NATIONAL AIRBORNE LIDAR MAPPING AND EXAMPLES FOR APPLICATIONS IN DEEP-SEATED LANDSLIDES IN TAIWAN

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ABSTRACT

For the purposes of geohazard study, a national airborne LiDAR mapping program spanning 2010 to 2015 was launched with the aim of simultaneously capturing the territory (36,000km2) by airborne LiDAR and digital imagery. The results include very detailed digital elevation models (DEM) and digital surface models (DSM) of 1m grid and digital aerial photograph of 50 cm grid, as well as an inventory of the geological disastrous features with the acquired LiDAR data and images. In total, 400 deep-seated landslides are obtained in a preliminary interpretation. In this paper, an example in Chasan Tribal Settlement of the large-scaled landslides is selected for validation to further inspected with other geological investigation means. The results of this paper demonstrate the merit of the national airborne LiDAR survey and the effectiveness of simple manual interpretation approach for a census of deep-seated landslides with LiDAR-derived images of various types of enhancement such as shaded relief.

Index Terms— Geohazard, Geomorphometry, Airborne LiDAR, Micromorphological features

1. INTRODUCTION

Typhoon Morakot hit Southern Taiwan on 8-9 August 2009. The area hit by the typhoon is around 10 thousand square kilometres. Landslides are one of the most important primary disasters. A national geohazard mapping program employing state-of-the-art technology of integrated airborne LiDAR and digital photography is launched by Central Geological Survey Taiwan from 2010 to 2015 [1]. Airborne LIDAR topographic mapping has been carried out with these datasets to better characterize topographic features of geological hazards and potential tectonic activities [2]. Key applications include (a) geological structures, (b) landform change of river beds, river terraces, and river channels, (c) landslide features, (d) high landslide vulnerable zones, and (e) Detailed mapping and assessment for selected areas near mountain settlements.

In this paper, the status of the national LiDAR mapping program is summarized. In addition, two examples of deep-seated landslides with image enhancement methods are given to demonstrate the unique capability of these datasets for large-scaled geological hazards under forest cover.

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2. METHODOLOGY

Taiwan is a geohazard prone country. To accommodate the physiographic conditions of dense forest and extremely high relief of terrains, the state-of-the art of technology of airborne LiDAR was adopted to obtain detailed topography for applications in geological interpretation. Thus, the methodology includes the airborne LiDAR survey, the quality assurance of the LiDAR datasets, and geohazard analyses with shaded-reliefs of LiDAR DEM and DSM.

2.1 The airborne LiDAR Survey and The Quality Assurance of the LiDAR data sets

The national LiDAR survey is carried out along with a third party quality assurance of LiDAR results. The LiDAR survey was conducted by four LiDAR survey teams. The quality assurance was assigned to a team organized by a survey professor. Airborne LiDAR is mainly used for landslide investigation to create accurate and precise high resolution digital elevation models (DEM). Basic products of airborne LiDAR usually include all points, ground points, DEM, and DSM [3]. The former two products are vectors of discrete points and the later two products are interpolated raster grids of the discrete points of the former two. Digital aerial photographs are also included in the specifications and recommendations of full waveforms are encouraged for mapping selected areas near mountain settlements [4].

2.2 Geohazard Analyses with 8-aspect shaded-reliefs

Figure 1 shows the 8-aspect shaded reliefs of deep-seated landslide A, shown in the upper left inset of the figure.

Expert-based Method for geohazard analyses is used in this program. LiDAR-derived shaded images or other enhanced images are used for visual interpretation. By the interpretation of LiDAR images and other ancillary information, results for the national program include (a) geological structures, (b) landform change of river beds, river terraces, and river channels, (c) landslide features, (d) high landslide vulnerable zones, and (e) Detailed mapping and assessment for selected areas near mountain settlements.

2.3 Interpretation of shaded-reliefs and guidelines for interpreting deep-seated landslides

For deep-seated landslides, detection and characterization are the most important task before any mitigation measure can be taken or any inference of landslide kinematics and mechanics can be made. Expert-based method is adopted for the detection of deep-seated landslides in this national program [5-6]. Surface topography indicative of past deep-seated bedrock landslides is very common in certain landscapes In some areas deep-seated landslides have transformed steep, high relief topography into lower-relief and lower-gradient topography, thereby reducing the occurrence of shallow failures in the affected areas. Unlike incipient shallow landslides in bedrock hollows, deep-seated landslides often show signs of instability such as scarps, tension cracks and tipped trees. Because most of the deep-seated landslides are either latent or located under forest cover, only a few of them which are in creeping or which are newly-happened in a catastrophe can be detected by aerial photos.

As shown in Figure 2, airborne LiDAR DEM can “see through” the canopy of forest cover. The upper part of the figure is an orthophoto where the landslide scarps are vague whereas the lower part of the figures shows the LiDAR-derived shaded relief with conspicuous landslide scarps. The merit of this new technology is obvious. A guidelines for interpreting deep-seated landslides with expert-based method is established accordingly.

3. RESULTS AND DISCUSSIONS

Figure 3 shows the Taiwanese LiDAR Mapping Plan spanning from 2010 to 2015. Standard products include ground points, all points, DEM, DSM, and orthophotos. The program is scheduled to be completed by the end of 2015. It is on schedule though encountered serious problems of weather conditions and high reliefs unfavorable to aerial sorties.

With the methodology discussed above, all potential deep-seated landslides are manually interpreted for the regions where standard products are completed from 2010 to 2013. Figure 4 shows the results of landslides. In total, more than 400 sites of deep-seated landslides are revealed in this study with image interpretation of airborne LiDAR results.

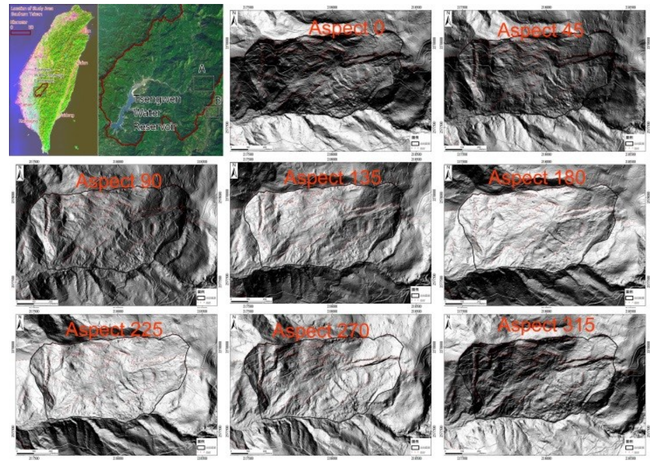

Figure 1: Example of 8-aspect shaded-reliefs of LiDAR DEM in Case A area

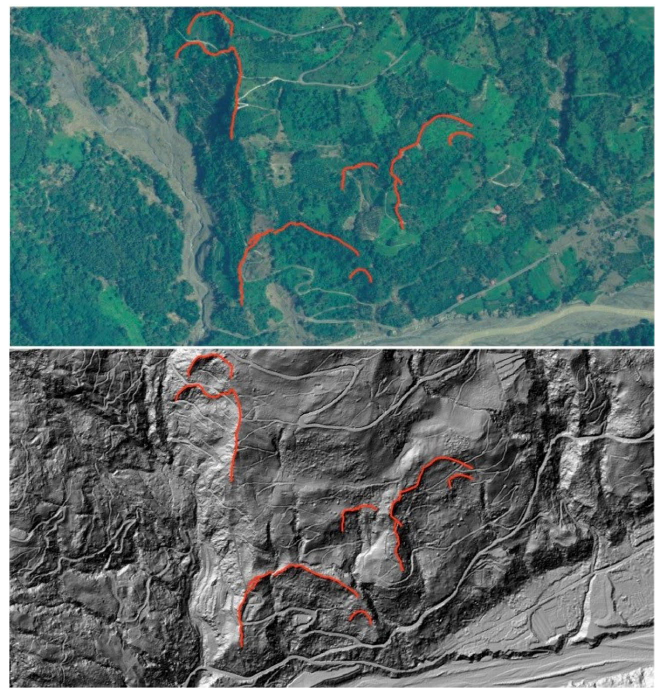

Figure 2: Case B: an example of LiDAR DEM for deep-seated landslides under dense forest cover. The top color aerial photo shows little information about the major scarps of large-scaled landslides because they are under forest cover. In contrast, LiDAR DEM shows the bare earth surface and thus reveals the landslides.

For further validation of the interpretation results of airborne LiDAR mapping, selected areas are further inspected in the field and interpreted with other geological investigation means such as aerial photo-interpretation. In this paper, as an example, the selected study site is Chashan Tribal Settlement in Alishan Mountain in the middle of Taiwan. Figure 5 shows the landslide interpretation with aerial photographs taken along with the airborne LiDAR data. The site designated as DS51 will be further investigated in the field. The micromorphological features of DS51 with LiDAR images of Chashan Aboriginal Settlement are shown in Figure 6 by visual interpretation. Generally, the area is rather unstable as manifested by all the major and minor scarps as well as fissures.

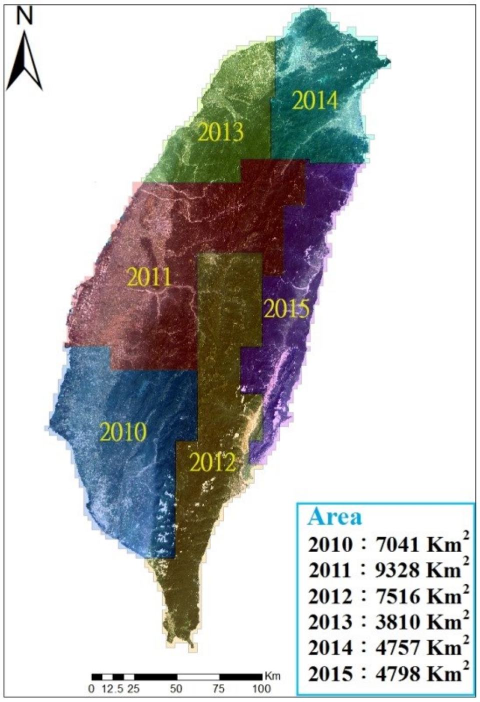

Figure 3: Taiwanese LiDAR Mapping Plan.

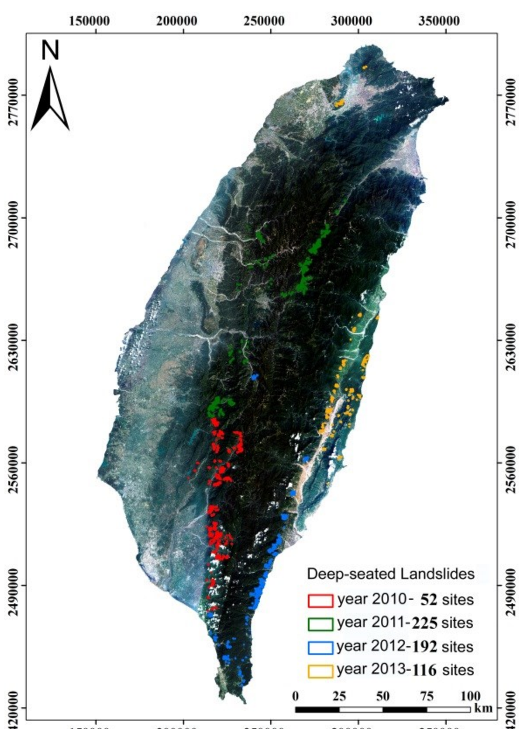

Figure 4: Deep-seated Landslides interpretation with LiDAR shaded relief.

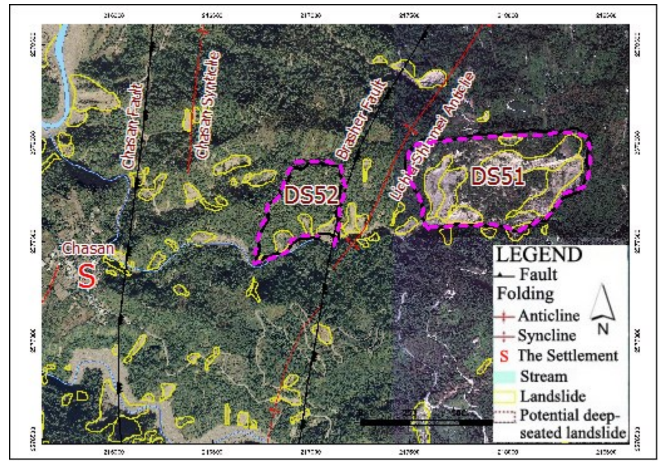

Figure 5. Airphoto interpretation of Chashan Aboriginal Settlement area with aerial photographs taken in December of 2009 after Morakot Event. Two major large-scaled landslides are observed by airborne LiDAR, e.g. DS51 and DS52.

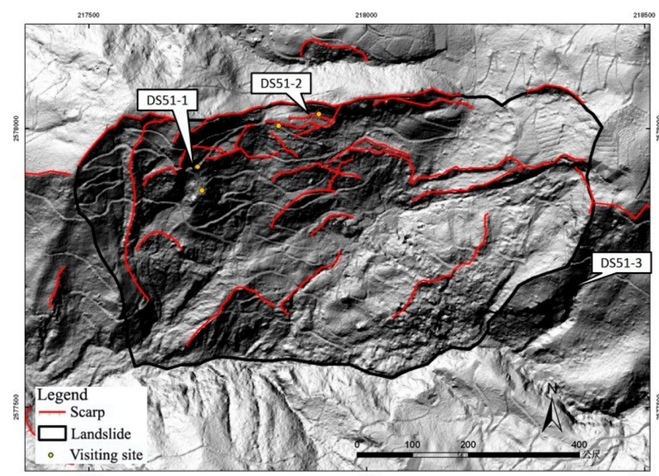

Figure 6. The micromorphological features of DS51 with LiDAR images of Chashan Aboriginal Settlement. Three sites as annotated were visited in the field.

Further evidences of deformation and sliding features such as detailed measurements of scarps, ridges, hummocky topography, erosions and tilting of electric poles can be observed in the field to validate the significance of the selected landslide. Three sites as annotated in Figure 6 were visited and they will be discussed in the following.

The features of Site DS51-1 are identified by aerial photographs, shaded-reliefs, geological maps and site investigation. This site is located to the west of an ancient landslide. As shown in Figure 7, height of the major scarp is estimated around 12 to 15 meters in the field. Extensional fissure and creeping features can be observed in the crop field of betel nut tree. Similarly, the features of Site DS51-2 are manifested by ground extensional fissures and a well-developed crown scarp is observed as shown in Figure 8. The location of Site DS51-3 is at the east site of the DS51 landslide, of which a specific feature is the major scarp is crossing the ridge and located at the other side of the ridge. These features can be observed on images, at the site, and from a remote ground photographs as shown in Figure 9.

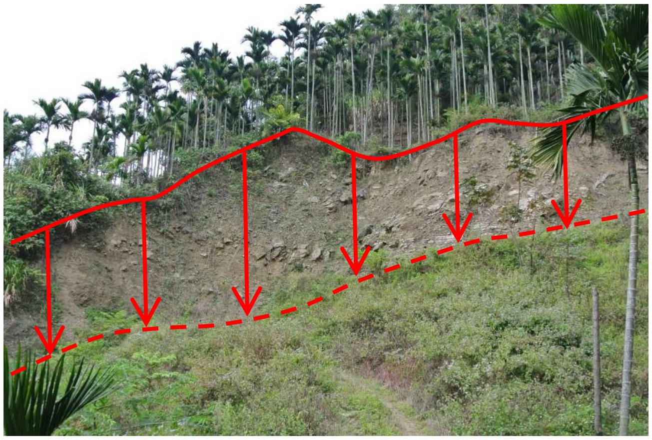

Figure 7. Photograph at site DS51-1 showing a scarp of around 12-15 meters.

Figure 8. Photograph at Site DS51-2 showing a scarp of around 0.5-1.0 meters..

Figure 9. Photograph of Site DS51-3 taken from a remote view showing the scarp to the east of Chasan Landslide.

4. CONCLUSIONS AND SUGGESTIONS

Taiwan is in a hazard prone terrain where geohazards take place after every frequent typhoons and earthquakes. In addition, deep-seated landslides are hidden under forest cover. The results of this paper demonstrate the merit of the national airborne LiDAR survey and the effectiveness of simple manual interpretation approach for a census of deep-seated landslides with LiDAR-derived images of various types of enhancement such as shaded relief.

Large-scaled or deep-seated landslides are disastrous landslides when they are reactivated. The threat of this type of landslides is larger than the frequent shallow landslides. It is worthy and rewarding for the government to pay more attentions to the prevention of this type of landslides especially in the physiographical environment of Taiwan. It is thus suggested to conduct a complete census of large-scaled landslides on basis of the datasets of the national LiDAR mapping.

5. REFERENCES

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