The Role of Small Format Aerial Photographs for First Response in Landslide Event

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Abstract. The first response phase during a disaster is the most crucial part of disaster management. It is necessary for the decision maker to know the information about disaster condition, the current affected location and further the potential affected location. In a disaster such as landslide, the specific information is needed to determine the current condition of the material flow. Aerial photograph is a helpful tool to identify the disaster condition since it is considered as a low cost tool compared to direct field observation. The current condition produced from aerial photograph can be used to determine further potentially affected area or to determine potential location to build the emergency shelter or to determine the route of evacuation and so on. In Indonesia, the main focus of first emergency response is how to find the victim as soon as possible without considering the current condition of the hazard. Without knowing the current condition of the hazard, a bad implication such as inducing further landslides might happen, which increase the number of victims. In fact, the current condition analysis is much helpful in deciding the proper action in first response, including finding the victims without increasing other implications. Thus, the aerial photos are considered as an option to identify the current situation of landslide events. Therefore, the study is aimed to measure the effectiveness of the landslide first response tool, especially small scale aerial photographs based on the time and the process of photo extraction. To achieve the main objective, there are 3 specific objectives including: 1) to capture the landslide area extent, including the area that used for modelling process, 2) to know the minimum duration taken to prepare the aerial photograph, 3) to measure the effectiveness of aerial photograph as a first response tool. The study was trying to find the duration of post landslide management when it used aerial photograph to help the management. The duration resulted by image acquisition and processing will be assessed whether it is effective or not to be a tool for post landslide management. The aerial photograph acquisition and processing was processed in several basic steps by using certain devices. The method used is differentiated into two steps which is data acquisition using DGI Phantom-4 then further processed by using the Agisoft Photoscan Software, which is processed on ASUS N551. Both processes will be evaluated based on its steps, results and duration taken for the whole process. Then the shortest duration of the process was used for post landslide management, including situation analysis, first response and civil protection. To evaluate the effectiveness of the aerial photograph, the critical analysis of landslide first response was conducted by literature review to know how long the optimal duration since landslide occurrence until the first response. The ideal duration from critical analysis and the duration of landslide first response using aerial photograph was compared. Finally, the effectiveness of aerial photograph utilization in post landslide management can be evaluated. UAV called DJI Phantom 4 was used to obtain the aerial photograph, while to operate the flight of UAV, DJI Phantom 4 was connected to android application namely Pix4D. The application setting is adjusted, such as 70% overlap percentage, flight height around 60-100 m, 90 degree camera angle and slow UAV speed. To cover the landslide area extent, 5 times of flight were needed. The first 2 flights acquired the head of the landslide with the purpose to get the information, whether the evacuation process is safety enough or not. In total, the duration of all flights is only 15 minutes. In reality the whole acquisition process took about 2 hours. It happened due to the preparation of flight as well as the field condition that is not easy to be reached because of the landslide occurrence itself. Subsequently, Agisoft 1.1 was used to process the whole aerial photo taken from the flight. Among the five times of flight, the
The first two which consist of the landslide head photos were processed directly in the field so that the evacuation step can be started as soon as possible. There are five steps in photo processing including importing photos, alignment, creating dense cloud, building mesh and building texture. It took the shortest processing duration about 38 minutes and 20 seconds with 4.12 cm resolution. In total, aerial photograph acquisition as well as the processing takes around 3 hours for 2.2 ha extent area. By those results, it can be concluded that the using of aerial photograph is effective enough, then further can be used in decision making including situation analysis, first response and civil protection. The aerial photograph will help the stakeholder as decision maker to know the first response step that they will take.

1. Introduction

The first response phase during disaster become an important demand and most frequently investigated in disaster management. Among all studies about disaster management (mitigation, preparation, response and recovery) [1], 25% of the studies investigated first response phase or emergency response, second to mitigation which is 48%. It is necessary for damage analysis and decision making during the disaster because the quick response of disaster is very much needed. The decision maker needs to know the information about disaster condition, the current affected location and further the potential affected location [2]. Therefore, the first response phase of a disaster is an important part in emergency management.

For a disaster such as landslides, the specific information is needed to determine the current condition of the material flow. Aerial photograph is a helpful tool to identify the disaster condition. It directly represents the actual relief after landslide occurrence so can be used for predicting the appropriate needs allocation such in landslide first response [3]. By using aerial photographs, the flow and the affected area can be identified. Then the current condition produced from aerial photograph can be used to determine further potentially affected area or to determine potential location to build the emergency shelter or to determine the route of evacuation and so on. Moreover, the advantage of using aerial photograph is that it considered as a low cost tool compared to direct field observation [4].

In Indonesia, landslide first response phase still needs to be developed. It happens due to the main focus of disaster management in Indonesia is still in mitigation phase. Even many mitigation strategies have already implemented in Indonesia, the landslide occurrence still cause a number of fatalities. Those kind of problem leads Indonesia to pay more attention to mitigation compared to first response phase [5]. Due to this difficulty, first emergency response in Indonesia is still focusing on how to find the victim as soon as possible without considering the current condition of the hazard. As a consequence, without knowing the current condition of the hazard, a bad implication such as inducing further landslides might happen, which increase the number of victims. In fact, the current condition analysis is much helpful in deciding the proper action in the first response, including finding the victims without increasing other implications. Thus, the aerial photos are considered as an option to identify the current situation of landslide events.

Many studies focusing on tools of interpretation for landslide event, yet the effectiveness of the tools were not taken into account. Ferrigno et al. used Gb-Insar for emergency management and monitoring the earthflow case study, including emergency, long-term stabilization and post operation phase [6]. Hou et al. studied the mapping and spatial features of landslide using some interpretation tools including terrain variation analysis and morphological analysis [2]. Then, Nadi & Edrisi studied the emergency response preparation using relief assessment which involved two teams including emergency response team and relief assessment team [3]. Another study payed more attention to the evolution of earth observation imagery to timely deliver the image for the first response phase of disaster [7].

From the previous studies, it can be concluded that the studies of the effectiveness of emergency response tools are still limited. Therefore, this study is aimed to measure the effectiveness of the landslide first response tool, especially small scale aerial photographs based on the time and the process of photo extraction. To achieve the main objective, there are 3 specific objectives including: 1) to capture the landslide area extent, including the area that used for evacuation process, 2) to know the minimum duration taken to prepare the aerial photograph, 3) to measure the effectiveness of aerial photograph as a first response tool.
2. Methodology

In this study, the effectivity of landslide first response is measured by using the duration of information collection for first response basic data. The shorter the duration, the more effective the first response is. In this study, the information collected to help the first response phase used aerial photographs as a tool. The duration resulted by image acquisition and processing will be assessed whether it is effective or not to be applied in post landslide management.

![Theoretical Framework](image)

**Figure 1.** Theoretical Framework

The aerial photograph acquisition and processing was processed in several basic steps by using certain devices. The method used is differentiated into two steps which is data acquisition using DGI Phantom-4 then further processed by using the Agisoft Photoscan Software, which is processed on ASUS N551. Both processes will be evaluated based on its steps, results and duration taken for the whole process. Then the shortest duration of the process was used for post landslide management, including situation analysis, emergency response and civil protection. To evaluate the effectivity of the aerial photograph, the critical analysis of landslide first response was conducted by literature reviews.

2.1. Aerial Photo Acquisition

The aerial photo acquisition was obtained using an unmanned aerial vehicle called DJI Phantom version 4 and was operated using Pix4D application which was open on Android platform. Technically, DJI Phantom was controlled by Pix4D application. Here are the sequences of aerial photo acquisition using DJI Phantom 4 and Pix4D [8]:

a. UAV track, which further called as mission, was created in Pix4D application. Mission grid extent was adjusted with the total area extent to be captured, flight height, and the flight duration.

b. Flight setting was adjusted in Pix4D to control the camera angle, output photos overlap, and UAV speed.

c. The UAV was connected to the Pix4D application until the mission was able to be run.

d. After all settings were set, the UAV was taken off to capture the aerial photo.

2.2. Aerial Photo Processing
After all captured aerial photos were collected, those photos were combined to be one single mosaic so
the imagery can be used in first response phase. The following steps are the sequences of combining
photos to be single mosaic using Agisoft 1.1 [9].

a. Importing photos. All captured photos were added to agisoft software.
b. Photos alignment. Photos alignment was done to create points cloud which are the points
connected from one photo to another.
c. Creating dense cloud. Dense cloud is point could expansion, so that many control points were
generated.
d. Building mesh. It was a 3D polygonal mesh representing the object surface based on dense
cloud created previously.
e. Building texture. It was the final step to build orthophoto mosaic which already consist of 3D
photos, not just 3D polygonal as the previous step.

2.3. Landslide First Response Measure
Different literatures have different steps of landslide first response. There are 3 steps in landslide first
response including situation analysis, operational strategy and plan, and detailed operational plan [10].
While in this study, there are 3 main activities during landslide first response, including situation
analysis, emergency response and civil protection [11]. To apply those 3 activities, collecting
information as the basic data becomes an important demand. It is important in achieving the
appropriate target in landslide first response, especially the distribution of humanitarian supplies to
affected areas [3].

Situation analysis is a phase which measure the current condition right after the landslide
occurrence or in other words, it can be interpreted from aerial photograph acquired after landslide
occurrence. The situation analysis might lead the safety procedures of the other two steps, including
emergency response and civil protection. Whereas the emergency response and civil protection phase
are the phase where the evacuation plan is started [11].

There are some points to be prepared to do those 3 activities in landslide first response, including
[12]:

a. Determining the extent of the area affected by the landslide.
b. Analyzing the topography of nearby area which use to determine entry and exit evacuation
routes as well as assembly point or evacuation area.
c. Determining the sectors if needed.
d. Analyzing the risky area among the affected area and determining the rank of the risk; the area
next to the presence of solid ground, the area nearby the leaking out water from the ground. It is
used to avoid the evacuation route construction in that area.
e. Determining the distance from threatened objects to the risky area or ongoing landslide. It is
used to make the rescue and evacuation priority.
3. Result and Discussions

3.1. Landslide Area
The landslide is one of many landslide happened on 9 November 2016 in Mayungsari village, Bener District, Purworejo Regency with 2.2 ha area extent. From all landslides happened during that day, the landslide was the largest one and also the largest landslides from the historical record in Bener District Purworejo. It was triggered by the extensive rainfall from several days before debris flow occurrence, then worsened by the high intensity of rainfall from 12 PM in the current day. The landslide material collapsed from east side to west side of the slope. The release extent area was 787,063 m² and was laid in 454,48 m altitude.

![Figure 2. Aerial photo of landslide area](image)

The high losses, such as agriculture and infrastructure losses, are received due to this debris flow occurrence. One bridge which is the main road connecting one hamlet to another, is reported interrupted due to this occurrence.

3.2. Aerial Photo

3.2.1. Aerial Photo Acquisition
UAV called DJI Phantom 4 was used to obtain the aerial photograph. Beside, to operate the flight of UAV, DJI Phantom 4 was connected to android application namely Pix4D. Using Pix4D application, the flight setting is adjusted depends on the need. The setting that is adjusted including overlaps percentage, flight height, camera angle and UAV speed. The overlap percentage in this study is 70 %, while flight height is varied around 60-100m depends on the vegetation height around the area, the camera angle is set in 90 degree, while UAV speed is set at slow speed.

![Figure 3. DJI Phantom 4 (left), Pix4d application (right)](image)
To cover the landslide area extent, 5 times of flight were needed. According to the total area, it can be captured by 2 times flight, yet in this case, the fact that the area was too long from east to west so that more than 2 times flight were required. The flight height is different each flight, depends on the condition of vegetation height surrounding the area. The higher the flight, the more the extent area can be covered so that a lot of photos captured.

| Flight | Total Photos Captured | Flight Duration |
|--------|-----------------------|----------------|
| 1st    | 50 photos             | 4 minutes      |
| 2nd    | 56 photos             | 3 minutes      |
| 3rd    | 28 photos             | 3 minutes      |
| 4th    | 23 photos             | 3 minutes      |
| 5th    | 127 photos            | 5 minutes      |

In total, the duration is only 15 minutes, while in reality it took more than 2 hours. It happened due to the field condition that is not easy to be reached because of the landslide occurrence itself.

3.2.2. Aerial Photo Processing
The whole photos captured from 5 times flight are combined into two photo mosaics. The first photo mosaic was combined from two groups of photos which resulted by the first two flights, while the rest were combined into another photo mosaic. The first photo mosaic consists of the landslide scrap photos which proceed directly in the field so the first response step can be started as soon as possible. In this step, the Agisoft 1.1 was used to process the whole aerial photos taken from the flights.

The steps in photo processing are importing photos, alignment, creating dense cloud, building mesh and building texture. It was proceed using low quality to get the fastest processing duration, so the first response can be started as soon as possible. Even the quality setting was low, the overall quality is capable enough to be used. It is proven by final resolution result which is 4.12 cm.

The table below depicts the duration of photos processing for the first group photos or the photo mosaic which obtained from two first two flights, which were processed directly in the field.

| Processing Step                  | Step Duration       |
|----------------------------------|---------------------|
| Importing Photos                 | 10 secs             |
| Photos Alignment                 | 7 mins 46 secs      |
| Creating dense cloud             | 2 mins 12 secs      |
| Building mesh                    | 8 secs              |
| Building texture                 | 1 min 24 secs       |

The final duration of the process was around 11 minutes and 40 seconds. Photos alignment took very long duration due to the function for creating point clouds from the photos.

The photos obtained from the last three flights could be processed whether directly in the field or not. The table below describes the duration of processing.

| Processing Step                  | Step Duration       |
|----------------------------------|---------------------|
| Importing Photos                 | 5 secs              |
| Photos Alignment                 | 20 mins 30 secs     |
| Creating dense cloud             | 3 mins 48 secs      |
| Building mesh                    | 8 secs              |
| Building texture                 | 2 mins 9 secs       |
In total, the duration of all processes were about 26 minutes 40 seconds. As same as the previous process, photos alignment was the longest process compared to another.

It was longer than the first process because the more photos obtained as well as the area covered was wider than the previous flight. The total photos captured in the first process were 106 photos, while the second process consists of 178 photos. If both processing were accumulated, it took 38 minutes 20 seconds duration to complete the photos processing.

As mentioned before, the mosaic processing consists of 5 main steps, including importing photos, alignment, creating dense cloud, building mesh and texture. The first step is importing the photos, which is the process to call all obtained photos to the software which further will be processed. Once, the photos are imported, Agisoft platform will show the picture exact location using blue bullet as shown in figure 4. The figure showed the arrangement of the photos depends on the setting that adjusted in the acquisition process.

![Figure 4. Importing photos in Agisoft](image)

Then the alignment process is a process to create point clouds or the points which represents the same point from one photo to another. In other word, the points produced in alignment process were existed in two or more photos, because it overlaps in more than one photo. In this step, the conjugate point are obtained automatically [13].

![Figure 5. Photos alignment in Agisoft](image)

Furthermore, dense cloud must be created to build the mosaic of the photo. The points around previous point cloud were produced in building dense cloud step, so it can be concluded that will be there were more points created in these steps.
The further process was building mesh which is a process to create 3 dimensional photo mosaic. In this step, the result depended on the previous dense cloud, so the texture was still rough.

The final process is creating the texture. The function of this step is to determine the actual texture of the area. 3 dimensional mosaic was better than the previous step.
3.3. The Effectiveness of Aerial Photograph for Landslide First Response

The effectiveness of disaster initial response can be measured by time efficiency of the initial action, such as quickly deploying evacuation team and the needs, overcoming the challenges on the disaster area, and coordinating with disaster response partner [14]. Therefore, this study tried to find the effectiveness from the duration of landslide first response.

The table below describes the steps of first response in the landslide occurrence, including the description of each step and the durations.

| Steps                        | Duration                                      | Final Duration |
|------------------------------|-----------------------------------------------|----------------|
| Data acquisition             | First two flights: 7 minutes                   | 2 hours        |
|                              | Last three flights: 11 minutes                 |                |
|                              | Actual duration in the field due to the accessibility: | 2 hours       |
|                              |                                              |                |
| Data Processing              | First two flight : 11 mins 40 secs            | 45 minutes     |
|                              | (it was included to data acquisition duration) |                |
|                              | Last three flights: 26 mins 40 secs           |                |
|                              | Actual duration including preparation and data export |          |
| Landslide First Response     | Determining the extent of the area : 15 minutes | 2 hours 15 mins |
| Base Information             | Topography analysis and risk analysis : 1 hours |                |
|                              | Determining sectors, evacuation routes, and assembly points : 1 hour minutes |     |

In total, aerial photograph acquisition, the processing, as well as basic information collection for landslide first response, took around 5 hours duration for 2.2 ha extent area. In fact, the evacuation process can be started right after the first two flights of aerial photos were taken and proceed or can be started less than 30 minutes after the landslide occurrence.

4. Conclusion

By those results, it can be concluded that the using of aerial photograph is effective enough, so further can be used in decision making including situation analysis, first response and civil protection. The aerial photograph will help the stakeholder as decision maker to know the first response step that they will take. The evacuation process can be started less than 30 minutes after the landslide occurrence, yet the whole basic information about landslide first response can be processed after 2 hours and 45 minutes after the landslide occurrence.

Some results of the study are:
- From aerial photo interpretation, the extent area of the landslide was 2.2 hectares.
- The minimum duration of data acquisition was 2 hours, while the data processing was around 45 minutes, then the basic information for landslide first response was collected in 2 hours and 15 minutes.
- The aerial photograph is effective enough for landslide first response to make the time become efficient and to reduce the other possibility of further landslides induce by evacuation process.

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