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Scaling regimes in landslide patterns: applications in the Umbria region (Italy)

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In areas characterized by high slope instability, landslide events play a predominant role in shaping the landscape. In order to improve forecasting, numerous techniques are used to identify areas prone to landslides on the basis of information acquirable from past events. However, no single model has been able to fully capture the complexity of the distribution of this phenomenon in space.

This paper studies the spatial distribution of landslides in the Umbria Region (central Italy). We investigate the scaling properties of patterns produced by two mechanisms, slides and flows. In the geomorphological context of the study area and due to the outcropping rocks, both landslide types are mainly triggered by rainfall and represent 80% of mass movements. The landslide inventory consists of about 24,000 events and it has been represented as two different types of maps: (i) a point map indicating the top points of landslides, and (ii) a polygon map showing the extent of each landslide event. The scaling properties of the landslides are investigated by applying the box-counting algorithm to maps (i) and (ii), respectively. The analysis reveals that the spatial development of landslides in the study area possesses a characteristic fractal structure. For map (i) a scaling domain is found within the range of 1-16 km with an exponent of 1.74 ± 0.03, while for scales below 1 km the pattern does not preserve its fractal properties. For map (ii) the result is partly different. Two scaling regimes are identified, separated by a scale threshold of 1 km. In the range of 1-16 km a scaling exponent of 1.76 ± 0.01 is observed, which is similar to the one obtained for map (i). However, for this map scaling is also found within the range of 25 m - 1 km, with an exponent of 1.35 ± 0.02.

The analysis of the frequency distribution of landslide areas reveals that the sizes of boxes used for the box-counting algorithm in the lower scale range are comparable to those of 98% of landslides. Therefore, the scaling exponent of 1.35 can be interpreted as reflecting geometric features characterizing landslides: their areas, shapes, and mutual spatial relationships. On the other hand, the two scaling exponents obtained in the range of 1-16 km (1.74 and 1.76) describe the spatial distribution of the landslides, rather than the features of landslide shapes.