# Criteria for the identification of landslide risk areas in Europe: the Tier 1 approach

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Landslides are local phenomena with potential regional and national consequences. In Europe, landslides pose a largely underestimated societal and economic threat. In the framework of the European soil thematic strategy, and the associated preparation of a directive on the protection and sustainable use of soil, landslides were recognized as a threat requiring specific strategies for risk assessment and management. The Soil Information Working Group (SIWG) of the European Soil Bureau Network (ESBN) developed a set of "common criteria" to identify areas where "soils are at risk" according to individual threats, including organic matter decline, erosion, compaction, salinisation and landslides. The proposed criteria adopt a nested geographical approach based on "Tiers" and exploit thematic and environmental data of different type, quality, and resolution using a variety of methodological and technological approaches. The Tier 1 assessment is aimed at the general (i.e., synoptic) identification of areas potentially subject to landslide risk, providing a low-resolution (1:1,000,000 scale) evaluation of landslide threats using existing thematic and environmental data. The Tier 2 assessment is intended to perform detailed analyses in the areas identified as potentially at risk by the Tier 1 assessment, and should provide results at a higher spatial resolution using existing and new data currently not available.

The main requirement for a Tier 1 assessment for the delineation of areas subject to soil threats in Europe is the availability of relevant input data (Eckelmann et al., 2006). At present, a continent-wide assessment of landslide susceptibility in Europe is feasible only adopting a qualitative evaluation technique. This is largely because systematic landslide inventory maps (i.e., maps showing the location and type of known landslides in an area) are not available for most European countries. The Tier 1 landslide susceptibility assessment can be performed using a reduced set of data, including information on the instability conditioning factors. Adoption of an index-based evaluation method can allow the production of a continent-wide landslide susceptibility map for Europe. The map will show areas not susceptible to landslides (i.e., areas where Tier 2 assessments are not required), and areas where a landslide threat exists, and where Tier 2 assessments are required.

Heuristic landslide susceptibility analysis is the simplest way to delineate landslide-prone regions when thematic information on ground material properties and topographic attributes are available, but information on the distribution of past and present landslides (i.e., a landslide inventory) is lacking (Guzzetti et al*.,* 1999; Guzzetti, 2006). Heuristic modelling for landslide susceptibility comprises a variety of index-based approaches that relay on the *a priori* knowledge on landslide instability, i.e., on the assumption that the factors leading to slope instability in an area are known. Reliability of the method depends on how well and how much geomorphological processes acting upon a terrain are known and understood to the investigator. Instability factors are classified, ranked, and weighted, according to their assumed or expected importance in causing landslides. Based on this information, subjective decision rules are established to identify unstable areas. Ideally, rules used to rank, weight and combine the instability factors should be based on detailed knowledge of the physical processes controlling slope instability.

In Germany, a national landslide inventory map and associated geographical landslide database is not available. However, high-resolution thematic data on topography, lithology, and soil, are available and were used to prepare a synoptic landslide susceptibility map (Fig. 1). For the purpose, a three-step, heuristic procedure was adopted. First, the information stored in the German Soil Database (BÜK 1000) was analyzed. The 72 bedrock/soil associations listed in the national database were classified heuristically by expert knowledge into six classes, based on their expected susceptibility to landslides. Each bedrock/soil association was classified based on the rock/soil type, the degree of weathering, the soil/regolith thickness, the presence of permeability contrasts and nature of soil/bedrock interfaces, and the presence of discontinuities. Next, a 50 m × 50 m digital elevation model (DGM 50) was used to obtain a map of terrain gradient. The slope map was reclassified into six classes, based on the expected propensity to landsliding of each class of topographic gradient. Finally, the landslide susceptibility map based on lithology and soil types, and the susceptibility map based on terrain gradient, were combined. Combination of the two maps was performed on individual pixels (50 m × 50 m in size), adopting a weighted average technique and assuming the same importance (i.e., equal weight) for the topographic and the lithological/soil information.

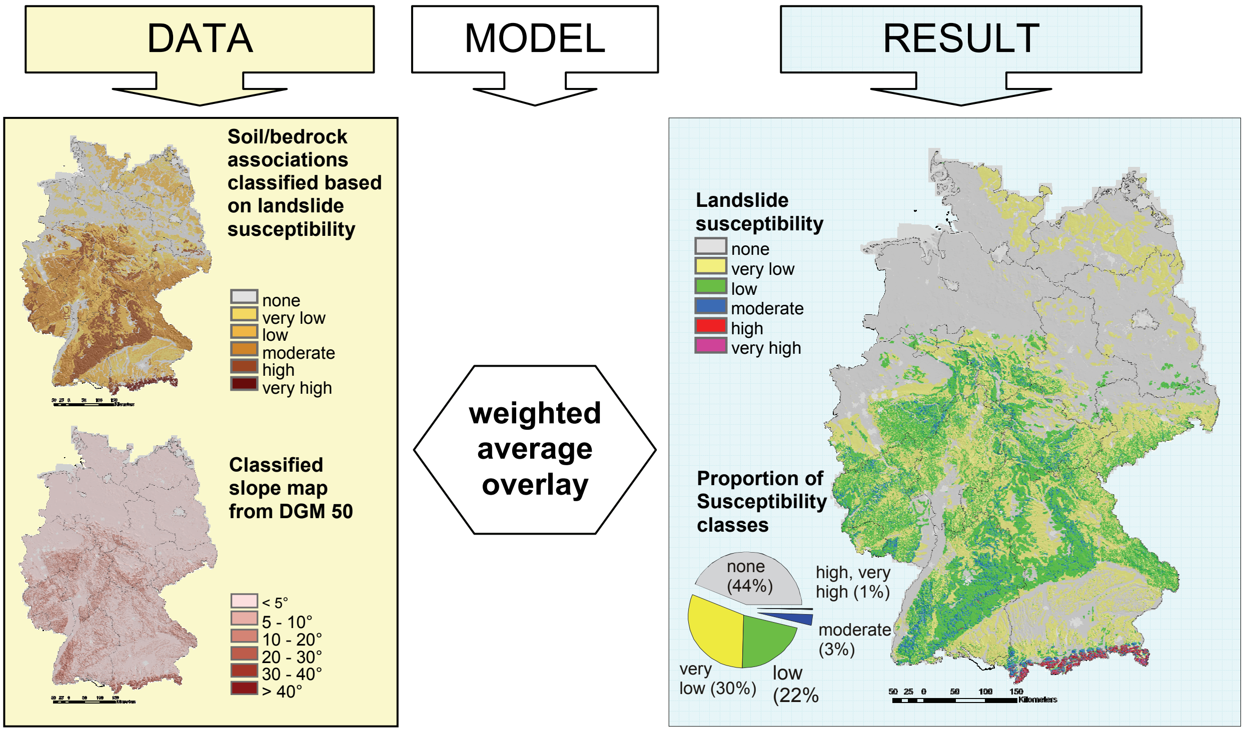


**Figure 1:** Heuristic landslide susceptibility model and map for Germany. The Figure shows thematic data used to ascertain landslide susceptibility, the adopted weighted overlay model, and the resulting susceptibility map. The susceptibility map has not been validated against landslide data.

The map shown in Fig. 1 portrays a qualitative zonation of landslide susceptibility in Germany, based on topographic and lithological/soil information. It is worth pointing out that no information on the location, type, or abundance of landslides was used to prepare the map. This is a limitation that should be considered when using the map. The geographical distribution of the susceptibility classes is in relatively good agreement with published field observations, and with the existing expert knowledge on landslides in Germany (see e.g. Glade and Crozier, 2005, and references therein). Visual inspection of the map reveals that areas classified as of moderate to very high susceptibility are located: (i) in the southernmost part of the country (e.g., in the Alpine region), where slopes are steep and landslide-prone soil/bedrock associations exist, (ii) along major, regional escarpments, (iii) along deeply incised rivers, and (iv) along the Baltic Sea coastal cliffs. Low to very low susceptibility classes extend in the hilly parts of the country, where soils are layered and slopes are gentle. Areas not susceptible to landslides correspond chiefly to flat areas. The map largely resembles an earlier qualitative landslide susceptibility map for Germany based on the heuristic analysis of a 1:1,000,000 scale geological map and topographic data prepared by Dikau and Glade (2003).

A similar susceptibility map can be prepared for Europe, because information on the ground conditioning factors (topography, and soil and bedrock properties) is available. It is a matter of debate if – or to what extent – other existing data on landslide conditioning and triggering factors (e.g., land cover, land use, climate, seismicity, etc.) should be used to prepare the European model of landslide susceptibility. To prepare the continent-wide landslide susceptibility model, we recommend using only a limited number of thematic factors. For preparing a heuristic landslide susceptibility model, expert agreement on appropriate scoring and weighting schemes for the thematic data used for the model is required. To improve the model, ground-conditioning factors should be re-classified to consider regional or local settings. It is important to evaluate and validate the obtained landslide susceptibility model with relevant landslide information available for different regions. Preparation of a European, heuristic landslide susceptibility model will represent a significant improvement with respect to the existing continental landslide hazard zonation map prepared by ESPON, i.e., the European Spatial Observation Network project (Schmidt-Thomé and Kallio, 2006).

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