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Examination of historical landslide time series: a test case from the Emilia-Romagna region, northern Italy

M. Rossi[1]*; A. Witt*[2, 3]*; B. D. Malamud*[2]*; F. Guzzetti*[1]*; S. Peruccacci*[1]

1. Consiglio Nazionale delle Ricerche, Istituto di Ricerca per la Protezione Idrogeologica, Perugia, PG, Italy.
2. Department of Geography, King's College London, London, United Kingdom.
3. Department of Nonlinear Dynamics, Max-Planck-Institute for Dynamics and Self-Organization, Göttingen, Germany.

Determining when, or how frequently, landslides can occur in an area is of primary importance for erosion and landscape evolution studies, and for landslide hazard and risk assessments. Studies of the temporal occurrence of landslides over extended periods are rare due to paucity and reliability of information. In this work, we exploit a catalogue of historical landslides in the Emilia-Romagna region, northern Italy, in the 52-year period 1951–2002. The catalogue consists of 2,255 reported landslides, and is based on historical archives and chronicles. In our analyses, we use two measures for the intensity of landsliding over time: (i) the number of reported landslides in a day (DL), and (ii) the number of reported landslides in an event (Sevent), where an event is one or more consecutive days with landsliding. From 1951 to 2002 in the study area there were 1057 days with $1 \le DL \le 45$ landslides per day, and 596 events with $1 \le Sevent \le 129$ landslides per event. We perform the following analyses with associated conclusions: (i) We examine temporal correlations of landslide intensities, measured by DL and Sevent, using power-spectral analysis and surrogate data analysis, and conclude that the landslide intensity series DL has strong temporal correlations, and Sevent has likely temporal correlations. (ii) We study temporal clustering in DL and Sevent, considering extremes over different landslide intensity thresholds, and we determine that DL and Sevent each have temporal correlations, but Sevent to a lesser degree. (iii) Using autocorrelation analysis, we examine correlations between successive inter-extreme occurrence times (τ), and find for DL linear correlations in τ. For Sevent results are inconclusive; however, using Kendall's rank correlation analysis, we find that the time series of τ are strongly correlated, for both DL and Sevent. (iv) We apply Fano Factor analysis, finding for both DL and Sevent the timings of extremes over a given threshold exhibit a fractal structure, and therefore clustered in time. (v) We find that the probability density of landslide intensities in the time series of DL and Sevent are power-law distributed, over at least two-orders of magnitude, strong evidence that the frequency-size of triggered landslide events over time scale as a power-law. If confirmed, this could have important implications for risk assessment and erosion modeling. (vi) Finally, we compare our time series of landslides with the daily rainfall record for a representative station in the study area. We find that for short antecedent rainfall periods, the minimum amount of rainfall necessary to trigger landslides varies considerably with the intensity of the landsliding (DL and Sevent); whereas for long antecedent periods the magnitude is largely independent of the cumulative amount of rainfall, and the largest values of landslide intensity are always preceded by abundant rainfall. Further, the analysis of the rainfall trend suggests that the trigger of landslides in the study area is related to seasonal rainfall.

Contact Information

Mauro Rossi, Perugia, PG, Italy, 06128, click here to send an email