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Evaluation of Spatial Agreement of Distinct Landslide Prediction Models

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The aim of the study was to assess the degree of spatial agreement of different predicted patterns in a majority of coherent landslide prediction maps with almost similar success and prediction rate curves. If two or more models have a similar performance, the choice of the best one is not a trivial operation and cannot be based on success and prediction rate curves only. In fact, it may happen that two or more prediction maps with similar accuracy and predictive power do not have the same degree of agreement in terms of spatial predicted patterns. The selected study area is the high Valtellina valley, in North of Italy, covering a surface of about 450 km2 where mapping of historical landslides is available.

In order to assess landslide susceptibility, we applied the Weights of Evidence (WofE) modeling technique implemented by USGS by means of ARC-SDM tool. WofE efficiently investigate the spatial relationships among past events and multiple predisposing factors, providing useful information to identify the most probable location of future landslide occurrences. We have carried out 13 distinct experiments by changing the number of morphometric and geo-environmental explanatory variables in each experiment with the same training set and thus generating distinct models of landslide prediction, computing probability degrees of occurrence of landslides in each pixel. Expert knowledge and previous results from indirect statistically-based methods suggested slope, land use, and geology the best “driving controlling factors”. The Success Rate Curve (SRC) was used to estimate how much the results of each model fit the occurrence of landslides used for the training of the models. The Prediction Rate Curve (PRC) was used to estimate how much the model predict the occurrence of landslides in the validation set. We found that the performances were very similar for different models. Also the dendrogram of the Cohen’s kappa statistic and Principal Component Analysis (PCA) were derived to test agreement among the maps. Nevertheless, no information was made available about the location where the prediction of two or more maps agreed and where they did not. Thus we wanted to study if also the spatial agreements of the models predicted the same or similar values.

To this end we adopted a soft image fusion approach proposed in. It is defined as a group decision making model for ranking spatial alternatives based on a soft fusion of coherent evaluations. In order to apply this approach, the prediction maps were categorized into 10 distinct classes by using an equal-area criterion to compare the predicted results.

Thus we applied soft fusion of the prediction maps regarded as evaluations of distinct human experts. The fusion process needs the definition of the concept of “fuzzy majority”, provided by a linguistic quantifier, in order to determine the coherence of a majority of maps in each pixel of the territory. Based on this, the overall spatial coherence among the majority of the prediction maps was evaluated. The spatial coherence among a fuzzy majority is defined based on the Minkowski OWA operators. The result made it possible to spatially identify sectors of the study area in which the predictions were in agreement for the same or for close classes of susceptibility, or discordant, or even distant classes. We studied the spatial agreement among a “fuzzy majority” defined as “80% of the 13 coherent maps”, thus requiring that at least 11 out of 13 agree, since from previous results we knew that two maps were in disagreement. So the fuzzy majority AtLeast80% was defined by a quantifier with linear increasing membership function (0.8, 1). The coherence metric used was the Euclidean distance. We thus computed the soft fusion of AtLeast80% coherent maps for homogeneous groups of classes. We considered as homogeneous classes the highest two classes (9 and 10), the lowest two classes, and the central classes (4, 5 and 6). We then fused the maps considering separately each homogeneous set of classes by obtaining the greatest spatial agreement for the highest two classes, then for the lowest two classes, while highlighting the greatest disagreement for the intermediate classes. We can conclude that predictive maps with similar predictive power may not be considered equivalent in terms of spatial patterns of predicted results. Most of the models produced equally (or, at least, not statistically different) predictions in terms of success/prediction rate curves. However, the spatial distribution of the prediction classes of each map was almost similar for the highest and lowest classes, but was not very similar for the intermediate classes.