Applying Remote Sensing Technology and Geographic Information System in Batu, East Java

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Abstract This research is aimed to map potential landslide areas, identify types of landslide, and draw a map of potential landslide level. This research was carried out in Batu, East Java. The research design that was used in the study was image interpretation of Landsat 7 Band 432 Satellite and primary data of the landslide causes (the data of soil and rocks, map interpretation, and variable scoring of landslide). ArcGIS 9.3 and ArcView 3.2 software was used for map analysis. The researcher also analyzed the soil texture, permeability and land plasticity index, bedding, weathering level, the density of joints, the depth of weathering, the existence of springs, slopes, and slope cutting. The research findings showed that the image of Landsat 7 Bands 432 in 1:11.000 – 1:15.000 scale could be used to interpret land use and land cover. Interpreted land use included housing, bare soil, irrigated rice field, rain fed rice field, moor, nursery area, garden, slope failure, natural forest, sengon forest, pine forest, and agro forestry.

Keywords: landsat image, land units, landslide, potential landslide, map of potential landslide.

1. Introduction

Landslide is land movement process, in which the soil moves vertically due to gravity-. The landslide can happen as the result- of heavy rain, steep slope, wea- thering,- variety of rock and geological structu-re-, and inappropriate land use [Malamud et al, 2004; Nasikh, 2016; Nasikh, 2017]. The landslide-usually occurs in the rainy season. As a result, its effect does not only happen on site, but also off site. The common effect of the landslide is huge number of sedimentation- [Serodio, 2005; Heru et al, 2014 ].

Basically, the landslide occurs as the result- of slope imbalance. The imbalance appears- as the result of internal and external forces of the slope [Chen, 2012; Anung and B.G.C.M [Bart, 2014]. External force of the slope is influenced by the slope, water, and land use change. Internal force of the slope is affected by the physical characteristic of the land itself [Dwikornita et al, 2009; Amar, 2012]. Slope is an angle made by plains and hori-zontal- land which is measured in percentage or degrees. The steeper the land, the more possibility the landslide happens. Physical characteristics which influence the landslide are land contour, permeability, and soil plasticity index. Those- qualities are determined by the host rock itself [Nasikh, 2013; Sutanto, 2010; Yigang et al, 2015; Qian et al, 2015].

Potential landslide area mapping is a start to reduce the risk of landslide. Thus, the problem appearing in this study is how to map potential landslide area in Batu, East Java. This study is aimed to recognize at least four things. First, it is to identify how clear the image of Landsat 7 Band 423 in 1:11.000 and 1:15.000 scale to interpret the landslide variables in Batu, East Java. Second, it is to identify land unit type in Batu, East Java. Third, it is to map the landslide distribution in Batu, East Java. Last but not least, it is to identify how potential the landslide in Batu.
2. The Methods

This study was a descriptive survey explaining about map interpretation process and Landsat 7 Band 432 images to draw a map of potential landslide area. Laboratory-test towards soil sample included texture, permeability, and soil plasticity index-testing. Landsat 7 Band 432 image interpretations used on-screen interpretations, in which the images were displayed on computer screen and the manual interpretations was carried out by analyzing the print out. The landslide potential was scored based on the land unit and the characteristic of ten landslide variables. Those ten landslide variables were soil texture, permeability, soil plasticity index, bedding, weathering level, density of joints, depth of weathering, and existence of springs, slopes, and slope cutting. The table 1-11 shows the scoring of each landslide variable.

| Table 1. Soil Texture | Score |
|-----------------------|-------|
| Sand                  | 1     |
| Sandy loam, loamy sand| 2     |
| Loam, clay loam, sandy loam | 3     |
| Clay, sandy clay, sandy loam | 4     |

Source: Lallianthanga, 2014

| Table 2. Soil Permeability |
|-----------------------------|
| Coefficient (cm/hour) | Category | Score |
| ≥ 6,5                  | High-very high | 1     |
| 2 - 6,5                | Average    | 2     |
| 0,5 - 2,0              | Low        | 3     |
| < 0,5                  | Very low   | 4     |

Source: USDA, 1994

| Table 3. Plasticity Index |
|---------------------------|
| Liquid Limit (%) | Score |
| ≤ 11             | 1     |
| 11 - ≤ 18        | 2     |
| 18 - ≤ 30        | 3     |
| ≥ 30             | 4     |

Source: Andayani et al, 2008

| Table 4. Bedding |
|-----------------|
| Category | Score |
| Horizontal, straight, tilt in plain-sloped land (0-8%) | Good | 1 |
| Unstructured in steep slope (20%), sloping in sloped land (8-14%) | Fair | 2 |
| Tilt in hard and straight bedding in sloping land (8-20%) | Poor | 3 |
| Tilt in soft and straight bedding in sloping land (2-0%) | Very poor | 4 |

Source: Cranfield et al, 2006

| Table 5. Weathering |
|---------------------|
| Weathering Criteria | Category   | Score |
| No weathering, rock crystal | Fresh-unweathered | 1 |
| The weathering process occurs in the open discontinuity which causes color version | Lightly weathered | 2 |
| Less than a half of the material decomposed- and or disintegrated into the soil, the center of the rock is till fresh | Weathered | 3 |
| More than a half of the material decomposed- and or disintegrated; the middle rock comple-tely- turns into soil | Heavily weathered | 4 |

Source: Dackombe and Gardener, 1983
120

Figure 1. The Flowchart of Research Process

Table 6. Weathering Intensity

| Depth (cm) | Category          | Score |
|------------|-------------------|-------|
| ≤ 50       | Shallow           | 1     |
| 50 - ≤ 75  | Shallow enough    | 2     |
| 75 - ≤100  | Fair              | 3     |
| ≥100       | Deep-Very deep    | 4     |

Source: Zuidam, 1979

Table 7. Existence of Springs

| The Existence of Springs per Ha | Score |
|--------------------------------|-------|
| No spring                      | 1     |
| 1-2 springs                    | 2     |
| ≥2 springs                     | 3     |
| Leakage paths                  | 4     |

Source: Holland, 1992

Table 8. Slope

| Slope    | Category   | Score |
|----------|------------|-------|
| 0 – 7%   | Sloped     | 1     |
| 8 – 20%  | Wavy       | 2     |
| 20 – 55% | Steep      | 3     |
| ≥56%     | Very steep | 4     |

Source: Zuidam, 1979

Table 9. Slope Cutting and Excavation

| Depth and Excavation Location | Score |
|-------------------------------|-------|
| No excavation                 | 1     |
| Shallow in the peak/upper slope or fair in the peak | 2 |
| Shallow in lower slope/valley or deep in the peak/upper slope | 3 |
| Deep in lower slope/valley | 4 |

Source: Holland, 1992
To determine the landslide potential, there are ten variables used. The lowest potential is scored 10, while the highest one is 40. The landslide potential is classified into three classes. The interval of each class is determined by using formula.

\[ I = \frac{R}{N} \]

In which:

I: Class interval of landslide potential level
R: The highest – lowest landslide potential
N: The number of potential class

Based on the formula above, it is revealed that the class interval of landslide potential is:

\[ Interval = \frac{40 - 10}{3} = 10 \]

Based on the class interval, the classification of landslide potential level is Table 11.

Table 11. Criteria of Landslide Potential Level

| Class | Interval | Landslide Potential Level |
|-------|----------|---------------------------|
| I     | 10-19    | Low (L)                   |
| II    | 20-29    | Middle (M)                |
| III   | 30-40    | High (H)                  |

Source: The Researcher’s Calculation

3. Results and Discussion

The Landsat 7 Band 432 images interpretation in the research object

As it has been mentioned above, the Landsat 7 Band 432 image interpretation was carried out on-screen by displaying them on computer screen as well as interpreting- the print out. The interpretation-process used eight components of interpretation. They were colors, textures, shapes, patterns, height, shadows, and object site and image association. The images- were in some varieties of scales, from 1:11,000 up to 1:15,000. The images were recorded on November 31st 2012. Thus, it could be concluded that there was a few change in land cover up to now. The researcher chose Band 432 combination- due to its visible appearance. It appeared- at panchromatic spectrum, so the images’ appearances and colors were pretty similar to the real objects.

The process of image correction used geometric-correction. It was carried out by choosing four objects in the image and seeking those particular objects in the field. After that, the coordinates of those objects were recorded and plotted in earth map in 1:25,000 scales. Therefore, the coordinates of the images had been attached- to the map coordinate. Those processes- were carried out by using ArcView 3.2 software in coordinate transform- register menu. In the register process, the result was appeared RMS (Root Mean Square) error. It pointed to 0.71, which meant that the image coordinate was allowed to be used.

Based on the Landsat 7 Band 432 image interpretation, it was revealed that land use variable and land cover were two variables which directly seen in the images. It was concluded that those two variables were the easiest variable interpreted-. Another easiest variable interpreted- was relief pattern; due to its association with land use. From the relief pattern, it appeared river branch pattern. The pattern could be clearly seen because the rivers were also clearly appeared in the image. The soil color and texture were also interpreted. After that, it was delineated (making borders) in the land units. The land unit was used as the landslide potential measurement unit [Sutanto. 2010; Amar, 2012; Adewuyi. 2009].

The image interpretation was limited to object interpretation, in which it was the landslide variables themselves. These were: (1) land use and vegetation cover type, (2) slopes, (3) river pattern and flow density, (4) soil color, and (5) appearance of rock structure and land contour. Therefore, it could be concluded that from the ten variables mentioned in the re-search method, only five variables interpreted. Land texture, soil plasticity index, and land permeability were tested in laboratory. The depth of weathering and slope cutting was investigated directly in the field.

The table 12. shows the land use and land cover interpretation in Songgokerto, Batu with coordinate 665734 S and 9129209 E. According to the Landsat 7 Band 432 image interpretation, the interpreted land use objects were: 1) housing, 2) bare soil, 3) irrigated rice field, 4) rain fed rice field, 5) moor, 6) nursery area, 7) garden, 8) slope failure, 9) natural forests, 10) sengon forests, 11) pine forests, and 12) agro forestry.
Table 12. The Image Interpretation of Landsat 7 Band 432 in Songgokerto

| No. | Color  | Texture       | Shape          | Pattern      | Height | Shadow | Site                        |
|-----|--------|---------------|----------------|--------------|--------|--------|-----------------------------|
| 1   | Green  | Mild enough   | Well-shaped    | Regular      | 2.3 Ha | Yes    | Slope, roadside             |
| 2   | Light brown | Mild  | Square       | Regular      | 4 Ha   | No     | Roadside                   |
| 3   | Green  | Rough        | Uncategorized   | At the direction of the slope | - | Yes     | Slope                       |
| 4   | Green  | Mild enough  | Well-shaped    | At the direction of the slope | - | Yes     | Slope close to main road    |
| 5   | Green  | Rough        | Uncategorized   | At the direction of the slope | - | Yes     | Slope                       |

Source: Result of Data Processing, 2013

The Distribution of Landslide Potential

Based on the map analysis using intersect technique in the geoprocessing and layers overlay, it was concluded that there were 46 land units from the combination of 7 land shapes- and land use. The 46 land units consisted of 9 units of volcanic slope (V7), 13 units of Fluvial plains (F5), 6 units of tuff lava deposition (V5), 7 units of plains between mountains (D6), 5 units of lower volcanic slope (V4), 4 units of middle volcanic slope (V3) and 2 units of upper volcanic slope (V2).

According to the map overlay analysis and Landsat 7 Band 432 image interpretations, it could be concluded that there was no relation-ship- between land use and land shape. For example: forests were not always in V2, V3, or V4; forests could also be found in F5 and V7. Based on the scoring of the landslide variables, it was revealed that 12 units of land units were in low potency of landslide, 30 units of land units were in fair potency of landslide, and 4 units of land units were in high potency of landslide.

High potency of landslide was in V3 that was used for rice fields, gardens, and moors as well as V2 that was used for forest area. The width of the area was 39, 7556 Km² or 19.97% of the width of Batu. The middle volcanic slope’s land shape was spread in the west part of Batu, which were west Songgokerto, Puntun, Gu- nungsari and west Tulungrejo, west Pandesari, and west Pesanggrahan. Most of the land was used as forests, but not all of the, were well-conserved. Teras bangku became the most common conversation in this area. However, there were some forests cut and the land was not farmed.

According to the observation and measurement, the type of landslide in Gunungsari- village was debris fall. There was no exposed host rock in the land shape, so there were no impermeable layers which became the slip plane. The landslide occurred in slope with 36 degree. There were no shrubs in the forest because most of them were cut. The width of slope failure was 45 m².

A landslide in Batu-Pujon main road occurred because of the heavy rain. The type of this landslide was slide type, in which the layers of andesite rocks underneath the road became the slip plane. The slope was 56 degree—which was categorized as steep slope. The effect of this landslide was a half of the road disappeared 9 meters.

Mud-flow was found in Bulukerto village (the village was categorized as V4). The mud-flow appeared due to heavy rain and its slope was pointed at 16 degree. There was no water in dry season. The land was used as apple and oranges garden [Andayani, et al, 2008; Heru, et al, 2014].

Mid potential landslide was 128, 7574 km2 or about 68% of Batu width. The potency of landslide was in V5-Tg, V5-Kb, D6-Pk, V4-Pk, V3-Pk, V7-Kb, V7-Sw, V7-Tg, and V2-Ht. Villages in this area were Bumiaji, Pandanrejo, Sidomulyo, Bulukerto, Sumbergondo, Sisor, Temas, Songgokerto, Beji, Torongrejo, Giripurno, Ngaglik, Sumberejo, a little part of Oro-or Ombo, Pesanggrahan, Junrejo, Torongrejo,- Pendem, Beji, Mojorejo, Dadaprejo, and Tlekung.

Low potential landslide occurred in D6 which was used as housing, D5 that was used as housing, moor, garden, and bare soil. Villages in this area were west Pandesari, middle Tulungrejo, and south Sidomulyo. The width of low potential landslide was 30, 5745 Km² or 15, 35% of the width of Batu.

4. Conclusion

There are three potential landslide areas in Batu. Areas with high potential landslide were west Songgokerto, Puntun, Gunung Sari, and west Tulungrejo. 128, 7574 Km2 areas with mid potential landslide were Bumiaji, Pandanrejo, Sidomulyo, Bulukerto, Sumbergondo, Sisor, Temas, Songgokerto, Beji, Torongrejo, Giripurno, Ngaglik, Sumberejo, a few part of Oro-or Ombo, Pesanggrahan, Junrejo, Torongrejo, Pendem, Beji, Mojo-rejo, Dadaprejo, and Tlekung village. 30, 5745 Km2 areas with low potential land-slide were west Pandesari, mid Tulungrejo, and south Sidomulyo.
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