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Landslide hazard assessment in urban areas - a case study in Lisbon County (Portugal)

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Landslide hazard assessment in urban environments, in spite of its relevance, is a particularly difficult task. In fact, the extent of constructed areas and the high rate of topography changes cause a decrease in quality and reliability of landslide inventories, resulting in a loss of quality of the end results. It is also very difficult to assess the reinforcement or instability effects of constructions, the spatial distribution of rainwater infiltration and seepage, and also the compilation of detailed geological maps containing the areal distribution of the upper soil or rock types.
To reduce the influence of these particular problems, and to solve some critical limitations of the available data, a progressive approach was applied to produce a landslide susceptibility map of Lisbon County. Considering that it was very difficult to compile a representative and accurate inventory of past landslides, a physically based approach was adopted.
The Lisbon area is covered by a detailed and high quality, field and borehole based 1:10,000 geological map, but that contains limited information on the extent and nature of superficial soils, mainly landfills. To complete this geological base map, several sets (1947-2004) of aerial photos were analyzed to identify and map landfill and excavations zones in areas covered by urban expansion in the last half century. The thickness of the landfills was assessed by analysis of existing large scale maps and borehole data. In the older part of the city, landfill extent and thickness was estimated using a large (>6,000) borehole database. Landfills areas cover more than 30% of the county area, with thickness of up to 15m, constituting a major revision of the base geological map.
To validate the results of the susceptibility model, a landslide inventory was compiled using aerial photos (1947-2004), field surveys and analysis of site investigation reports and publications.
The landslide susceptibility was assessed using an infinite slope stability model to compute the Safety Factor of the slopes in 5m pixel terrain units derived from a 1:1,000 topographic map, which was object of extensive editing to remove effects of constructions, buildings and contour line elevation errors. The thickness of the potentially unstable upper soil slice was based on the landfill mapping and Standard Penetration Test data of the borehole database, and the geotechnical properties (unit weight, cohesion and friction angle) were based on site investigation and publications analysis. The results of this preliminary model provided a high success rate, in part due to the improvements of the lithological base, but also on the limited extent of the landslide inventory.
For further improvement of the model, a hydrogeologic model of the groundwater flow was produced, based on available information on water wells, springs and site investigation borehole data, and incorporated in the previously produced physically based model. The results were again validated against the landslide inventory using a success rate curve.
Although the in situ characteristics of the geological materials and the available information may vary significantly in different urban clusters (borehole data, aerial photos, topographic and geological maps, hydrogeological and geotechnical data) the methods and approaches used may be useful in landslide susceptibility assessment of densely occupied urban areas.

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