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Landslide hazard zonation using rainfall threshold based temporal probability

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A qualitative model for hazard zonation mapping of rainfall triggered slope failures is presented in this research for the Western Ghats geo-environment situation. For the hazard modeling, a landslide inventory map was prepared from technical reports, road maintenance records and detailed field work, covering a 34-year period from 1978 to 2011. Most landslides are shallow translational debris slides and debris flow triggered by northeast monsoonal rainfall.

A heuristic approach model was used to map the susceptible slopes in GIS by considering slope angle, lithology, structure, relative relief, land use/cover and hydrogeology as thematic variables. The resulted susceptibility map classified the area into five zones, varying from very high to very low. The temporal probability of landslides was estimated indirectly using the annual exceedance probability of the threshold rainfall required to trigger landslides in a given rain zone. A reliable relation was established between the trigger (rainfall), its magnitude and the occurrence of landslides using rainfall threshold analysis. Based on the exceedance probability value, determined using Poisson probability model, the rainfall zones were grouped into four classes, from high to very low. As the frequency of the trigger itself does not provide information on the spatial distribution of potential landslides, it was combined with landslide susceptibility to produce a qualitative landslide hazard map. By using 5 by 5 matrix, a qualitative landslide hazard map was obtained depicting slopes of different hazard category varying from high to very low class primarily by heuristic combination. The hazard modeling and validation of maps were carried out on a medium scale covering a 100 sq. km area in Nilgiri hills of Southern India.

The obtained results indicate that area is devoid of very high hazard class. This is because the annual exceedance probability of one or more rainfall threshold does not fall under very high category (>70%) and therefore landslides are not expected to occur annually. In few areas, although the slopes show very high to high susceptibility to landslides, but due to very low temporal probability these are classified as moderately hazard.

This research showcases an innovative approach to qualitatively estimate hazard of rainfall-induced slope failures at a medium scale covering large area. It is to understand that almost all hill slopes are vulnerable to mass movements, depending on the intensity of rainfall, but since infrastructural development is unavoidable and demand of suitable area for settlements keeps growing; therefore only susceptibility map alone will not suffice the purpose. In fact hazard maps give the correct picture of the stability condition require for land use planning. A high susceptible slope, though regarded as unsuitable for development, can be considered suitable if it falls under low hazard category. Therefore we recommend that for land use planning it is imperative to have information on the time of failure or the likelihood of a slope to fail in a given time. The results are, therefore of important societal value and can provide inputs for proper land use planning.

The threshold model developed in this research can also be utilised for landslide forecasting and development of an Early Warning System for a river catchment. This model can be calibrated for other geo-environmental condition, provided a good network of rain stations, daily rainfall data of past dates and information on the date of landslide events are available.