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Discussions

Interactive comment on "Debris flow susceptibility mapping using a qualitative heuristic method and Flow-R along the Yukon Alaska Highway Corridor, Canada" *by* A. Blais-Stevens and P. Behnia

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Interactive comment on "Debris flow susceptibility mapping using a qualitative heuristic method and Flow-R along the Yukon Alaska Highway Corridor, Canada" by A. Blais-Stevens and P. Behnia Dr. Oppikofer (Referee)

General comments The paper by Blais-Stevens and Behnia on "Debris flow susceptibility mapping using a qualitative heuristic method and Flow-R along the Yukon Alaska Highway Corridor, Canada" presents a comparison and validation of two approaches for debris flow susceptibility assessment. The qualitative heuristic method aims at identifying debris flow source areas based on a series of geological and morphological criteria, such as the slope angle and aspect, distance to drainage network, superficial deposit type and permafrost occurrence, which are then ranked and combined into a susceptibility index based on expert knowledge. The second approach is the Flow-R model for debris flow initiation and propagation. Source areas in Flow-R are determined using partly other criteria than in the heuristic model (curvature for example) and computes then the runout area for each source cell. The authors validated the susceptibility models using an inventory of debris flow events. The manuscript is complete, nicely illustrated and well written. One of the major flaws of the study is the different way of determining potential debris flows source areas in the two approaches. Why using different criteria and why not combining both approaches. The heuristic approach yields a susceptibility index for each grid cell of the digital elevation model and could thus be used as input parameter in the Flow-R model. Combining thereby both approaches would greatly improve the comparison of susceptibility maps with the debris flow inventory and deposit maps. The heuristic approach yields a susceptibility index for each grid cell of the digital elevation model and could thus be used as input parameter in the Flow-R model.

Addressing major flaw: We have decided to leave both methods as separate methods to define potential sources. Although we agree that the susceptibility index in the heuristic method could be used as input parameter for the Flow-R method. In our first attempt at using Flow-R, we decided to follow Horton et al's method as closely as possible and use those results to verify if our assumption of determining a source area from the debris flow that is, at least 500 m uphill from the apex of the deposit, was plausible. We also have explained in more detailed the objectives of the paper in the Introduction

Specific comments 1-Other important improvement to the manuscript include a better justification and discussion of the scores and weights used in the heuristic susceptibility index. I would like to see a discussion why a higher probability of permafrost

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occurrence gives a higher score for the susceptibility index. I see the role of the active layer in permafrost regions as factor for debris flow initiation, however areas that have certainly permafrost and maybe even permanent permafrost might rather stabilize the hillslope material and impede debris flow initiation. We agree with the reviewer. Thus we contemplated and because of the uncertainty of the permafrost distribution model and its potential impact (or lack thereof) on debris flows and the broad scale of the surficial geology map, we modified the heuristic method by deleting permafrost as a data layer and included plan curvature in the heuristic as in the Flow-R method. It is a good suggestion for a future exercise to combine both methods. Because we modified the heuristic method (equation 1), we also carried out a new validation success rate curve with the inventory, which gave us slightly better results (Figure 3).

2-Please also justify the choice of weights when combining the different factors. Some of the parameters used in the source area detection in Flow-R, namely the curvature and the upstream catchment area, should also be added into the heuristic model with appropriate classes, scores and weights. We elaborated on the choice of weights and used plan curvature as a parameter in the heuristic method instead of permafrost probability distribution model.(Section 4.1)

3-A significant problem of the produced susceptibility maps is that the debris flows do not cover the entire debris flow fans, but only the present channel. Over long time, however, present channels may get blocked and new channels form all over the fans. We agree and that is why we mention in Section 4.2.1.3 Evaluation and the Conclusion that some of the debris flow deposits (the inventory used for validation) have been building since the last glaciation (for more than 10,000 yrs).

4-It is therefore crucial for a debris flow susceptibility map to cover the entire fans. An appropriate choice of the spreading algorithm parameters might solve this problem. We tested several spreading algorithm parameters using a wide range of values, and have shown the ones that cover most of the debris flow fans (Section 4.2.1.2 Susceptibility assessment). It is not surprising to us, given the length of time these fans have taken

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to build that not all the mapped debris flow deposits are covered using the Flow-R method. However, the propagation map displays areas within the deposit that are potentially threatening in present-day conditions.

Technical comments (page number/line number): 3510/9-10: remove mention how the slope angle and aspect are obtained Done

3511/12: observed landslide types include "debris flows" instead of "debris flow deposits" Done

3511/21: the first sentence is unclear; We added some explanation in the 1st sentence

3512/5: "higher resolution" instead of "higher precision" Done

3514/14-17: this general part about debris flow modeling should be in the introduction; focus the section 3 on previous works in the YAHC OK done

3515/14: delete "geological" as also other map types (e.g. permafrost) are used We have deleted other maps as permafrost was deleted due to its uncertainty.and also added plan curvature which is derived from DEM

3515/21: insert comma after "slope aspect" Done 3516/8: problem with formatting of the letters "ff" which transform into a special symbol (at several places throughout the paper) We do not see this in our version of the manuscript. . .? Perhaps it is appears when the manuscript is converted to pdf? We are not sure where in the manuscript this problem occcurs

3516/15-19: long and complicated sentence that should be split in two and partly rephrased, especially to explain the influence of slope aspect on the drainage system We rephrased (deleted permafrost and included plan curvature) and rearranged the structure of the sentences.

3517/5-20: can be removed when using the source areas of the heuristic model in the Flow-R propagation model. As mentioned above. We decided to leave the two methods as separate methods, but to use plan curvature in the heuristic method instead of permafrost distribution due mainly to the uncertainty of the distribution and that plan curvature seemed to be a better parameter to use as suggested by the reviewer and as used in Flow-R.

Furthermore, I do not understand the limit of 500 m from the fan apex, as there are many debris flow sources further upstream. Because the susceptibility map resulting from the heuristic method only gives us the potential zones of initiation, and our inventory only displays the deposit, we validate by making the assumption that the source area likely comes at least within a catchment 500 m uphill from the apex of the deposit within the steep channel. We understand that the source area could come from a higher and longer distance, but we established what we assume is a realistic limit. In addition, we demonstrated in Fig 5 that a lot of the 500 m catchment source areas overlap with calculated source areas from Flow-R. See end of section 4.2.1.1.

3517-3521: section 4.2 summarizes the Flow-R method in great detail. This can be shorted a lot by focusing on the application of the method, referring the reader to the paper by Horton et al. (2013) for theory and computational aspects. In addition there are issues with the formatting of equations We shortened the text and referred to the method outlined in Horton et al's 2013 paper.

3521-3522: the source area delineation in Flow-R should be replaced with the source areas from the heuristic model, but including some more parameters in it. Move the sections on "Source area delineation" to the appropriate place and rephrase As mentioned above, we decided to leave the methods as separate methods. However, we did substitute plan curvature parameter in Flow-R in the heuristic method. It was also a way for us to validate our assumption of outlining a potential source (within 500 m uphill from the apex of the deposit) by defining potential sources quantitatively using Flow-R. (see end of section 4.2.1.1),

3521/19: I do not understand the unit 2 /100 m-1. Is this equal to 0.02 m-1 or does it mean something special...? The unit of curvature is m-1. The -2/100 m-1 is what we observed as a standard way of writing the unit value for plan curvature. We followed Horton's method as well as textbooks and ArcGIS. One of the textbooks explained that because the values of the curvature are typically small, the results of the curvature functions are the actual curvature multiplied by 100 so it results to 1/100 m-1.

3521/24: discuss why using very low curvature values as threshold. Are debris flows in the YAHC less channelized than in the Alps or in Norway for example, or are there other reasons for using much lower curvature values than in other case studies? We made an error in writing the curvature threshold value; it is -1 /100 m-1 rather than -0.1. Therefore, it is not as small. It is a mid-range value used by Horton et al., and Fisher et al., We have corrected this in the text and in the Figure 4 caption.

3523/20: do the chosen inertial algorithm parameters match published data. If yes, please refer to them, else justify the parameter choice We added Horton et al., 2013 reference because we followed one of the approaches outlined by them.

3525/22-23: why is one fan not reached by the model? Was the source area not detected or the run-out too short? We assume this is for debris flow fan E;, the runout is likely too short in this case, because the first source area defined in the model is about 6 km upstream from the apex of the deposit. We added this observation in the text.

Are debris flows with high water content (= debris floods) possible, for example when a debris flows enters a channel with high water flow Debris floods have not been separated from debris flows given our limited historical data.

3526: remove references to publications and figures in the conclusions Done

Table 1: did you associate a rating to the unit "Rock, Anthropogenic"? Yes, it is included with Organics and alluvium just above

Figures: some of the figures are very small and nearly impossible to decipher at the

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current scale. Full-page figures would be appropriate for Figs. 2, 5, 6 and 7; full-width figures for Figs. 1, 4 and 8. Yes, we agree.

Figure 1: In a) it should be "Denali fault" instead of "Denati fault" Corrected

Figure 4: why does the debris flow in Williscroft Creek in a) stop before the fan apex? Likely because the threshold value of -1.5/100 m-1 is not the appropriate threshold value used in the calculations, but rather -1.0/100 m-1 is as shown in 4B. This is why we selected threshold value of -1.0/100 m-1 instead of -1.5/100 m-1 (or smaller than -1.5/100 m-1).

Remove the number "1" in b). The North arrow was converted to a number 1 in the conversion or uploading

In the legend write " 1.5" instead of " 0.1.5". Done

Figure 5: legend: delete "of Fig. 5" after "location" Done Figure 8: remove the number "1" in c) The same problem with conversion; it is a North arrow.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 3, 3509, 2015.