HISTORICAL AERIAL PHOTOGRAPHS USED FOR ANALYZING TOPOGRAPHIC CHANGES OF HSIAOLIN LANDSLIDE AREA

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Abstract: Typhoon Morakot attacked Taiwan on 6th August 2010 and exhibited a historical record of accumulated rainfall of 2854 mm in 3 days. Hsiaolin Village was smashed by the massive debris flow originated from the deep-seated Hsiaolin Landslide. Unanimously, the trigger factor was rainfall. Nevertheless, there have been a lot of debates with controversial remarks about the cause of the deep-seated landslide. The purpose of this study is to check the land surface evidences related to pre-clues of the landslide with historical aerial photographs. In total, 15 aerial photographs in 6 years are used in this study, i.e. 1966, 1982, 1988, 2002, 2005, and 2007. Firstly, parameters of Interior Orientation for various types of aerial camera are applied. Then, orthophotos of the area acquired right before Morakot Event are used for geodetic control and airborne LiDAR digital surface model (DSM) acquired in 2005 are used for vertical control. Thirdly, all stereo-pairs of various years are used to generate DSM and orthophotos for the respective year. Finally, comparisons of the orthophotos and DSM in various years are made to check the topographic change in sequence of time. The accuracy of aerial triangulation is around one meter. No ground cracks or fissures can be observed before Morakot event. This may imply that no obvious deformation took place before the event or the deformation features were hidden by forest cover. Nevertheless, it was observed that the outer shape of deforestation area on 1988 photos coincided with the crown area of the deep-seated landslide. Further observation of the large-scaled landslides in the neighborhood revealed that the crown boundaries are mostly coincided with deforestation boundaries. This may indicate a link between activities of deforestation and deep-seated landslides for this study area.

1. INTRODUCTION

There are more than one million of historical aerial photographs covering Taiwan spanning from 1940s. Historical aerial photographs are invaluable treasure in recording land surface features spanning back to the historical time. Historical aerial photographs are useful tools which records temporal and spatial features of physiographical and cultural nature and thus they are useful for further applications in land-use and land-cover, disasters, indigenous people resettlement and so on.

Five periods of aerial photographs covering early Taiwan can be summarized: (1) 1943~1945: Aerial photos were taken by US Army Air Force and US Marine Corps for surveillance of Taiwan before bombing. (2) 1947~1952: Aerial photos were taken by US Air Force for map making purposes. (3) 1953~1972: Aerial photos were taken by ROC Air Force for topographic mapping and inventory of forestry resources. (4) 1973~1976: Aerial photos were taken by ROC Air Force for detailed assessment of forestry resources. (5) after 1976: Aerial photos have been systematically and routinely taken by Agricultural and Forestry Aerial Survey Institute (AFASI), i.e. the Aerial Survey Office of Forestry Bureau (Fan, 2011; Fan et al, 2013).

Typhoon Morakot attacked Taiwan on 6th August 2010 and exhibited a historical record of accumulated rainfall of 2854 mm in 3 days. Hsiaolin Village was smashed by the massive debris flow originated from the deep-seated Hsiaolin Landslide. Unanimously, the trigger factor was rainfall. Nevertheless, there have been a lot of debates with controversial remarks about the cause of the deep-seated landslide. Therefore, the purpose of this study is to check the land surface evidences related to pre-clues of the landslide with historical aerial photographs, and, thus to explore the possibility of finding pre-clues for early warning of such disasters.

2. METHODOLOGY

In total, 15 aerial photographs in 6 years are used in this study, i.e. 1966, 1982, 1988, 2002, 2005, and 2007. Firstly, parameters of Interior Orientation for various types of aerial camera are applied. Then, orthophotos of the area acquired right before Morakot Event are used for geodetic control and airborne LiDAR digital surface model (DSM) acquired in 2005 are used for vertical control (Liu and Fei, 2011a and 2011b). Thirdly, all stereo-pairs of various years are used to generate DSM and orthophotos for the respective year. Finally, comparisons of the orthophotos and DSM in various years are made to check the topographic change in sequence of time.

As shown in Figure 1, stereo-pairs of aerial photographs were acquired by strip photography with forward overlaps of more than 60% and strip side overlaps of more than 25%. With the stereo-pairs, aerial triangulation and ortho-rectification can be conducted to obtain DSM image and orthophotos of each time of aerial photographs. As shown in Figure 2, to achieve a better accuracy, ground control points (GCPs) are obtained from LiDAR DEM and DSM images which are obtained by recent National Airborne LiDAR Mapping Project (Liu and Fei, 2011a and 2011b). Thus, accuracy of one meter of parameters for exterior orientation and relative orientation are achieved.

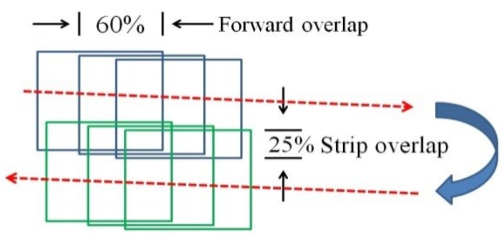

Figure 1 Schematic diagram of aerial photography

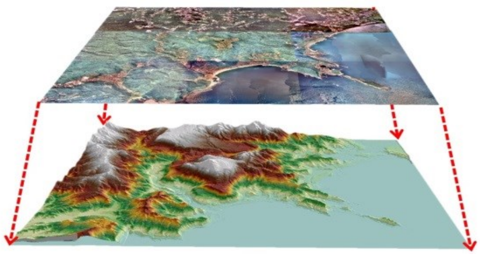

Figure 2 Ground control points are obtained by orthophoto and LiDAR DEM/DSM

3. RESULTS AND DISCUSSION

Figure 3 shows the resultant orthophotos of top part of Hsiaolin Landslide and patch of deforested land in 2007、2005、2002、1988、1982, and 1966, respectively.

The accuracy of aerial triangulation is around one meter. No ground cracks or fissures can be observed before Morakot Event. This may imply that no obvious deformation took place before the Event or the deformation features were hidden by forest cover. Nevertheless, it was observed that the outer shape of deforestation area on 1988 photos coincided with the crown area of the deep-seated landslide. Further observation of the large-scaled landslides in the neighborhood revealed that the crown boundaries are mostly coincided with deforestation boundaries. This may indicate a link between activities of deforestation and deep-seated landslides for this study area.

As shown Figure 3, on the orthophoto of 1988, a deforestated scar of 0.4 square km can be observed. The logging trails and some erosion features are obvious. On the orthophoto of 1982, a deforestated scar of 0.17 square km was located to the right north of Hsiaolin Landslide. Figure 4 is a normalized DEM which was established by subtraction 2005 LiDAR DEM from 2005 LiDAR DSM. Similarly, Figure 5 show two normalized DEMs with 1982 DSM and 2005 DSM, respectively. The later one can be treated as quasi-forest-heights in the respective time. In average, the average height of forests in the deforestated land in 1982 was 12.9 m with a maximum height of 47.4 m whereas it was 7.4 m with a maximum of 36.4 m. No obvious increasing of average height after 20 years. This may partly resulted from the uncertainty of estimation. However, if we look into the normalized DEM in 1982 and that in 2005 as shown in Figure 4 and Figure 5, a coincidence of landslide boundaries with the deforestation scars are obvious. This may imply that the activities of deforestation could be the potential initiating factor of the deep-seated landslides in the area though this may require more observations in more areas.

The analysis of normalized DEM in respective year can be an effective approach leading to the understanding of deforestation in the historical time. Similar observation should be carried out for drawing a conclusion in the cause of landslide initiation.

The uncertainties and errors of this study are resulted from aerial triangulation and orthographic rectification which are subjected to the quality of the historical aerial photographs, the land cover change, the geographic locations, and the IO and EO control parameters. In general, at least of 5 m accuracy can be achieved for black and white aerial photographs in the mountainous terrain and it will be as good as 1 m if the color aerial photographs taken after 1999 are used. For plain land, an accuracy of 0.5 m can be achieved.

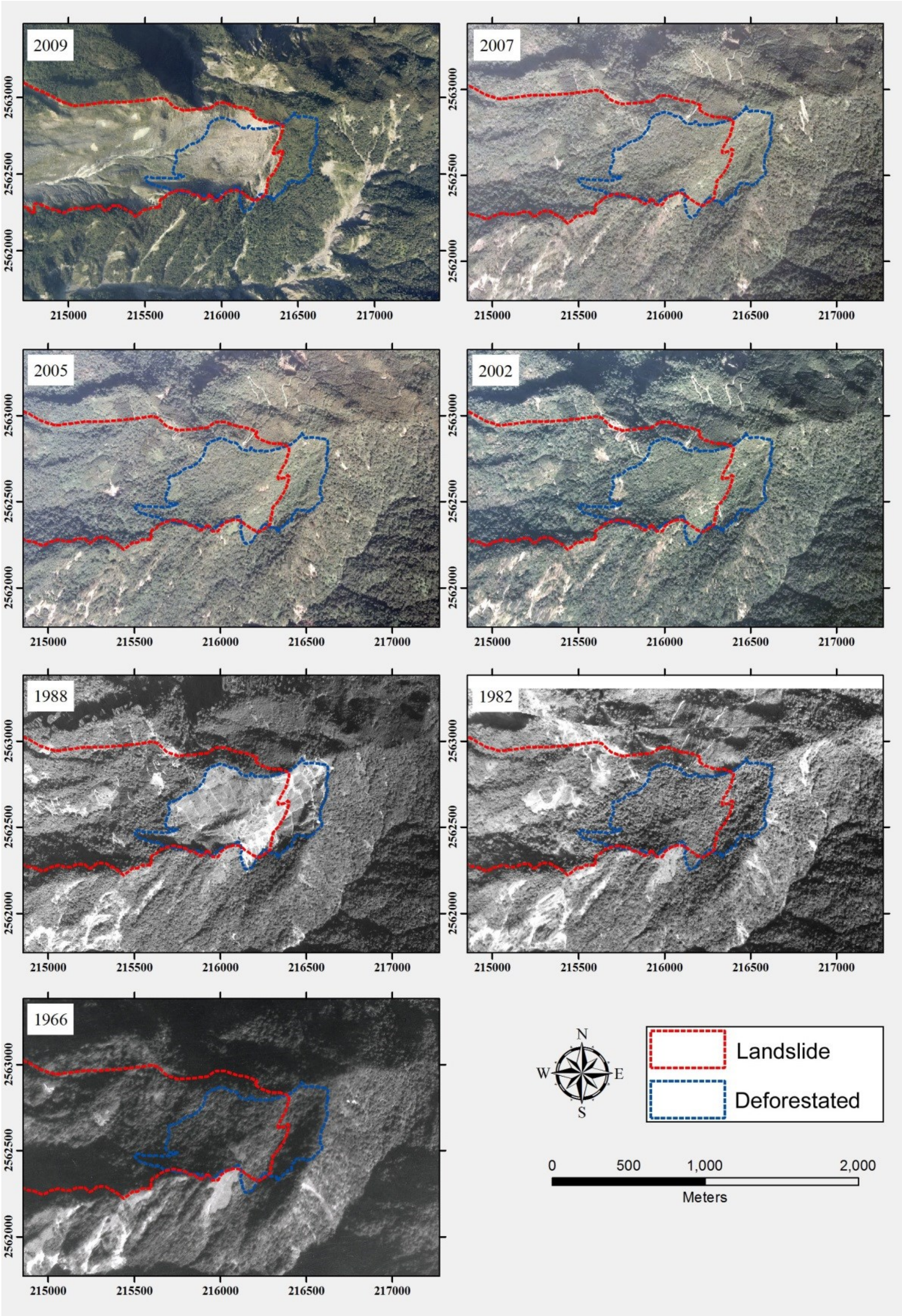

Figure 3 Orthophotos of top part of Hsiaolin Landslide and patch of deforested land in 2007、2005、2002、1988、1982, and 1966, respectively.

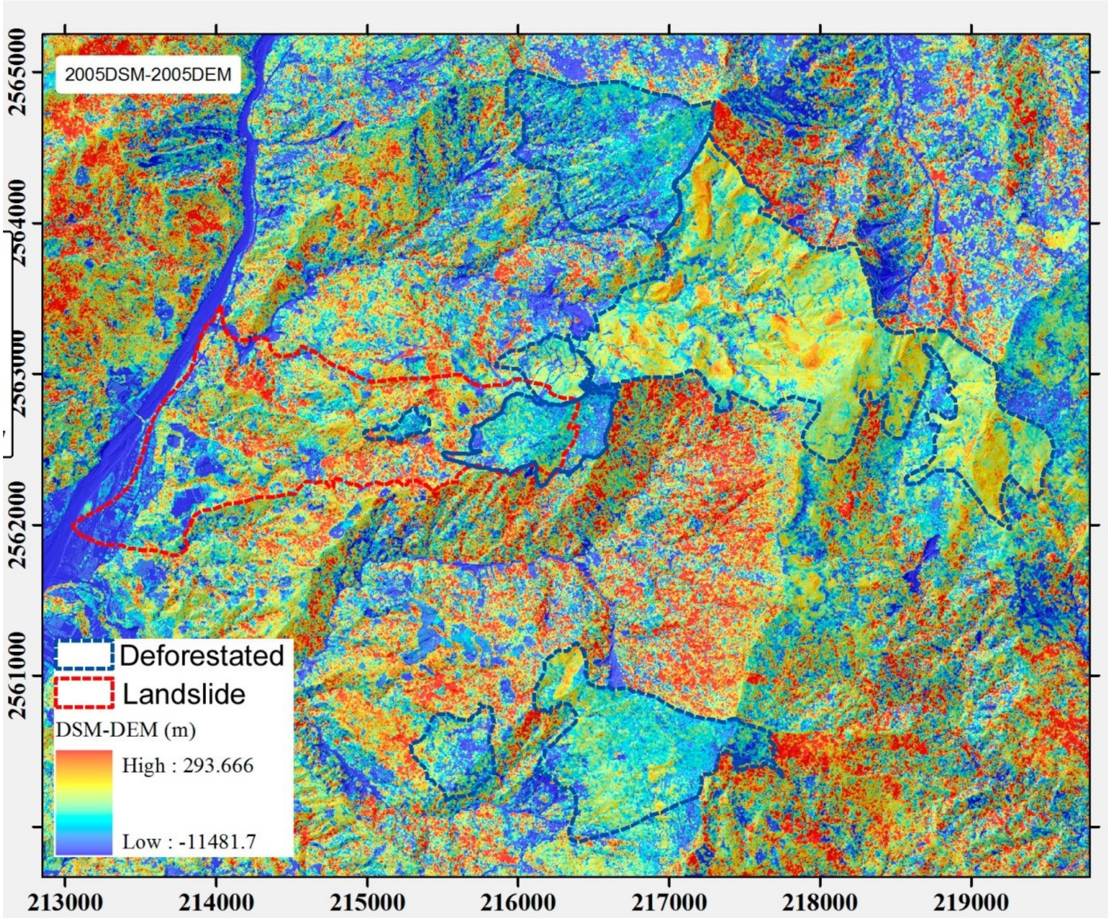

Figure 4 A normalized DEM with 2005 DSM

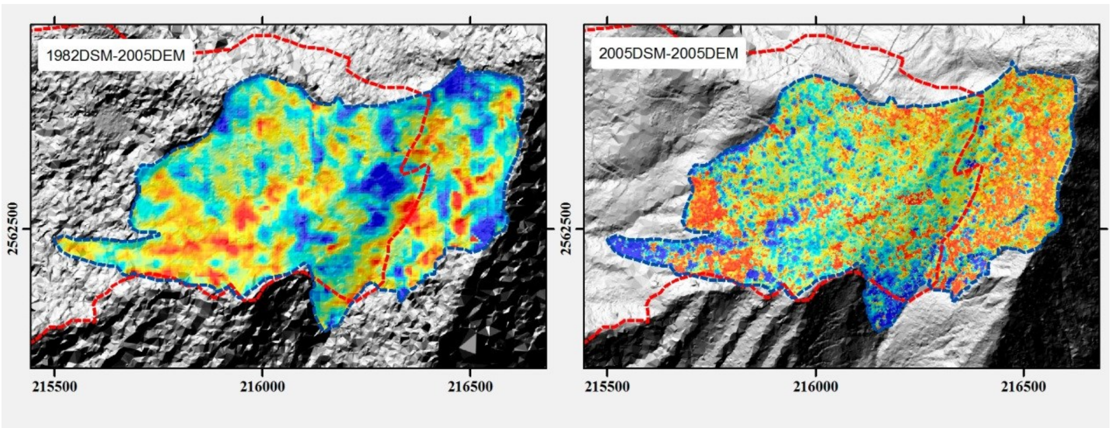

Figure 5 A normalized DEM with 1982 DSM and 2005 DSM, respectively

4. CONCLUDING REMARKS

Aerial photographs are an objective record of land features both in temporal and spatial domains. Invaluable assessment can be conducted to understand the historical changes of land uses, landscapes, landslides, urban expansion, and so on. In this paper, topographic changes of Hsiaolin Landslide with 6 times of aerial photographs from 1982 to 2009 right after the event are observed with the selected approach. Though tensile cracks have not been observed on the series of orthophotos, deforestation activities started in 20 years ago might be in close relationship. It is suggested for further study that more cases of deep-seated landslides and deforestation land can be conducted to verify the relationship. In addition, there are more than one millions of historical aerial photographs in Taiwan area spanning from 1943 to present. These are invaluable treasures for environmental studies. More applications and methodologies can be perceived from these data sets.

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