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Susceptibility maps for landslides using different modelling approaches

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Abstract This study focuses on the comparison of different modelling approaches and is part of the research project "MoNOE" (Method development for landslide susceptibility modelling in Lower Austria). The main objective of the project is to design a method for landslide susceptibility modelling for a large study area. For other objectives of the project see Bell at al. in this volume. To reach the main objective two different statistical models, Weights of Evidence and Logistic Regression are applied and compared. By using nearly the same input data in test areas it is possible to compare the capabilities of these different methods. First results of the comparison indicate that in valleys and on south directed slopes the results of the two different modelling approaches are quite similar. The results on north directed slopes show differences. In the ongoing work the reason for these differences will be analysed. Also it will be necessary to find adequate validation methods for the two modelling approaches.

Keywords Susceptibility modelling, Weights of Evidence, Logistic Regression.

Introduction

Landslide susceptibility maps can form a powerful tool for preventive spatial planning on a regional scale. Particularly on a regional scale landslide processes and their dynamics are still poorly understood and susceptibility modelling and the implementation of the resulting maps is a challenge for geoscientists. Therefore, it is of high importance to identify a landslide susceptibility model, or combination of models, that result in robust and reliable susceptibility maps.

This study focuses on the comparison of different statistical modelling approaches as part of the research project "MoNOE" (Method development for landslide susceptibility modelling in Lower Austria). The research project and its objectives are described in detail by Beel at al. in this volume. The main objective of the project is to design a method for landslide susceptibility modelling for a large study area (about 10.200 km²) and to produce landslide susceptibility maps which are finally implemented in the spatial planning strategies of the Lower Austrian provincial government.

Study area and data collection

The study focuses on 2/3 of the area of the province Lower Austria in the northeast of Austria. The study area covers districts where landslide events have been recorded by the Lower Austrian provincial government in the past 60 years. The geographical expansion and the position of the study area are shown in Fig 1.

Methods and models are developed and tested within three test districts of Lower Austria, the districts of Waidhofen/Ybbs, Amstetten and Baden. The optimised methodology will finally be applied to the entire study area, which covers 20 districts.

The entire project focuses on the landslide types fall and slides, whereas in this study only the type slide will be addressed (classification after Cruden & Varens, 1996). To enable susceptibility modelling, landslide inventories for the respective landslide types were compiled and relevant spatial data (e.g. geology, DTM, orthophotos) was gathered, prepared and homogenized. For a detailed description of the collected data and the landslide inventory see Bell et al. and Petschko et al. in this volume. Based on this data it is now the aim, to choose the "best-fit" modelling method or a combination of methods to reach the main objective of the project.

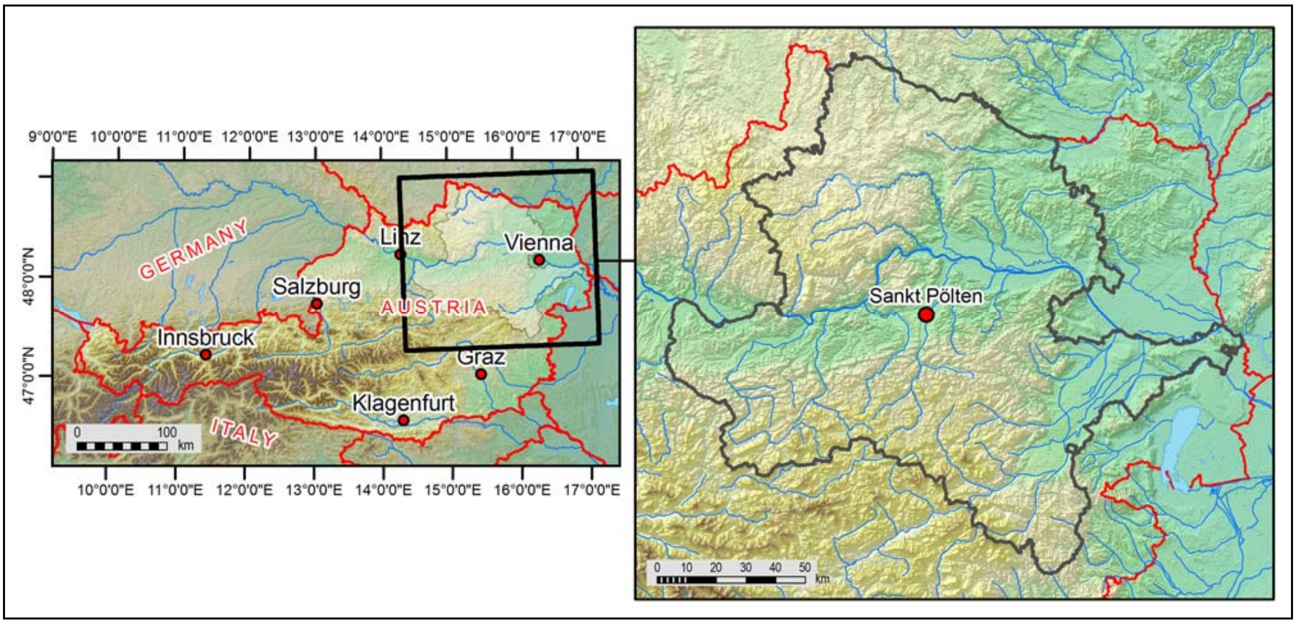

Figure 1 Study area in the northeast of Austria, covering 2/3 of the area of the province Lower Austria.

Model input data and landslide inventory

The high amount of gathered and homogenized spatial data makes the use of various input datasets as model input data possible (compare Bell et al. in this volume). First modelling tests showed, that a comparison of the modelling methods is easier, when only very view and most significant input datasets are used. Therefore for this study the following input datasets were applied:

1. Landcover (derived from satellite images, 10m x10m resolution)
2. Geology (scale of 1:200,000, simplified to lithological relevant parameters)
3. Slope (derived from the LiDAR DTM, rescaled to 10m x 10m resolution)
4. Aspect (derived from the LiDAR DTM, rescaled to 10m x 10m resolution)
5. Landform classification (derived from the LiDAR DTM, 10m x 10m resolution)

The parameters slope and aspect were computed by using the Spatial Analyst-Extension by ESRI for ArcGIS 9.3.1. The parameter landform classification was computed by using the Topographic Position Index - Extension for ArcGIS 9.3.1 (Jenness, 2006).

As mentioned above, the collected data allows additional inputs of datasets to be used in the future, such as distance to geological structures, distance to rivers, distance to very old landslides, topographic wetness index and other parameters. However, the benefits of using this datasets for each modelling method have to be evaluated.

As Petschko et al. in this volume describe, two different landslide inventories were used within the three test districts: the Building Ground Register of the Geological Survey of Lower Austria, which contains only point information, and a newly prepared landslide polygon inventory based on the interpretation of the multiple hillshades of the LiDAR DTM. For the test in this study two identical excerpt of the Building Ground Register were used.

Modeling Methods

To reach this objective two different statistical models, Weights of Evidence (WofE) and Logistic Regression (LR) were applied and compared.

The WofE method was applied using the “Spatial Data Modeler” Toolbox for ArcGIS 9.3. (Sawatzky et al., 2009). WofE modelling was described by Bonham-Carter et al. (1989) and was used by different authors for landslide susceptibility modelling in recent years, e.g. Neuhäuser & Terhorst (2006).

The method is an application of Bayes’ Rule of Probability. It is assumed that landslides happen when certain evidential parameters occur, and the causality of this process is time-independent. A set of training points (inventory of landslides) is used to calculate the weights of predictor variables from various evidential themes. Evidential themes are raster maps with the information from the input datasets mentioned before. The combination of the weights from all used evidential parameters produces a response theme. This is an output map that expresses the probability that a unit cell will contain a landslide event.

Logistic Regression was carried out using a combination of ArcGIS and the OpenSource statistics package R. The LR method was described by Atkinson et al. (1998) and was also used by many authors for landslide susceptibility modelling in recent years, e.g. Ayalew & Yamagishi (2005) and Rossi et al. (2010).

This method is based on the evaluation of the statistical relationship of explanatory variables which are mainly terrain parameters with the dependent variable which contains the spatial distribution of landslides in the test study area. Beside the input parameters for the information on landslides a second point samples of the same size are generated randomly in ArcGIS 9.3 for the analysis: one with the points of the Building Ground Register and one outside of all known landslides. After fitting the model in the open source statistics software "R" the regression coefficients are used to calculate a landslide susceptibility map for the test study area.

Results

Fig. 2 shows two geographical identical detail images of the results of the susceptibility modelling in the test districts. The left image is computed using the Wofe method, the right image is computed with the LR method. In both approaches the same input parameters landcover, geology, slope and aspect were used. In the LR modelling the additional parameter landform classification was applied. In both approaches the landslide inventories are identical excerpt of the Building Ground Register of the Geological Survey of Lower Austria. The authors see this comparison as first draft and as basic approach for the ongoing work.

In Fig. 2 it is visible, that in the valleys and on south directed slopes the results of the Wofe and LR modelling a quite similar. On the other hand the results on north directed slopes show big differences. These differences in spatial details must still be carefully analysed in the ongoing work. However, it is now possible to compare the capabilities of the different methods and software solutions.

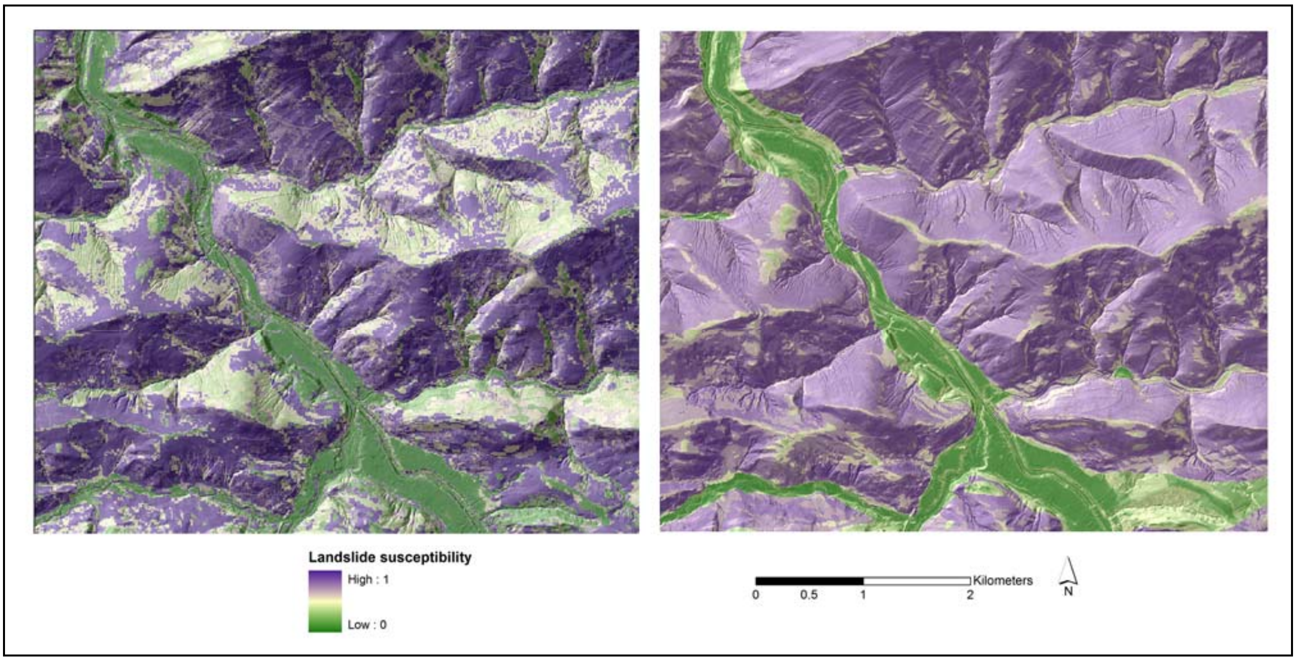

Figure 2 Comparison of two geographical identical detail test areas of the results of the susceptibility modelling. The left image is computed using the Weights of Evidence method, the right image is computed with the Logistic Regression method. In both approaches similar input parameters are used (landcover, geology, slope and aspect in both models, landform classification in the LR model). The landslide inventory for both models is an identical excerpt of the Building Ground Register of the Geological Survey of Lower Austria.

Discussion / Conclusion

Experiences gathered during modelling these preliminary results showed that the large study area and very heterogeneous geology pose a huge challenge for the modelling. Thus, modelling strategies have to be modified to meet these challenges. Considerable efforts will be spent on the validation of the resulting maps for the different modelling methods. The comparison of the first modelling results using WofE and LR and nearly identical input parameters in the MoNOE project showed quite similar results. Nevertheless, in spatial details differences can be observed, which might cause distinct consequences when implemented in the spatial planning strategies.

Acknowledgments

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