Nat. Hazards Earth Syst. Sci. Discuss., 3, C2981–C2985, 2016
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Natural Hazards and Earth System Sciences Discussions
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NHESSD
3, C2981–C2985, 2016

Interactive comment on "Characteristics of landslides in unwelded pyroclastic flow deposits, southern Kyushu, Japan" *by* M. Yamao et al.

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Received and published: 15 January 2016

We found this review to be very helpful and it corroborated many of the comments raised by RC C2211. All comments and suggestions raised are addressed in the paragraphs that follow.

General Comments:

1. In response to this comment and comments from other reviewers, we now include a new topographic map with the landslides delineated and additional information on weathered Shirasu physical properties (see new Table 1) and land cover. We have also added two new paragraphs in Section 2 that summarize the soil and land cover information: "Physical and mineralogical properties of Shirasu are presented in Table

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1. The rapidly weathered soil mantle has little structure with porosity values often exceeding 60% and bulk density values often < 1 g cm-3 (Yokoyama, 1970; Chigira and Yokoyama, 2005). Due to the dominance of sand-sized material, Shirasu has a relatively narrow particle size range – about half of the mass is within the 0.125 to 1.0 mm range (Iwamatsu et al., 1989). The small clay content often contains halloysite, a clay mineral typically associated with unstable soils (Cohesion values have been reported up to 10 kPa, and internal angle of friction is comparable to other similar materials (Umehara et al., 1975; Sako et al., 2000; Chigira and Yokoyama, 2005). Distinct hydrological pathways (including soil pipes) and processes occur in Shirasu deposits because of the high porosity and low density of the soil (Haruyama, 1974; Jitousono et al., 2002)." "Land cover in rural regions of Kagoshima Prefecture where unwelded pyroclastic flow deposits exist consists of mixed broadleaf forests, Japanese cedar and cypress plantations, and interspersed agricultural areas (Figure 3). On the steepest slopes, where repeated slab-type failures occur, little vegetation develops (Figure 3). Because the government databases we used focused on landslide damages, a large extent of the landslides reported herein occurred in urban and residential areas."

2. We have added a more detailed explanation of the mechanism of landslide initiation by pore water pressure accretion and have added references for both types of initiation mechanisms. We introduce this new material in the third paragraph of Section 2 as follows: "These deeper landslides are typically triggered by rainfall infiltration and possibly the influence of pipeflow causing a positive pore pressure to develop during storm events (e.g., Teramoto et al., 2006; Taniguchi, 2008). However, these landslides can also be influenced or caused by increased weight due to accumulated rainwater and loss of matric suction (e.g., Chigira and Yokoyama, 2005; Fukuda, 2011)." Based on this reviewer's comments, we now realize that we have caused some confusion by categorizing landslides as "shallow slab-type failures" and "deep planar landslides". Because this second category is not really deep (i.e., about 1-2 m), we have revised the wording throughout the paper and noted these as 'slightly deeper' or 'deeper' landslides in comparison to the very shallow slab-type failures (which are < 1 m deep).

Another issue that this reviewer alludes to in this comment is somewhat in contrast to the suggestion by reviewer RC C2387. Basically the question is – where should we first introduce the concept of the two landslide generation mechanisms? We have reorganized the paper and added some new information (and deleted some information we felt was redundant). Modification/reorganizations to the paper are as follows: We retain the short mention of the trigger mechanisms in the Introduction, as these are based on findings of other researchers. We introduce the concept of how different types of Shirasu landslides are likely initiated via different mechanism in Section 2 (third paragraph). We removed mention of trigger mechanisms from the first three subsections of the Results section. We moved former Section 3.3 to 3.4 where we now illustrate how increased weight and loss of suction may affect Shirasu landslides. And then we address these mechanisms (by inference) in both the Discussion and Summary and Conclusions sections. Hopefully these changes will satisfy the somewhat conflicting concerns of both RC C2296 and RC C2387.

3. As noted in our response to general comment #1, we now provide more information on the rather homogeneous Shirasu soil mantle that covers about 50% of southern Kyushu (also see new Table 1). In particular, we discuss that the effective cohesion that is assumed in our hypothetical example (Figure 6) helps maintain the stability of the slope up until near-saturation. The following sentence was added to the end of Section 3.4: "For lower values of C, FS would be reduced further, but the effect of suction loss with progressive wetting would be less."

Specific Comments:

A new map is now included in Figure 4 showing elevation (gray-scale) and locations of landslides in our database together with locations of rain gauges. As noted in the response to RC C2211's comment, we regret the confusion caused by Figure 2; this is not an actual profile cross section, but rather a hypothetical illustration of the hydrogeomorphic processes that shaped the Shirasu deposits in this general landscape. This is now clarified in the text.

In this study site description, I believe we have noted the trigger mechanism of the slightly deeper landslides – i.e., “These deeper landslides are typically triggered by positive pore water accretion, but can also be influenced or caused by increased weight due to accumulated rainwater and loss of matric suction.” We have added an additional sentence as well as noted in our response the General Comment #2. The database we used only identified landslides after failure occurred, thus we do not have ground water table or pore pressure data.

As suggested by RC C2211, we have clarified API and adjusted API throughout the paper. The particular phrasing for this sentence(s) has been changed to: “. . . (5) antecedent precipitation index (API) for both 7- and 30-day periods (API7 and API30, respectively). In our reported API values, we subtracted the mean evapotranspiration rate in southern Kyushu (2.6 mm d-1; Takagi, 2013) from API for the period of assessment (i.e., 7 or 30 days).”

See response to item #3 in General Comments. As noted in Comment #3 and as requested by RC C2211, we have added this information in the new Table 1 as well as adding a new paragraph in the text relatyed to soil properties; five new references appear to support Table 1 plus other previously cited papers.

Table 1 was has been added (see response to RC C2211)summarizing the range of soil properties; variability is not given (only ranges) because data came from diverse sources.

We checked these values in the text and in Figure 6 and found that they are correct – we did round these off to one decimal point and they are now changed to 2 decimal points. Please note that this reduction in FS refers to the case with increase in weight (by water) only.

Technical Comments:

We modified symbols for consistency and use SI units throughout.

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Caption of Figure 6 has been modified as recommended and we now list these properties in the text and new Table 1 as suggested by RC C2211.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/3/C2981/2016/nhessd-3-C2981-2016-supplement.pdf

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 3, 6351, 2015.

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Interactive Comment