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Probabilistic landslide hazard map with a fifty years reoccurrence period

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Landslides and landslips cause considerable damage in the hilly Goriska brda region, W Slovenia. Farmers have to continuously repair the terraces on steep slopes due to landsliding. In some places it requires a few weeks work annually. Most of the landslides are triggered on steep slopes; water being the most important triggering factor next to geological setting (flysch). Underground water level is rather high in permeable and thick sediments. Long-lasting and abundant precipitation may overload the slopes and cause mass movements. Farmers usually prevent mass movements by re-directing underground water and leading it to lower positions. Heavy precipitation was recorded in Goriska brda in autumn 1998. On 6th September 114 mm of rain was measured and on 13th October 100 mm. In both cases the return period exceeded five years. On 6th October as much as 175 mm of precipitation was measured in 24 hours, having the return period of 50 years. 433 mm of rain was recorded in the period from 28th September to 13th October (average yearly precipitation totals reach 1600 mm). On average, 31 mm of daily precipitation was measured in this period. Landslides were triggered by heavy rain, falling on already rain-soaked ground. More than 800 landslides appeared in short time, occupying 1.7% of the area. They mostly appeared on farmland and caused considerable damage. Using the field data of more then 800 landslides, and calculating using the Dempster-Shafer algorithm we elaborated a probabilistic landslide hazard map. The map allowed us to determine or estimate the probability of landsliding in case of fifty years reoccurrence period precipitation. We also evaluated risk regarding to land use. Most of the landslides (60%) were triggered in vineyards that cover about 40% of the total area, about one tenth of the landslides were triggered in the forests that cover about a third of the total area. Less than one tenth of the landslide areas are covered by grasslands, and one twentieth by fields and orchards. The

landslides originated on about 3% of built-up areas, including roads. About 45% of the landslides were triggered on the slopes with inclination 12-20°, almost a quarter on the slopes with inclination 6-12°, a sixth on the slopes with inclination 12-22°, and one seventh on the slopes with inclination less than 6°. Landslides were the most frequent (23%) on west facing slopes that are parallel to the dip of strata. About one fifth of the landslides were triggered on southeast facing and northwest facing slopes and one tenth of the landslides were triggered on the south and southwest facing slopes. Most of the landslides were triggered in the distance 40-100 m from the crests, the most frequent being the distance of 70 m. Landslides threaten one third of main roads. One tenth of them (10 km) lead through mostly endangered areas. About one quarter of local roads are threatened by landslides, more than half of them are not endangered directly (54 km). But two thirds of 629.5 km of filed roads lead through landslide areas and one quarter through highly landslide-prone areas. Only about one quarter of field roads are not endangered by landslides. According to the map about one half of the Goriska brda hills are highly endangered by landsliding and about one third is moderately endangered. One quarter of the area is little endangered while one fifth of the Goriska brda hills are not directly endangered by landsliding. The landslides are more frequent than expected in vineyards and olive plantations. The ascertainment is connected to the fact that about one half of the vineyard terraces are built on the landslide-prone areas and only about a quarter on the areas with low possibility of landsliding. One third of buildings in the area were built on landslide-prone areas, half of the latter being highly endangered. Landslides do not endanger one quarter of buildings. The map is a big step forward, compared to the ones, evaluated by deterministic modelling (and matrix methods). It may be used for urban planning and also within geomorphology - it as a good foundation for geomorphological mapping.