

APPLYING DIGITAL PHOTOGRAMMETRY TO SPATIAL DISTRIBUTION OF DEBRIS VARIATION

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ABSTRACT:

This study applies original aerial photographs to reconstruct orthoimages and extract digital terrain model (DTM) for images of various periods. The area of research is located at the Daluowan stream of the watershed of Wushe reservoir in Taiwan. In 1999, the Chi-Chi Earthquake caused numerous landslides in this area. In 2004, the intense rainfall from the Mindulle typhoon triggered the debris flow at the stream which caused the deposits of debris from Lushan area to Wushe reservoir in the downstream of the Daluowan stream. According to the image classification of landslides in 2005, one can obtain the results of the debris variation and spatial distribution by analyzing the elevation variation of DTM. This research calculated debris variation during 2003 to 2005 with true DTM data of the aerial image of each period. Using the spatial model of Erdas and ArcGIS to analyze data, this data can overlay DTM and orthoimages and understand the true DTM of the site, elevation variation of stream profiles and the debris quantity of landslide. The RMSE of analyzed DTM (5*5METER) are 1.37~2.35 meter for the results of the various periods. The Daluowan stream is influenced by the landslide of the Tunyuan and Yunhai zones. The landslide volume in Tunyuan and Yunhai are 1,596,747 and 1,001,913 m³ respectively. According to the reference, using the experience model to estimate the landslide volume of two study zones are 560,000 and 1,500,000 m³ respectively. The upstream area of the Daluowan stream still has a large amount of debris deposits. The amount of accumulative debris is 3,392,503 m³. Therefore, it will be a great threat for the Lushan area and Wushe reservoir when typhoons or intense rainfalls occur.

1. INTRODUCTION

Photogrammetry has the advantage of rapidly measuring large-scale terrain and obtaining accurate images in the changes of terrain and surface features. Historical Digital Elevation Models (DEM) derived by automated procedures from aerial photograph archives can provide valuable information for evaluating long-term landscape responses to environmental change in sensitive proglacial terrain over a wide range of spatial and temporal scales (Schiefer and Gilbert, 2007). It can output ortho-rectified images and Digital Terrain Model (DTM) with geodetic coordinates (Wolf and Dewitt, 2000). Because instrument precision and solution software have made great progress in recent years, Photogrammetry can take the place of the conventional survey, especially of the inconvenient areas in the traffic. The DTM using Photogrammetry can apply to topographic measurement, observation of profile and spatial analysis, etc (Miller and Laflamme 1985). Morphometric changes may be quantified by subtracting DEM sections extracted by digital photogrammetry for different dates of archived photography, a straightforward operation within a raster-based geographic information system (GIS). This approach has been used for reconstructing volumetric changes of land surfaces caused by a variety of geomorphic processes, including permafrost creep (Wangenstein et al., 2006), dune migration (Brown and Arbogast, 1999), gully incision (Betts et

al., 2003), coastal cliff erosion (Adams and Chandler, 2002), mass movements (Hapke, 2005), volcanic deformations (Baldi et al., 2002), and glacier recession (Rivera et al., 2005).

This study applies digital photogrammetry to reconstruct topographic data of the landslide area in the upstream of the watershed. Then, spatial analysis of GIS was used to calculate the volume of debris and analyze the profile of the stream with the DTM of various periods. For past research about the topography of a site, it must survey the slope or channel of a stream. It is so difficult to survey topography in high altitude and large-scale area that overcoming topographic elevation is not impossible now by conventional techniques (Gruen and Murai, 2002). But aerial images include past and present spatial data which was used to extract DTM of various periods in the landslide area (Casson, etc., 2003).

This area of research is located at the Wushe reservoir watershed in Taiwan. In 1999, Chi-Chi Earthquake caused numerous landslides at the upstream area of the watershed. In 2001, the intense rainfall during the Toraji typhoon triggered the debris flow at the stream which caused the deposits of debris from the Lushan area to Wushe reservoir in the downstream of Daluowan stream. More serious deposits of debris were caused by Mindulle typhoon in 2004.

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In order to understand the influence of collapsed and deposited debris caused by several typhoons in the study area, this research applies digital photogrammetry to measure large-scale terrain in high altitude area and extract DTM from aerial images in 2003 and 2005. Then, this is compared with the variation amount of landslide during the two years. For the past research in this area, landslide volume was only estimated by the experience model. This research also compares the result of this study to the estimated value of the past.

2. STUDY AREA

This area is located at Wushe reservoir watershed in the upstream area of Choushui river catchments, as shown in Figure 1. The area of Wushe reservoir watershed is 22170 ha. The formation in this area is mainly the Miocene Lushan Formation and less the Eocene Pilushan Formation in the Backbone Range belt of the Central Range. The Lushan Formation consists largely of black to dark gray argillite, slate, and phyllite with occasional interbeds of dark gray compact sandstone and disseminated marly nodules. The slate formation in this area is highly jointed and cleaved. The surface of rock stratum was heavily broken in Chi-Chi earthquake. Due to the intense rainfalls from Toraji and Mindulle typhoon in recent years, or a second collapse of the originally unstable slope triggered a landslide. This research mainly discusses the debris variation of landslide area in the Daluowan stream of the upstream of the Wushe reservoir watershed.

3. METHODOLOGY

The aerial images of this study were obtained from the Aerial Survey Office during 2003 to 2005, which were taken in the Daluowan stream. This area is located at the watershed of Wushe reservoir. The aerial elevation is 5000 to 5400 meter, the scale is 1/5000 and the resolution of scanning image is 14µm. The original aerial photographs were extracted data of DTM in 2003 and 2005. This research calculated debris variation and the spatial distribution with true DTM data of the aerial image of every period (Gonzalez and Woods, 2002).

This research calculated the debris variation and the spatial distribution for the bare land of collapsed or deposited debris with the aerial image of every period. For the recent collapse, vegetation has not resumed yet so that the reflective coefficient of the image is strong, the present color is white and the shape is irregular in the image interpretation of bare land (Lillesand and Kiefer, 2000). It is easy to interpret bare land. Based on the extent of image interpretation in 2005, the debris variation of landslide was estimated by spatial analysis of photogrammetry and GIS.

The software of this research is the LPS model of ERDAS IMAGINE, it was used to rectify ortho-images and extract DTM. Main setup and hypothesis are as follows: 1. This research calculated 5 to 7 original aerial images once every strip as the continuous aerial images of several strips during 2003 to 2005. 2. The camera parameter was given by Aerial Survey Office (Table 1). 3. Ground control points were chosen as fixed points outside the landslide from ortho-images rectified by the Aerial Survey Office. It is an important assumption that these ground control points were not influenced by sliding areas. These ground control points were used to match ortho-images every period. 4. The influence on the precision of digital photogrammetry includes triangulation precision, the quality of images and operation error.

ID of camera	RMK TOP-1	RMK TOP-2
Serial number of camera	144116	149968
Type of camera	RMK TOP 15	RMK TOP 15
Type of camera lens	PLEOGON A3	PLEOGON A3
Date of calibration	1994.08.30	2001.09.18
Focus(mm)	152.818	152.242
Shape of frame	point	point
IPP X ₀ (mm)	0.001	0.001
IPP Y ₀ (mm)	-0.004	0.011

Table 1. Parameters of camera

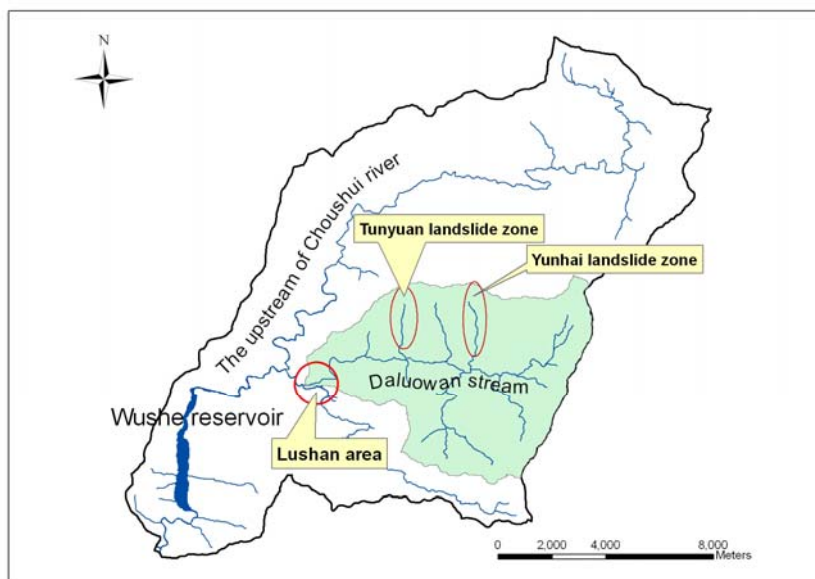


Figure 1. Location of the Li-Shan Landslide

Using the spatial model of ArcGIS to distinguish watershed and analyze flow direction of the study area, this data can overlay DTM and precede further analysis, operation and integration as shown in the flow chart (Figure 2). DTM of every period was used to create and overlay the profiles of the streams. It is presented as an elevation variation of the stream for every period. Then, using Modeller function of ERDAS IMAGINE to subtract DTM data of two years, it can determine debris variation during two years.

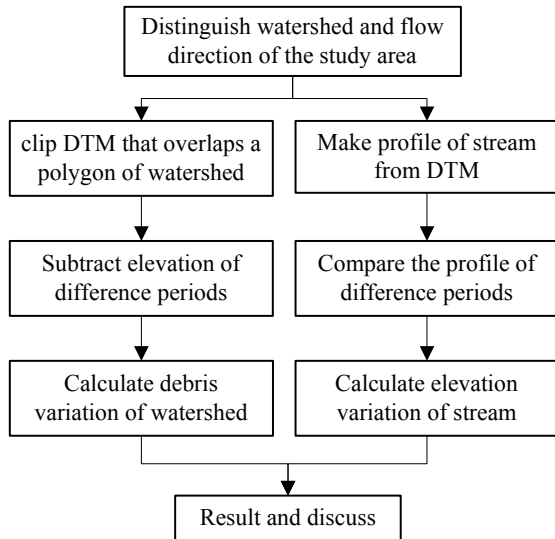


Figure 2. Flow chart of analysis procedure

The depth of landslide was only estimated using the experience model in the past, but the result of calculation was not precise. It is very difficult to really represent the situation of site. This research calculated the elevation variation of the landslide area. Debris volume is the product of elevation variation and grid size. It showed the debris variation and the spatial distribution during two years in the study area.

4. RESULTS AND DISCUSSION

This research extracted DTM of the Daluowan stream watershed with aerial images in 2003 and 2005. Daluowan stream is mainly influenced by the landslide of Tunyuan and Yunhai zones which is located upstream of the Daluowan stream. The landslide volume in Tunyuan and Yunhai are calculated by photogrammetry, including aerial triangulation and ortho-rectification. In Table 2 and Table 3, represents the range of DTM mass point errors for the Tunyuan and Yunhai zones. RMSE is the abbreviation of Room Mean Square Error. GroundX, GroundY and GroundZ mean the errors of direction X, direction Y and direction X respectively. The error range indicates that the accuracy of the extracted DTM is low. The results of extracted DTM are shown in Figure 3.

ZONE	Tunyuan	
YEAR	2003	2005
RMSE	2.3520	1.3716
GroundX	0.4427	0.2629
GroundY	0.4296	0.5266
GroundZ	1.0360	1.2048

Table 2. Error of extracted DTM in Tunyuan zones (meter)

ZONE	Yunhai	
YEAR	2003	2005
RMSE	1.9825	2.1687
GroundX	0.0801	0.9273
GroundY	0.5094	1.1550
GroundZ	1.2858	1.6690

Table 3. Error of extracted DTM in Yunhai zones (meter)

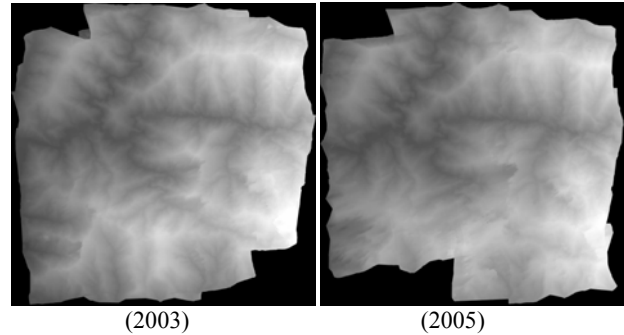


Figure 3. The result of DTM in 2003 and 2005

This research uses DTM data to analyze the profile of stream, average slope, elevation change and debris variation. The profile of the Daluowan stream is shown in Figure 4.

The origin of the profile is the confluence of the Daluowan and Mahebo stream. The arrows of the figure mean the confluence of tributary and main of Daluowan stream and the circular sign is the location of waterfall. The elevation change of the upstream of the waterfall is not obvious. And the elevation of the downstream of the Tunyuan landslide has increased.

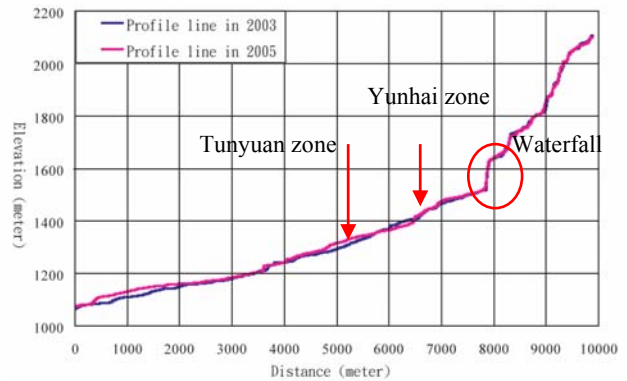


Figure 4. Profile of Daluowan stream

The stream profile of the Tunyuan landslide is shown in Figure 5. The origin of the profile is the confluence of the Tunyuan and Daluowan streams. Figure shows that there are deposits of debris in the stream. The bare land of the landslide was chosen by image interpretation in the Tunyuan zones, as shown in Figure 6 and Figure 7, it represents the distribution map of elevation variation in the bare land of landslide.

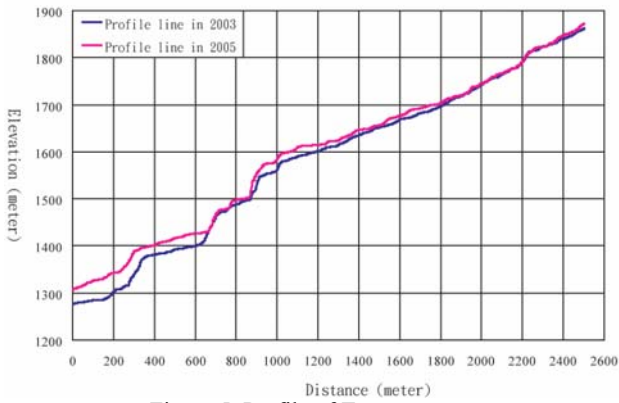


Figure 5. Profile of Tunyuan zone



Figure 6. Extent of landslide in Tunyuan zone

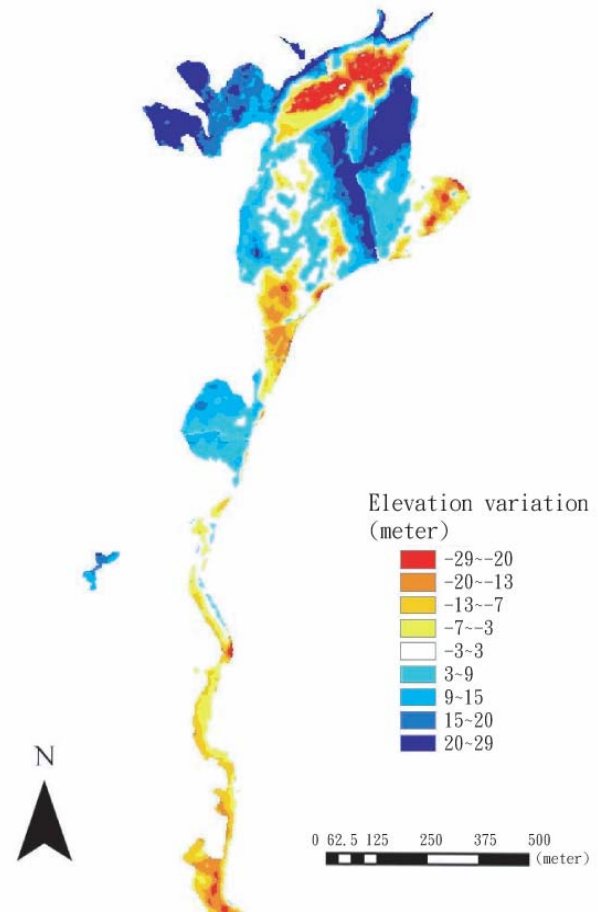


Figure 7. Distribution map of elevation variation of landslide in Tunyuan zone

The stream profile of the Yunhai landslide is shown in Figure 8. The origin of profile is the confluence of the Yunhai and Daluowan streams. Figure shows that there are deposits of debris and erosion in the streams. The bare land of the landslide was chosen by image interpretation in the Yunhai zones, as shown in Figure 8. Figure 9 and Figure 10 represent the distribution map of elevation variation in the bare land of the landslide.

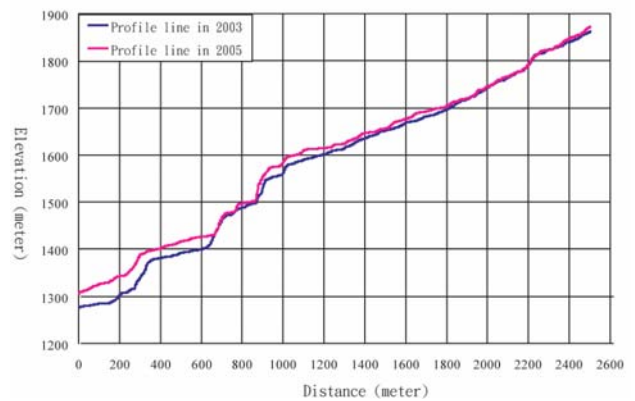


Figure 8. Profile of Yunhai zone

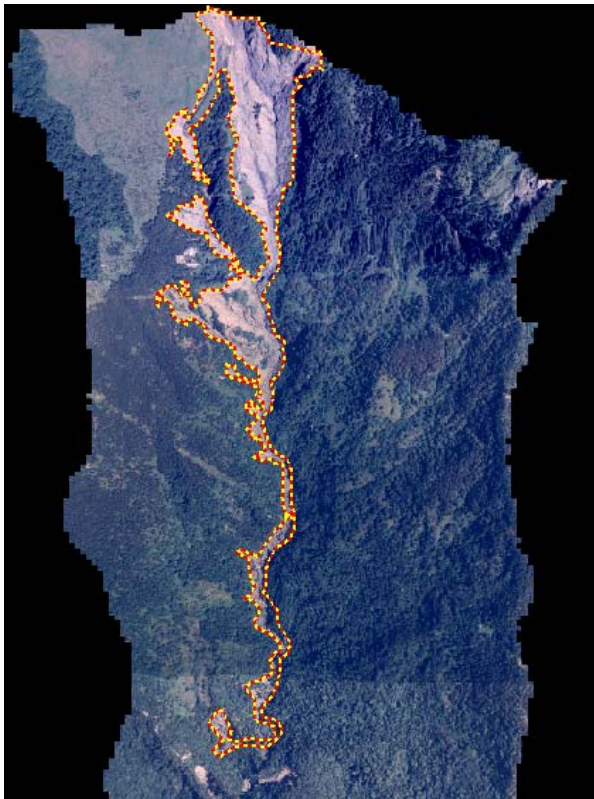


Figure 9. Extent of landslide in Yunhai zone

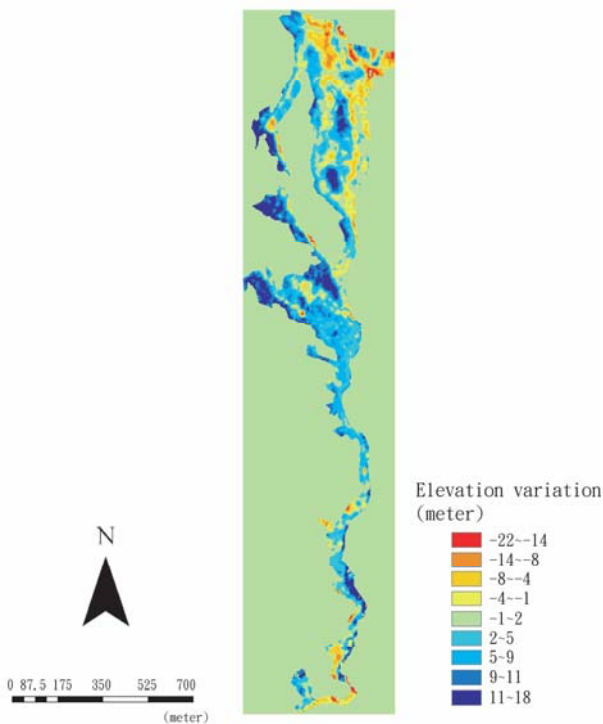


Figure 10. Distribution map of elevation variation of landslide in Yunhai zone

Table 4 shows the average slope in the Daluowan stream and its tributary in 2003 and 2005. The slope changes over time to more gradual.

	2003	2005
Daluowan stream	10.54	10.20
Tunyuan zone	23.38	22.66
Yunhai zone	22.75	22.52

Table 4. Average slope in the Daluowan stream and its tributary in 2003 and 2005 (degree)

This research applied photogrammetry to extract DTM of every period. Calculated debris variation by GIS can evaluate the danger degree in this area. The results of debris variation in Tunyuan and Yunhai zones are shown in Table 5. The amount of accumulative debris in Daluowan stream is 3,392,503.93 m³

	Collapse (m3)	Deposit (m3)
Tunyuan zone	1,596,747	105,791
Yunhai zone	1,001,913	303,605

Table 5. The amount of collapse and deposit in Tunyuan and Yunhai zones

Between 2003 and 2005, there was little deposit in the midstream and upstream of Tunyuan and Yunhai zones. There was the most erosion in this zone and the area of erosion is greater and greater. The debris came from a great deal of landslide when the Chi-Chi earthquake occurred. Slope toe and stream bed deposited the debris. The debris flow occurred during the typhoon. Some debris was moved to the downstream and Wushe reservoir, the other was deposited on the stream bed.

According to the reference, the experience model was estimated the depth of landslide to be 5 meter in this area. The landslide volume of two study zones by experience model are 560,000 and 1,500,000 m³ respectively (Soil and Water Conservation Bureau, 2003). Table 6 compares with debris volume of difference method.

	Experience model (m ³)	Photogrammetry (m ³)
Tunyuan zone	560,000	1,596,747
Yunhai zone	1,500,000	1,001,913

Table 6. Debris volume of difference estimated method

It shows that the calculation of experience model was not precise. This research calculated debris variation and the spatial distribution with true DTM data of the aerial image of every period. Therefore, the deposited debris will be a great threat for downstream area when typhoons or intense rainfall occur.

5. CONCLUSION

This research applied spatial analysis of Erdas and ArcGIS software to create a distribution map of debris variation and the profile of a stream bed. The erosion and deposit of the streamway occurred in the study area. It is easy to find the

phenomenon of erosion in the midstream and upstream. On the other hand, it is easy to deposit debris in the downstream. After a typhoon or intense rainfall, some debris was moved to the downstream, the other was deposited on the stream bed.

Daluowan stream is mainly influenced by the landslide of the Tunyuan and Yunhai zones. According to the result of the study, the landslide volume in Tunyuan and Yunhai were 1,596,747 and 1,001,913 m³ respectively. Debris has silted up the check dams in this area. There is little deposit in the upstream of the Daluowan stream. If a typhoon or intense rainfall occurs, the deposited debris would move downstream. It will be a great threat to the Lushan area and Wushe Reservoir.

This research using photogrammetry to extract DTM can calculate an accurate amount of debris variation of every period. The spatial distribution of debris variation can enable understanding of the degree of erosion or deposit in different sections of stream and then provide guidance for remediation in the future.

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