A Time-series Analysis of Sediment Transport in Tsaoling Landslide Using Photogrammetry and SAR Interferometry

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INTRODUCTION

Tsaoling Landslide is widely known among worldwide researchers due to its landslide prone characteristics and distinctive features. After its catastrophic failures firstly recorded in 1862, this area suffered from frequent catastrophic failures including the 1999 Chichi Earthquake. In this study, we firstly use aerial orthophotos from 1979 to 2009 to generate 6 digital terrain models (DTM) of Tsaoling Landslide at 2 m resolution. These surface changes were inspected by short-term evaluations after Chichi Earthquake (1999-2009). The evolution of the riverbed profile indicates that incision took place in the upstream section of the Chinshui River and deposition took place in the downstream section. This leads to that the river slope became milder ten years after the earthquake. Second, we attempt to track recent landslide movements from TerraSAR-X/TanDEM-X (TSX/TDX) Satellite to generate 4 DTMs with 3 m resolutions over the period from November of 2011 to April of 2014. This enables us to extend the post-seismic observation period from 2009 to 2014 with two different operations.

DTM GENERATION USING INSAR

Digital Terrain Model (DTM) is a useful tool for the studying of large-scale landslides by comparing datasets obtained before and after the events. During the past decades, DTM has been developed from low-resolution aerial photo or optical images to high-resolution images obtained through airborne LiDAR or Unmanned Aerial Vehicle (UAV), providing more possibilities for monitoring landscape changes. However, these measurements have their own limitations, e.g., high cost, sensitive to working conditions or small coverage. On the other hand, InSAR technique, which has been successfully applied to investigate natural hazards such as landslide and earthquakes, can also be used to generate high-quality DTM. Nevertheless, DTMs generated by the repeat orbit interferometry still have some constraints, such as spatial-temporal decorrelation, atmospheric artifact and distortions from other signals (e.g., ground deformation). To tackle these constraints, TanDEM-X (TDX) satellite was launched by DLR and European Aeronautic Defense and Space Company (EADS) Astrium in 2010 to form a constellation with TerraSAR-X (TSX) launched in 2007. As the constellation can acquire an interferometric image pair within several seconds, it is very suitable to generate high-quality global DTM.

RESULTS

In this study, we used 4 periods of DTMs produced by TDX satellite and 6 periods of DTMs produced by aerial photograms. From landscape observations in aerial photos, the Taochiashan deposit and Chunqiu cliff demonstrate rapid recession from the river. We selected two observation sections at the sites with fastest recession and calculated their recession rates based on the 4. Chunqiu cliffs and the Chingshui River are selected to determine the spatial pattern of morphologic changes of the landslide (**Figure 1**). The results show that: (a) A large amount of collapses occurred on dip slopes in the period from 2011 to 2014 and on surrounding debris deposits during the rainy seasons; (b) The average recession rate of the Chunqui Cliff decreased from 33.8m/yr to 46.1 m/yr compared with the result between 1999 and 2009; (c) The Tsaoling Landslide has lost 6.90×10^6 m^3 of soil from November of 2011 to April of 2014, which shows a positive correlation of 0.853 with rainfall; (d) The Chingshui River is undergoing a gradual bed erosion with a volumes of 1.84×10^6 m^3.

CONCLUSION

Apart from photogrammetry, this paper has adopted an iterated DInSAR technique to generate DTMs of Tsaoling Landslide, and successfully extended the timeline of time-series analysis from 2009 to 2014 for a long-term analysis, in particular geomorphological changes and the current state of the main sliding area. The results show that erosions and deposits mainly occurred in unstable geological strata, such as Debris deposit, Cholan formation and Chingshui shale, during the rainy season when typhoons stroke the area with abundant rainfall. Five cliffs and the Chingshui River were selected to analyze the changing feature of terrain in this area. We have found that the largest erosion and collapse, which is about 70 m, occurred during March of 2012 to July of 2013 with the several sub-sliding areas from range about 10 to 50 m^2.

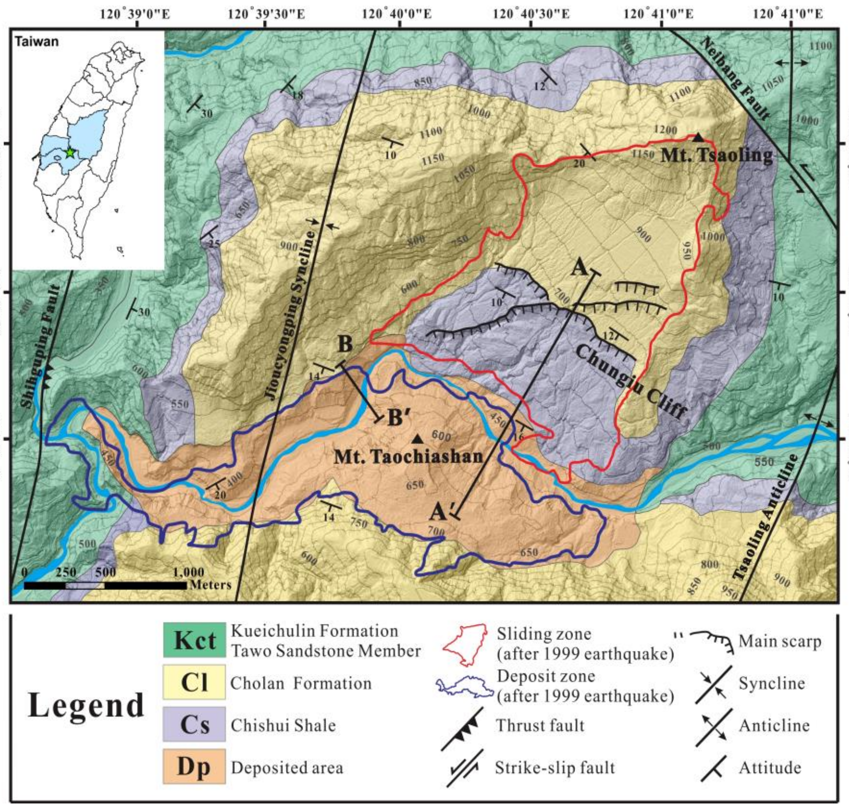

Fig 1. Geological map of the study area. Red area shows the Tasoling landslide sliding area and blue area shows the Taochiashan deposited area triggered by 1999 Chichi Earthquake.

Keywords: Photogrammetry; TerraSAR-X/TanDEM-X; Time-Series Analysis; Tsaoling Landslide