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Discussions

Interactive comment on "Application of a fast and efficient algorithm to assess landslide prone areas in sensitive clays – toward landslide susceptibility assessment, Sweden" *by* C. Melchiorre and A. Tryggvason

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General Comments:

This paper presents work involved in exploring landslide susceptibility mapping for Sweden, with a particular focus on specific statistical methods relying on very high resolution topographic data from airborne LiDAR. The paper is difficult to read and will benefit from efforts to edit primarily for clarity / focus, and to a much lesser extent for improved English grammar. I'm not entirely sure the purpose of the paper: is it to

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present a new landslide susceptibility map, or rather simply to present the results of selected statistical explorations, with the goal of improving methodology to allow the later development of an improved susceptibility map? I think it can be a worthwhile contribution in either case, but needs some revision to make its intent and outcomes more clear. While I have made a lot of comments, this doesn't mean I don't appreciate the work. I think the manuscript needs a lot of work to make it more readable, but I think there has been some good work done and would like to see this work recorded in the literature eventually.

Specific Comments:

Abstract (general) – the objective(s) of the paper is (are) not clearly stated

Abstract line 5-6 – I don't know what is meant by "... able to detect soil and slope criteria guaranteeing a faster execution..."

Introduction (page 7774), second sentence – this sentence contains two distinct, different and unconnected thoughts. I'm not sure why lives or transport corridors are threatened because the landslides occur in gentle terrain.

pg 7774 lines 3-4 – claim that "... do not show evident signs of ..." needs a citation (or revision to soften / generalize the statement). While I agree there is generally little, if any, obvious advance warning of landslides in sensitive clay, there have been cases with documented movement for some years prior to eventual global failure (e.g. Demers, D., S. Leroueil, J. D'astous, 1999, "Investigation of a landslide in Maskinongé, Quebec," Canadian Geotechnical Journal, Vol. 36, pp. 1001-1014)

lines 16-17 – "... the terrain prone to landslides in sensitive clay can be discriminated from stable terrain using the ratio dH/dL..." I do not have that reference, do those authors claim precisely that, or have you paraphrased? I'm sure that nobody can discriminate stable from unstable sensitive clay terrain solely on the basis of slope angle.

On a related note, you use dH/dL throughout the paper, is there any reason you can't

use a more intuitive term, like slope angle? It seems unnecessarily technical.

line 25 – what is a "local visibility operator?" I think I understand this is some kind of viewshed interpretation, but I don't know this term and don't think it is in common use, so needs to be defined

Pg 7776 lines 2-3 – ". . . there will be numerous areas that violate the dH/dL criterion. . ." What is the basis for using a dH/dL criterion, and what is a/the dH/dL criterion? The term and concept of its use come almost from nowhere and need a better introduction for the reader

line 10 – QCSI needs to be explained / described. You do this later. Here is appears without introduction, so at the least needs a citation.

lines 11-20 - the objectives presented here are not very clear, and this may be in part because the preceding text (introduction) is not very concise, and difficult to follow.

line 21 – spelling Southwestern

Pg 7777 line 2 – ice-marginal

Line 3 – glaciomarine (mistake occurs throughout the paper)

Line 4 – what is Holocene "transgression?" Maybe you mean regression?

Line 8 – ". . . interbedded with fine-sand layers in their lowermost portions. . ." Does this mean they are ice-proximal (or anything else about genesis)? Is this somehow pertinent to the story you are telling or can it be deleted?

Line 11 – ". . . when the sea level was 125 m above present. . ." I don't think you mean sea level was higher, I think you mean (?) the land was depressed and the marine limit is recorded at $\sim$ 125 m on the current (isostatically raised) landscape?

Line 16 – need to defend (or remove) ". . . intense" with a citation

Line 23 – discusses / mentions "glacial fine clay" and "post glacial silt" and "glacial/post

glacial clay;" can you say anything about the genesis, are these deposits lacustrine, glaciolacustrine, marine or glaciomarine? These seem to me to be important distinctions, much more important / relevant than "glacial" or "post-glacial"

Pg 7778 line 8 – ". . . to detect areas above a specified dH/dL threshold. . ." is presented like the reader should know what it means. I think you are referring to the use of an angle threshold to identify landslide susceptible areas?

line 9 – "ArcGIS" needs a citation

line 17 – what bearing on line of sight does ". . . information on depth to bedrock. . ." have?

Section 3.1 is, generally, unclear and hard to follow. The overview description of the algorithm is, to me, unintelligible.

Line 21 – "surrounding cells" means what. . . immediately adjacent cells? Some (nearby?) neighbourhood of cells?

Line 22 – ". . . elevation of the cell is lowered. . ." I can't process this description. If the cell is lowered, it's angle with adjacent cells gets steeper, not flatter, no? Not sure what I'm not following, but this needs a clearer description.

The last sentence on this page is unclear, I cannot make out what it means.

Pg 7779 line 14 – what is "neck size?" This is obviously a critically important concept in the paper but is nowhere defined. In the same line, what is a "sample" in ". . . width of a few samples. . .?"

Line 20 – use of QCSI is begging for some kind of explanation of what it is prior to this point

Line 25 – write out NNH in full before abbreviating it

Line 7780 line 2 – what is granulometry? Do you mean texture, or grain size?

Line 4 – cite a source for the SGU product used as a bedrock map

Line 5 – cite the data sources for the three different SGU databases

Lines 13-14 – the "depth to bedrock map; is it generated as a raster with "depth to rock" used directly, or as a raster with "rock elevation" that is then used to infer "depth to rock" from available topography (by subtraction)? This is an important difference that leads to different uncertainties in the resulting map.

Related to the above, did you do any QA / processing to resolve anomalies in the bedrock depth map? I assume there must have been issues with this map given the various sources of data with different spatial densities of input data.

Line 18 – the bedrock map "resolution" is 50 m, but what is its spatial accuracy and how does this vary across the map? I assume the 50 m resolution relates to your choice of pixel size, and not to the spatial density of the input data. Am I wrong?

Lines 24-25 – the landslide scarp map's development needs to be described (or a reference about its development cited) in order to be understood and accepted by the reader, not simply presented as a "product of SGU." Was it produced as part of the present work? If so, it needs to be fully described in this paper or in a preceding, related paper or document.

Line 29 – what are the "time-dependent factors?" and how/why are they not important?

Page 7781 line 1 – add "occurrence" after "probability of landslide..." Further, without knowing more about the cited model (perhaps some basic explanation) it is difficult to know what is meant by "... probability of landslide (sic) is basically the probability of failure."

Line 7-8 – Retrogression distance is, I think, only very weakly linked to sensitivity, and several authors draw correlations to other factors. See for example: Bjerrum, L., 1955, "Stability of natural slopes in quick clay," Geotechnique, Vol. 5, pp. 101-119; Carson, M.A., 1977, "On the retrogression of landslides in sensitive muddy sediments,"

Canadian Geotechnical Journal, Vol. 14, pp. 582-602; Lebuis, J., J.-M. Robert, P. Rissmann, 1983, "Regional mapping of landslide hazard in Quebec," In Symposium on Slopes on Soft Clays, Swedish Geotechnical Institute Report No. 17, Linkoping, pp. 205-262; Carson, M.A., G. Lajoie, 1981, "Some constraints on the severity of landslide penetration in sensitive deposits," Géographie physique Quaternaire, Vol. 35, No. 3, pp. 301-316; and in particular, Tavenas, F., P. Flon, S. Leroueil, J. Lebuis, 1983, "Remolding energy and risk of slide retrogression in sensitive clays," In Symposium on Slopes on Soft Clays, Swedish Geotechnical Institute Report No. 17, Linkoping, pp. 423-454

Line 10 – "small scale" = "regional scale?"

Line 15 – how do you extract geometry "before" the landslide from post-landslide Li-DAR?

Line 17 – again I find the term "the ratio dH/dL" hard to get my brain around, could you call this something intuitive? Similar to travel angle, although that term would extend to the toe of the debris, which you presumably cannot measure for most of these landslides.

Line 18-19 – what is the interpreted "maximum value of QCSI" and how is it determined? Is this the maximum value enclosed within the footprint of the landslide?

Line 19 – what do you mean by "landslide scarp?" From context I assume you mean the whole perimeter of the landslide, although "scarp would not normally be used in this sense, as the toe of the landslide, for example, is not a scarp. If you are talking about the perimeter of the landslide feature you have traced, perhaps you should call it the perimeter or outline of the body of the landslide (and emphasize it does not include the displaced debris, unless it does).

Line 24 – provide a citation to defend that these two statistical measures are "mainly used" as I will admit I've never seen them used before.

Page 7782 line 9 – mentions that you use two maps to validate the models: the landslide scarp map and the landslide probability map. I don't believe the later parts of the paper discuss any comparison between your models and the landslide probability map, unless I've forgotten or missed it.

Line 22 – replace "from" with "of"

Page 7783 line 16 – what is meant by "Receiver Operating Characteristic?" You mention it here, and later you note that you tested the model against it, but it is not cited or described, and you don't present any actual results. I suggest you either describe / cite this fully so the reader can understand and accept it, or delete any mention of it.

Lines 17-20 – you give a very brief overview of aspects of the Gilbert skill and the Heidke skill, which are subsequently relied on a great deal in your analysis. Some additional detail is needed; for example, how do you " remove true positives due to random chance" and how / why do you remove samples that are "correctly classified due to random chance?"

Lines 21-23 – in the ROC curve which quantities are plotted on the x and y axes? It's not obvious which orientation of these noted measures determines the interpreted area. My instinct on first read is to assume (1 – specificity) is plotted on the y axis but I don't know that is correct.

Page 7784 line 5 – "landslide scarp map was converted from a vector to a raster..." Before reaching this point I assumed (incorrectly?) the scarps were polylines. However I now assume you must be talking about polygons? I'm still not clear...

Line 8 – how do you determine the "height of the slope before the landslide event" from post-landslide topography? Needs an explanation.

Line 9 – how do you estimate dL, "the maximum retrogression distance" from post-landslide topography? Again, needs an explanation; I assume this could not be automated but rather was based on expert judgement?

Line 11 – "71 scarps" is not very many, or does not seem like very many. How big is the whole set from which you selected 71, and how were these selected (randomly? Based on some selection criteria?)? Recognizing it was not the intent of this work, I think you could obtain immense value from interpreting every landslide scarp possible from the high resolution topography.

Line 13 – how was a point automatically selected? This strikes me as a very difficult process to animate and needs some explanation.

Line 15 – "... the maximum value of QCSI was extracted..." Why (and how) did you choose the maximum value? Why not some other measure, possibly the average value, possibly some other statistical measure?

Line 18 – did you look at other measures of QCSI (mean, median, etc) to see if there was a better relationship?

Line 21 – what does "AA.VV." stand for? This is an odd name for an author.

Line 25 – you mention using best/worst case soil maps, but unless I'm mistake, your results only discuss the use of the best case soils map. You should either present both sets of results, or delete mention of unused work, or explain why you don't show both sets of results.

Line 25 – I don't think the term "QCSI-dependent soil class map" really describes what you used the QCSI map for, rather I think you simply divided the QCSI map into different slices / ranges of QCSI value. I don't think you should try to tie that back to "soil class" since the QCSI map is not a soil class map.

Page 7785 line 2 – what is the "classification system used at SGU" and why should the reader accept it as a useful or meaningful basis? Provide a description and/or citations and defend its use in your work.

Lines 2-6 – your process of assigning soil classes is not clear to me.

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Lines 7-10 – your process of assigning "soil classes" to the QCSI map is not clear to me.

Line 11 – this paragraph jumps into identification of optimal filters, but you haven't yet really explained (or the explanation wasn't sufficiently clear) what you will do with the soil maps, so it feels jarring to jump to the filtering procedure without yet knowing the basis analytic methodology.

Line 16 – why use only 1:10? Is this used solely to test model performance (i.e. you are isolating this parameter to understand variability of other parameters) or is this intended as an eventual model feature?

Line 24 – the results of the Gilbert score are not shown…" I don't think you should discuss methods or results you don't intend to share, but rather should focus on core results essential to the work only. Otherwise it becomes distracting to read about other non-essential tests you performed, that were, in the end, irrelevant to the outcome

Page 7786 line 14 – you need to present / cite / defend the "standard procedure used at SGU" and not expect the reader to accept it as valid.

Line 19 – "decreased according to the QCSI…" What value was used to determine the slope angle, the maximum/mean/median/mode in the landslide body? Some value at the river's edge? The actual value at the pixel under consideration?

Line 20 – what is "the same" for both the first and second part of the analysis? I can't follow this sentence.

Lines 26-28 – after reading this sentence many times, I have no idea what it means. Please clarify what you did. Perhaps this requires several short, clear sentences, not one long sentence.

Page 7787 line 5 – "the performance of the model deteriorated…" I can't see this from the figure, since its meaning isn't adequately explained. Also, what is the sensitivity threshold?

Lines 19-20 – garbled sentence "... the not filtered and the filtered and unfiltered maps..."

Lines 20-21 – your use of "high values" and "low values" is confusing (and probably wrong?); I think you mean 1:22 is a "high value" right? That is a very low angle, so should be a "low value" of cross-sectional angle, not a high value. Low angles have high dL/dH values but not high angles. This terminology is used (and needs to be corrected) elsewhere also.

Page 7788 line 3 – "ROC curves" mean what? They are not well defined, and if they won't be shown, should not be mentioned, in my view. If they were considered critical to your core purpose you would likely be inclined to show them.

Lines 10-13 – I cannot understand what has been done / is being described in the sentence starting with "By looking..."

Line 14 – what is the "total area classified..." I don't believe it has been defined or illustrated. At this point in the paper, I am left wondering what role the landslide probability map has played in the work, I don't believe its use has been mentioned in the discussion of the work.

Line 26 – what do you mean by "... the model has very good performance..." I don't believe you have defined "good performance in a precise way or demonstrated good performance in an intuitive way.

Page 7789 line 5-6 – The sentence beginning with "Also, it should be noted..." begs the question "so what?" How does that selection bear on your results? You need to complete this thought to show the reader why that selection was important.

Line 7 – what is your basis for claiming the filtering procedure will "slightly" decrease the selection of the positive sample?

Lines 21-22 – you say the QCSI-dependent cross-sectional angle thresholds did not improve model performance, but I found it very hard to follow what you did with those

inputs to judge whether your approach was valid. Is there a better way to use that map?

Page 7790 line 3-5 – "optimal" in what sense? I think you are saying the statistics you used are "best" in some sense when you use those thresholds. This might be "best" in the sense of capturing most area of past landslides with minimum excess, but would not be "best" in the sense of determining worst case limits for possible retrogression, for example.

After having read the paper, I'm left with the impression that your work shows that only a simple soils map is needed to identify landslide-susceptible areas, and nothing you explored offers an improvement on that. I'm also left with the impression that your work shows that a retrogression angle of 1:13 is the "best" in some sense, for use with the soil types. I feel like this is a disappointing conclusion to the work, and is largely indefensible, since we know with certainty that retrogression distance can be much longer than that, and in your database many examples were traced with longer retrogression distance. I may, however, be misunderstanding the intent of the work. If it is simply to build an approach for statistical analysis, moving the yardsticks forward a little, it's probably good work. If the intent is to offer this as a robust method for landslide susceptibility mapping, as is, then I would be wary of its use, except perhaps for attracting the eye to areas with broad soil classes that might include landslide-susceptible sensitive clay (presuming some topographic limitation is also applied to focus within areas of marine invasion).

Table 1 – true positives, true negatives, false positives/negatives need to be defined

Table 2 – is the worst case soil class list used in the work? If so it's not clear to me and needs to be better explained. If not, delete the column.

Figure 2 – are there any points above your threshold line in the other landslide "scarps" outside your subsample of 71 features? What about higher values of QCSI?

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On a related note, I think it would be a very valuable statistical effort to obtain angles and QCSI statistics for every landslide visible in the LiDAR; I think that could generate a very useful contribution to the profession, or at least have the potential to strengthen the meaning of the QCSI map (or suggest other ways of strengthening it).

Figure 3 – how is map area defined, is this a length in pixels, or area. . . for example, does 24 p mean 4 x 6 pixels or the like? Needs better explanation.

Figure 4 – you suggest that lower area p.t.l. means "better" model performance, but this is only true if the model isn't eliminating more area with potential landslides. This measure has to be used carefully.

Figure 4 – part B appears to be missing?

Figure 6 – I can't figure out what this graph means, requires better explanation.

Figure 9 – what about "worst case" soil class? What is the "sensitivity threshold?" Needs definition / explanation.

The paper needs a Figure showing the map resulting from the best case model output, with traces of mapped landslides shown for a qualitative comparison.

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