Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2017-227-AC1, 2017

Natural Hazards and Earth System Sciences Discussions
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EGU

Interactive comment on "Geomorphological evolution of landslides near an active normal fault in Northern Taiwan, as revealed by LiDAR and unmanned aircraft system data" *by* Kuo-Jen Chang et al.

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Received and published: 7 September 2017

Thank you for the helpful comments on our manuscript. Please find below our response and modifications that we have revised in the manuscript following the referee's comments and suggestions.

Anonymous Referee #1 This study analyzed landslide morphological characteristics and geomorphological evolution using lidar and UAS data in northern Taiwan. The morphological reconstruction showed that the total volume of landslides reached 820

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Discussion paper

x 10ˆ6 mˆ3. This paper is interesting for the evaluation of landslide evolution and the assessment of related landslide hazards. However, the reviewer has some comments regarding landslide types, data, and methods that would need to be verified by authors.

Referee #1-1. Little information on landslide types in the study area was explained in the manuscript. Landslide types are important for discussing the landslide evolution. It would be better to show landslide types and processes analyzed in this study referring Varnes (1978) or Cruden and Varnes (1996).

Response #1-1: According to the criteria of landslide classification proposed by Varnes (1978), the two major landslides analyzed in this study may be classified as rotational or translational slide. Detailed characteristics of the two slide types commonly include circular crown, main scarp, minor scarps, circular transverse ridges and lateral franks. We have newly added a paragraph in the manuscript to explain the observed landslide types in the study area. The paragraph is as follows: "As mentioned and illustrated in Figs. 5 and 6, the CSL is marked with circular crown, main scarp, circular concentric transverse ridges in the rear of the main body, whereas, most of the landslide morphologic components in the XSL have been modified by human activities. For example, the crown area of the landslide has been developed into a graveyard with clearly preserved lateral franks. According to the criteria of landslide classification proposed by Varnes (1978), the two major landslides, from the currently observed landslide geomorphologic components, suggest that the landslides are best classified as rotational or translation slides."

Referee #1-2. The authors emphasized importance of UAS and lidar data. However, it was not clear how did authors use these DSMs for the geomorphological analysis, respectively. For example, the authors explained that USA had the disadvantage that the DSMs included the vegetation height. How did authors use the DSMs for the analysis? Were the geomorphological analysis and the reconstruction performed by lidar data alone?

Response #1-2: Both the airborne LiDAR and UAS datasets are used in this study. The UAS DSM and the orthomosaic photos generated in this study are as high as 8.5 cm in pixel resolution, thus, the ground information is much more easily identified for regions of building and sparse vegetation. Especially, within the two major landslides CSL and XSL, the terrains have been affected by human and agricultural development, which is marked by a terrain with minor and low vegetation. The UAS DSM dataset is useful for processing and separating the DSM and DEM derived from airborne LiDAR dataset, because the UAS DSM is most informative at distinguishing the ground facts. In response to the comment, the above-mentioned points are added in the revised manuscript as follows: "The UAS images, which generate 8.5 cm pixel resolution in both the orthomosaic photo and DSM, distinguish clearly the ground and non-ground features, such as buildings and sparse vegetation. Moreover, this information is helpful at improving the airborne LiDAR data processing and point clouds classification. In the study area, two different landforms can be readily distinguished, i.e., dense forest and sparse vegetation region resulted by human and agricultural development. Figs. 4c, 4d, 4e and 4f demonstrate the two landform regions with different vegetation coverage. The landform region with sparse vegetation corresponds and is almost equal to the region of landslide. The UAS DSM generated in this study is very similar to so-called DEM, because the terrain is not concealed by the forest canopy. Thus, the geomorphologic analysis outside the landslide region depends mainly on the airborne LiDAR DSM and DEM in our study. Overall, the UAS and airborne LiDAR datasets can be mutually compensated for the geomorphological analysis in this study."

Referee #1-3. The volume of the CSL was six times larger than that of the largest landslide ever reported in Taiwan which was triggered by the Chi-Chi earthquake. How did the authors assume that the CSL triggered by the single earthquake event? Additionally, the authors assumed that current topography in the CSL corresponded to the slip surface of the original landslide (Fig. 13). Did authors have geological evidences of that? Detection of the slip surface is important for estimating the volume.

Response #1-3: Thank you for the helpful comments. To avoid misleading the readers, we have revised and added some texts in the manuscript. We don't think that the entire cut-and-fill volume of CSL was triggered only by one single event. However, from the geomorphologic features denoted in Fig. 10 (Zones A, B and C), the regions show different degrees of preservation of the landslide geomorphologic components. These observations suggest that more than one sliding event has occurred in the study area. Thus, the CSL can be interpreted to have occurred by a combination of multiple landslide events. Yet, it is difficult to propose how many landslide events have occurred in the study area. Regarding the landslide volume, the position and morphology of the slip surface indeed will affect the calculated cut-and-fill volume. In this study the slip surface is difficult to observe in the field due to soil cover and has not been definitely identified. Nevertheless, the sedimentary rock basement and the volcanic rock cover have been well mapped both on the geologic map and in field survey in the region (Fig. 1). Based on the distribution of rock types, it is supposed that the contact between the volcanic cover and the underneath sedimentary rocks may serve as a weak plane for the slip surface. On the other hand, the calculated landslide volume is derived from the difference of DEM, which denotes only the minimum volume, and does not take into account the remaining debris still resting on the supposed slip surface, especially for the larger landslide CSL. All the above-mentioned points are now improved in the text to avoid misleading information. The revised texts and in which sections of the manuscript are listed as follows:

– 4.2 Estimation of the landslide dimensions: "... The cut-and-fill volume is based on the difference of DEM, which indicates the minimum volume and does not account for the remaining debris on the slip surface. On the other hand, the volume does not consider how many landslide events have occurred to induce such volume due to insufficient evidence. " – 5 Discussion: "... However, from the geomorphologic features denoted in Fig. 10 (Zones A, B and C), the regions show different degrees of preservation of the landslide geomorphologic components. The CSL can be interpreted to have occurred from a combination of multiple landslide events. In addition, the CSL and XSL preserved different degrees of landslide geomorphologic components, and the creeks as illustrated in Figs. 5 and 11 developed within the depletion zone with different drainage patterns and varying incision depths. These observations suggest that more than one sliding event has occurred in the study area. . . . . . . The remaining displaced material in the CSL suggests a combination of multiple landslide events. However, most of the displaced material in the XSL has been eroded away and it is not possible to estimate how many events are involved in the XSL. . . . Regarding the landslide volume, the position and morphology of the slip surface indeed will affect the calculated cut-and-fill volume. In this study the slip surface is difficult to observe in the field due to soil cover and has not been definitely identified. Nevertheless, the sedimentary rock basement and the volcanic rock cover have been well mapped both on the geologic map and in field survey in the region (Fig. 1). Based on the distribution of rock types, it is supposed that the contact between the volcanic cover and the underneath sedimentary rocks may serve as a weak plane for the slip surface. On the other hand, the calculated landslide volume is derived from the difference of DEM, which denotes only the minimum volume, and does not take into account the remaining debris still resting on the supposed slip surface, especially for the larger landslide CSL, as shown in Fig. 10."

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-227/nhess-2017-227-AC1-supplement.pdf

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