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Natural Hazards and Earth System Sciences
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Discussions

Interactive comment on "Landslide susceptibility analysis by means of event-based multi-temporal landslide inventories" *by* C. M. Tseng et al.

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First of all, we wish to thank the two reviewers for their comments to the manuscript and their constructive suggestions. In this revised version of the paper, we have tried our best to address the comments and incorporate as much of the reviewers' recommendations.

Here our detailed reply to each reviewer's comments Reviewer 1 The effect of rainfall amounts on landslide occurrence must be described and discussed, because rainfall amounts are probably different within the study area.

The accumulated rainfall maps of the four typhoon events based on the 1.3km x 1.3km mesh type rainfall data provided by Central Weather Bureau in Taiwan has been added in the revised manuscript, as well as the rainfall statistics are added in Table 2. We describe the effect of rainfall amounts on landslide occurrence in the revised manuscript.

Relationships between slopes and foliation attitudes must be referred, because they have strong effects on the occurrence of landslides instead of distances between slopes and lineations that is not specified.

Foliation actually play an important role in the occurrence of landslides, however this information is probably difficult to obtain in a global geological map. Thus in our study we consider the global accessible geological structure information like faults and folds.

There are some papers that rock avalanches are preceded by gravitational slope deformation. I suggest the authors to refer to these papers and discuss briefly why they have not included that factor to evaluate landslide susceptibility.

Tsou et al., (2011) and Chigira (2014) mentioned "Most of the rock avalanches are preceded by gravitational slope deformation with topographic features, in which small scarps along future head of landslide are the most representative; the scarps can be identified in topographic images made by high resolution airborne LiDAR DEMs and may suggest the instability just before catastrophic failure." No doubt this is an important and efficient way to find the potential landslides, however scarp identification using high resolution topography data like LiDAR DEMs are required. The preparation of landslide inventories in our paper is based on image interpretation. According to the classification proposed by Varnes (1978), rock avalanches is classified into flow type movement similar like debris flow or debris avalanches, not the same as the debris slide mapped and evaluated in our paper. Usually the flow type movement occur in the downstream of landslide toe since it need more concentrated water. The flow type movement is characterized by the long and narrow shape in images thus should be ruled out in landslide mapping.

P1140, L23-24: Baye's theorem needs a reference

The reference of Baye's theorem is added in the revised manuscript.

P1140, L25: I do not understand the meaning of "to map four different rainfall scales: : :inventories."

Rainfall scale in our paper means the average accumulated rainfall amount of the study area. Typhoon Kalmagei has similar average rainfall amount and rainfall center compared with Typhoon Sinlaku, however it revealed quite different slope aspects distribution of landslides as we discussed in our paper.

P1141, L14-L16: The ages of the rocks must be referred. Gravel and sand seem to be riverbed deposits, which must be mentioned.

We add the description in the revised manuscript.

P1142, L 10-L11: NDVI needs a reference.

The reference of NDVI is added in the revised manuscript.

P1142, L16-L19: The authors say that scars of deep-seated slides are included. If so, it would be better they mapped landslide scars or rock/debris avalanches rather than shallow debris slides.

In the satellite images interpretation before and after typhoon, only when the vegetation was stripped off due to landslide movement can be identified. In our paper, we mainly evaluate slide type movement (debris slide), not flow type like rock/debris avalanches. The flow type movement is characterized by the long and narrow shape in images which were ruled out in our landslide mapping.

P1142, L24-L26: I wonder the averaged cumulative rainfall means the average in the study area or not. I think the distribution patterns of rainfall amounts need to be referred, because they must have influenced landslide occurrence.

The averaged cumulative rainfall actually is the average value of whole study area. For the understanding of rainfall pattern in different typhoon events, the accumulated rainfall maps of the four typhoon events has been added in the revised manuscript, as well as the rainfall statistics are added in Table 2.

P1143, L27 – P1144, L1: redundant.

The description is simplified in the revised manuscript.

P1144, L1-L2: Landslides also occurred in meta-sandstone areas, and only sand and gravel areas had much less numbers of landslide, which suggests that riverbed had few landslides.

Riverbed had few landslides due to the gentler slope.

P1144, L9-L10: I think rainfall distribution is more important than the wind and rainfall direction.

The description has been modified in the revised manuscript.

P1144, L20-P1145, L2: Slope aspects of landslides must have relationships with the attitudes of foliations, so this point must be discussed.

As described above, the information of foliations attitudes is practically difficult to obtain in a global area geological map. In our study, Typhoon Kalmaegi show quite different aspect distribution of landslides, not like the other three typhoons. Thus this difference is most likely influenced by rainfall spatial distribution like whether the slope is facing windward or leeward.

P1146, L1-L2: The authors must describe the geological structures to be considered in the study area, because I see only a word of lineation in Figure 4.

The main geological structures we considered are faults and folds and have been added in Fig.1 in the revised manuscript.

P1146, L6-L7: I do not see that a large number of the landslides were in the area of the interval 1400-2000 m.

Distance interval 1400-2000 still exhibit little higher landslide ratio compared with other intervals. We revise the descriptions in the revised manuscript.

P1146, L12: To measure the distance between a landslide and a stream, definition of the distance is necessary.

The method to calculate the landslide area in each classified interval can be described by this sketch. Take a landslide as example, the total landslide area is A (=A1+A2+A3), then area A1 is classified into the class <50m, area A2 is classified into the class 51-100m, area A3 is classified into the class 101-150m, as well as for the other landslides.

Fig.1

P1147, L17: AUC need to be spelled out and explained at the first appearance.

There is a complete spelling in Abstract and Introduction, respectively.

P1147: Calculated parameters, like W+. W-. C, ln(Qf) need to be shown.

The calculated parameters were summarized as supplement of reply.

P1150, L19: Landslides analyzed are not only small-ones but also large ones like Hsiaoling.

Here the term "small-scale landslides" we want to express the rainfall amount more close to the critical threshold of landslides. Probably it is not a proper description, we modified the description as "...median scale rainfall induced landslides tend to render better model performances....".

P1151, L2: Is this threshold a rainfall amounts? Yes

P1151, L10-L11: When the aspects of landslides are discussed, the attitudes of foliation need to be included.

The information of foliations attitudes is probably difficult to obtain in our global study area.

P1153-1155: The description in the conclusions is redundant, because some are only repetition of what is written in the discussion. I suggest to make it more compact.

We rewrite the conclusion in the revised manuscript.

Figure 1: The numbers along the frame are too small to read. They seem to be special coordinates. I think degrees of latitude and longitude would be better.

We redraw Fig. 1, the coordinates is changed and the rivers and geological structures like faults and folds are added in the figure.

Figure 2: New formed landslides in the legend must be newly formed landslides or new landslides. Study area in the legend is not necessary.

The landslides mapping included landslides that are an extension of pre-existing landslides, as well as newly formed landslides. We redraw Fig.2 in the revised manuscript.

Table 2: It is strange that only 60 mm of rainfall brought by the typhoon Mitag induced so many landslides. The authors mention typhoon scale in the text, so their scales need to be added in the table.

The 60 mm is the averaged accumulated rainfall of whole study area. The peak rainfall amount reached to 225 mm. The accumulated rainfall maps of the four typhoon events has been added in the revised manuscript, as well as the rainfall statistics are added in Table 2. In Typhoon Mitag, less rainfall also induced considerable landslides probably because one another Typhoon Krosa (4-7 Oct 2007) affected the study area one month ahead of Typhoon Mitag. Typhoon Krosa brought the average and maximum accumulated rainfall 585 mm and 918 mm, respectively. The critical rainfall threshold of landslide occurrence in Typhoon Mitag could be possibly became lower due to the high water content of soil effected by the previous typhoon.

Figure 3: Slope (ï¿§). The symbol of the degree is odd. Stable area is odd in this category so it would be better to describe as area with a slope less than 5ï¿§.

Fig.3 has been removed according to another reviewer's suggestion.

Figure 4: In the landform column, there are concave, straight, and convex types for valley, slope, and ridge, respectively. They must be defined in the text. We add the description of landform definition in the revised manuscript.

References Chigira, M., 2014. Geological and geomorphological features of deep-seated catastrophic landslides in tectonically active regions of Asia and implications for hazard mapping. Episodes Journal of International Geoscience 37(4), 284-294. Tsou, C.Y., Feng, Z.Y., Chigira, M., 2011. Catastrophic landslide induced by Typhoon Morakot, Shiaolin, Taiwan. Geomorphology 127, 166–178. DOI:10.1016/j.geomorph.2010.12.013.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/3/C354/2015/nhessd-3-C354-2015-supplement.pdf

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 3, 1137, 2015.

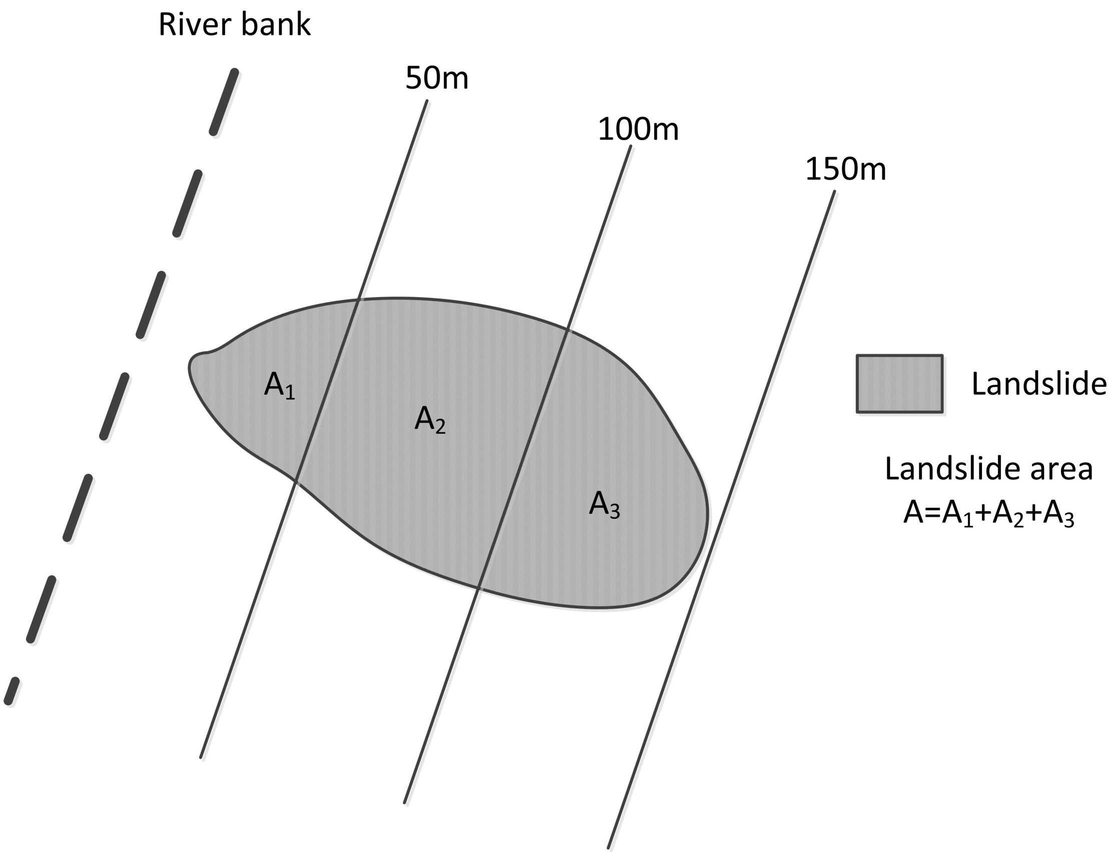

Fig. 1. sketch for measureing the distance to stream

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