Aerial Photographs of Landslide on Clapar, Madukara District of Banjarnegara as a Spatial Geodatabase

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Abstract. Landslide is a natural disaster that commonly happen in Banjarnegara Regency. Spatial geodatabase is required to help understanding the landslide, planning for post-disaster recovery, even helping for prepare the upcoming disaster that may happen. The purpose of this research is for providing an orthophoto mosaic as high-resolution imagery and a Digital Surface Model (DSM), and compare it with Digital Model (DEM) generated from terrestrial surveying. The DSM and DEM were compared to see which method was the best to provide a precise spatial geodatabase in natural disaster spot, especially at Clapar’s Landslide.

Keywords: Aerial Photography, Digital Surface Model, Landslide, Spatial Geodatabase

1. Introduction
Landslide is defined as mass movement of material, such as rock, earth, or debris. This movement is primary affected by gravitation force. A rapid mass movement can cause human injury and loss in infrastructure, life, and assets. This event is described as disaster which frequently happens in area with hilly topography.

Landslide occurs in area with significant steepness of slope (around >15°). A slope with developedsoils, sufficient intensity of rainfall, and type or arrangement of rocks with dip angle will increase the possibilities of landslide event [6].

Banjarnekegara is one of the region which has frequent events of landslide. Since January 2015 until July 2017, 17 cases of landslide had been happening and causing more than 1200 people forcedly evacuating [2]. Topography with moderately steep condition and relatively high-intensity of rainfall become main factors for landslide in Banjarnegekara.

In March 25th 2016, a landslide attacked the small part of this region called Clapar Village, destroying houses, infrastructures, and plantations. This event causes a necessity of data and information of the landslide, yet due to the debris the access to the location is difficult to reach. Therefore, a technology is needed to facilitate the access to the location and data collecting effort.

Remote sensing has many methods and technologies that can be used to collect, map and extract information of landslide. Aerial photography is one of the propitious methods to gain landslide imagery with high-spatial resolution formatted in small scale area. UAVs (Unmanned Air Vehicles)
have become popular platform to facilitate this method by using sensor that has greater results than satellite imagery. UAVs also provide low altitude flight, effectiveness of time in gaining images, low cost budget than using satellite imagery, and less cloud disruption [5]. Recent advances show that the result of using UAVs also can be used to build Digital Model in surface or elevation basis based on overlapping imageries [8]. This method has been used in many researches related in various hazards mapping, such as validation of flood susceptibility map around Kudus region by[7]. Hence, using this method is suitable for accessing, extracting and collecting data and information about Clapar’s landslide.

This paper presents the use of aerial photography imageries provided by UAV to collect data of landslide area. The data processed into Digital Surface Model (DSM) which provides elevation information of the materials accumulated by the debris. The result is compared with DEM provided by terrestrial surveying in same study area. The comparison is done by looking at 3D models built from both models, and implementing map algebra to identify height differences between two digital models.

2. Study Site
Clapar village is located in an area with a high-level intensity of landslide hazard. This level can be seen from how the landslide is occurred frequently in this region, Banjarnegara. Data provided by Badan Nasional Penanggulangan Bencana (BNPB) shows that there were 25 landslide locations had been recorded, including Clapar Village, in range from 11-12 December 2014. The largest landslide in Clapar Village itself was occurred in March 25, 2016, swallowing almost half of the village’s region. The hazard happened due the spring that should be flowing down form the river but because the lack of space, the water seeped onto the ground, making the soil very soft, and causing the ground to flow as gravitation pull it down. The physical characteristics of the site itself also had quite-impacting factors to the landslide, such as low-stability type of soil and steep slope, making the motion to move faster.

Topology area with steep slope makes the condition of soil moving faster. Rainfall reaching in Clapar is calculated for about 301 to 400 millimeters per month. Clapar has a specific rock formation called Rambatan Formation. Clapar landslides Crown in the village is located at an elevation of 837 meters above sea level with a slope of 23%. While the tip of the tongue landslide Clapar located at an elevation of 705 meters above sea level with a slope of 12%. The crown part of the landslide was known to be used in plantation of Salacca zalacca or Salak. Clapar possible landslides village lied in fault zones or fault of the north-south direction.

![Figure 1. Location of landslides on Clapar, Madukara District of Banjarnegara](image-url)
3. Data and Methods

3.1. Data

3.1.1. UAV. Aerial photographs used to build the orthophoto mosaic and Digital Surface Model were taken with DJI Phantom 3 Professional. DJI Phantom 3 Professional is a drone that well-known for its easy-to-fly so everyone just can fly it and take any aerial photos or videos. DJI 3 Professional is equipped with 1/2.3” CMOS camera with 12.4 megapixel effective pixels that paired with 3-axis gimbal [3]. This features make DJI Phantom series is widely-used in aerial photography and videography.

The aerial photographs were taken in one days, but need two days to measure all of the GCPs. The landslide was photographed at 25th May 2016 around 01.00 P.M.. The GCPs measured at 25th-26th May 2016 around 09.00 P.M. until 03.00 P.M..

The photos were taken manually by the pilot. Pilot estimate how big the endlap and sidelap oh each photos. The landslide were taken twice with different direction to overcome problems that may occur because of the pilot mistook the photo and lead to a photo without proper endlap and sidelap causing its cant be arranged into a mosaic. The first flight direction is horizontally to landslide, or north-east to south-west. The second flight direction is vertically to landslide, or north-west to south-east.

![Flight paths of the drone when took the photos above landslide horizontally (A) and vertically (B)](image)

Figure 2. Flight paths of the drone when took the photos above landslide horizontally (A) and vertically (B)

3.1.2. Ground Control Points. Ground Control Points or GCPs are well-defined natural features or pre-marked artificial features that appear on the photographs and whose location in reference system are known [1]. GCPs that used were cross-shaped artificial features made from cardboard and painted orange. This crosses were ±1 meter long. The GCPs distributed in the main area of the landslide so they represent the different terrain heights and can be seen easily from above because there is no other object in the landslide that will cover it. The coordinates of the GCPs were determined using Leica Viva GS08 Global Navigation Satellite System (GNSS) Receiver with Real Time Kinematic (RTK)-Network Transport of RTCM via Internet Protocol (NTRIP) methods
3.2. Methods

3.2.1. Aerial Photography. The making of Elevation Differences Map from aerial photographs and terrestrial survey consists of three steps: 1) generate a orthophoto mosaic and DSM from aerial photographs and GCPs coordinate that measured by GNSS using Agisoft Photo Scan Professional; 2) generate a DEM from elevation points by terrestrial survey (Total Station and Theodolite) using Kriging interpolation in ArcMap 10.3; and 3) generate Elevation Differences Map using Raster Calculator in ArcMap 10.3.

Agisoft Photo Scan Professional was used to generate orthophoto and DSM from aerial photograph and GCPs coordinate that measured by GNSS. Agisoft Photo Scan Professional used beacuse it is widely known for its easy to use for generating orthophoto and DSM in many previous studies[4].

Kriging interpolation method has applications in spatial prediction and automatic contouring that measure distance and orientation between data (Shekhar and Xiong, 2008). Elevation points from terrestrial survey interpolated using automatic contouring feature in Kriging.

Elevation Differences Map is a map that represents the differences of height from DSM that generated from aerial photographs and DEM that generated from elevation points by terrestrial survey. Elevation Differences Map is actually a raster map that every pixel value generated from an equation DSM pixel value minus DEM pixel value. This operation can be done using Raster Calculator in ArcMap.

![Figure 3](image3.png) Example of the GCP sightings in aerial photographs (A) and the distribution of the GCPs at the area of landslide (B).

![Figure 4](image4.png) Flow chart of the project.
3.2.2. **Terrestrial surveying.** Landslide study area has topography or the appearance of the high and low clumps of landslide. Measurements of terrestrial survey were intended to collect altitude data. These measurements were conducted over three days from May 24-26, 2016. The measurements process took approximately 6 hours from 09 pm to 15 pm o'clock. The study area is divided into three parts to be measured effectively. Each section has a relationship and reference the same with each other. Theodolites were the main tool and is located in on of the baseline, followed by Total Station as secondary tool. Baseline is made from the west which is at the higher slopes and eastward toward the lower slope height.

Measurements using Theodolith were done manually, while the Total Station had more practical measurement methods than theodolite. Total Station was assisted by a prism with a laser system that was able to determine the angle, distance and point coordinates automatically. All information collected by the total station stored in an external computer where the data could be manipulated and added to the CAD program. Using data collected and stored by surveying tools, the DEM were processed with kriging interpolation methods.

4. **Results**

4.1. **Orthophoto Mosaic**

Orthophoto mosaic is generated from aerial photographs which has spatial resolution for about 0.054 meters. Orthophoto mosaic itself shows the wide of area damaged by landslide disaster. The landslide area extends for about 1096 meters length and 132 meter width, with orientation from north west to south east. Most of the area damaged by landslide was identified as *Salacca zalacca*, also known as Salak. This landslide also destroyed few local houses and a main local road.

![Figure 5. Mosaic orthophoto of the landslide.](image)

4.2. **DEM generated from terrestrial surveying**

DEM (Digital Elevation Model) generated from interpolation between points from terrestrial measurements represents shape of landslide’s aftermath. The amount of points used to generate DEM is 349 points. The points itself were not distributed equally in landslide area. To compare DSM provided from aerial photography with DEM provided from terrestrial surveying, we only choose 221 points. The result from the comparison shows differences of height variation between 670 meters to 628 meters, covering area which extends 52400.66 m².
4.3 **DSM generated from aerial photographs**

DSM generated from aerial photograph imageries has spatial resolution for 0.1 meters. To compare it with DEM accumulated by terrestrial surveying and aerial photography, DSM was intersected in identical area with DEM generated by terrestrial surveying.

4.4 **Elevation Differences Map**

Elevation Differences Map generates from the differences of pixel value from DSM generates from aerial photographs and DEM generates from terrestrial surveying. Pixel value from DSM and DEM represent elevation points of the landslide therefore Elevation Differences Map represent the differences from these two methods of surveying.
5. Discussion

DEM generated from aerial photography results differences from terrestrial surveying. Both model are intersected in the middle of study area, which is shown by figure 9. The first DEM shows higher elevation in north-west landslide area yet lower elevation in south east area. Both models have maximum difference for about 68min the northwest. The differences between both DEM are narrowing in the middle, and back enlarging in south-east part. DEM generated from aerial surveying has more similarities with the real form of landslide than the DEM generated from terrestrial surveying.

![Map Differences Elevation making process](image)

The big differences between DEM based on aerial photography and DEM based on terrestrial surveying can be caused by the amount of measured points that were used in terrestrial surveying hadn’t been distributed equally around the study area. There were many points that weren’t accessible because of study area’s condition which was dangerous and not stable to be stepped on. The south-
west part of the area was formed by high slope with unstable soils, which was caused by the presence of small river. The south-east part was also inaccessible because the terrain’s condition was very dangerous to be stepped on. Those factors caused difficulties for terrestrial surveying to measure points that were planned in those two area. Most of the part of landslide area weren’t stable to be observed, with soils’ condition that weren’t quite solid to hold the instrument for surveying. The different situation occurred in aerial photography process. Most of the part of landslide area was accessible and can be collected as aerial imageries data. The differences of height based on DEM can be also caused by the accuracy in measuring coordinate of surveyed points.

DEM generated by aerial photographs was more efficient in process that terrestrial surveying. It had taken three days to collect data from all parts of landslide area by terrestrial surveying with the effective time of 6 hours per day, while it only needed two days by aerial photography to collect all data and process it. The result generated from aerial photographs also shwives more representing form of landslide area than terrestrial surveying.

6. Conclusion
Digital Surface Model that generated from aerial photographs and GCPs by GNSS give better representation of landslide’s terrain than the terrestrial surveying’s DEM. DSM can represent the variation of the terrain surface with more impressive visualisation because aerial photographs can easily cover all of the area of landslide so every inch of terrain’s data can be extracted become elevation points. Actual elevation and location was generated from GCPs coordinate by high-precision GNSS. DSM and orthophoto mosaic are more suitable as spatial geodatabase than DEM from terrestrial surveying because its more presenting the real terrain in the disaster spot so it can be more representative for the reader of the geodatabase.

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