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Discussions

Interactive comment on "Landslide susceptibility near highways is increased by one order of magnitude in the Andes of southern Ecuador, Loja province" *by* A. Brenning et al.

A. Brenning et al.

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We thank the anonymous referees for providing thoughtful, constructive and detailed comments on our manuscript. We have improved out manuscript based on these comments and are pleased to present our point-by-point responses, which we hope will satisfy the referees and editor. In general terms, the main changes we made to the manuscript include the following:

- Quality of the landslide inventory is described in more detail, indicating that field-mapped and air photo based inventories are consistent with each other and not subject

to bias.

- The issue of land use versus highway effects is discussed in more detail. While we agree that this is a valid concern, we believe that we have good reasons to believe that land use does not distort our results.

- More detailed information on geology has been included.

Please find the detailed authors' responses (AR) to comments of Referee #2 (RC) below.

Anonymous Referee #2

RC: 1. The paper is clearly organized and all the steps of the analysis are clearly explained. But what is not always clear is how the input data for each attributes were derived e.g. state of plant succession etc.

AR: We thank the referee for the positive remarks and would like to refer to section 2.2 for details on the calculation of predictor variables. Regarding the classification into seven classes of plant succession, we decided to omit this information from the revised manuscript since it is not closely enough linked to this study's objectives.

RC: 2. The paper applies the GAM and GLM techniques to predict landslide susceptibility near highways in Loja province. However there are several techniques used by different researchers to make landslide susceptibility map. Please mention, why did you choose GAM and GLM and what are differences from other techniques? Why did you use two techniques GAM and GLM? What are the benefits of GAM and GLM?

AR: We appreciate this comment, which underlines the importance of methodological research comparing different landslide susceptibility models (e.g., Brenning, 2005 in NHESS, Goetz et al., 2011 and Brenning, 2012a, full references given in the manuscript). Instead of repeating what has been said elsewhere, we would like to point the reader more explicitly to recommendations made in another recent paper (Brenning, 2012a). The following text was added at the beginning of section 2.3: "In this study we follow the recommendations of Brenning (2012a) and Goetz et al. (2011), which emphasize the suitability of the generalized additive model (GAM) and the generalized linear model (GLM) or logistic regression model for landslide susceptibility modeling compared to alternative approaches such as weights of evidence or machine learning techniques."

RC: 3. Moreover, an important part of the landslide dynamics is completely neglected which is the vegetation. What role is the vegetation playing?

AR: This is an important comment, considering the west-east as well as altitudinal trends in (natural) vegetation throughout the study region. However, natural vegetation has largely been replaced due to land use in our study area, the 300-m buffer around the highway, limiting the possible influence of (natural) vegetation on landslide susceptibility. (For a discussion of land use patterns, see response to comment (3) of Referee #1.)

We would also like to point out that the regional vegetation gradient is included in our model through the inclusion of precipitation and elevation as predictors. Thus, confounding with major vegetation trends can be excluded. Of these two variables, only elevation played a statistically significant role (Table 3); neither of the interactions with highway distance showed important effect sizes (Table 4). While this does not imply that vegetation has no influence in general, we can be confident that the influence of deforestation and land use (section 2.1) – which are less directly determined by climate – blurs possible patterns that would have occurred if vegetation along highways was closer to its potential natural condition.

RC: 4. Engineering geological data should include for landslide susceptibility mapping in road corridor because joint orientations are the major landslide dynamic during road construction.

AR: We agree with the reviewer that joint directions, strike and dip play an important role regarding the predisposition of a slope to failure. Hence, we added this information

to section 2.1 and section 4.3. If such data was available at a fine scale, it might yield new insights. However, the joint system is similar in the two main geological units. The dip to the east might favour instability of eastward facing slopes, which cannot be confirmed based on our data (Table 4). Therefore, we doubt that joint orientations would be a significant predictor in modeling. RC: 5. Landslide were initiated after construction of road. It is always better and good idea to compare landslide susceptibility before road construction and after road construction. It will show the displacement of susceptible zone.

AR: We agree with this observation and recommendation as long as possible differences in the occurrence of landslide-triggering rainfall events can be accounted for. In particular, detailed knowledge of the occurrence of high-intensity rainfall events would be required in order to ensure that landslide occurrences during, e.g., a 10-year period prior to highway construction is comparable to landslide occurrences 10 years after construction. This particular confounding problem of longitudinal observational studies, which is difficult to eliminate, is absent in the cross-sectional design used in our study, since locations near and distant from highways were exposed to the exact same potentially landslide-triggering rainfall events. This control for the main confounding factor, the trigger, outweighs, in our opinion, any possible advantages of a longitudinal design. This being said, pre-highway landslide data was not available for our study region.

RC: 6. Please mention about the limitations of this research.

AR: We added one new paragraph to section 4.1 in response to specific comments of both referees regarding highway effects, land use, and inventory completeness. Furthermore, some limitations of our work and/or future research directions are pointed out in sections 4.2 and 4.3.

RC: 7. There is inconsistency in landslide initiation points (please see pages 1950 and 1953).

AR: This has been resolved – please see response to comment (4) of Referee #1.

RC: 8. As far as I know, all the statistical model should be validated. Authors used all landslide point to calculate success rate. Success rate is used to check how well the final weight map can "predict" the landslide pattern with which it was made. I recommend to calculate prediction rate using excluded landslides (<100 m2). The prediction rate gives a good estimation of the predictive power of the map.

AR: We are in full agreement with the referee regarding the need for model validation, i.e. estimation of predictive performance. We therefore performed (spatial) cross-validation, which is capable of estimating predictive performances more reliably than by using a fixed hold-out or validation set. This approach is explained in section 2.3 in some detail. We follow many other authors in the field of classification modeling when using the AUROC instead of the success rate curve as a performance measure.

No changes made.

RC: 9. How did you select the initiation point of landslide? It's a statistical method based on landslide density, in the figure landslides seems large, why did not you use scarp polygon for susceptibility mapping? Clarify.

AR: While we agree that potentially all grid points from the landslide scarp could be used to represent conditions under which landslides are initiated, the approach used here is widely used in the literature and has several practical advantages: (1) Using multiple points per landslide scarp would create nearly-identical (pseudo-replicated) additional data with little value for improving statistical model results. (2) Sample size is already large (with >2000 landslides), the referee's proposed approach is most valuable when the sample size is small.

No changes made.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 2, 1945, 2014.