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Validation of the Slovenian national landslide forecast system using contingency matrices

Mateja Jemec Auflič and Jasna Šinigoj
Geological Survey of Slovenia, Geological information center, Ljubljana, Slovenia (mateja.jemec@geo-zs.si)

Slovenian national landslide prediction system, MASPREM, has started in September 2013 (Jemec Auflič et al., 2016). The MASPREM system forecasts landslide probability twice a day for 24-hours ahead. Forecasting landslides is based on the landslide susceptibility map, statistically defined rainfall threshold values and rainfall forecast models. Geological settings of the area, diverse geomorphology, tectonics and climate regimes increase the probability of landslide occurrences. It is estimated that more than 10,000 landslides were triggered in the past 30 years. Since the spatial distribution of the rainfall stations is very sparse (1 rainfall gauge per 460 km2, while for example in Tuscany it's 1 rain gauge per 70 km2) the MASPREM system is based on rainfall threshold values which were determined using a non-parametric statistical method chi-square ($\chi 2$) for each lithological unit. Maximum daily rainfall above 60-70 mm proved to be critical for landslide occurrence, especially in more loose soils and in less resistant rocks (e.g., Quaternary, Tertiary, Triassic, and Permo-Carbonian rocks). In accordance to different soil characteristics in the regions and available rainfall forecast models, ALADIN and nowcasting model INA, the five different MASPREM models have been developed. Therefore, MASPREM calculates the five different landslide scenarios parallelly. The validation of the five models was based on the computation of the statistical indicators from 2 x 2 contingency matrices. This elementary matrix shows the correlation between landslide events and warnings, both of them expressed in four classes: (TP) true positives (correct predictions), (TN) true negatives, (FP) false positive (false predictions), (FN) false negative (missed predictions). For the five year validation period of MASPREM models (2013 -2018) the results showed that the Probability Of Detection (POD), also known as Hit Rate, which is the proportion of the events that were predicted correctly, is 53% for the models with applied two-day antecedent rainfall, while for the model without antecedent rainfall it is only 11%. The Probability Of False Detection (POFD), also known as False Alarm Rate, which is the proportion of correct predictions when the event did not occur, is around 10% for models with antecedent rainfall and 2% for the model without antecedent rainfall. The Probability Of False Alarm (POFA), also known as False Alarm Ratio, which is the ratio between the number of false alarms and the total number of correct forecasts, ranges between 35% to 53%. The higher values are for the models with antecedent rainfall. Overall MASPREM performance indicates that the system is able to capture the crucial factors in determining the general landslide location, even if it cannot predict a specific area. Additional calibration of input parameters and the landslide inventory, as well as improved spatially distributed rainfall forecast data can further enhance the model's prediction.

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