



The determination of empirical rainfall thresholds to trigger debris flows in Northern Taiwan

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The empirical rainfall thresholds to trigger debris flow in northern Taiwan are obtained by using recording rainfall data and FORMOSAT-2 images. 94 debris flows are recognized in the FORMOSAT-2 images taken after the Typhoon Aere in 2004 and 31 debris flows are identified in the image taken after the Typhoon Matsa in 2005. The corresponding rainfall information in places where debris flows occurred is interpolated from 10 minute interval rainfall data recording at 84 stations by using Kriging method. To eliminate the scaling effect induced by Kriging method, the dimensionless semi-variogram model is applied in the rainfall data interpolation. In order to get more debris flow events to derive the empirical threshold, topographic and geological characteristics are used to group the gullies which have potential to trigger debris flows into 21 clusters. According to the mechanical properties of exposed strata, the study area is divided into seven distinct geological districts that include pre-Tertiary schist, pre-Tertiary slate with metamorphic sandstone, Miocene sandstone and shale, Pliocene sandstone and shale, Pleistocene sandstone and conglomerate, Pleistocene volcanic rock, and Quaternary river terrace deposits. Debris flows that occurred during the Typhoon Area and Matsa mainly distributed in area covered by Miocene sandstone and shale, and pre-Tertiary slate with metamorphic sandstone. Because the mean gradient and catchment area size of gullies are proportional to the stream order (Strahler, 1950), the Horton-Strahler stream order is used in this study to group and to represent the topographic characteristics of gullies. The 40 m DEM is used to determine the topographic characteristics and the stream order of gullies. Comparing the river system derives from DEM and debris flows identified from FORMOSAT-2 images, debris flows in northern Taiwan mainly occurred at gullies with the stream order less

than 4. The empirical rainfall threshold to trigger debris flows is determined by the plot of rainfall intensity versus the cumulative rainfall. The critical limit that is traced to envelop 90% of the points on the plot is chosen as the threshold to trigger debris flows. For the gullies distribute in slate and metamorphic sandstone, the threshold for stream order 1, 2, and 3 is described by $R+18.6I=751.4$, $R+19.9I=1228.9$, and $R+24.0I=1713.1$, respectively (where I = rainfall intensity, R = cumulative rainfall). For the gullies distribute in Miocene sandstone and shale, the threshold for stream order 1 and 2 is described by $R+15.8I=1116.6$, $R+12.5I=1120.5$, respectively. The above mention results are consistent with previous data that obtained from individual gully in the study area.