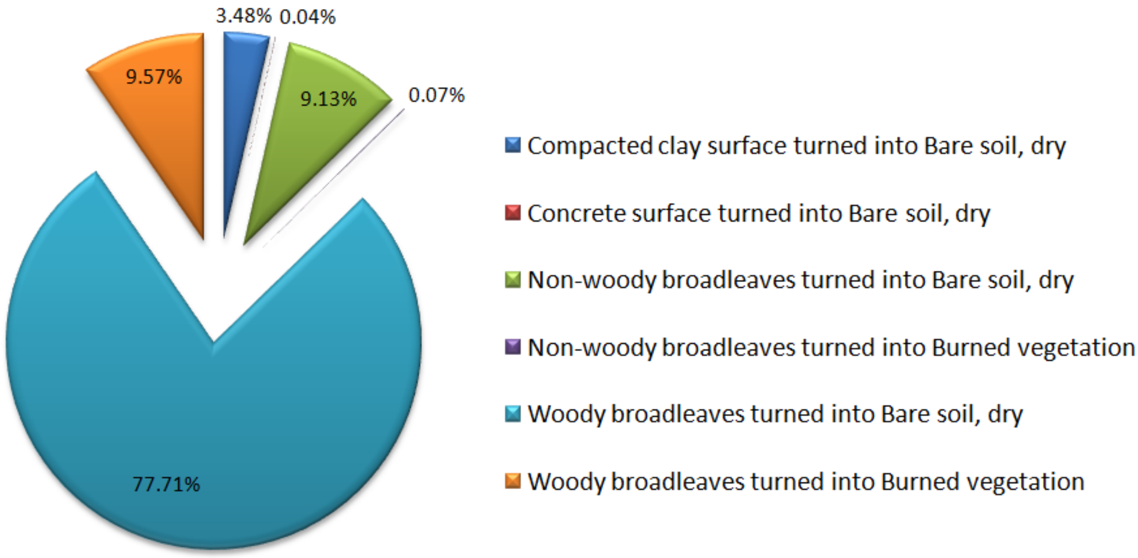


Figure 33. Pie chart of landcover changes after Merapi volcanic disaster 2010

According to the figure 33 and table 26 above, 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 %).

Based on the land cover change maps, hazard map and imagery interpretation, it can be further analyzed the type of hazard that hit the region. 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. The table 27 below shows the total area of each type of hazard for each village in the Cangkringan sub-district. Areas affected by pyroclastic surge was the most extensive that is 59.98% of the entire area affected by the volcanic disaster in the Cangkringan sub-district, while the area affected by pyroclastic flows and lahars are respectively 34.42 % and 5.60 %. Disaster affected area (1717.75 Ha) is greater than the broad changes in land cover (1582.96 Ha). It is because the area of bare soil along the river Gendol before and after the eruption of Merapi remained as bare soil, but that area actually affected by pyroclastic flows, pyroclastic surges or lahars.

Table 27. Total area affected by hazard types of Merapi volcanic disaster 2010

Nr	Hazard types	Width area in Village (Ha)					
		Argomulyo	Glagaharjo	Kepuharjo	Umbulharjo	Wukirsari	Total
1	Lahars	39.59		6.11	30.65	19.83	96.19
2	Pyroclastic Flows	38.51	189.15	297.42	9.84	56.41	591.33
3	Pyroclastic Surges	28.34	404.97	252.46	309.38	35.09	1030.23
	Total	106.44	594.12	555.98	349.88	111.33	1717.75

Source: Data analysis (2013)

The figure 34 below shows the type of hazard in the affected area of Cangkringan sub-district.

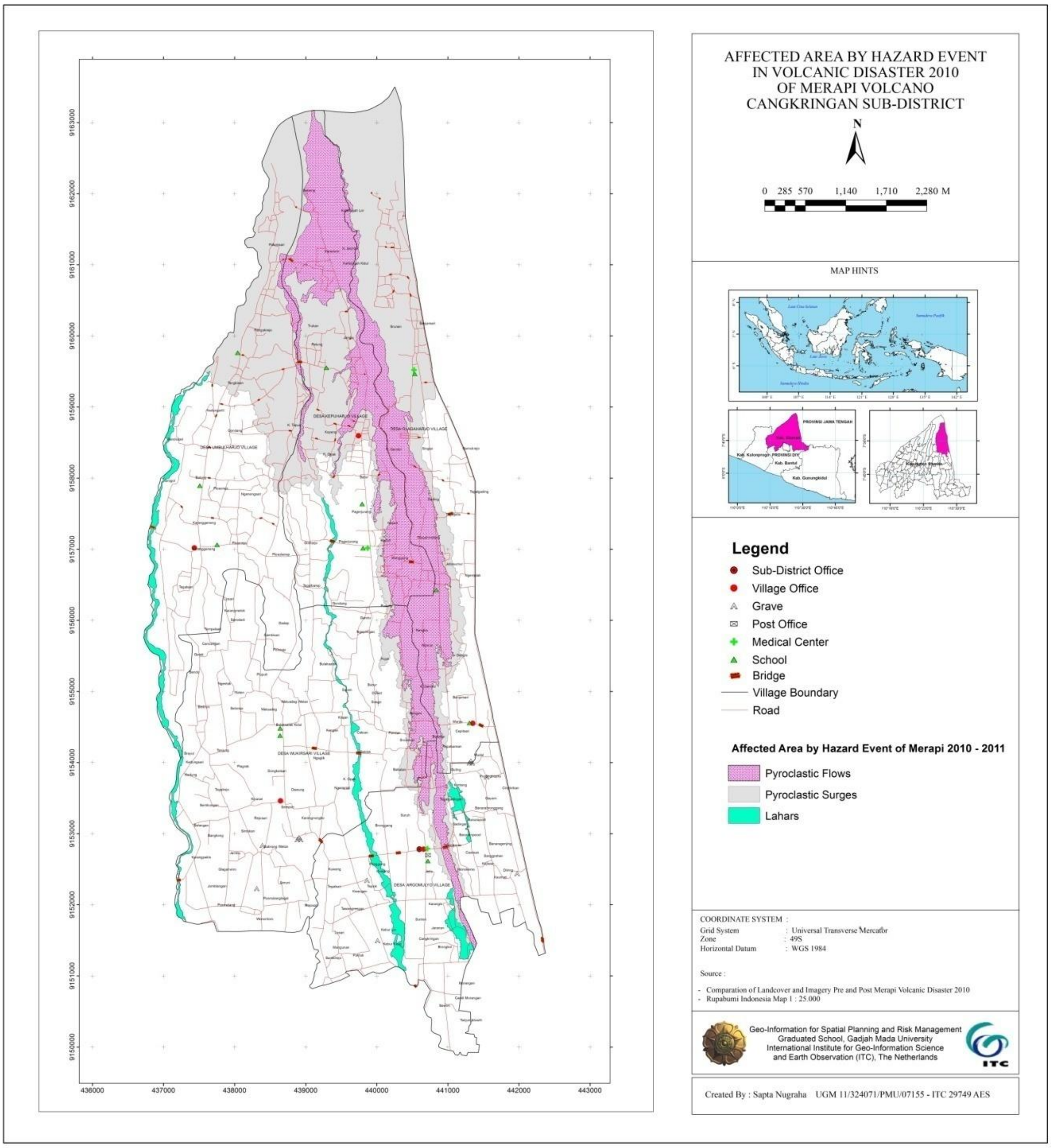


Figure 34. Hazard event on affected area of Merapi volcanic eruption 2010

To determine the use of land affected by the type of hazards that occur in the eruption of Merapi is done by overlaying maps of land use prior to the eruption of Merapi and the type of hazard. The table 28 shows the landuse types affected by the different types of hazard after Merapi Eruption 2010. According to table 28, most of landuse types are affected by three types of hazard. Mixed garden is very spacious affected by pyroclastic flow, which is an area of 809.06 Ha (47.1%) and affected by pyroclastic surges with an area of 402.23 Ha (23.42%). Rural settlement also affected by pyroclastic flow to an area of 21.64 Ha (1.26%), affected by pyroclastic surges with an area of 30.21 Ha (1.76%) and affected by lahars with an area of 1.47 Ha (0.08%).

Table 28. Landuse types affected by the different types of hazard

Nr	Landuse affected by hazard type	Width area in Village (Ha)					
		Argomulyo	Glagaharjo	Kepuharjo	Umbulharjo	Wukirsari	Total
1	Dam affected by Pyroclastic Flows	0.08	0.25	0.27		0.04	0.64
2	Dryfield with cashcrops affected by Pyroclastic Flows		8.49	11.60			20.09
3	Dryfield with cashcrops affected by Pyroclastic Surges		18.82	7.42	22.61		48.84
4	Education/school affected by Pyroclastic Flows		0.33				0.33
5	Education/school affected by Pyroclastic Surges		0.07	0.24	0.23		0.55
6	Forest affected by Lahars				0.41		0.41
7	Forest affected by Pyroclastic Flows		0.18	9.42			9.60
8	Forest affected by Pyroclastic Surges		25.12	12.02	68.47		105.61
9	Golf course affected by Pyroclastic Surges			7.15			7.15
10	Government office affected by Pyroclastic Flows			0.00			0.00
11	Government office affected by Pyroclastic Surges			0.60	0.33		0.93
12	Inundated Rice field (Sawah) affected by Lahars	28.55			6.10	4.99	39.64
13	Inundated Rice field (Sawah) affected by Pyroclastic Flows	6.94		0.17	0.76	4.54	12.42
14	Inundated Rice field (Sawah) affected by Pyroclastic Surges	8.61				8.86	17.48
15	Lahar Field affected by Pyroclastic Flows	16.63	38.24	67.02		2.51	124.39
16	Lahar Field affected by Pyroclastic Surges		3.67	6.25			9.93
17	Mixgarden affected by Lahars	9.58		6.11	24.14	14.81	54.64
18	Mixgarden affected by Pyroclastic Flows	14.02	136.45	196.93	8.99	45.83	402.23
19	Mixgarden affected by Pyroclastic Surges	18.41	346.29	211.10	208.05	25.21	809.06
20	Police office affected by Lahars	0.03					0.03
21	Reservoir affected by Pyroclastic Surges				0.47		0.47
22	Rural settlement affected by Lahars	1.44				0.03	1.47
23	Rural settlement affected by Pyroclastic Flows	0.84	5.22	12.00	0.09	3.49	21.64
24	Rural settlement affected by Pyroclastic Surges	1.32	11.00	7.67	9.21	1.02	30.21
	Total	106.44	594.12	555.98	349.88	111.33	1717.75

Source: Data analysis (2013)

The figure 35 below presents a comparison of specific land use for building objects in each of the villages in Cangkringan sub-district affected by 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.

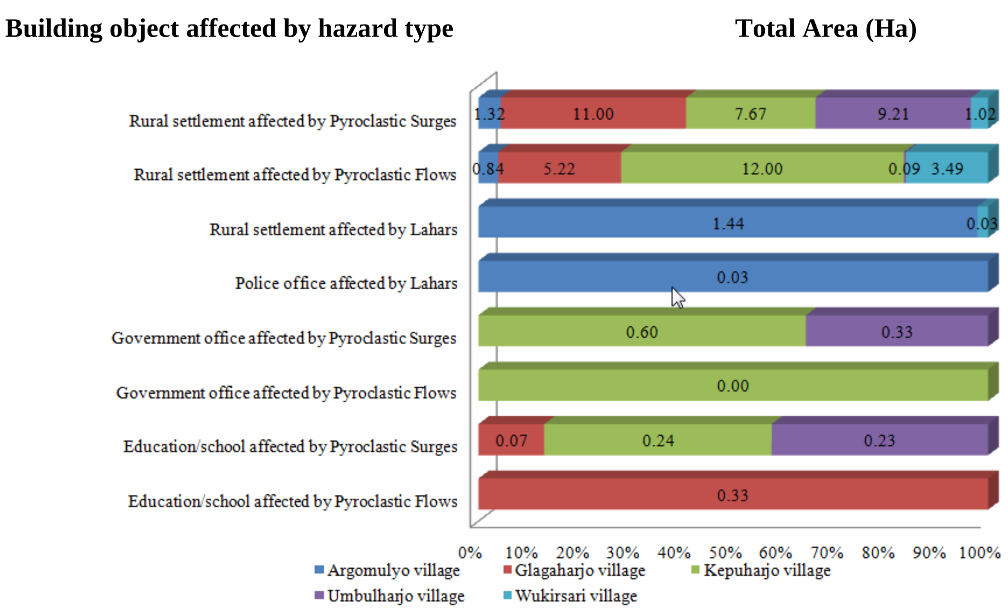


Figure 35. Building object affected by hazard type of Merapi volcanic eruption 2010

The map of landuse affected by those hazards is shown in the figure 36 below:

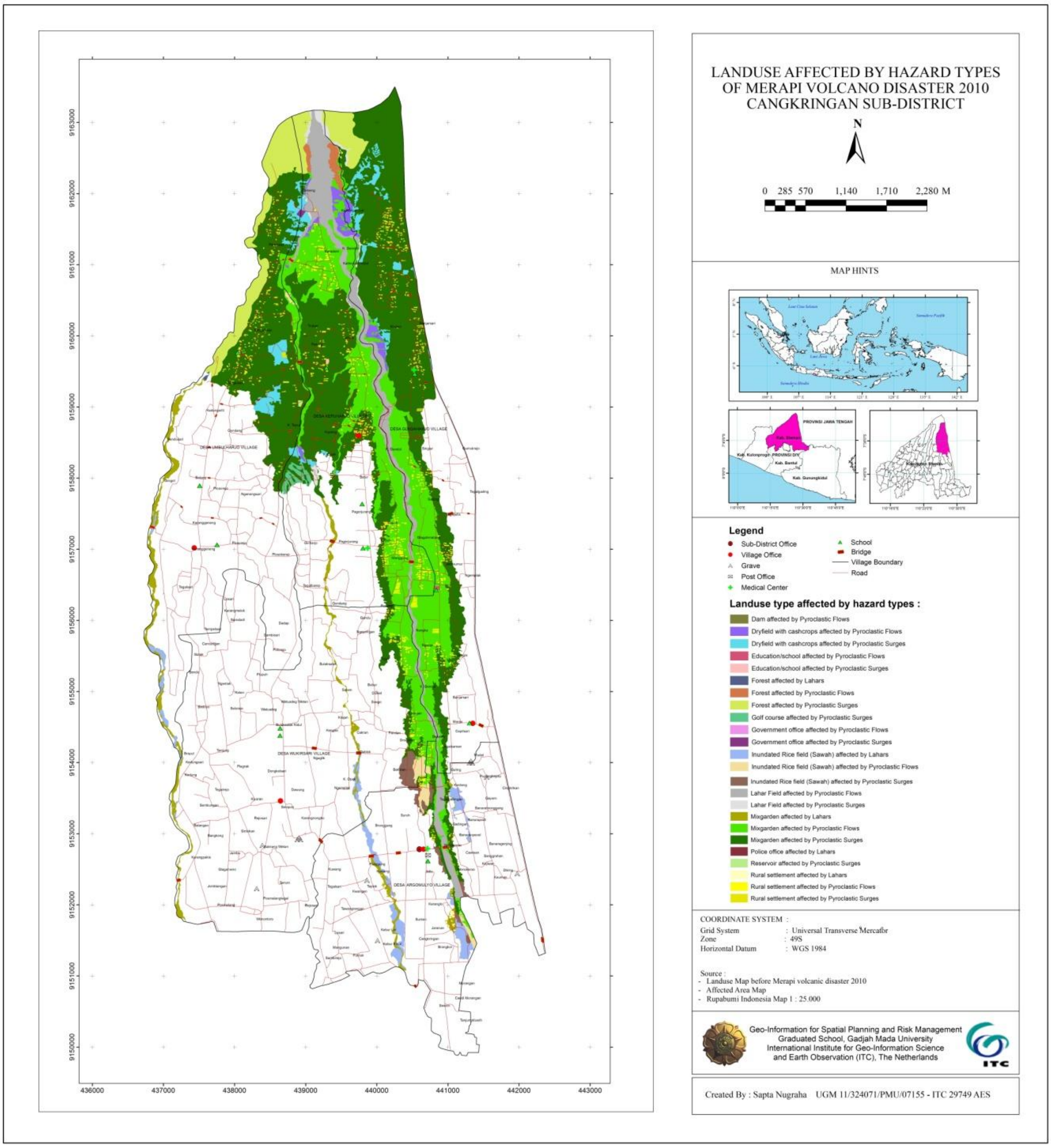


Figure 36. Map of landuse types affected by the different types of hazard

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. Building damage interpretation is based on criteria and visual appearance as below:

a. Building vanish/not visible, totally colappse, and lifted off/missing roof

Figure 37 shows that building by criteria vanish/not visible, totally collapse and missing/lifted off roof condition is very clear to be interpreted. Building shape can not be observed anymore due entirely buried by volcanic material. Based on true color composite of satellite imagery, it will be seen with the gray color to light gray which is the color of pyroclastic material.

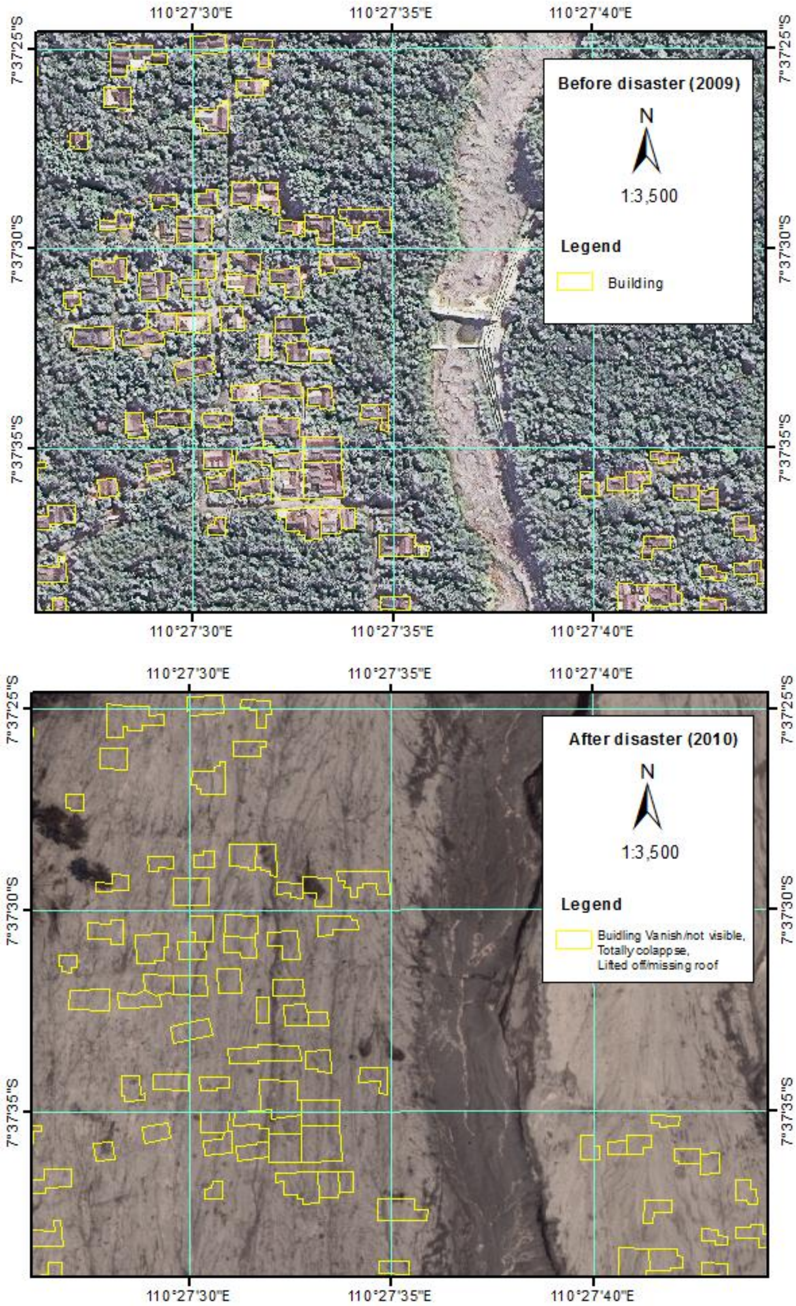


Figure 37. Building with criteria vanish/not visible, totally colappse, and lifted off/missing roof

b. Building unclearly visible/building can still be identified, totally colappse, and lifted off/missing roof

Building in condition after disaster as shown in the figure 38 is relatively difficult to be identified, but the ruins of buildings can still be identified from high-resolution satellite imagery with rough texture and dark gray color interspersed with bright gray.

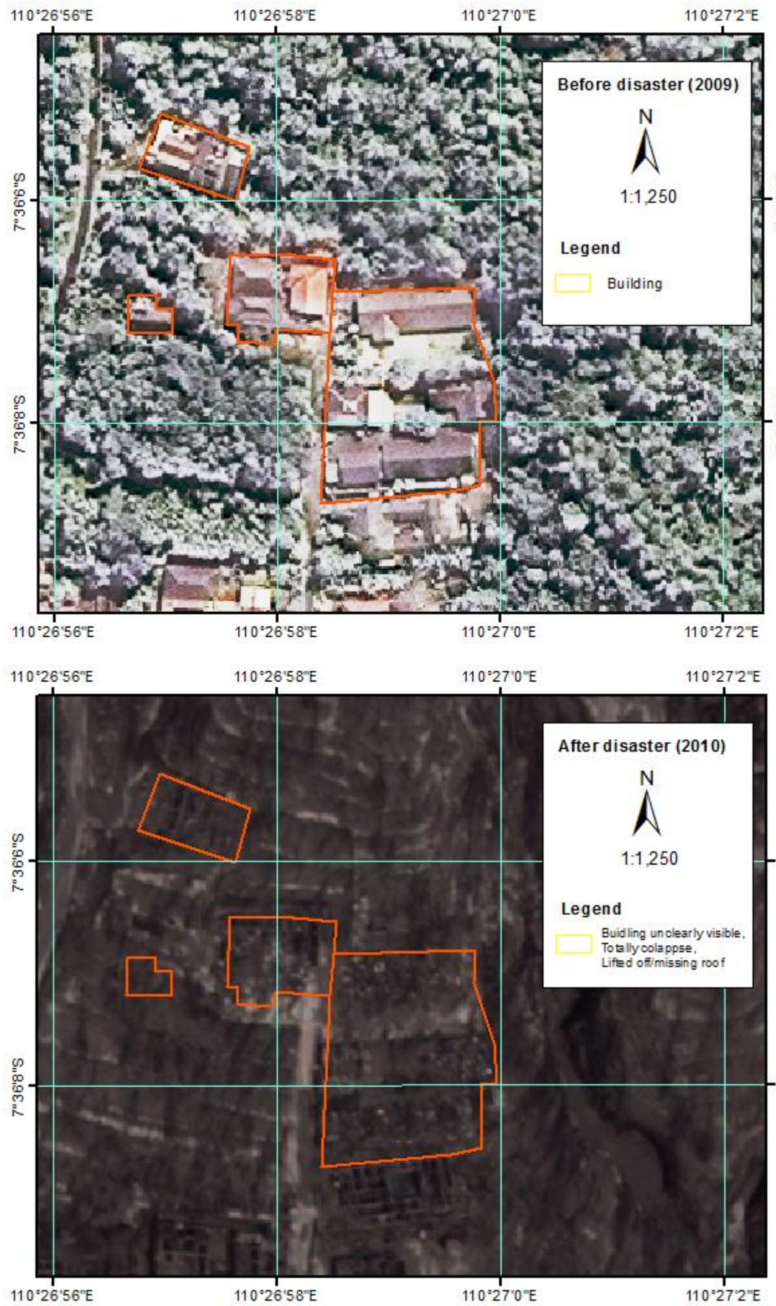


Figure 38. Building with criteria unclearly visible/building can still be identified, totally colappse, and lifted off/missing roof

c. Building clearly visible/building still stands, partially collapse, and partialy lifted off or major damage on roof tile

Figure 39 below shows that building is can be identified because still stand, change in shape in some part and major damage on roof or lifted off in some part. This can be observed in high-resolution satellite imagery with a dark gray color interspersed with black color. The black color indicates roofs damaged/lost.

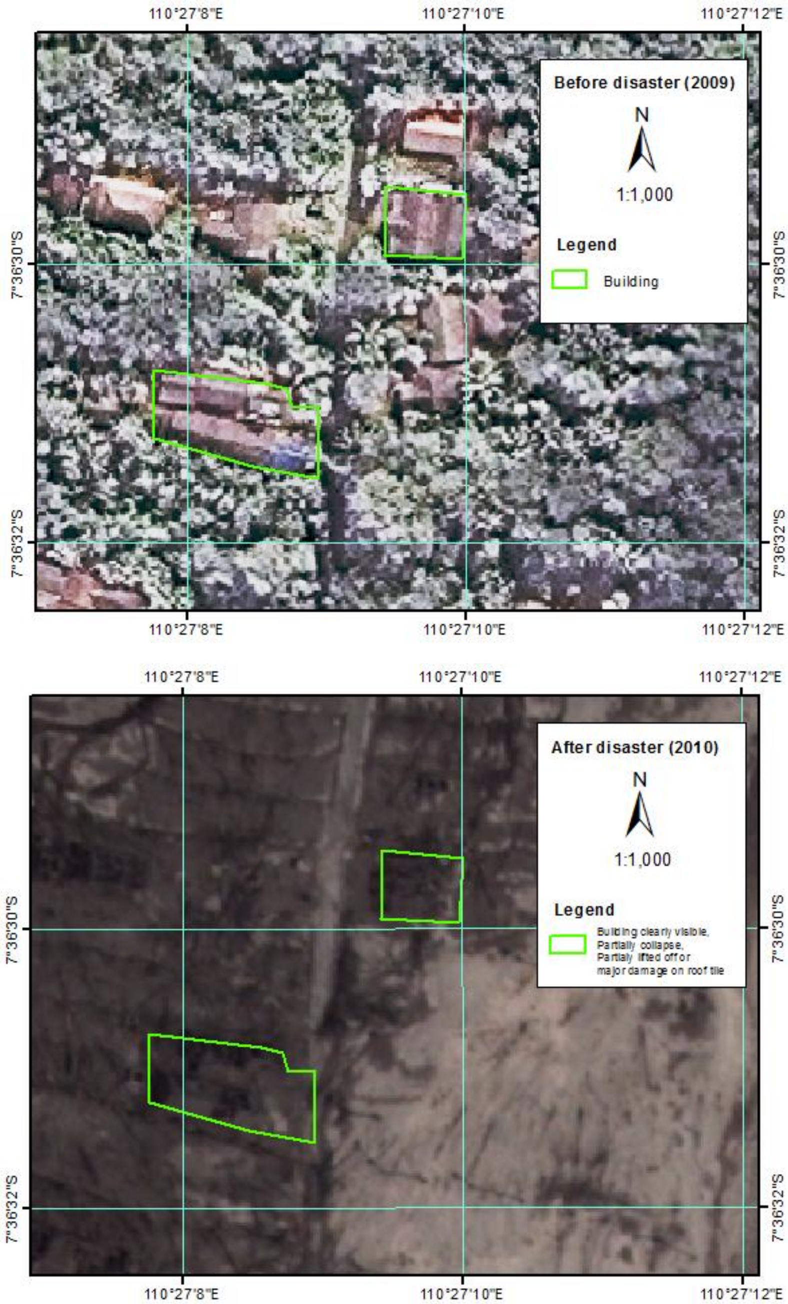


Figure 39. Building with criteria clearly visible/building still stands, partially collapse, and partialy lifted off or major damage on roof tile

d. Building clearly visible/building still stands, partially collapse, and lifted off/missing roof

In figure 40, building is still stand but partially collapse. Roof of building is totally missing or totally lifted off. Shape of the building can still be observed from high-resolution satellite imagery, but in some parts of the shape is different because of the collapsed buildings. The roof is not observable, black color in the building shape shows the pattern of the remaining space in the building.

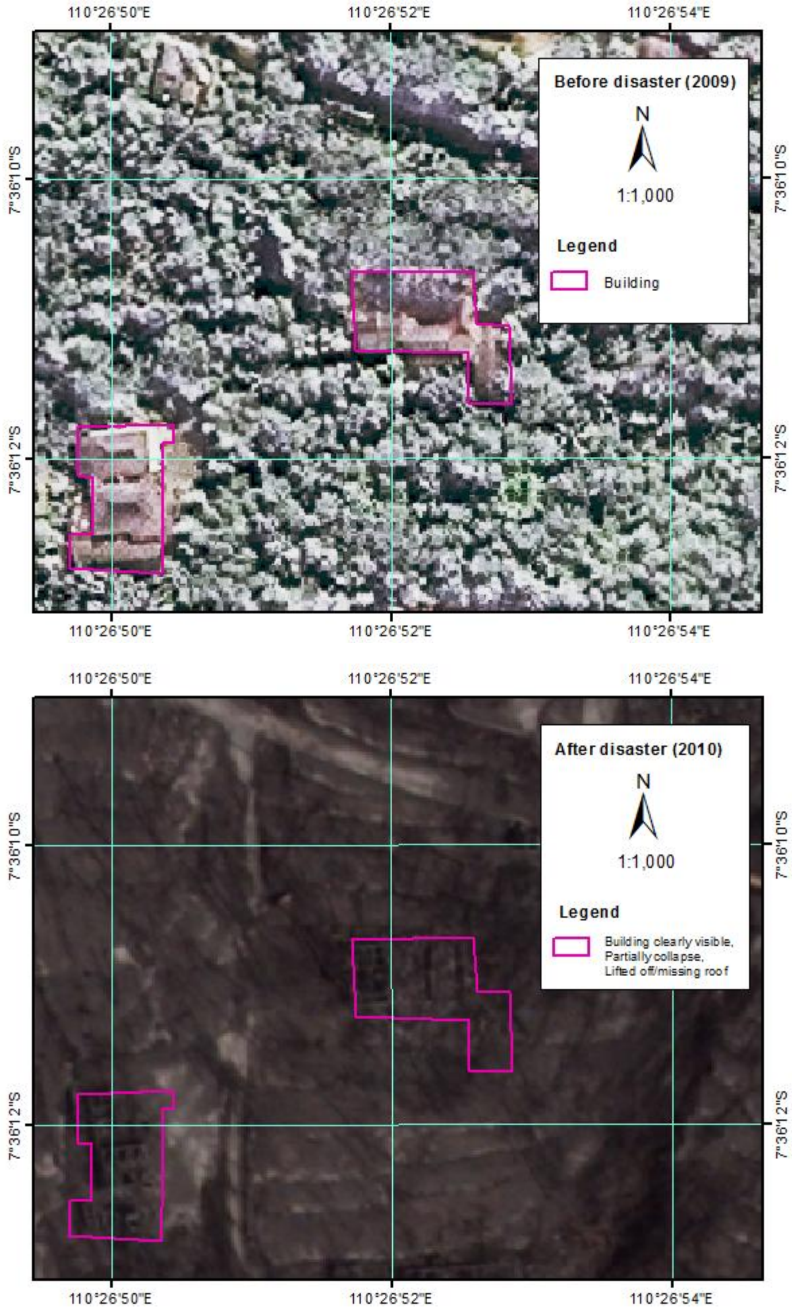


Figure 40. Building with criteria clearly visible/building still stands, partially collapse, and lifted off /missing roof

e. Building clearly visible/building still stands, no collapse, and partialy lifted off or major damage on roof tile

Based on the observation of high-resolution satellite imagery as shown in figure 41, the visibility of building is very clear and no collapse that can be identified by no change in building shape (the shape of the building remains the same), but the roof of building has major damage/partially lifted off in a fairly large area which is characterized by a broad blackish gray color.

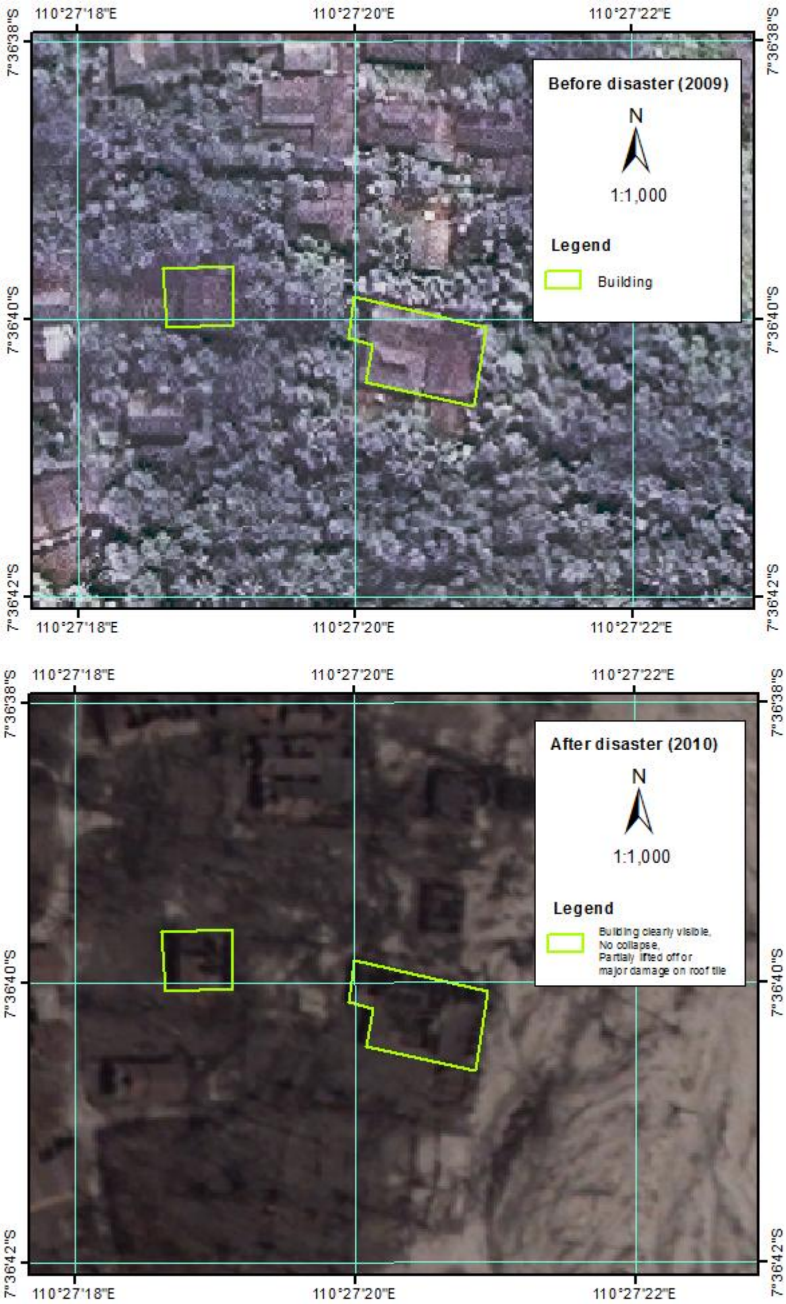


Figure 41. Building with criteria clearly visible/building still stands, no collapse, and partialy lifted off or major damage on roof tile

f. Building clearly visible/building still stands, no collapse, and lifted off/missing roof

Building as in figure 42 is still stand and no collapse happen, but the entire building roof is missing/lifted off. In the building shape, black color shows the pattern of the remaining space in the building that clearly observed due entirely missing roof.

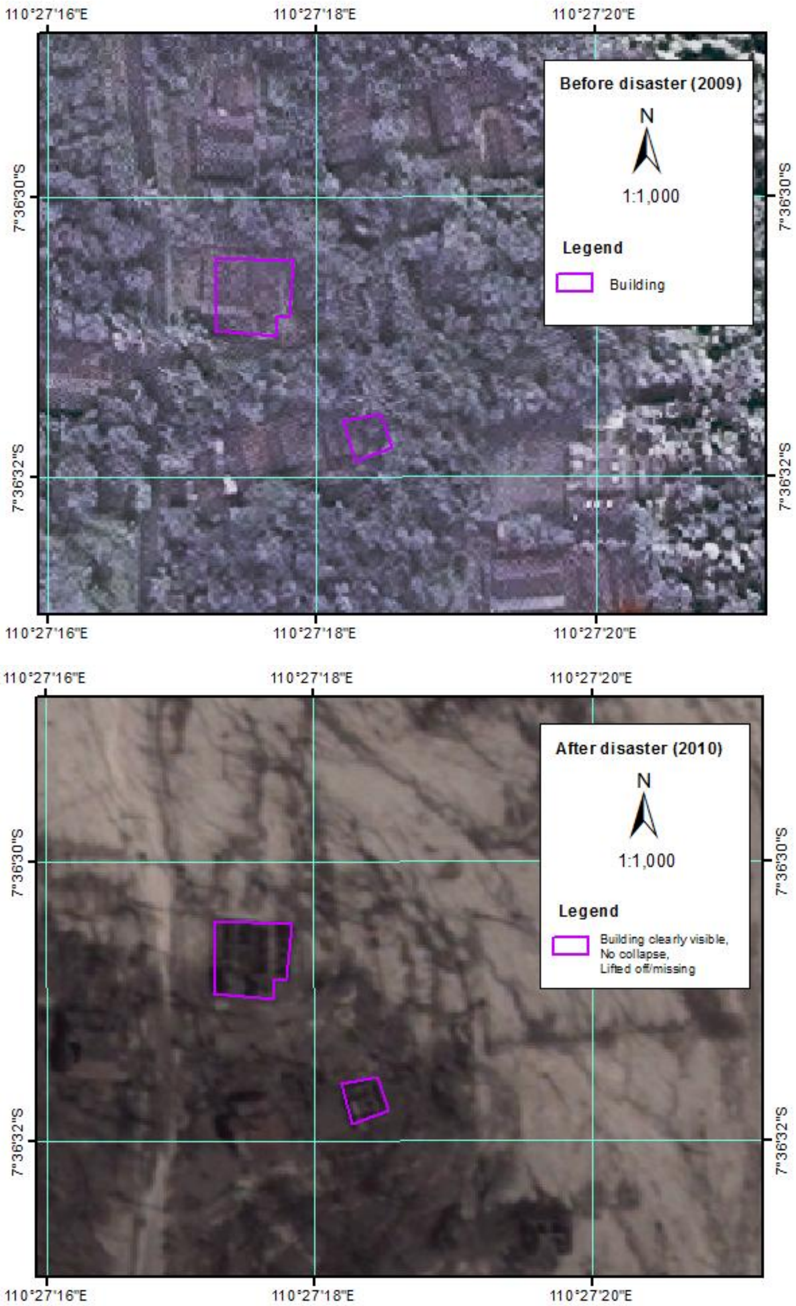


Figure 42. Building with criteria clearly visible/building still stands, no collapse, and lifted off/missing roof

g. Building clearly visible/building still stands, no collapse, and minor damage on roof tile

In figure 43 below that compare imagery before and after disaster, visibility of building is very good, no collapse (no shape change) and only minor damage happen in roof tile that can be identified by different color pattern (brownish gray color interspersed with black) in roof tile in a small area. The actual color of the tiles on the roof was brown. Gray color on the roof is the color of volcanic ash material that covered the roof. The black color is caused by the small portion of tiles that has been damaged.

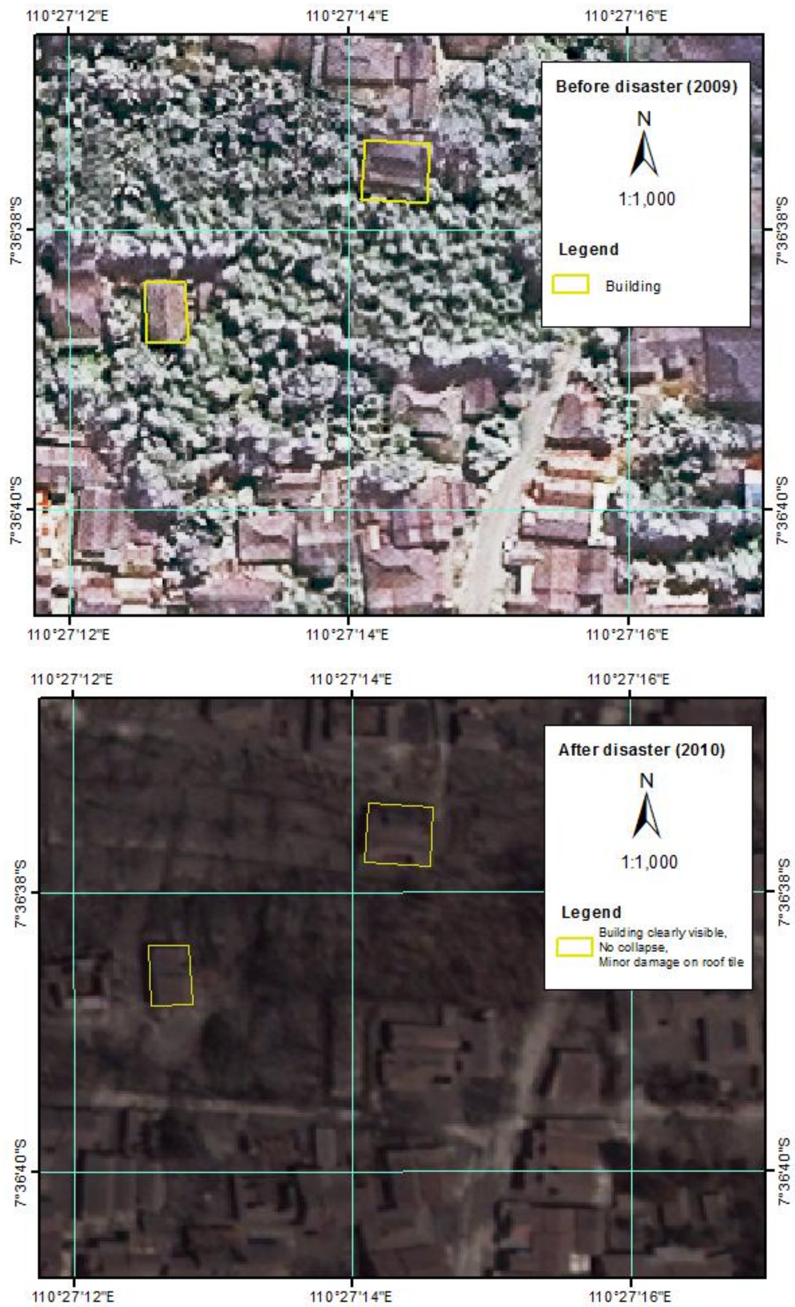


Figure 43. Building with criteria clearly visible/building still stands, no collapse, and minor damage on roof tile

h. Building clearly visible/Building still stands, No collapse, No damage on roof

Building that shows in figure 44 indicated that no damage can be seen from imagery. There is no damage on roof and no building shape change that can be identified. Brown slightly gray colored roof because the roof was covered by volcanic ash material which is relatively thin. There is no black color or black pattern on the roof which is an indication that the roof of the building is not damaged.

Figure 44. Building with criteria clearly visible/building still stands, no collapse, and no damage on roof tile

The table 29 and the figure 45 below shows the results of the building damage interpretation from high-resolution satellite imagery:

Table 29. Building damage interpretation from satellite imagery

Nr	Building damage from high resolution satellite imagery interpretation (Building Visibility, Building 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, Partially collapse, Lifted off/missing	84
6	Building clearly visible/Building still stands, Partially 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**

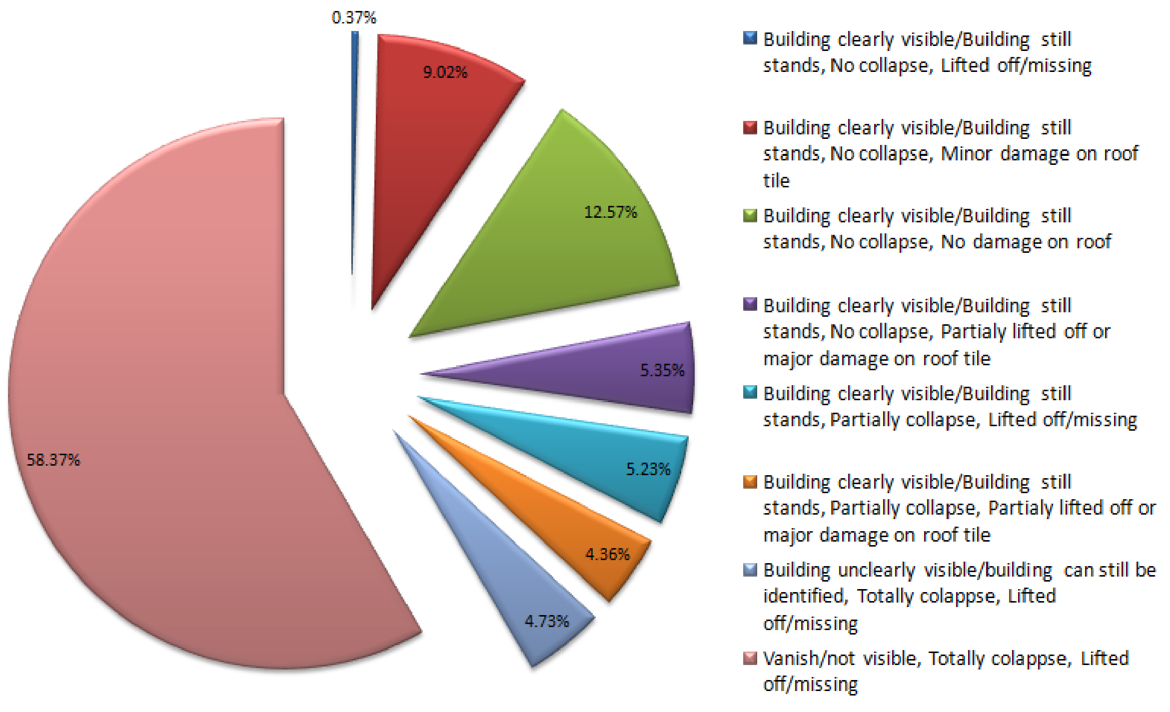


Figure 45. Pie chart of building damage interpretation from satellite imagery

According to the table 29 and the figure 45 above, 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. The total number of buildings that can be interpreted as the individual buildings from high-resolution satellite imagery is 1607 units. Of these, 202 building unit is interpreted as building suffered no damage or damage can not be observed from satellite image interpretation because the building clearly visible/building still stands, no collapse and no damage on roof. Damage to the building is not entirely observable from above using satellite imagery such as broken windows and window / doors that have been charred. Building which has been interpreted that the building was not damaged, may be damaged on building components that are not visible from satellite imagery. Spatial distribution of building damage based on the interpretation shown in the figure 46 below.

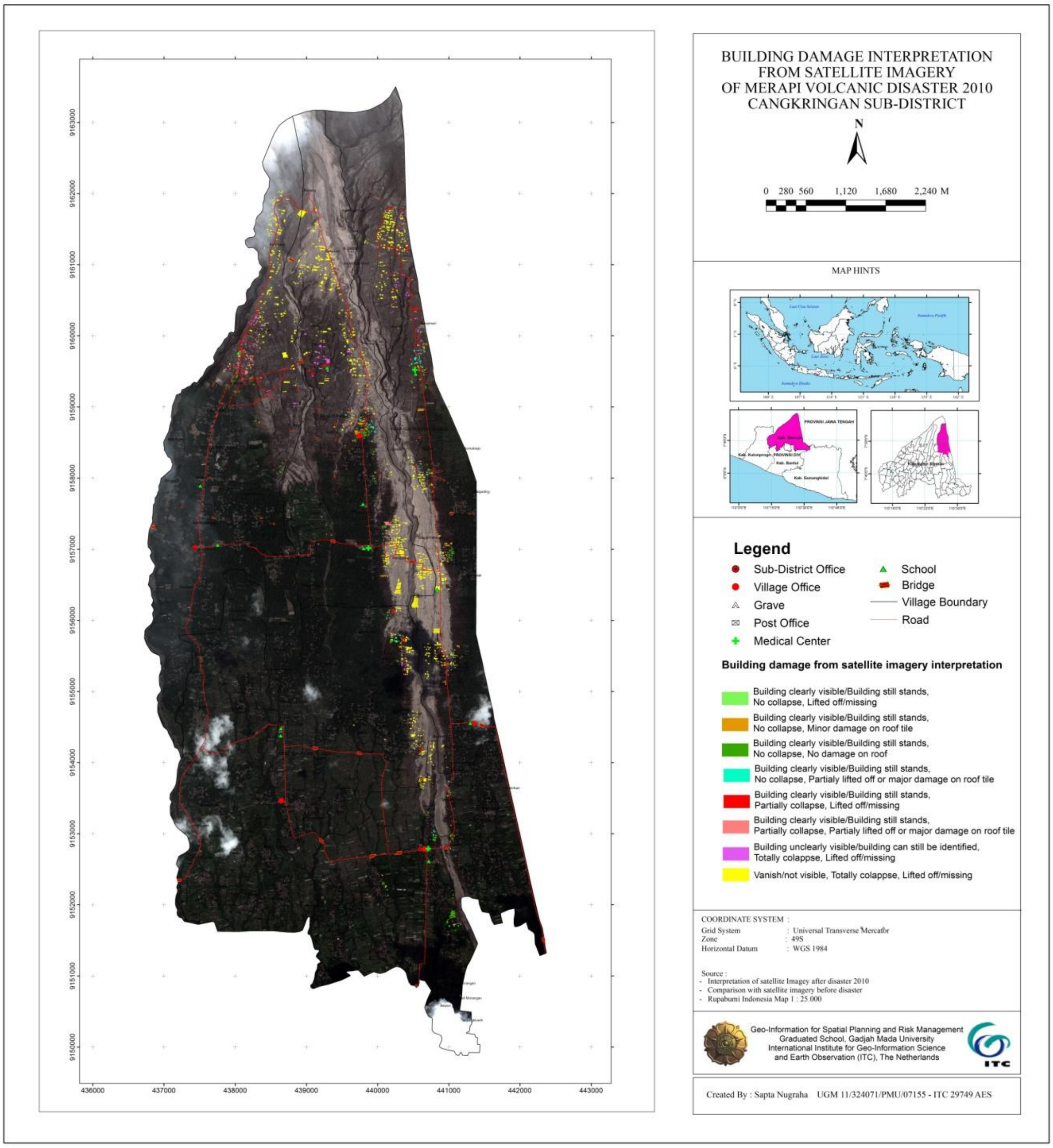


Figure 46. Building damage map from satellite imagery interpretation

Different types of volcanic hazard might cause different effects/damage to buildings. If the building damage map resulted from satellite imagery interpretation is overlaid with volcanic hazard event map of Merapi eruption 2010, it generated the map as shown in figure 47 and the table 30. From the table 30, building that affected by pyroclastic flow with damage criteria of vanish, totally collapse and lifted off/missing roof has the highest amount of 566 unit, while by the same criteria but affected by pyroclastic surges has total of 368 unit. Based on the maps that have been generated above, further field work carried out for data retrieval using geotagged photos by Geojot.

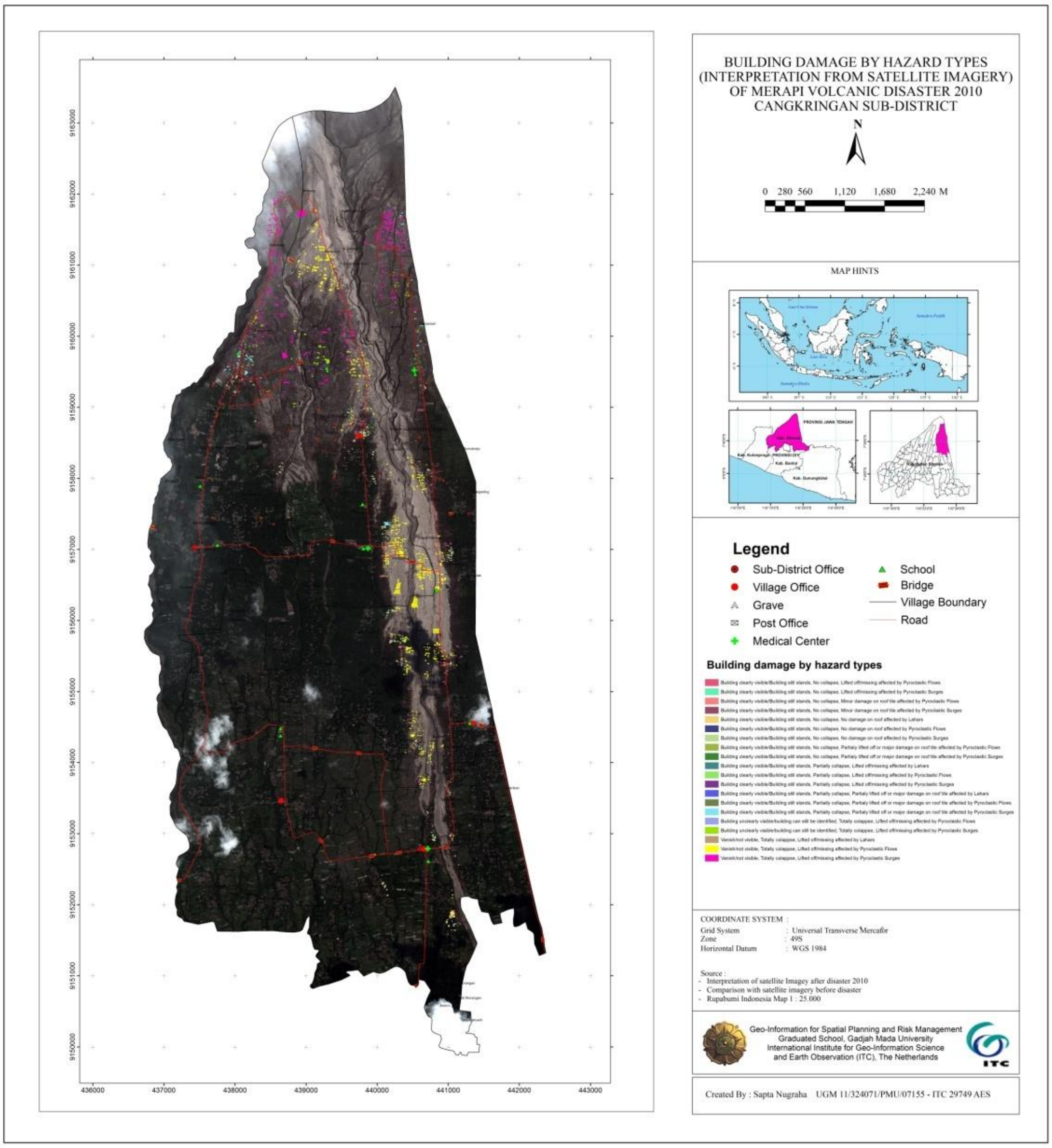


Figure 47. Building damage map by hazard type (from satellite imagery interpretation)

Table 30. Total unit of building damage (from satellite imagery interpretation) by hazard types

Nr	Building damage (from satellite imagery interpretation) by hazard types (Building Visibility, Building collapse, Building Roof)	Total (unit)
1	Building clearly visible/Building still stands, No collapse, Lifted off/missing affected by Pyroclastic Flows	1
2	Building clearly visible/Building still stands, No collapse, Lifted off/missing affected by Pyroclastic Surges	5
3	Building clearly visible/Building still stands, No collapse, Minor damage on roof tile affected by Pyroclastic Flows	15
4	Building clearly visible/Building still stands, No collapse, Minor damage on roof tile affected by Pyroclastic Surges	130
5	Building clearly visible/Building still stands, No collapse, No damage on roof affected by Lahars	45
6	Building clearly visible/Building still stands, No collapse, No damage on roof affected by Pyroclastic Flows	3
7	Building clearly visible/Building still stands, No collapse, No damage on roof affected by Pyroclastic Surges	154
8	Building clearly visible/Building still stands, No collapse, Partialy lifted off or major damage on roof tile affected by Pyroclastic Flows	8
9	Building clearly visible/Building still stands, No collapse, Partialy lifted off or major damage on roof tile affected by Pyroclastic Surges	78
10	Building clearly visible/Building still stands, Partially collapse, Lifted off/missing affected by Lahars	1
11	Building clearly visible/Building still stands, Partially collapse, Lifted off/missing affected by Pyroclastic Flows	21
12	Building clearly visible/Building still stands, Partially collapse, Lifted off/missing affected by Pyroclastic Surges	62
13	Building clearly visible/Building still stands, Partially collapse, Partialy lifted off or major damage on roof tile affected by Lahars	2
14	Building clearly visible/Building still stands, Partially collapse, Partialy lifted off or major damage on roof tile affected by Pyroclastic Flows	17
15	Building clearly visible/Building still stands, Partially collapse, Partialy lifted off or major damage on roof tile affected by Pyroclastic Surges	51
16	Building unclearly visible/building can still be identified, Totally colappse, Lifted off/missing affected by Pyroclastic Flows	5
17	Building unclearly visible/building can still be identified, Totally colappse, Lifted off/missing affected by Pyroclastic Surges	71
18	Vanish/not visible, Totally colappse, Lifted off/missing affected by Lahars	4
19	Vanish/not visible, Totally colappse, Lifted off/missing affected by Pyroclastic Flows	566
20	Vanish/not visible, Totally colappse, Lifted off/missing affected by Pyroclastic Surges	368
	Total (unit)	1607

5.3. Damage Interpretation from geotagged photograph

Geotagged photos depict the condition of the photographed object. If the object is photographed building, the condition of the building can be identified. The condition of the buildings affected after a volcanic eruption can be interpreted based on the damage that occurred to buildings. Interpretation of building damage based on the structural condition of the building and non-structural conditions. By knowing the structural and non structural condition of the building can be used to analyze the level of damage and the feasibility to live again. The condition of the structural elements of the building such as foundations, columns, beams, walls, floors, roof structures can be identified from geotagged photos. The condition of non structural elements of the building such as windows, fences and other supporting components can also be obtained from the information geotagged photos.

To perform the interpretation of building damage based on these components on geotagged photos, can be facilitated 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. The design of the building damage attributes were adopted and modified from the criteria used by Baxter (2005) and BNPB (2011b). This is to adjust the type of disaster damage to volcanic and general criteria used by the government of Indonesia. The criteria of building damage by pyroclastic flows/surges are shown in the table 31.

Table 31. Geojot photos attribute design for pyroclastic flow/surge hazard on building damage

Building : - Not visible, totally collapse or large collapse - Partialy collapse - Still stands/no collapse	**Fence :** - Fence push over - Partially collapse/bent - Fencing intact and unbent - No damage
Main structure : - Large part damage - Small part damage - Minor damage - No damage	**Supporting component :** - Totally damage - Many damaged - Small part damage - No damage
Building roof : - Lifted off - Partialy burned/lifted - Minor damage - No damage	**Functionality :** - Harm - Relatively can be functioned - Can still function
Wall : - Most broken/cracked/removed - Crack in plaster walls - Minor crack - No damage	**Damage percentage :** - > 70 % - 30-70 % - < 30 %
Windows : - Imploded and frame missing - Blown out but frame intact/burnt - Small part broken/burnt - No damage	

Source: Adopted and modified from Baxter (2005) and BNPB (2011b)

Based on the attributes of damage to buildings, damage assessment list in Geojot is created as shown in Figure 48.

Figure 48. Geojot photos attribute list for pyroclastic flow/surge hazard on building damage

Based on the attributes that have been designed, the building damage level can be compiled in table 32 below.

Table 32. Building damage level base on attribute design

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)

Based on the criteria used in table 32 above, the description of the damage to roofs, windows and fence are typical of building damage assessment for volcanic disaster. The roof that is missing / lifted / burning with buildings structure that are still standing only found in volcanic disaster. Characteristics of window frame burned or lost only can be found on the type of volcanic disaster.

Figure 49 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.

Figure 49. Building example after volcanic disaster

In the building above in figure 49, it can be seen that the large building collapse happen, 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. The figure 50 below shows the data entry of building damage interpretation from geotagged photograph loaded on the Geojot attributes form:

Figure 50. Building damage interpretation in Geojot

Figure 51. Building damage interpretation report from Geojot to GPS Photo Link (direction of 290 ° WNW)

The geotagged photograph as shown in figure 51 above 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). If one side of the building are still not able to describe the entire building, it would require another geotagged photos taken from the other side can clearly describe the damage. The geotagged photograph in figure 52 was taken from the other side (direction of 187° S) showing the building (yellow line) had collapsed so that the only remaining building on the front side, while figure 53 shows Field of View (FOV) in Geojot online map by direction of 187 ° S from camera position to the building object. Blue circle with black arrows show the coordinates / location where the camera captures the object building and shooting direction, the purple triangle shows Field of View (FOV) of shooting towards the direction of the object and yellow arrows indicate the object photographed buildings. Accuracy of the GPS when photographing that building object is 5 meters. 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.

Figure 52. Building damage interpretation sample (direction of 187 ° S)

Figure 53. Geojot field of view (FOV) by direction of 187 ° S
from camera position to the building object

The figure 54 below shows the condition of the current building damage after the eruption in November 2010. Many large stones strewn around the damaged building (damage caused by pyroclastic flow) which is an indication of the cause of damage to the building.

Figure 54. Nearest condition after volcanic disaster 2010 (manually geotagging)

5.4. Differences in visual appearance of damage for different type of volcanic hazards as seen from the geotagged photograph in Cangkringan Sub-distric

Based on a map of the area affected by the Merapi eruptions of 2010, there are three types of hazards that exist in Cangkringan: the pyroclastic flow, pyroclastic surges and lahars. Based on the analysis, that hazards can cause the total destruction of the building, but in general damages for each type of hazard can be distinguished as follows.

a. Damage due to pyroclastic flow

The characteristics of building damage due to pyroclastic flow are:

- Building lost/vanish due to a very thick buried materials
- No scars are visible without digging of volcanic material that buried
- Pyroclastic flow with low intensity with a pile material that is not burying the house, then a window or door that is made of wood burned

The damage described in the above description is shown in the figure below 55:

Figure 55. Building that damage by pyroclastic flow and pyroclastic surge
(Photo source: BPBD Sleman)

In figure 55 above, half of the building affected by pyroclastic flow until the building is lost. The building that still stands was affected by pyroclastic surges and trees missiles. The structure of the remaining roof made of iron curved because of the heat and trees missiles.

For pyroclastic flow with lower intensity, the material that buried part of the building will have an impact on fire/burned on the windows or doors made of wood because the material is very hot. Figure 56 shows the impact of pyroclastic flow with the lower intensity.

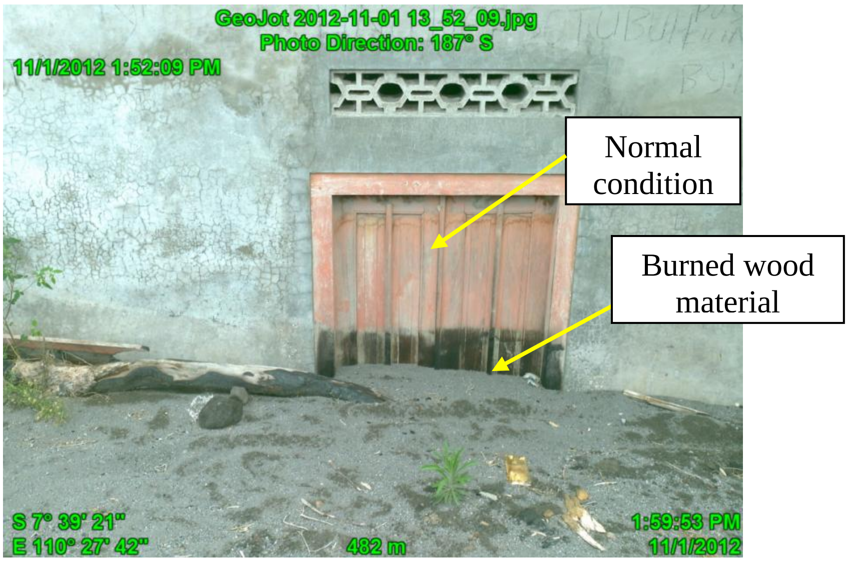


Figure 56. Building that damage by pyroclastic flow with lower intensity

b. Damage due to pyroclastic surge

The characteristics of building damage due to pyroclastic surges are:

- The building could be lost and buried by a relatively thick material
- The structure of the building that is still standing is characterized by missing or burned window or broken of windows glass, or the frame is still there or burned.
- Missing or damaged roof but the building is still standing
- Most of the building ruins can be found

Damage to buildings due to pyroclastic surges can be described as picture 57 below:

Figure 57. Building that damage by pyroclastic surge (Photo source: BPBD Sleman)

c. Damage due to lahars

The characteristics of building damage due to lahar are:

- The building may be a total float if that is on the main line of lahars
- Building buried by volcanic material, but wood on the windows and doors do not burned
- The building is still standing, no damage on roof
- The wall of the building partially lost

Figure 58 below illustrates the damage caused by lahars:

<table>
<tr><td>Before</td><td>
</td></tr>
<tr><td>Process</td><td>
</td></tr>
<tr><td>After</td><td>
</td></tr>
</table>

Figure 58. Building that damage by lahars (Photo source: BPBD Sleman)

Based on the figure 58 above, after the lahars hit the building, the walls of the building partially lost in one corner of the building and surrounding suffered cracks, structural columns at the corners of the building was large damaged, missing window glass, sand piles in buildings up to a half meter. Damage is caused by lahars that bring large boulders and tree trunks that hit the wall so that the wall cavities.

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

Automatically geotag 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 geotag photos with GPS Lock-Off scenario, GPS Lock-On scenario and QR Code scenario.

a. GPS Lock-Off scenario

In GPS Lock-Off 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. Distance information is filled in on the attributes of the geotagged photograph. Geojot provides facilities for reading Laser Distance Meter with Bluetooth technology if Laser Distance Meter that is used also has bluetooth facility. Figure 59 below shows distance measurement between camera position and the object photographed with Laser Distance Meter.

Figure 59. Measuring the distance between camera position and the object photographed with Laser Distance Meter (Laser Ace 300)

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 as shown in figure 60. 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.

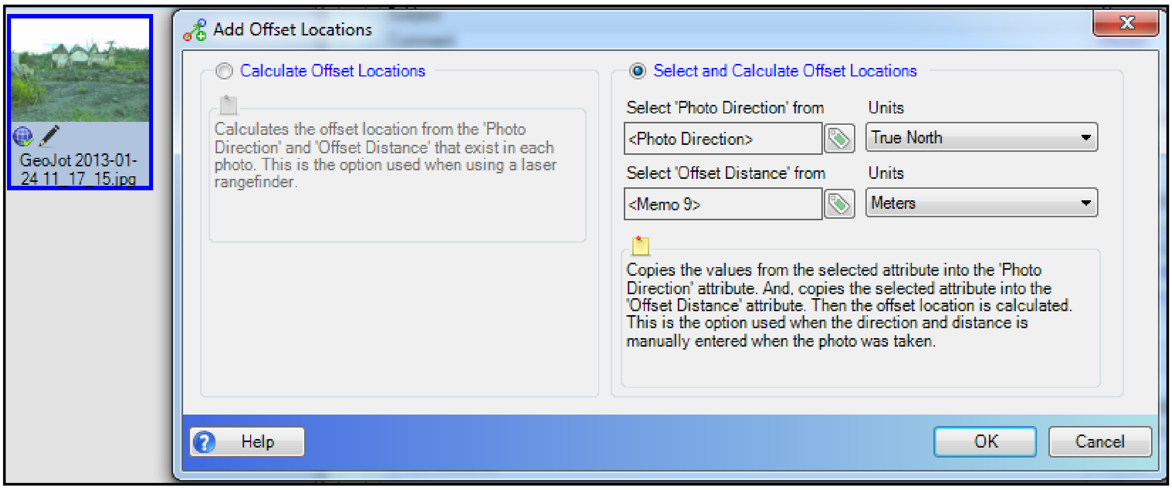


Figure 60. Calculation offset location by photo direction and offset distance in GPS Photo Link

The figure 61 below shows the result of shifting camera coordinate into object coordinate. Camera location coordinates is shifted as far as 20 meters in the direction of 261° W from its original position resulting offset latitude and longitude. Koordinat hasil offset ini adalah koordinat obyek bangunan.

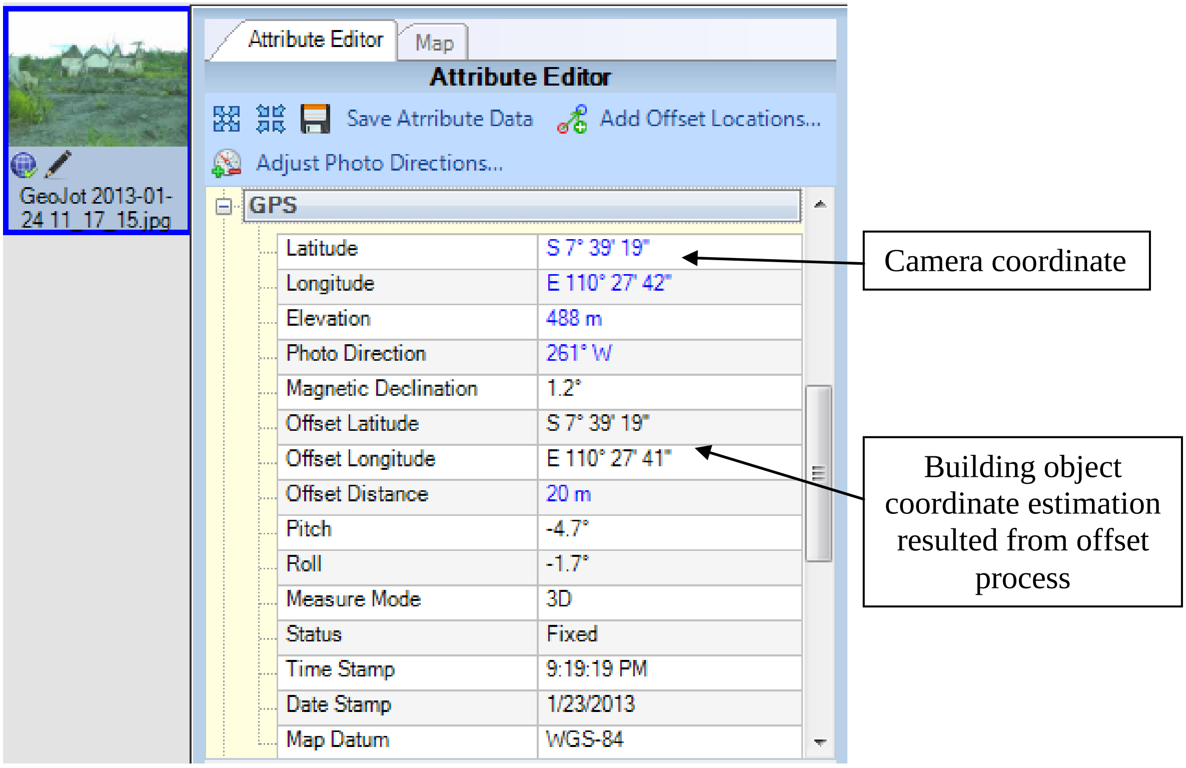


Figure 61. Building object coordinate resulted from offset process in GPS Photo Link

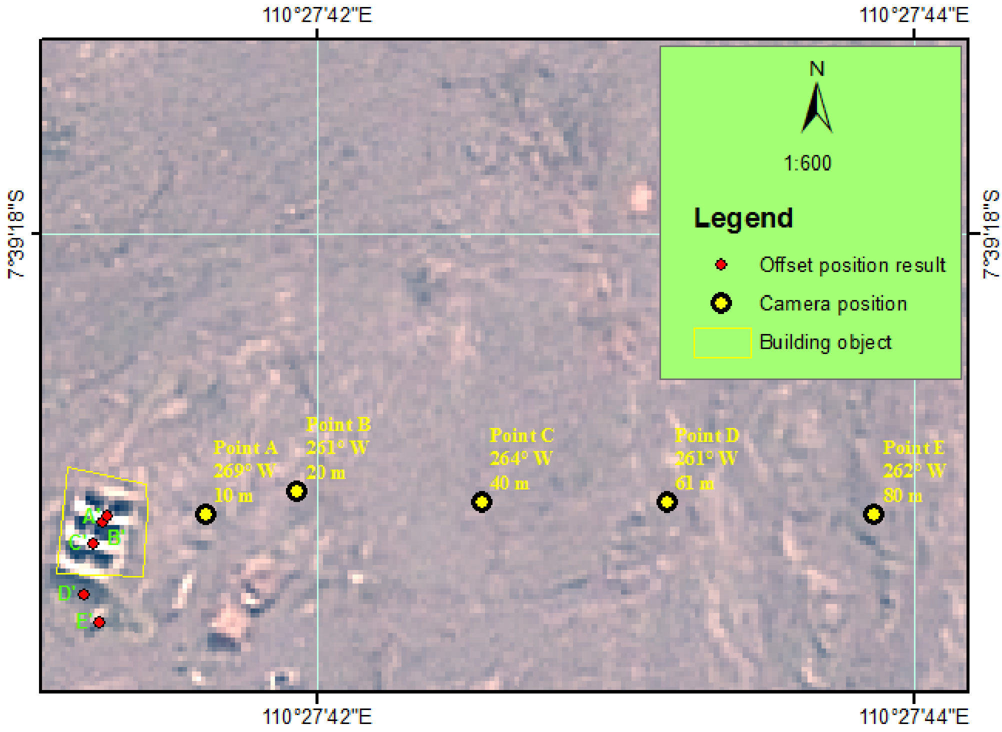


Figure 62. Offset position result from different variation of distant

The figure 62 above shows the offset distance variation to determine the position of the object that has been photographed. 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 the figure 63.

Figure 63. Combine of geotagged photograph attribute and imagery interpretation attribute by mean of GIS (spatial join process)

b. 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 of GPS-Lock On scenario is shown in the figure 64 below.

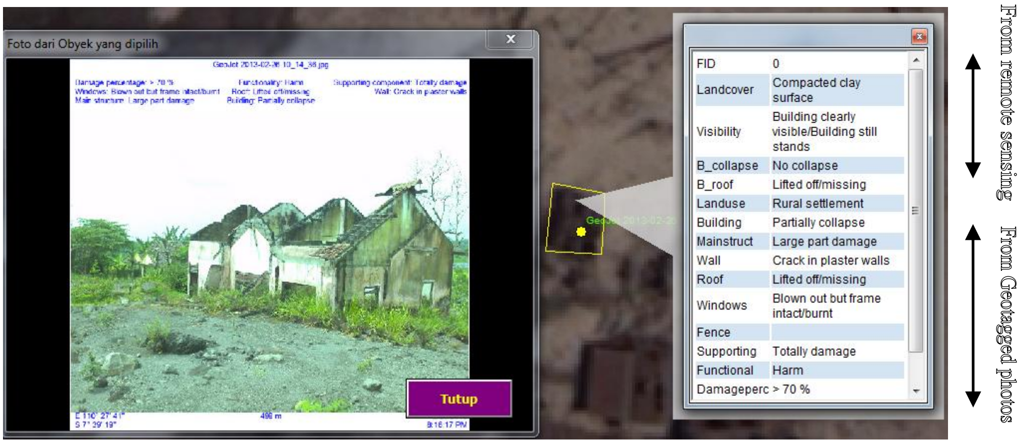


Figure 64. Combine of geotagged photograph attribute and imagery interpretation by GPS Lock-On scenario

c. QR Code Scenario

Each object of a particular building should have a unique identity. Identity can be used to identify the building and match them with a database building. 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 in the building sample of Cangkringan Sub-district is shown in the figure 65 below.

Figure 65. QR Code scenario on building

In normal conditions, QR Code with size 15 cm x 15 cm can be read by a Barcode Scanner camera at a distance of ± 2 meters. Read and entry of Building QR Code in Geojot is shown in the figure 66.

Figure 66. Building QR Code read and entry in Geojot

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. By utilizing heat resistant materials expected to be used for volcanic disaster-prone areas. 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. A thick cover of volcanic ash that may cover QR code can be removed first so that the code can be read by a QR Code camera / barcode scanner.

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. The building with the condition vanish or washed away by volcanic disasters can be assumed that the attached QR Code will also be destroyed/lost. It can be used as a post-disaster damage data collection assumption. By using QR Code, building that will be recorded is building that has slightly to medium 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 can be known the building that was not recorded using QR Code in the field. 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 medium damage.

QR Code test conducted in the Bakalan sub-village, Argomulyo village, Cangkringan sub-district. Buildings are individually mapped from high-resolution satellite imagery and comes with building owner's name and building identity number according to the design of QR Code. Building object in the Bakalan sub-village before Merapi eruption 2010 can be mapped into 62 building unit as shown in figure 67 and the table in Appendix 1. Based on the total number of buildings before the disaster, 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 as shown in Table 33. Table 33 also shows the results of the building damage assessment on the 17 buildings. 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.

Table 33. Buildings with a QR Code that can still be recorded in Bakalan village

Nr	Existing QR Code reading result in Bakalan sub-village (Sub-district name\Village name\Sub-Village name\Building owner\Building Identity Number)	Damage Level
1	Cangkringan\Argomulyo\Bakalan\Agus Susilo\1	Slightly damage
2	Cangkringan\Argomulyo\Bakalan\Wiryanti\2	Slightly damage
3	Cangkringan\Argomulyo\Bakalan\Sumanto\4	Heavy damage
4	Cangkringan\Argomulyo\Bakalan\Nur Kudus\5	Slightly damage
5	Cangkringan\Argomulyo\Bakalan\Agus Darmanto\6	Slightly damage
6	Cangkringan\Argomulyo\Bakalan\Narto Wiyono\7	Slightly damage
7	Cangkringan\Argomulyo\Bakalan\Dirjo Atmojo\8	Slightly damage
8	Cangkringan\Argomulyo\Bakalan\Sarjono\10	Medium damage
9	Cangkringan\Argomulyo\Bakalan\Noto Diyono\14	Heavy damage
10	Cangkringan\Argomulyo\Bakalan\Sosro Supriyono\19	Heavy damage
11	Cangkringan\Argomulyo\Bakalan\Eko Bejo Subekti\20	Heavy damage
12	Cangkringan\Argomulyo\Bakalan\Darmo Wiyono\21	Medium damage
13	Cangkringan\Argomulyo\Bakalan\Supeno\29	Heavy damage
14	Cangkringan\Argomulyo\Bakalan\Hardi Mulyono\30	Heavy damage
15	Cangkringan\Argomulyo\Bakalan\Supardi\42	Medium damage
16	Cangkringan\Argomulyo\Bakalan\Yanto Karyono\43	Slightly damage
17	Cangkringan\Argomulyo\Bakalan\Jumilah\44	Slightly damage

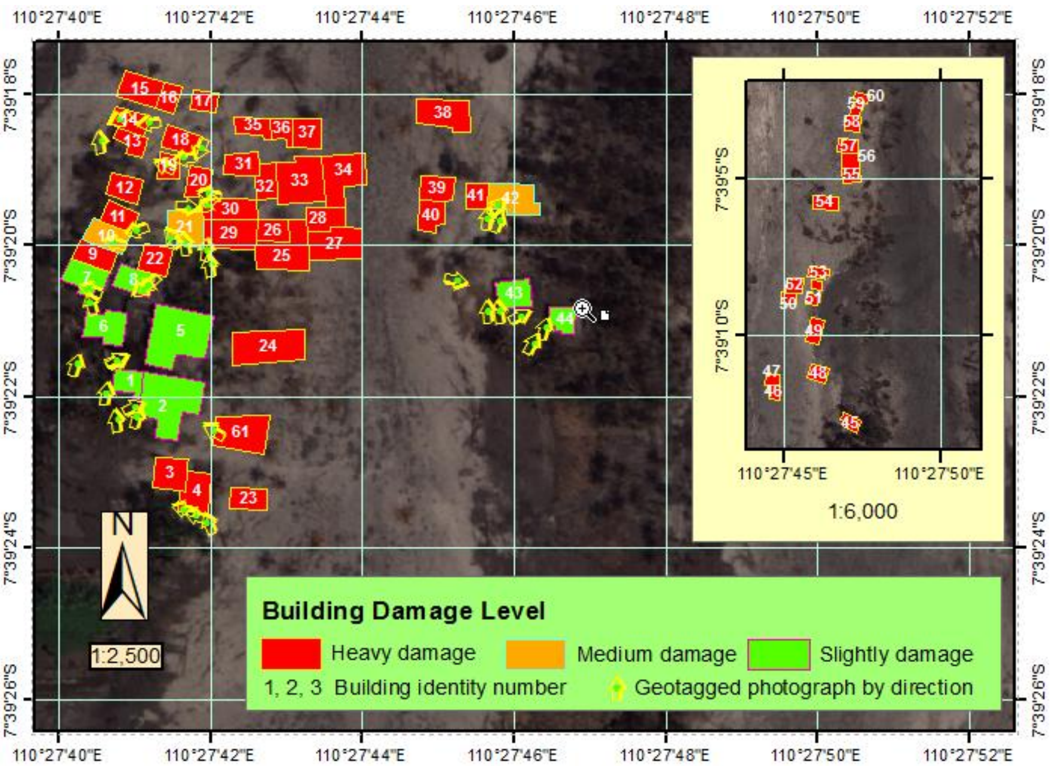


Figure 67. Building damage level in Bakalan sub-village

Overall, samples from the building damage level assessed using remote sensing and geotagged photograph as shown in Appendix 2. Distribution of geotagged photograph samples can be seen in figure 68 below:

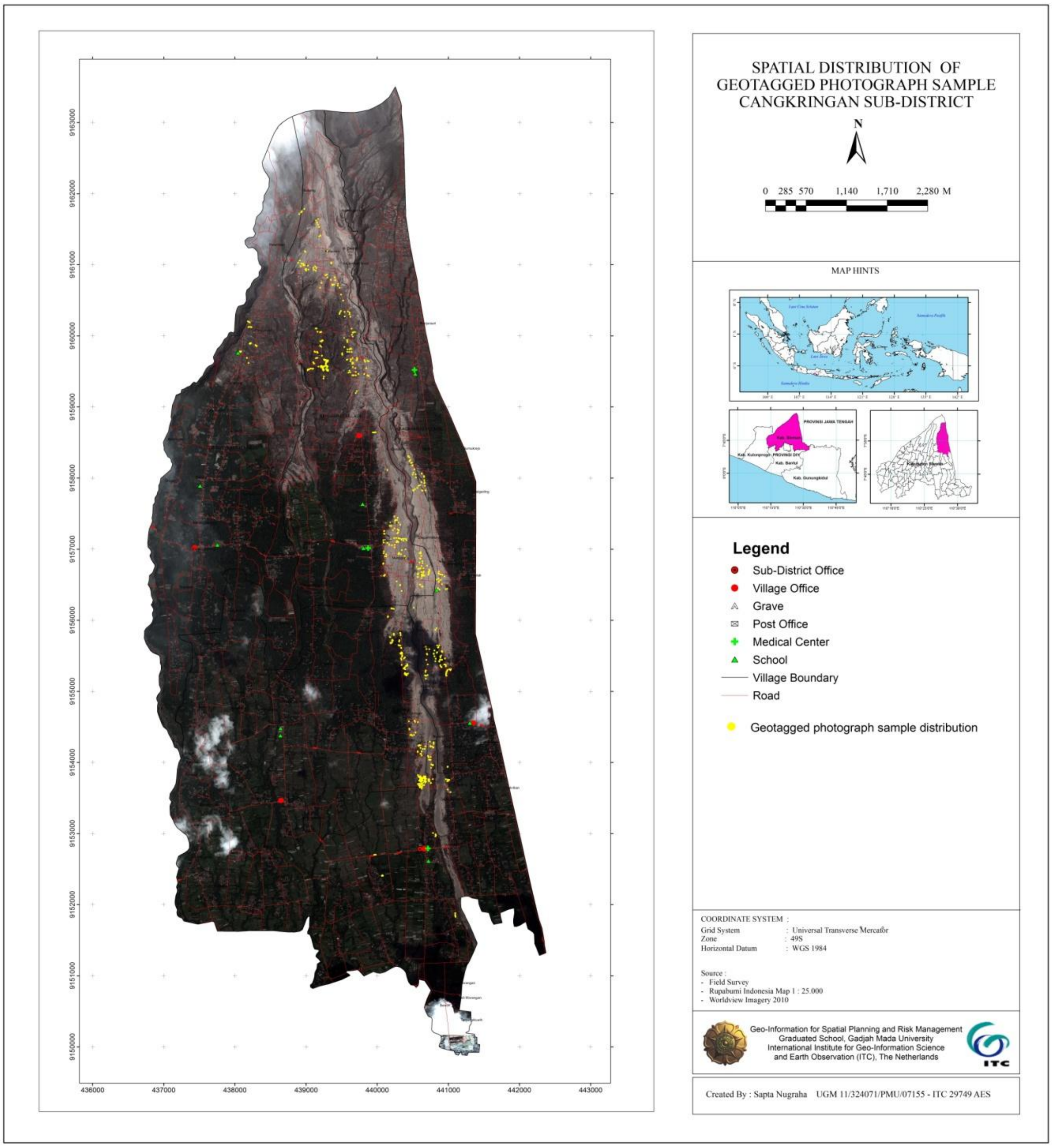


Figure 68. Spatial distribution of geotagged photograph samples

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 geotagged 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 69 and table 34.

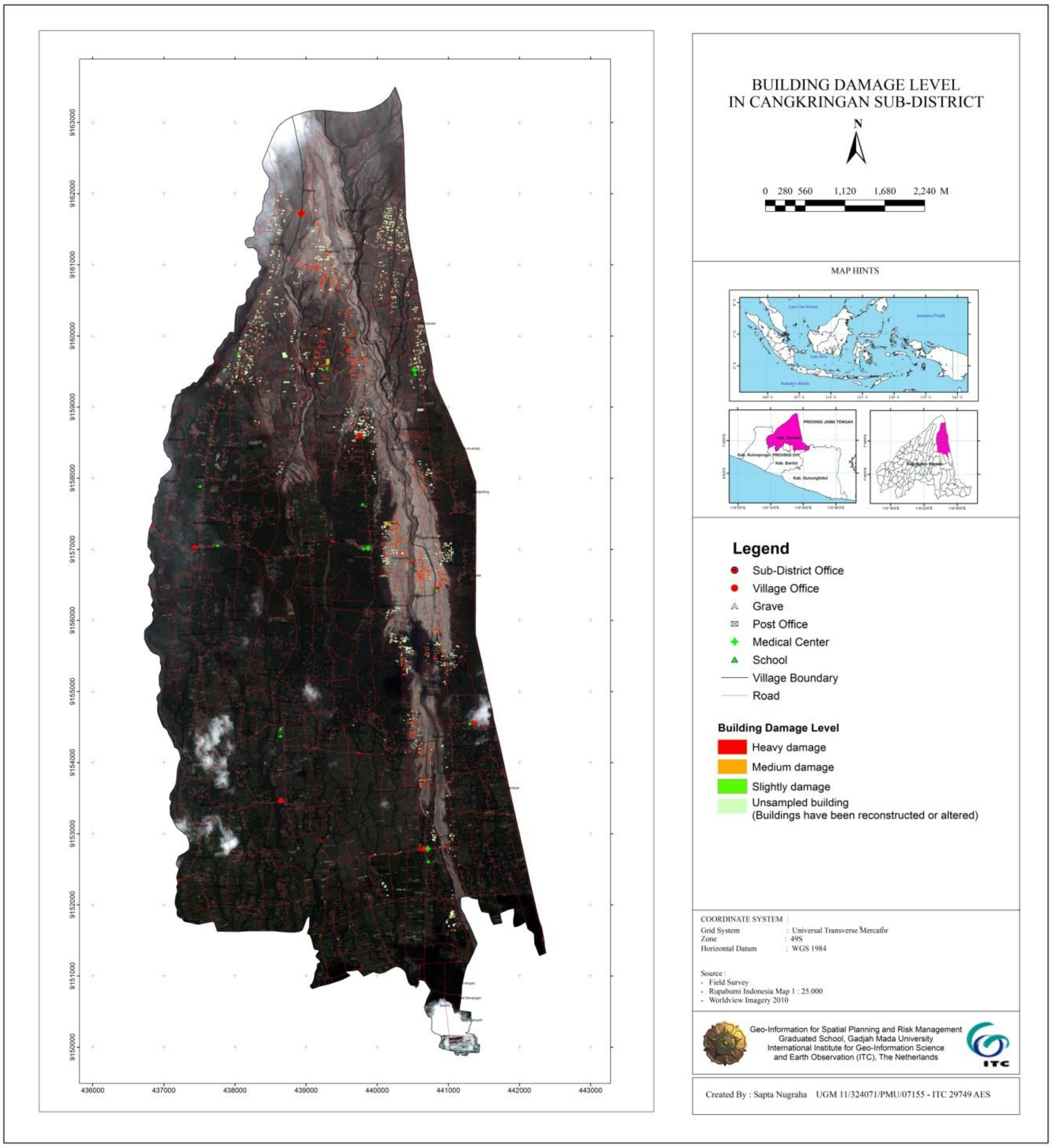


Figure 69. Building damage level for sampled buildings in Cangkringan sub-district

Table 34. Building damage level for sampled buildings by volcanic hazard types

Nr.	Damage level by hazard	Argomulyo village (unit)	Glagaharjo village (unit)	Kepuharjo village (unit)	Umbulharjo village (unit)	Wukirsari village (unit)	Total (unit)
1	Heavy damage	40	59	195	6	27	327
a	Lahars	2					2
b	Pyroclastic Flows	32	57	145		26	260
c	Pyroclastic Surges	6	2	50	6	1	65
2	Medium damage	5	6	10	1	4	26
a	Lahars	1					1
b	Pyroclastic Flows	1	2	2		3	8
c	Pyroclastic Surges	3	4	8	1	1	17
3	Slightly damage	10	3	2	1	9	25
a	Lahars	3					3
b	Pyroclastic Flows			1		4	5
c	Pyroclastic Surges	7	3	1	1	5	17
	Total (unit)	55	68	207	8	40	378

Based on figure 69 and table 34, each type of disaster either pyroclastic flows, pyroclastic surges and lahars can cause different levels of damage that are slightly damage, medium damage and heavy damage. 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 medium 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. Base 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 picture 69 and table 34 where the buildings in the villages closest to the peak of Merapi (Kepuharjo and Glagaharjo village) are the most heavy damaged buildings that can be found.

5.6. Training for Disaster Management Agency

In order for damage assessment method with a combination of geotagged photos, remote sensing and GIS can be done by the disaster management agency, it is necessary to personal training in disaster management agencies and relevant government agencies. Training has been conducted in the room and on the field practice which has been carried out in December 2012 as shown in the figure 70.

Figure 70. Training of proposed method in the room and the field
to disaster management agency and relevant government agencies

5.7. Comparation of 2D and 3D Geotagged Photograph

Comparison between 2D and 3D geotagged photos is done by testing for a variety of distances to the object of the assessed building damage. In case this is done by comparing the level of clarity of property damage that can be tapped 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 as shown in figure 71 below.

Figure 71. 3D Anaglyph photograph observation

Figure 72 below shows the distribution of the distance scenario to the first building object that were sampled. There are nine scenarios used within the distance of 80.1 m, 70.2 m, 60.5 m, 50.2 m, 40.1 m, 30.1 m, 20.3 m, 10 m and 5 meters.

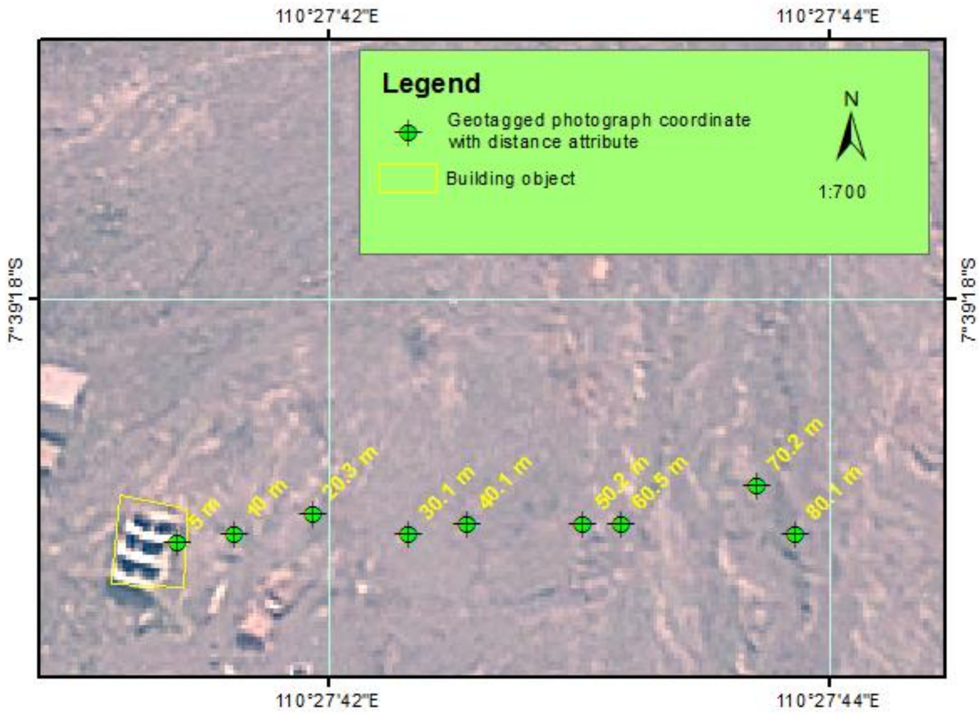
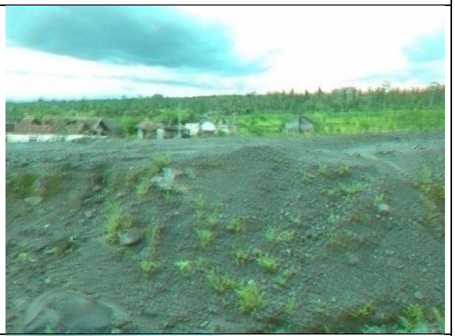


Figure 72. Distribution of geotagged photograph for distance variation of Building Sample 1

For the nine scenarios distance as above, comparison of the visual appearance of 2D and 3D geotagged photos are shown in Figure 73 below.

Distance to building (m)	2D geotagged photograph	3D Anaglyph geotagged photograph
80.1		
70.2		
60.5		
50.2		
40.1		

Distance to building (m)	2D geotagged photograph	3D Anaglyph geotagged photograph
30.1		
20.3		
10		
5		

Figure 73. 2D and 3D geotagged photograph visual comparison
based on distance variation on Building sample 1

Based on the observations of building damage in a variety of scenarios within 2D and 3D geotagged photos above, observations of building damage at a distance closer to the object it is better to look at structural damage, damage on roof and damage on windows. Observation of structural damage to buildings, roofs and windows more clearly and accurately use 3D Anaglyph photos instead of using 2D geotagged photos for depth perception obtained. At relatively far distance (80 meters), structural damage such as beam damage as shown in figure 73 above by yellow arrow are more clearly observed in 3D Anaglyph photos.

The second sample is the same building as the figure 69, but taken from a different side to the longer distances because of conditions in the field which allows for a greater distance scenario. Farthest distance is taken at a distance of 250 m. Variations distance used is shown in figure 74 below.

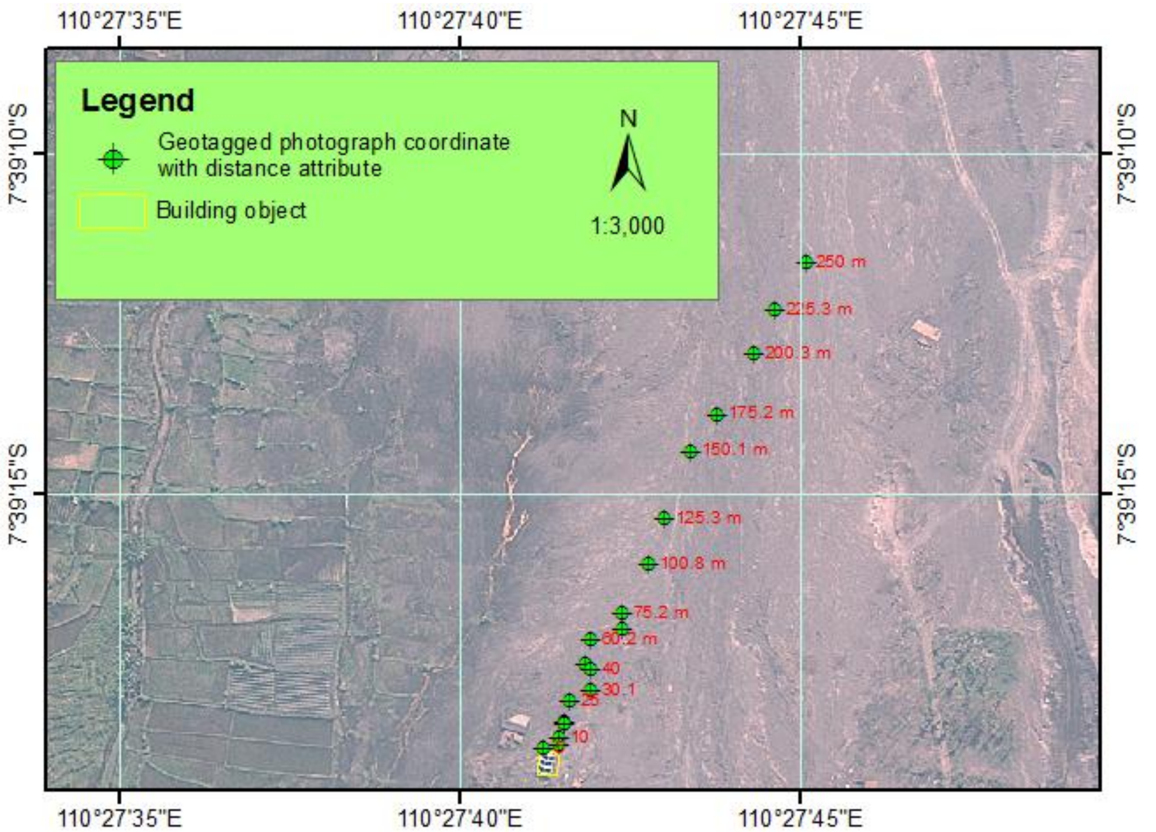


Figure 74. Distribution of geotagged photograph for distance variation of Building Sample 2

Comparison of visual appearance of 2D and 3D geotagged photos are shown in the figure 75 below. When making comparisons, photos can be enlarged so that the object of the building can be seen more clearly.

Distance to building (m)	2D geotagged photograph	3D Anaglyph geotagged photograph
250		

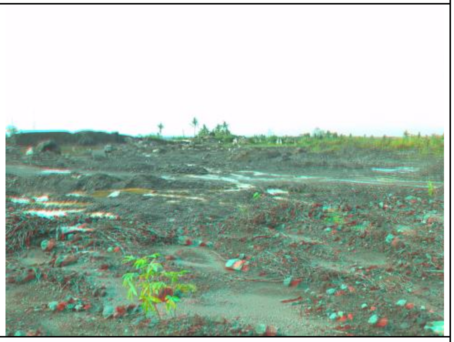
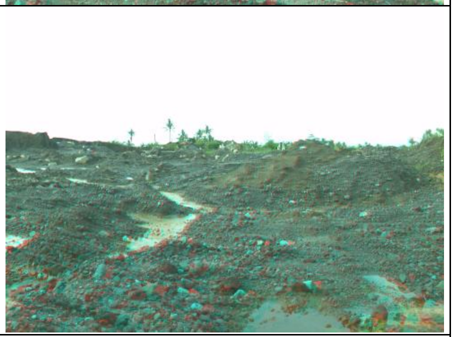
<table>
<tr><th>Distance to building (m)</th><th>2D geotagged photograph</th><th>3D Anaglyph geotagged photograph</th></tr>
<tr><td>200</td><td>
</td><td></td></tr>
<tr><td>150</td><td>
</td><td></td></tr>
<tr><td>100</td><td>
</td><td></td></tr>
<tr><td>50</td><td>
</td><td></td></tr>
<tr><td>10</td><td>
</td><td></td></tr>
</table>

Figure 75. 2D and 3D geotagged photograph visual comparison based on distance variation on Building sample 2

Based on the figure 75 above, at a distance of 250 meters from the building objects, building damage particularly damage to roofs and structures can still be tapped with a clear picture both 2D and 3D, but the condition of the windows can not be observed. 3D Anaglyph photos provide the capability of building damage observations better than the 2D photos because of the depth perception to building object and surrounding of buildings.

Building as the third sample was in the Glagaharjo village with seven variations of the distance of 150.4 m, 125 m, 106.5 m, 75.1 m, 50.2 m, 25.2 m and 10.2 m as shown in Figure 76.

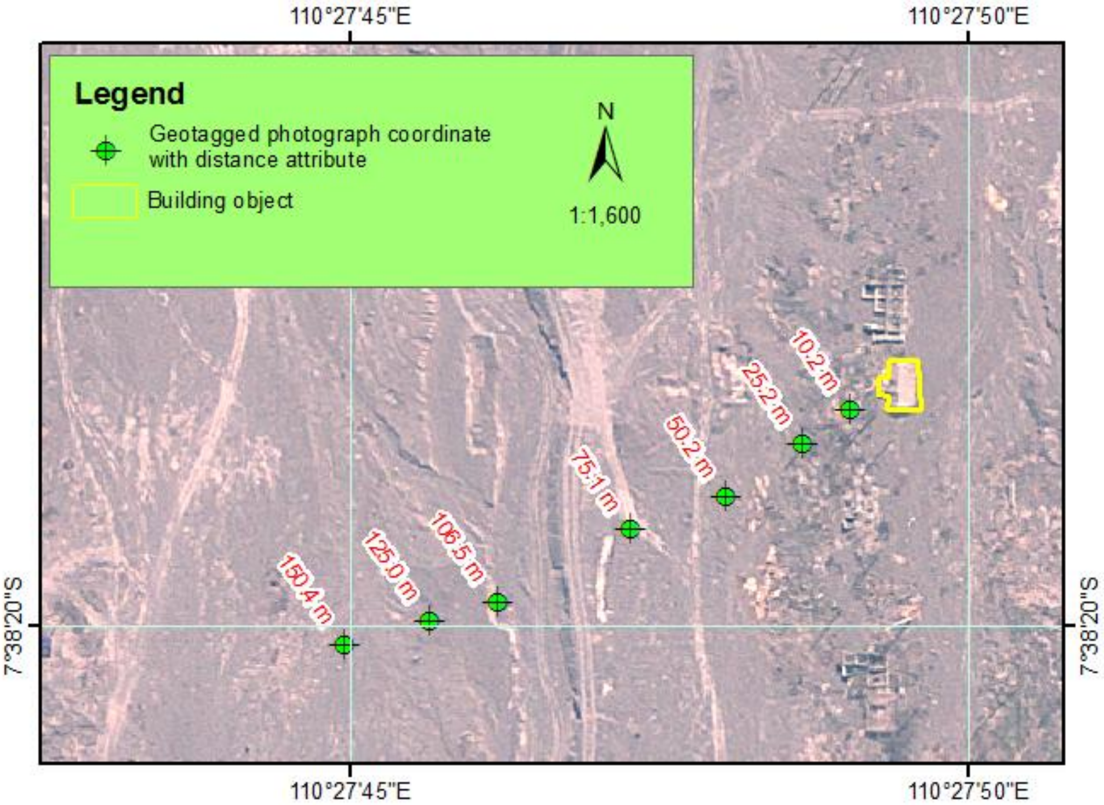


Figure 76. Distribution of geotagged photograph for distance variation

Comparison of visual appearance appearance 2D and 3D geotagged photos depicting damage to buildings based on variations in the distance is shown in Figure 77 below.

Distance to building (m)	2D geotagged photograph	3D Anaglyph geotagged photograph
150.4		

Distance to building (m)	2D geotagged photograph	3D Anaglyph geotagged photograph
125		
106.5		
75.1		
50.2		
25.2		

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

Figure 77. 2D and 3D geotagged photograph visual comparison
based on distance variation on Building sample 3

Based on figure 77 above, 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.

5.8. Evaluation of Utilization of Geotagged Photograph, Remote Sensing and GIS for Post Disaster Damage Assessment compare to current system of Post Disaster Damage Assessment in Merapi Eruption 2010

Evaluation of the system was conducted with the Disaster Management Agency of Sleman and Public Work Department of Sleman. Post-disaster damage assessment system 2010 that is used Sleman government in Merapi case, especially building damage assessment using population-based data as the name of the home owner or the head of families affected by the Merapi eruption in 2010, both affected by pyroclastic flows / surges and affected by lahar. The system is directly located at a relatively detailed level because the data are based on the name of the affected population, which is not easy to do without the use of population data update as the owner of the building. The villages as a bottom government organization have very important role in data collection, especially damage to buildings.

The system is relatively advantageous because the data is based on the family name of the owner of this house officer can directly provide information regarding whether or not the affected homes owned by the eruption of Merapi 2010 on the data tables owned, even annotate directly the level of damage to buildings. However, the government does not have the spatial database houses so that the position on the field is only known by people such as village heads. After the 2010 eruption of Merapi, no documentation of each house spatially. Data verification of each house is done a year later in late 2011 when the government wants to provide permanent housing assistance to people affected by the eruption of Merapi 2010. The data remains relatively weak verification can result in very dynamic changes in the data and the possibility of redundancy.

Documenting affected buildings by disaster and the level of damage done qualitatively by the head of sub-village. The government in this case the Department of Public Works has provided criteria for the assessment of damage to buildings as a guide. Documenting with this way relatively quickly because the officers directly determine the level of damage based on the criteria given. If the terrain allows unimpeded, then for data collection in a village building damage can be done in less than a day. At the end of 2011 verification conducted by a team of approximately 5 people from BPBD, DPPD, DPU, head of sub-village and staf of village office. Within a day, the verification data collection can be done up to 20-50 home depending on the ground conditions. A cost incurred in one day is IDR 40.000,00 for each surveyor.

Based on the assessment of the use of geotagged photograph, remote sensing and GIS for post-disaster damage assessment by the Disaster Management Agency of Sleman and Public Work Department of Sleman, the data produced more accurate / reliable than the current system of disaster damage data collection in Merapi 2010 eruption. With this new system, building spatial data and interpretation of building damage can be obtained from high-resolution satellite imagery. Geotagged photos used are very clear documentation of the damage. Interpretation of building damage from geotagged photos is highly objective and can be directly carried out so it can reduce the data verification work in the field again.

Post-disaster damage assessment using geotagged photographs, remote sensing and GIS is not cheaper than the system used during the eruptions of 2010. High-resolution satellite imagery to be used is expensive, especially multitemporal imagery condition before and after the disaster. Device for geotagging photos, Geojot software and GIS software to be used is also relatively expensive. Although more expensive, but the system will generate data more objective and accurate.

Post-disaster damage assessment using geotagged photographs, remote sensing and GIS generally is not faster than the system used by government. Identification of changes in land cover damage to the building and interpretation of satellite images requires a relatively long time, especially with the lack of human resources. The use of geotagged photographs with Geojot relatively easily and quickly. For one geotagged photograph with 11 attributes (with measurement of distance and QR Code reading) requires the fastest time of $\pm$ 2 minutes. By this time, it can be assumed that in one day more than 50 buildings can be recorded so that the assessment of building damage is faster than the verification process of building damage done by the government. Overall, post-disaster damage assessment system using geotagged photograph, remote sensing and GIS is slower than post-disaster damage assessment conducted by the government at the time of the eruptions in 2010, but the system is more reliable and more accurate for the results.

5.9. Testing by Disaster Management Agency of Sleman

Test conducted by the Disaster Management Agency and the Public Works Department of Sleman district includes assessing building damage using 2D and 3D geotagged photos on several buildings in the Bakalan sub-village, Argomulyo village, Cangkringan that was affected by Merapi eruption in 2010. Figure 78 shows the testing process of 2D and 3D geotagged photo interpretation for building damage assessment.

Figure 78. Testing of 2D and 3D geotagged photograph by
Disaster Management Agency of Sleman and Public Works Department of Sleman

Based on the test results obtained, the 3D Anaglyph geotagged photograph more clearly to observe damage to buildings rather than 2D geotagged photograph. Damage to buildings equally can be interpreted from 2D and 3D geotagged photograph, but 3D Anaglyph geotagged photograph provide better level of clarity for better observation of structural damage to the building.

Furthermore, according to the Disaster Management Agency of Sleman and Public Works Department of Sleman, geotagged photograph either with GPS Lock-On or GPS Lock-Off that is combined with building QR Code is the best way for building damage data collection. QR code that is read by Geojot shows the building's identity information so that the errors can be minimized. QR Code also has another advantage that is not too needed local knowledge as local knowledge held by the head of the sub-village on the names of the owner of the house before the assessment of the damage done.

5.10. Cost to Convert System for Post Disaster Damage Assessment

Post-disaster damage assessment especially building damage assessment conducted by the government of Sleman is not using geotagged photographs and GIS. Analysis of land cover changes from satellite imagery before and after the disaster that used high-resolution remote sensing imagery is not yet done. Data collections are conducted by way of survey on the field and make the data tabulation. To convert from the system used by the government to the system using geotagged photographs, remote sensing and GIS, it will require equipment data collection and human resources that are owned by the Disaster Management Agency of Sleman and Public Works Department of Sleman. Based on the interview with the Disaster Management Agency of Sleman and Public Works Department of Sleman, both offices had not had a whole complete system that will be applied (Android device, Geojot and ArcGIS software) and human resources that could implement such a system. However, both these offices already have a computer. Assuming both these offices have the resources 30 people (5 teams), hence the need for conversion to the system is shown in table 35.

Table 35. Cost to convert the current system of damage assessment to proposed system

Nr	Needs	Quantity	Cost
1	Android device support camera and GPS	5	IDR 20.000.000
2	Geojot and Geojot Core (Geojot Core as same as GPS Photo Link)	5	IDR 16.450.000
3	ArcGIS Desktop (ArcView Concurrent License)	1	IDR 43.370.000
4	Training for 3 days	30 people	IDR 4.500.000
	Total Cost		IDR 84.320.000

Based on table 35 above, the basic need to use the post-disaster damage assessment system with geotagged photos, remote sensing and GIS is worth IDR 84.320.000. Relatively high cost is due to the absence of most of the equipment used for post-disaster damage assessment with geotagged photographs, remote sensing and GIS.

Chapter 6. Conclusion and Recommendation

6.1. Conclusion

Conclusions for each research objective is as described below:

1. *Develop method for volcanic post-disaster damage assessment from geotagged ground photograph in combination with remote sensing and GIS in Indonesia.*

   The current volcanic post-disaster damage assessment of building damage assessment method in particular by local disaster management agency in case of Merapi volcanic disaster in 2010 made using the input data input in the form of a table of village level recorded by the head of the sub-village. Table data compiled by the name of the home owner / head of the family is still not good validation because not supported by documentation and maps.

   The data required for the assessment of damage to buildings on a case Merapi eruption is data that describes the condition of the building, especially the condition of the structure and the appropriateness of the building to be occupied again. Interpretation of damage to buildings with high-resolution satellite imagery can be tapped into building visibility, building collapse (change in shape of the building) and the condition of the roof. Damage such as column and beam structure that collapsed, the walls were collapsed or cracked, window conditions can not be observed from satellite imagery. 2D and 3D geotagged photograph able to tap into all of the data required for the assessment of damage to buildings.

   Damage to buildings caused by different types of volcanic hazards (pyroclastic flow, pyroclastic surges and lahars) is relatively different. In general, the building that disappeared without a trace because it was affected by pyroclastic flow. Building structure that is still standing, but the roof is missing/lifted off and the missing windows or burned windows is characteristic of pyroclastic surge damage. Damage due to lahar is most difficult to identify because the appearance of the roof structure from high-resolution satellite imagery is generally intact. Volcanic material that buried the wooden building does not cause burning in the window or door. It clearly distinguishes between damage from pyroclastic flows and lahars. Hot material from pyroclastic flow causes buried building elements that are made from wood will burn.

   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.

2. *Testing the volcanic post-disaster damage assessment method that use geotagged ground photograph in combination with remote sensing and GIS.*

   Using geotagged photograph with a combination of remote sensing and GIS in general is not faster than the method used by the government when building damage assessment Merapi eruption 2010.On screen visual Interpretation of land cover in detail from high-resolution satellite imagery takes a long time, unless it already has a database of land cover / land use at the detail level. The government relatively quickly because it only uses data tabulation and data collection done from the low government organizations. Especially for data collection building damage with geotagged photograph on the ground is faster than the verification process carried out by the government. For geotagged photograph with 11 attributes, building damage assessment takes time $\pm$ 2 minute (> 50 building per day). Verification of building damage by government produces data of 20-50 buildings every day.

   Based on the results of tests conducted by Disaster Management Agency of Sleman and Public Works Department of Sleman district, they can interpret geotagged photograph properly and can get the sense of three dimensions on a 3D geotagged photograph. Based on the opinion of those agencies, the 3D geotagged photograph is better than 2D geotagged photograph in observing structural damage to buildings. Geotagged photograph with a combination of QR Code on the building is better than geotagged photograph with only GPS-Lock Off or GPS Lock-On method. Building with QR Code that still exists and can still be read can be assumed that the building is likely to have slightly or medium damage level. For buildings that are vanish or totally collapse, building QR codes will not be recorded by the surveyor, it can indicate that the building suffered heavy damage.

   To convert the system of post-disaster damage assessment using geotagged photograph, remote sensing and GIS in the Local Disaster Management Agency of Sleman, it will cost about IDR 84.320.000. Substantial costs because Local Disaster Management Agency of Sleman district does not yet have the necessary tools for this purpose. Cost does not include the cost of purchasing the high-resolution satellite imagery of the disaster site.

6.2. Recommendation

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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APPENDIX

Appendix1. Building QR Code Scenario for Bakalan Sub-village

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

Nr	Text	Building QR Code
1	Cangkringan\Argomulyo\Bakalan\Agus Susilo\1	
2	Cangkringan\Argomulyo\Bakalan\Wiryanti\2	
3	Cangkringan\Argomulyo\Bakalan\Cipto Hanolo\3	
4	Cangkringan\Argomulyo\Bakalan\Sumanto\4	
5	Cangkringan\Argomulyo\Bakalan\Nur Kudus\5	
6	Cangkringan\Argomulyo\Bakalan\Agus Darmanto\6	
7	Cangkringan\Argomulyo\Bakalan\Narto Wiyono\7	
8	Cangkringan\Argomulyo\Bakalan\Dirjo Atmojo\8	
9	Cangkringan\Argomulyo\Bakalan\Topo Suratno\9	
10	Cangkringan\Argomulyo\Bakalan\Sarjono\10	
11	Cangkringan\Argomulyo\Bakalan\Warno Dimejo\11	
12	Cangkringan\Argomulyo\Bakalan\Prapto Sukisno\12	
13	Cangkringan\Argomulyo\Bakalan\Pairo Utomo\13	
14	Cangkringan\Argomulyo\Bakalan\Noto Diyono\14	
15	Cangkringan\Argomulyo\Bakalan\Partono\15	
16	Cangkringan\Argomulyo\Bakalan\Asmo Pawiro\16	
17	Cangkringan\Argomulyo\Bakalan\Muh Widi Sutrisno\17	

18	Cangkringan\Argomulyo\Bakalan\Haryanto\18	
19	Cangkringan\Argomulyo\Bakalan\Sosro Supriyono\19	
20	Cangkringan\Argomulyo\Bakalan\Eko Bejo Subekti\20	
21	Cangkringan\Argomulyo\Bakalan\Darmo Wiyono\21	
22	Cangkringan\Argomulyo\Bakalan\Mangun Rejo\22	
23	Cangkringan\Argomulyo\Bakalan\Sunarto\23	
24	Cangkringan\Argomulyo\Bakalan\Bambang Sanyoto Putro\24	
25	Cangkringan\Argomulyo\Bakalan\Mardi Utomo\25	
26	Cangkringan\Argomulyo\Bakalan\Nyono Basuki\26	
27	Cangkringan\Argomulyo\Bakalan\ Suharto\27	
28	Cangkringan\Argomulyo\Bakalan\ Risman Sujarwo\28	
29	Cangkringan\Argomulyo\Bakalan\Supeno\29	
30	Cangkringan\Argomulyo\Bakalan\Hardi Mulyono\30	
31	Cangkringan\Argomulyo\Bakalan\Yitno Subiyanto\31	
32	Cangkringan\Argomulyo\Bakalan\Sriyanto\32	
33	Cangkringan\Argomulyo\Bakalan\Mitro Mulyono\33	
34	Cangkringan\Argomulyo\Bakalan\Hadi Wiyono\34	
35	Cangkringan\Argomulyo\Bakalan\Barjo Wiyono\35	
36	Cangkringan\Argomulyo\Bakalan\\Abidin Dungga\36	

37	Cangkringan\Argomulyo\Bakalan\Harto Sugiyono\37	
38	Cangkringan\Argomulyo\Bakalan\Suparno\38	
39	Cangkringan\Argomulyo\Bakalan\Wiryo Inangun\39	
40	Cangkringan\Argomulyo\Bakalan\Sukarni\40	
41	Cangkringan\Argomulyo\Bakalan\Jaswadi\41	
42	Cangkringan\Argomulyo\Bakalan\Supardi\42	
43	Cangkringan\Argomulyo\Bakalan\Yanto Karyono\43	
44	Cangkringan\Argomulyo\Bakalan\Jumilah\44	
45	Cangkringan\Argomulyo\Bakalan\Subirat\45	
46	Cangkringan\Argomulyo\Bakalan\Sarwono\46	
47	Cangkringan\Argomulyo\Bakalan\Suwito Harjo\47	
48	Cangkringan\Argomulyo\Bakalan\Wardoyo\48	
49	Cangkringan\Argomulyo\Bakalan\Sukinem\49	
50	Cangkringan\Argomulyo\Bakalan\Sudarno\50	
51	Cangkringan\Argomulyo\Bakalan\Wafirudin\51	
52	Cangkringan\Argomulyo\Bakalan\Pujo Darsono\52	
53	Cangkringan\Argomulyo\Bakalan\Agus Hendrayuwana\53	
54	Cangkringan\Argomulyo\Bakalan\Sulistyo Pranowo\54	
55	Cangkringan\Argomulyo\Bakalan\Walijo\55	

56	Cangkringan\Argomulyo\Bakalan\Mulyo Wiyono\56	
57	Cangkringan\Argomulyo\Bakalan\Muhdi Wiyono\57	
58	Cangkringan\Argomulyo\Bakalan\Barjo Wiyono\58	
59	Cangkringan\Argomulyo\Bakalan\Sutarto\59	
60	Cangkringan\Argomulyo\Bakalan\Sugianto\60	
61	Cangkringan\Argomulyo\Bakalan\Masjid Bakalan1\61	
62	Cangkringan\Argomulyo\Bakalan\Masjid Bakalan2\62	

Appendix 2. Damage assessment result from combination of geotagged photograph attributes and high-resolution satellite imagery interpretation by mean of GIS for buildings samples

Nr	Sub-district	Village	Landcover	Landuse	Remote Sensing Interpretation (High-resolution satellite imagery): Building Visibility (Visibility)	Building collapse (B_collapse)	Building roof (B_roof)	Building Coordinate (Center of Polygon): Longitude	Latitude
1	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Police office	Building clearly visible/Building still stands	No collapse	No damage on roof	110.4556817	-7.664909466
2	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Building clearly visible/Building still stands	No collapse	Partialy lifted off or major damage on roof tile	110.4633873	-7.662498147
3	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Building clearly visible/Building still stands	No collapse	No damage on roof	110.4650905	-7.65675712
4	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Building clearly visible/Building still stands	No collapse	Minor damage on roof tile	110.4629571	-7.655826743
5	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Building clearly visible/Building still stands	No collapse	No damage on roof	110.4627767	-7.655734203
6	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Building clearly visible/Building still stands	No collapse	Partialy lifted off or major damage on roof tile	110.4650415	-7.655640025
7	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Building clearly visible/Building still stands	No collapse	Minor damage on roof tile	110.4615167	-7.656130498
8	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Building clearly visible/Building still stands	No collapse	No damage on roof	110.4615457	-7.655887863
9	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Building clearly visible/Building still stands	No collapse	No damage on roof	110.4613652	-7.656057085
10	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Building clearly visible/Building still stands	No collapse	Partialy lifted off or major damage on roof tile	110.463074	-7.662372052
11	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colapse	Lifted off/missing	110.4565837	-7.667546498
12	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Building clearly visible/Building still stands	No collapse	No damage on roof	110.4652636	-7.657077625
13	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Building clearly visible/Building still stands	No collapse	Partialy lifted off or major damage on roof tile	110.4616126	-7.656465589
14	CANGKRINGAN	ARGOMULYO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colapse	Lifted off/missing	110.4617828	-7.656243681

Nr	FileName	Latitude (Lat)	Longitude (Lon)	Ele (m)	Dir	FOV	Geotagged photograph attributes: Latitude	Longitude	TimeStamp	DateStamp	Elevation	PhotoDirec	Make	Model	Software
1	GeoJot 2012-10-29 09_56_49.jpg	-7.6649594	110.4557705	428	286.5	42	S 7° 39' 54"	E 110° 27' 21"	10:04:29 AM	10/29/2012	428 m	287° WNW	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
2	GeoJot 2012-12-13 17_00_11.jpg	-7.6623845	110.4634094	460	196.2	42	S 7° 39' 45"	E 110° 27' 48"	5:01:36 PM	12/13/2012	460 m	196° SSW	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
3	GeoJot 2012-10-04 14_43_06.jpg	-7.656666	110.4649544	465	126.3	42	S 7° 39' 24"	E 110° 27' 54"	2:50:23 PM	10/4/2012	465 m	126° SE	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
4	GeoJot 2012-11-01 14_25_49.jpg	-7.6558292	110.4628301	485	61.8	42	S 7° 39' 21"	E 110° 27' 46"	2:33:32 PM	11/1/2012	485 m	62° ENE	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
5	GeoJot 2012-10-04 15_03_11.jpg	-7.6556575	110.462594	481	116.5	42	S 7° 39' 20"	E 110° 27' 45"	3:10:28 PM	10/4/2012	481 m	117° ESE	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
6	GeoJot 2012-10-04 14_11_12.jpg	-7.6555073	110.4650831	486	223.9	42	S 7° 39' 20"	E 110° 27' 54"	2:18:28 PM	10/4/2012	486 m	224° SW	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
7	GeoJot 2012-11-01 13_41_15.jpg	-7.656312	110.4615641	481	354.7	42	S 7° 39' 23"	E 110° 27' 42"	1:48:59 PM	11/1/2012	481 m	355° N	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
8	GeoJot 2012-10-04 15_57_11.jpg	-7.6561081	110.4617357	484	310.0	42	S 7° 39' 22"	E 110° 27' 42"	4:04:28 PM	10/4/2012	484 m	310° NW	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
9	GeoJot 2012-11-01 13_46_36.jpg	-7.6561725	110.4613066	482	355.3	42	S 7° 39' 22"	E 110° 27' 41"	1:54:20 PM	11/1/2012	482 m	355° N	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
10	GeoJot 2012-12-13 17_03_41.jpg	-7.6622128	110.4630876	517	180.6	42	S 7° 39' 44"	E 110° 27' 47"	5:05:06 PM	12/13/2012	517 m	181° S	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
11	GeoJot 2012-12-09 15_49_32.jpg	-7.6676309	110.4566932	409	339.6	42	S 7° 40' 03"	E 110° 27' 24"	3:50:53 PM	12/9/2012	409 m	340° NNW	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
12	GeoJot 2012-10-04 14_37_01.jpg	-7.6570094	110.4653192	473	239.0	42	S 7° 39' 25"	E 110° 27' 55"	2:44:18 PM	10/4/2012	473 m	239° WSW	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
13	GeoJot 2012-11-01 13_41_56.jpg	-7.6563442	110.4616284	480	198.7	42	S 7° 39' 23"	E 110° 27' 42"	1:49:41 PM	11/1/2012	480 m	199° SSW	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
14	GeoJot 2012-10-04 15_56_23.jpg	-7.6561189	110.4618859	485	194.0	42	S 7° 39' 22"	E 110° 27' 43"	4:03:40 PM	10/4/2012	485 m	194° SSW	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]

Nr	MagneticDe	Pitch	Roll	MeasureMod	Status	ExposureTi	FNumber	ISOSpeedRa	FocalLengt	MapDatum	Building visibility n collapse (Building)	Mainstructure (Mainstruct)	Wall	Roof	Windows	Fence	Supporting component (Supporting)	Functionality (Functional)	Damage percentage (Damageperc)	Hazard	Damage level (Damage_Lev)	Note
1	1.2°	0.5°	-1.6°	3D	Fixed	3/2500"	f/2.8	100 ISO	4.42 mm	WGS-84	Still stands/no collapse	Small part damage	Crack in plaster walls	No damage	Blown out but frame intact/burnt		Many damage	Relatively can be functioned	30 - 70 %	Lahars	Medium damage	
2	1.2°	2.0°	-2.1°	3D	Fixed	87/2500"	f/2.8	100 ISO	4.42 mm	WGS-84	Still stands/no collapse	Minor damage	No damage	Partialy burned/lifted	Blown out but frame intact/burnt		Small part damage	Relatively can be functioned	30 - 70 %	Pyroclastic Surges	Medium damage	
3	1.2°	-3.2°	-1.1°	3D	Fixed	1/625"	f/2.8	100 ISO	4.42 mm	WGS-84	Partially collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Blown out but frame intact/burnt		Many damage	Harm	> 70 %	Pyroclastic Surges	Heavy damage	Heavy damage by lahars in 2011
4	1.2°	2.1°	-1.5°	3D	Fixed	3/2500"	f/2.8	100 ISO	4.42 mm	WGS-84	Still stands/no collapse	No damage	No damage	No damage	Small part broken/burnt		No damage	Can still function	< 30 %	Pyroclastic Surges	Slightly damage	
5	1.2°	-0.1°	0.5°	3D	Fixed	3/2500"	f/2.8	100 ISO	4.42 mm	WGS-84	Still stands/no collapse	No damage	No damage	Minor damage	Small part broken/burnt		Small part damage	Can still function	< 30 %	Pyroclastic Surges	Slightly damage	
6	1.2°	-1.6°	-1.1°	3D	Fixed	3/2500"	f/2.8	100 ISO	4.42 mm	WGS-84	Partially collapse	Small part damage	Most broken/cracked/removed	Minor damage	Blown out but frame intact/burnt		Many damage	Harm	> 70 %	Pyroclastic Surges	Heavy damage	
7	1.2°	-1.4°	-2.3°	3D	Fixed	7/5000"	f/2.8	100 ISO	4.42 mm	WGS-84	Still stands/no collapse	No damage	No damage	Partialy burned/lifted	Small part broken/burnt		Small part damage	Can still function	< 30 %	Pyroclastic Surges	Slightly damage	
8	1.2°	-4.6°	-1.9°	3D	Fixed	19/10000"	f/2.8	100 ISO	4.42 mm	WGS-84	Still stands/no collapse	No damage	No damage	Minor damage	Small part broken/burnt		Small part damage	Can still function	< 30 %	Pyroclastic Surges	Slightly damage	
9	1.2°	2.5°	-2.4°	3D	Fixed	33/10000"	f/2.8	100 ISO	4.42 mm	WGS-84	Still stands/no collapse	No damage	No damage	No damage	No damage		Small part damage	Can still function	< 30 %	Pyroclastic Surges	Slightly damage	
10	1.2°	-1.4°	-2.1°	3D	Fixed	189/10000"	f/2.8	100 ISO	4.42 mm	WGS-84	Still stands/no collapse	No damage	No damage	Minor damage	Blown out but frame intact/burnt		Small part damage	Can still function	< 30 %	Pyroclastic Surges	Slightly damage	
11	1.2°	-3.5°	-2.3°	3D	Fixed	209/10000"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Lahars	Heavy damage	
12	1.2°	-2.4°	-1.0°	3D	Fixed	3/2500"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Many damage	Harm	> 70 %	Lahars	Heavy damage	Heavy damage by lahars in 2011
13	1.2°	-8.1°	-2.1°	3D	Fixed	13/10000"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Partialy burned/lifted	Blown out but frame intact/burnt		Totally damage	Harm	> 70 %	Pyroclastic Surges	Heavy damage	
14	1.2°	-20.8°	-1.4°	3D	Fixed	11/5000"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Flows	Heavy damage	

Nr	Sub-district	Village	Landcover	Landuse	Remote Sensing Interpretation (High-resolution satellite imagery): Building Visibility (Visibility)	Building collapse (B_collapse)	Building roof (B_roof)	Building Coordinate (Center of Polygon): Longitude	Latitude	FileName	Latitude (Lat)	Longitude (Lon)	Ele (m)	Dir	FOV	Latitude	Longitude	TimeStamp	DateStamp	Elevation	PhotoDirec	Make	Model	Software
222	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colappse	Lifted off/missing	110.4528236	-7.602512052	GeoJot 2012-11-09 11_14_41.jpg	-7.6025176	110.4528737	902	253.5	42	S 7° 36' 09"	E 110° 27' 10"	11:15:35 AM	11/9/2012	902 m	254° WSW	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
223	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colappse	Lifted off/missing	110.4548365	-7.602408492	GeoJot 2012-11-13 15_47_56.jpg	-7.6021314	110.4548049	902	184.0	42	S 7° 36' 08"	E 110° 27' 17"	3:48:53 PM	11/13/2012	902 m	184° S	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
224	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Building unclearly visible/building can still be identified	Totally colappse	Lifted off/missing	110.4480695	-7.602363663	GeoJot 2012-11-14 10_15_19.jpg	-7.6024747	110.4480028	881	18.3	42	S 7° 36' 09"	E 110° 26' 53"	10:16:16 AM	11/14/2012	881 m	18° NNE	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
225	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colappse	Lifted off/missing	110.4545659	-7.602322563	GeoJot 2012-11-13 15_44_29.jpg	-7.6022387	110.4545045	908	153.8	42	S 7° 36' 08"	E 110° 27' 16"	3:45:25 PM	11/13/2012	908 m	154° SSE	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
226	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colappse	Lifted off/missing	110.4534146	-7.602152081	GeoJot 2012-11-09 11_17_55.jpg	-7.6020777	110.4534101	907	351.3	42	S 7° 36' 07"	E 110° 27' 12"	11:18:48 AM	11/9/2012	907 m	351° N	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
227	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colappse	Lifted off/missing	110.4527236	-7.602143054	GeoJot 2012-11-09 11_12_55.jpg	-7.6023245	110.4528952	901	263.7	42	S 7° 36' 08"	E 110° 27' 10"	11:13:48 AM	11/9/2012	901 m	264° W	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
228	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colappse	Lifted off/missing	110.4525641	-7.602091108	GeoJot 2012-11-09 11_26_19.jpg	-7.6019597	110.4527235	908	257.2	42	S 7° 36' 07"	E 110° 27' 10"	11:27:11 AM	11/9/2012	908 m	257° WSW	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
229	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colappse	Lifted off/missing	110.4522314	-7.601960353	GeoJot 2012-11-09 11_31_00.jpg	-7.6019812	110.45223	907	309.6	42	S 7° 36' 07"	E 110° 27' 08"	11:31:53 AM	11/9/2012	907 m	310° NW	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
230	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colappse	Lifted off/missing	110.4521601	-7.601964422	GeoJot 2012-11-09 11_31_40.jpg	-7.6019704	110.4521656	907	60.9	42	S 7° 36' 07"	E 110° 27' 08"	11:32:33 AM	11/9/2012	907 m	61° ENE	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
231	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colappse	Lifted off/missing	110.4530818	-7.602000336	GeoJot 2012-11-09 11_25_21.jpg	-7.6017773	110.4529166	907	180.1	42	S 7° 36' 06"	E 110° 27' 10"	11:26:14 AM	11/9/2012	907 m	180° S	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
232	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colappse	Lifted off/missing	110.4539693	-7.601940111	GeoJot 2012-11-09 11_20_46.jpg	-7.6017666	110.4534745	910	89.3	42	S 7° 36' 06"	E 110° 27' 13"	11:21:39 AM	11/9/2012	910 m	89° E	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
233	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colappse	Lifted off/missing	110.4543711	-7.601920403	GeoJot 2012-11-13 15_41_44.jpg	-7.6020455	110.4544401	905	330.5	42	S 7° 36' 07"	E 110° 27' 16"	3:42:40 PM	11/13/2012	905 m	331° NNW	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
234	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Vanish/not visible	Totally colappse	Lifted off/missing	110.4536414	-7.601874827	GeoJot 2012-11-09 11_19_49.jpg	-7.6019382	110.453496	909	38.3	42	S 7° 36' 07"	E 110° 27' 13"	11:20:42 AM	11/9/2012	909 m	38° NE	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]
235	CANGKRINGAN	KEPUHARJO	Compacted clay surface	Rural settlement	Building unclearly visible/building can still be identified	Totally colappse	Lifted off/missing	110.4485117	-7.601670068	GeoJot 2012-11-14 10_20_11.jpg	-7.6017773	110.4482388	879	37.0	42	S 7° 36' 06"	E 110° 26' 54"	10:21:09 AM	11/14/2012	879 m	37° NE	Motorola Mobility	Xoom	GPS-Photo Link Version:5.2 [D]

Nr	Geotagged photograph attributes: MagneticDe	Pitch	Roll	MeasureMod	Status	ExposureTi	FNumber	ISOSpeedRa	FocalLengt	MapDatum	Building visibility n collapse (Building)	Mainstructure (Mainstruct)	Wall	Roof	Windows	Fence	Supporting component (Supporting)	Functionality (Functional)	Damage percentage (Damageperc)	Hazard	Damage level (Damage_Lev)	Note
222	1.2°	-8.3°	-2.4°	3D	Fixed	13/10000"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Flows	Heavy damage	
223	1.2°	-4.9°	-0.4°	3D	Fixed	1/250"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Flows	Heavy damage	
224	1.2°	-4.2°	-1.0°	3D	Fixed	7/5000"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Blown out but frame intact/burnt		Totally damage	Harm	> 70 %	Pyroclastic Surges	Heavy damage	
225	1.2°	-5.2°	-0.2°	3D	Fixed	23/5000"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Flows	Heavy damage	
226	1.2°	-2.9°	-1.2°	3D	Fixed	1/625"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Flows	Heavy damage	
227	1.2°	-5.9°	-1.3°	3D	Fixed	7/5000"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Flows	Heavy damage	
228	1.2°	-1.3°	-2.2°	3D	Fixed	1/625"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Surges	Heavy damage	
229	1.2°	-9.0°	-0.9°	3D	Fixed	7/2500"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Flows	Heavy damage	
230	1.2°	-7.1°	-0.6°	3D	Fixed	9/5000"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Surges	Heavy damage	
231	1.2°	-5.9°	-1.8°	3D	Fixed	7/5000"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Flows	Heavy damage	
232	1.2°	-10.1°	0.2°	3D	Fixed	3/2500"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Flows	Heavy damage	
233	1.2°	-0.3°	-1.9°	3D	Fixed	67/10000"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Flows	Heavy damage	
234	1.2°	-4.7°	0.3°	3D	Fixed	3/2000"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Imploded and frame missing		Totally damage	Harm	> 70 %	Pyroclastic Flows	Heavy damage	
235	1.2°	-2.7°	-0.8°	3D	Fixed	1/625"	f/2.8	100 ISO	4.42 mm	WGS-84	Not visible, totally collapse or large collapse	Large part damage	Most broken/cracked/removed	Lifted off/missing	Blown out but frame intact/burnt		Totally damage	Harm	> 70 %	Pyroclastic Surges	Heavy damage	