MAPPING EARTHQUAKE HAZARD BY USING GIS AND MULTI-CRITERIA ANALYSIS IN BANTUL REGENCY

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ABSTRACT

Earthquakes are natural events that are difficult to predict and are always causing casualties or major damage. The concept of mitigation associated with the earthquake hazard requires a hazard map that can be used as the basis of land use regulation in order to avoid casualties in case of disaster. Map of the earthquake hazard have been prepared based on a combination of geologic map information; lithology (rock structure) map, earthquake intensity map, slope map, and a map of fault lines. GIS Method of multi-criteria analysis is used as a means of model simulation. The result of the disaster analysis map shows 13% of the area categorized as low or very prone to stability in case of earthquakes, with the main factor is the existence of fault lines. The result of comparison with previous studies showing there is a similarity level of damage and disaster map analysis, with notes need to increase the level of detail map geological information to improve the accuracy of maps of disaster.

Keywords: earthquake, hazard, GIS, multi-criteria analysis

ABSTRAK

Gempa adalah kejadian alam yang sulit diprediksi dan selalu menimbulkan korban jiwa maupun kerusakan yang besar. Konsep mitigasi terkait dengan bencana gempa bumi memerlukan sebuah peta bahaya yang bisa dijadikan dasar pengaturan penggunaan lahan dengan tujuan menghindari korban jika terjadi bencana. Peta bencana gempa bumi disusun berdasarkan kombinasi peta informasi geologi yaitu peta litologi (struktur batuan), peta intensitas gempa, peta kelerengan, dan peta jalur patahan. Metode GIS multi-kriteria analisis digunakan sebagai alat simulasi model . Hasil peta analisis bencana menunjukan 13% area masuk kategori stabilitas rendah atau sangat rawan jika terjadi gempa bumi, dengan faktor utama yaitu keberadaan jalur patahan. Hasil komparasi dengan studi-studi sebelumnya menunjukan ada kesamaan tingkat kerusakan dan peta bencana hasil analisis, dengan catatan perlu adanya peningkatan tingkat kedetailan peta informasi geologi untuk meningkatkan akurasi peta bencana.

Kata kunci: gempa bumi, rawan, SIG, analisa multi kriteria

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INTRODUCTION

Earthquakes are considered as natural hazards, which become the main interest of environment experts. Impacts of earthquakes are producing environment physical damage until cause of death. Refers to BNPB (2007), the impact of earthquake caused at least 120.000 death victims among 2002 up to 2006. That impact also brought economic loss and regional development incline. Experiences in Aceh tsunami (2004), Yogyakarta earthquake (2006), and the newest occurrence in Padang (2009) made experts to reach solution to minimize the impacts of earthquake. Mapping the earthquake hazard potential should be done first in mitigation concept to identify susceptibility area when earthquake hazard occurs. Earthquake hazard map developed by combination of geological information, which used combination between GIS and multi-criteria analysis method. The hazard map was represented from ground stability factor, which depend on 4 (four) main factors; litology/rock structure, earthquake intensity, slope, and existing fault. The hazard map result has benefit to identify susceptible location from earthquake evidence, also give input to decision maker for land use arrangement and regulation.

Objectives of Research

The objectives of research is to identify the criteria for hazard factors in earthquake phenomena, and combining the criteria by using GIS capability and comparing with actual evidence, which represent with the number of victims and damage structure.

Location of Research

Location of research is located in the Bantul Regency, Yogyakarta Province. The coordinate geographic position is in latitude 07°44'04"- 08°00'27" S, and longitude between 110°12'34"- 110°31'08 E. The capital city of Bantul Regency located in sub district Bantul. Bantul regency consists of 17 sub districts. Bantul regency has boundary with Yogyakarta and Sleman City in north, Gunung Kidul in east, Kulon Progo in west, and Indian Ocean in south (Figure1).

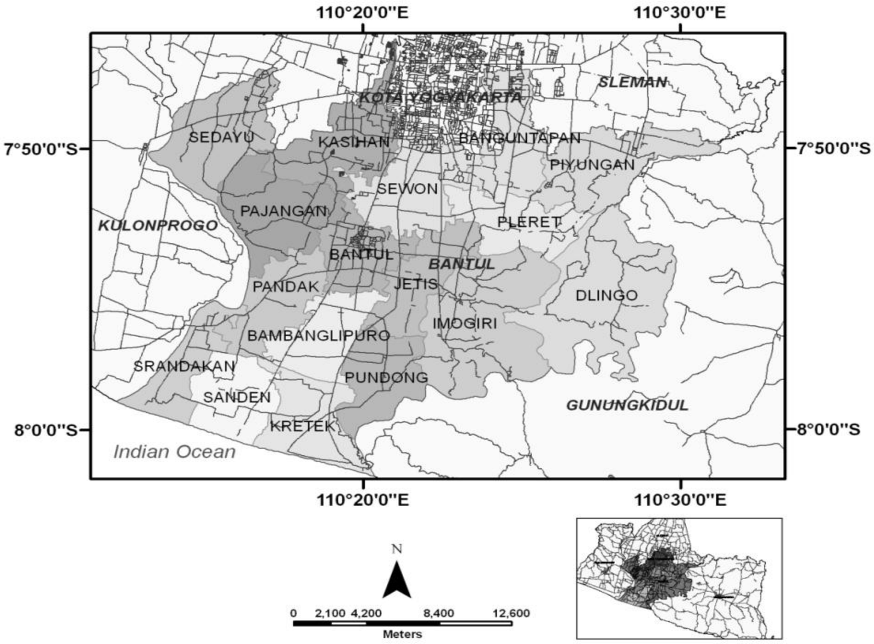

Figure 1: Location of Research

METHODOLOGY

The method of research mapping earthquake hazard is shown in figure 2. First part research method is to review and identify hazard potential factor. Rock structure (litology), slope (and relief), earthquake intensity, and existing of fault are the most affected when earthquake occurs observed from ground stability context. Those factors were selected and examined by geological experts, which was explained in manual of spatial planning for mountain eruption vulnerability area, and earthquake vulnerability area develop by ministry of public work (Table 1).

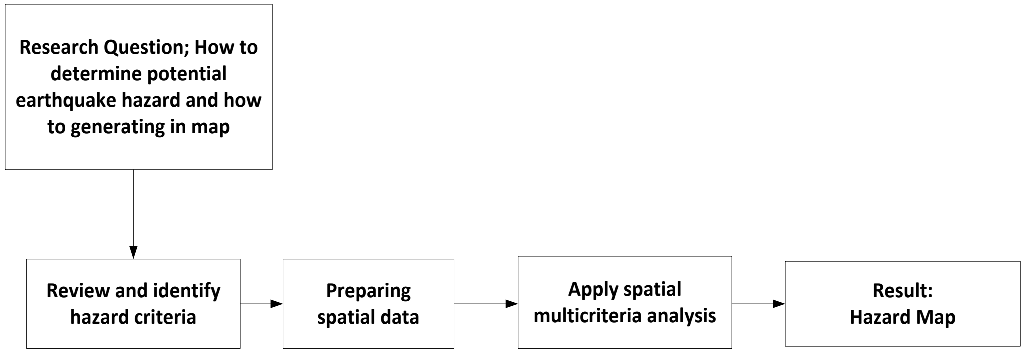

Figure 2: Schematic diagram of ground stability mapping methodology

Table 1: Main data hazard research

No.	Information	Type of Data	Scale	Source	Year of Published
1.	Rock Structure	Polygon	1:100,000	ESDM 1)	2007
2.	Slope	DEM	30 X 30 meters	SRTM 2)	2007
3.	Earthquake Intensity	Polygon	1:100,000	ESDM	2007
4.	Existing Fault	Polygon	1:100,000	ESDM	2007

1) Ministry of Mineral Resources and Energy – Republic of Indonesia, Center for Volcanology & Geological Hazard Mitigation.
2) Shuttle Radar Topographic Mission (SRTM). 30 meter spatial resolution. http://www2.jpl.nasa.gov/srtm/dataprod.htm.

Hazard Analysis

Simple weighted method was used to produce hazard vulnerability map, compose geological spatial information which has score and weighted value based on reference. The combination between score and weighted value in geological information determines the level of ground stability. Ministry of Public Work Government of Indonesia (2007) has classified the level of stability into 3 (three) classes which are; not stable, less/moderate stable, and stable. Each class has cumulative score based on the combination between attribute values in geological information. The equation of hazard analysis related with ground stability shows below:

$H_z = \sum W_{RSi\text{-}n} +. W_{SLi\text{-}n} + W_{Ei\text{-}n} + W_{GSi-n}$

Where;

H_z = Hazard zone based on ground stability, resulted by weighted overlay in GIS

$W_{RSi\text{-}n}$ = Total weight rock structure

$W_{SLi\text{-}n}$ = Total weight slope

$W_{Ei\text{-}n}$ = Total weight earthquake intensity

W_{GSi-n} = Total weight geological structure

Ground Stability Score Rating

The level of ground stability rating divided into 3 (three) categories; high stability, less stability, and low stability, which has range value for each category (table 2). The total maximum score is 60, and for minimum score is 15.

Table 2: Total Score Classes

Classification of Stability	Rating Score
High Stability	15 - 30
Less (Moderate) Stability	31 – 45
Low Stability	46 – 60

GIS Analysis Process

GIS process in hazard assessment used raster based and raster analysis to produce hazard map. The assigned of score and weight for each criteria used reference which produce by ministry of public work with title manual of spatial planning mountain eruption vulnerability area, and earthquake vulnerability area year 2007.

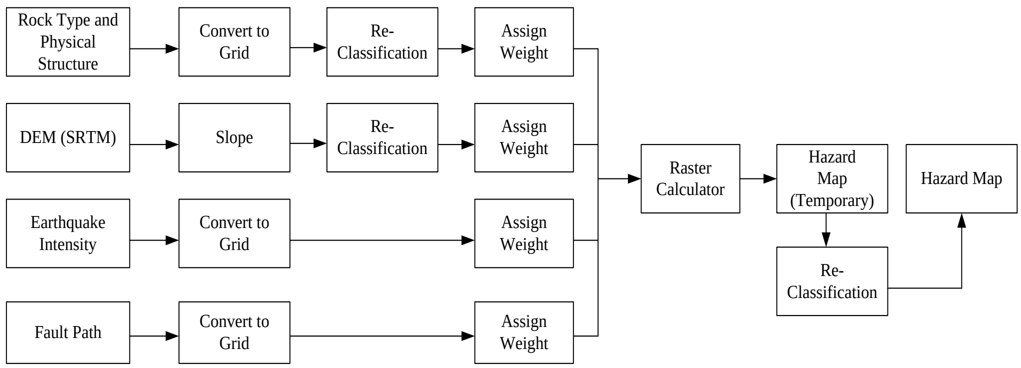

Figure 3: Schematic diagram GIS process

RESULT AND DISCUSSION

Statistical hazard zone describes the majority level of ground stability is medium. The second majority of ground stability is high stability, and then the rest is low stability (Figure 5). Those facts describe half area should be considered carefully from earthquake hazard, especially for low and medium stability area. The explanation is the combination of earthquake intensity factor and fault impact area causes medium and high value.

The point of interest in this research is a very hazardous area which located in line with Opak's fault. The impact of earthquake in fault line caused heavy damage for structure in the surface. Closeness to fault line area cannot be avoided although we have implemented high technology for structure, in the same manner as explained by Bell (1999). Totally 13% hazardous areas (Figure 6) are close or get high impact from fault line, and in fact that area is majority classified into settlement area. In example, by used overlay between google earth image and fault layer shown in district of Pleret where passed by fault line, which has high density for settlement distribution (Figure 7).

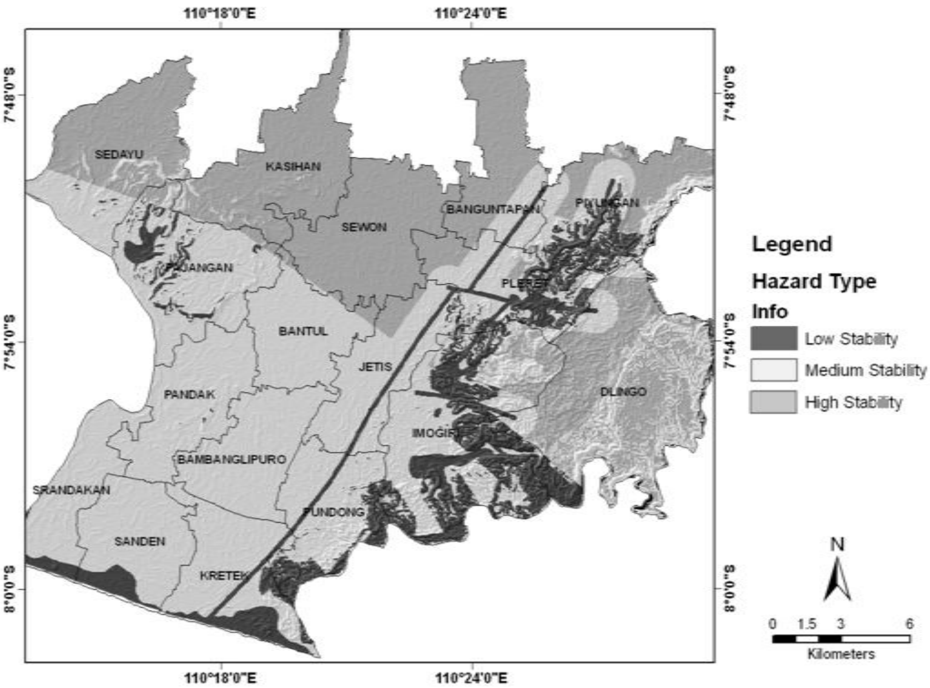

Figure 5: Hazard Map

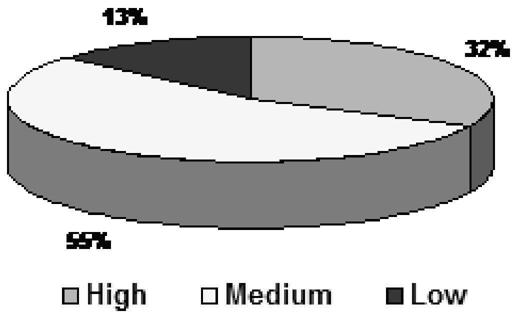

Figure 6: Percentage level of ground stability in research area

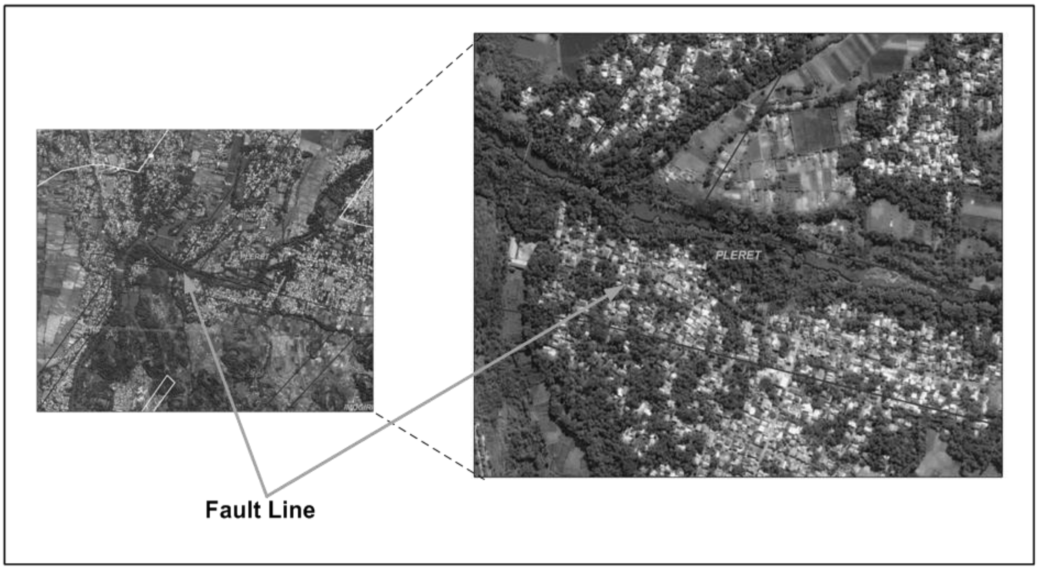

Figure 7: Area where is in place fault line (area insert in double red line)

The proportion analysis for hazard level in every sub districts shows overall ranking for hazard level. To identify the hazardous area, we started from areas which have low ground stability. Imogiri, Pleret, Pundong, Piyungan, Kretek, Srandakan, Dlingo, Banguntapan, Sedayu, Pandak, and Bambanglipuro are classified into potential hazardous area (Figure 8). Especially in Imogiri, Pleret, Pundong, Kretek, Piyungan, they have low ground stability more than 20 percent (Figure 8).

The second hazardous areas are located and distributed in almost whole Bantul area. The most area which covered by medium ground stability are Bambanglipuro, Pandak, Bantul, Srandakan, Sanden, Jetis, Pajangan, and Pundong. Those areas have medium stability area percentage of over 50% and may even exist over 90%. The medium ground stability area means that area has less ground stability, or it cannot be defined as permanent stable area.

The high stability area in research study is represented by districts of Sewon, Kasihan, Banguntapan, Sedayu, and Dlingo (Figure 8). Those areas have over 50% which classified into stable area. The affecting factors relates to stability areas are the physical characteristic areas which haven't fault line, flat topography, and the compactness of rock structure.

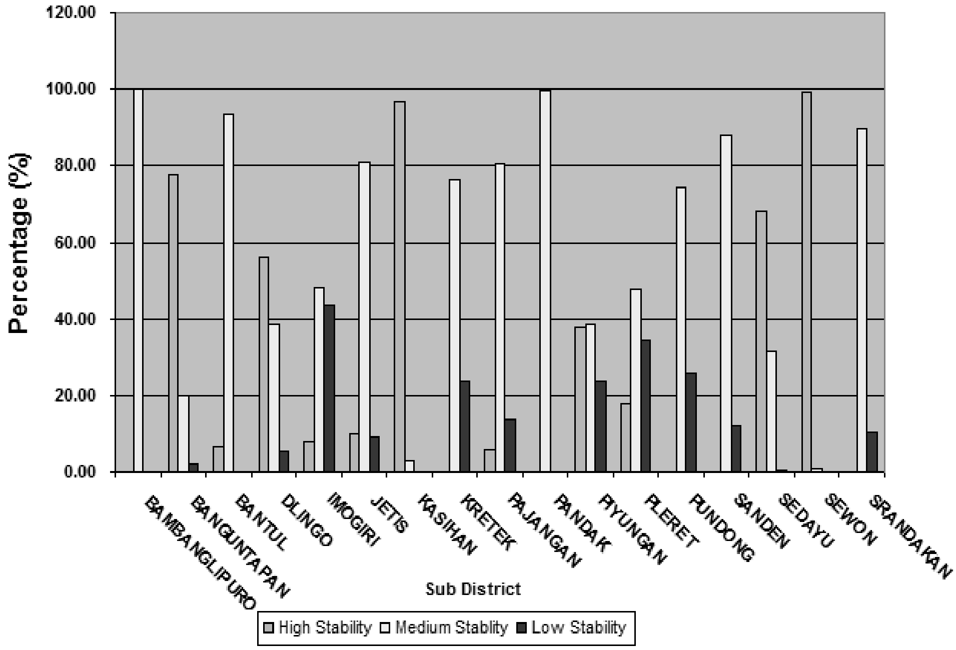

Figure 8: Proportion of Ground Stability in Every Districts

Several areas should get attention although classified into stable area. For example, Dlingo, Piyungan, Pajangan, and Pleret also have low stability area. The level of earthquake intensity for stable area is still classified in dangerous situation; in level V to VI MMI can be felt by all and low to medium potential damage for structure and built up environment, that mean in high stability area did not free from earthquake threat.

Comparative model with previous field studies

Although several locations such as Sewon, Kasihan, and Banguntapan are classified into high stability, they are not totally free from earthquake impact. The previous earthquake research and evidence shown in Bantul and whole Jogjakarta Province are susceptible from earthquake hazard. That fact can be described in pre-assessment damage area developed by United Nations Institute for Training and Research (UNITAR) in 2006, which the damage impact of earthquake was distributed in random (Figure 9).

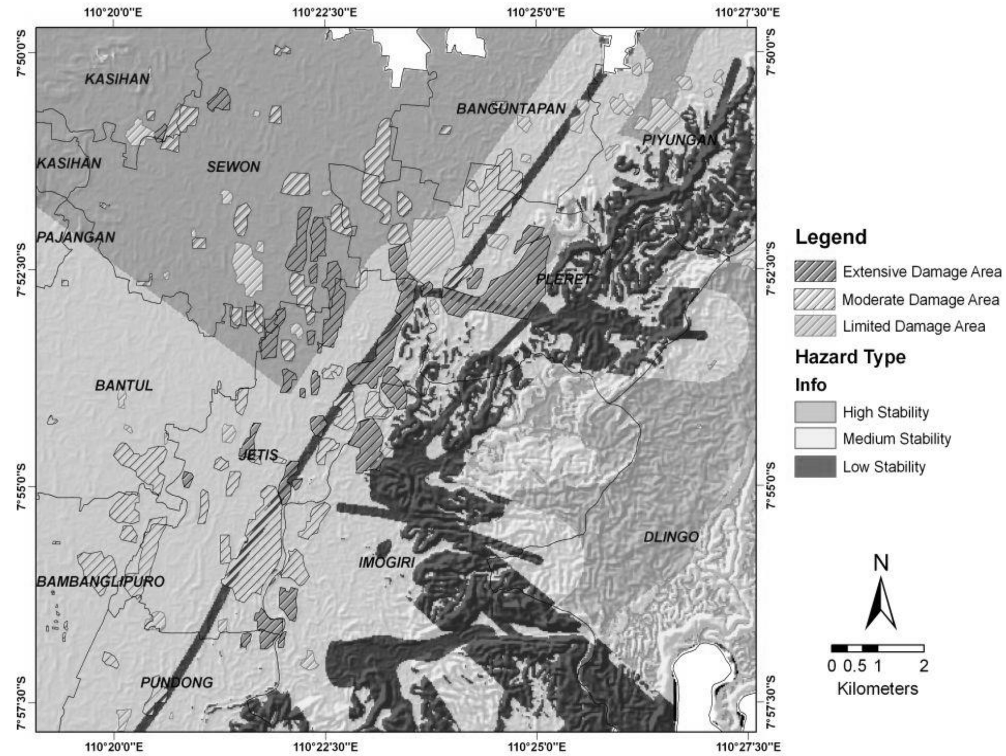

Figure 9: Map of Pre Assessment Damage Area by UNITAR Overlay with Hazard Map

The location of damaged area was majority classified into medium and low stability area. District of Jetis, Pleret, Imogiri, Piyungan, Pundong and Banguntapan has low stability area which influenced from fault line location. The conditions exacerbated by the number of activities centered in the area, for example District of Jetis, Pleret, and Banguntapan has many economic activities and settlement area. Those districts have attached Opak's fault lines which right in the location of economic activity and population settlements.

Ground checking activity used GPS shown that the location of damage is similar to the observation by UNITAR in 2006 (Figure 10). Two kind's data was used, first developed by EERI which code naming L1 to L6 in 2006, and field survey activities part of this research in June 2009. Activity field survey in June 2009 showed the former location of damage in some places, which coded naming M1 up to M33 (Figure 10). Implementation of a survey conducted with the help of local community guide in several districts. The former location of damage distributed in some locations such as District of Pundong, Jetis, Imogiri, Pleret, Piyungan, and Banguntapan. The survey results in 2006 did not much different results in 2009 survey, which location affected by earthquake.

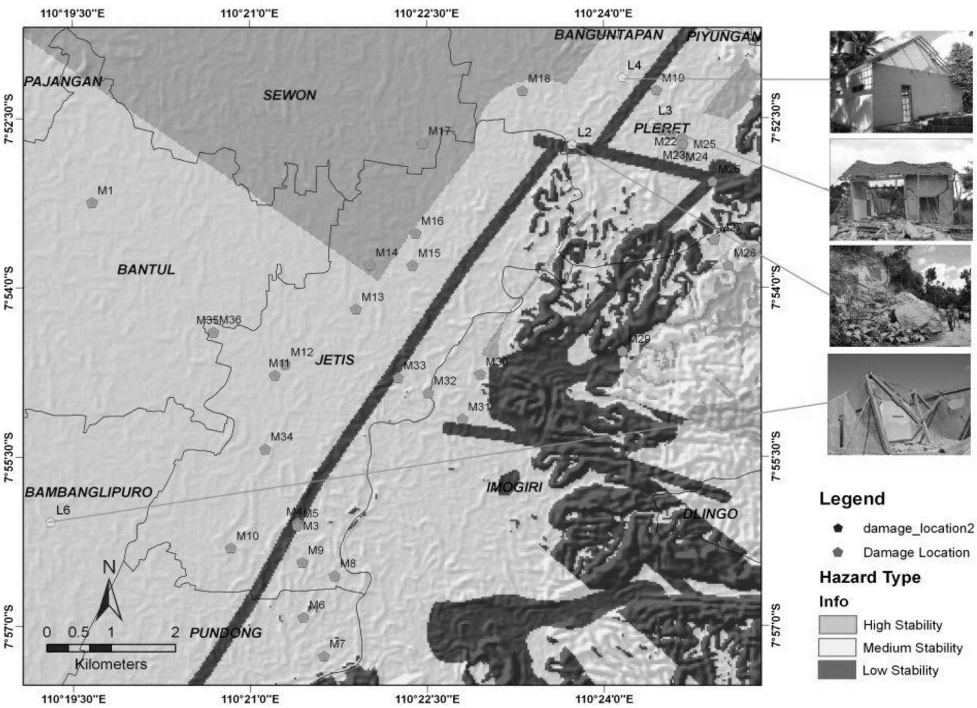

Figure 10: Damaged Location Acquired by GPS Overlay with Hazard Map

CONCLUSION

The conclusion are described and structured in line with objective of this research.

- Based on the map analysis, the high stability of the land due to absence of fault factors in addition to steep slopes and rock structures that support. Areas categorized as having a high degree of stability such as District of Sewon and Kasihan.

- Fault way is a major factor in increasing the value of disaster of a region, this is evidenced by the number of victims killed or injured and damage to buildings. Area through which the fault lines and has a medium and high-level disaster exemplified in the district of Pundong, Imogiri, Pleret, Piyungan, and Banguntapan.
- The second cause of a decreased level of ground stability is influenced by factors of slope, where the steep slope increase disaster factor. Slope factor as stated in earlier studies may lead to further disasters in the form of landslides or rock avalanches. Imogiri are examples of areas with steep slopes that have a low degree of ground stability.
- The resulting map is still too general as this disaster database, because there is still no availability of data in detail scale, for example 1:25000 or 1:10000 map scale. Another constraint related with map accuracy is differences in map scale, which led to a general outcome.
- Determination of criteria for disaster needs further study include the use of scoring and weighting that may only be applied in the study area.

RECOMMENDATION

Some recommendations for further investigation are related to identifying earthquake hazard;

1. It is necessary to scale geological map in more detail to improve the accuracy of hazard prone areas.
2. Necessary to identify early on the impact of further disasters like landslides due to earthquake such as landslide, ground rapture, and liquefaction.

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