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Characterization of landslide intensity in the Arno river basin, Italy

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An essential part of any landslide hazard and risk assessment procedure is the prediction of the character of the intensity. In itself, intensity should express the potential impact energy, hence destructive power, of a landslide. Usually the intensity is considered as depending upon kinetic energy, mass and/or velocity.

In this work we have tried to define a methodology for characterizing the landslide intensity, in particular we have tried to apply a general rule for the determination of intensity for a large number of mapped landslides at the basin scale and to predict the intensity in landslide-free areas.

The selected site is the Arno river basin, in Central Italy, where a large database of over 27000 landslides has been recently mapped over an area of about 9000 km^2. Most of the mass movements registered are rotational or planar slow-moving slides. A large number of them (about 90%) is characterized by recurrence, intermittency and very small velocities, ranging between 1e+001mm/y and 1e+003mm/y.

We have developed a simple procedure that relies on the assumption that intensity and in particular kinetic energy are mainly connected to mass since the movements are very slow. In particular we will examine, here, the problem of assessing a suitable value for the intensity of landslide affected areas as well as landslide-free zones.

As already noted by Cruden & Varnes (1996) landslide mass, or better, volume, can be computed by assuming for a rotational slide a semi-ellipsoidal shape. In particular the volume is; $V = 1/6\ \pi\ D_r W_r L_r$, where D_r is the depth of the surface rupture, W_r is the width of the displaced mass and L_r is the length of the rupture surface.

Starting from the inventory map in digital form, which represents landslide polygons in two dimensions over a projected geographic coordinate system, the average parameters of landslide geometry can be derived from the following assumptions: i) $W_r$and L_r are derived from the area of the phenomenon, the slope angle and the distance between the scarp and the toe of the landslide through simple geometrical relations; ii) D_r is computed following the relation proposed by Cruden & Varnes (1996) according to which the value of the ratio of the D_r to L_r ranges between 0.15 and 0.33.

Regarding the computation of the volumes of the planar slides a constant depth has been assumed.

The application of such computation to the entire Arno river basin inventory has led to a first quantitative assessment of intensity, showing that the volume of the mapped landslides ranges between 10^2 m^3 and 10^8 m^3.

This very simple approach, however, does not give any information on the expected intensity in landslide-free areas.

We know that a certain area is characterized by a sort of frequency size signature for landslides that constrains the relationship between volume and recurrency.

We have seen, furthermore, that this linkage has been generally verified as a power-law type.

However, the frequency volume relationship for landslides depends on many different factors that vary over space and time. The larger the area considered, the worst is the fit of the power-law to the data. For this reason, it is safe to assume that areas with different geomechanical and morphological settings will have different forms of the power-law distribution.

To account for this we have subdivided the Arno river basin according to 27 UCU (Unique Conditions Units) defined intersecting three factors: lithology, slope gradient and slope profile curvature and separately computed the power-law fitting for each UCU. These factors have been considered the most relevant in influencing the possible volume of the typical landslides of the Arno river basin.

The hypothesis that lithology and geomorphological factors influence the parameterization of the volume-frequency power-law is indirectly confirmed by a large number of studies carried out worldwide and by the basic principles of soil and rock mechanics and represents a good tool for making an estimation of the intensity in landslide-free areas.