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Changes in land cover and shallow landslide activity: A case study in the Spanish Pyrenees

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Abstract

The Pyrenees, like many other mountain areas in Europe, have experienced depopulation and land abandonment during the 20th century. This has encouraged vegetation recovery in formerly occupied areas, including reforestation to promote woodland. The objective of this study is to analyse the effects of these changes on shallow landsliding, a process responsible for erosion and land degradation in many mountain areas. A sequence of aerial images reveals a slight decrease in the landslide occurrence rate in the last half of the 20th century and a parallel increase in the landslide extinction rate, i.e. the rate at which evidence of landslide activity is removed by vegetation colonisation. A logistic regression routine was used to assess the influence of land use and vegetation recovery in the occurrence of shallow landslides. The result shows that the former arable fields on the valley slopes still facilitate landsliding, even after land abandonment and revegetation by shrubs or trees. A shift in the topographic location of landslides was also detected, pointing to an increased importance of water redistribution in the slopes after prolonged rainfall periods.

Keywords: Shallow landslides; Revegetation; Topographic location; Logistic regression; Spanish Pyrenees

1. Introduction

Shallow landsliding is one of the most common geomorphic processes in the mountain areas of the world (Innes, 1983; Johnson and Rodine, 1984; Blijenberg, 1998). Shallow landslides usually have small to medium dimensions and typically affect the soil mantle and upper regolith, tending to evolve into unconfined debris flows which can affect infrastructure, houses or cultivations. Shallow landslides also constitute a major process of land degradation and, in many areas, are responsible for a substantial fraction of the total sediment delivered from a catchment. These are the reasons why they have been widely studied (Innes, 1983), including the prediction of their location by multivariate analysis and Geographical Information Science (i.e., Carrara et al., 1999).

The development of positive pore pressures in soil and colluvium profiles due to the infiltration of water during intense and/or prolonged rainfall periods is usually considered the main triggering mechanism (Wieczorek, 1987; Van Asch et al., 1999), although other processes like earthquakes or volcanic eruptions can also play an important role in some regions. In populated mountain regions, shallow landslides often result

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from the interaction between environmental and human factors (Caine, 1980; Blijenberg, 1998). In particular, forest logging, fire and cultivation on hillslopes are considered the most important in triggering shallow landslides (García-Ruiz et al., 1988; Cannon, 2000; Squier and Harvey, 2000). It is thus widely accepted that changes in land use significantly affect shallow landsliding. An increase in the rate of occurrence of landslides following forest logging or land clearance has been described in many studies such as Furbish and Rice (1983), Collison et al. (1995), Fannin et al. (1996), and Cruden and Miller (2001). Therefore, revegetation is often recommended for slope stabilization (Morgan and Rickson, 1995). However, there is a lack of studies on the effects on shallow landsliding of natural revegetation after land abandonment and reforestation over a long time period.

This paper focuses on shallow landslide activity in the Ijuez Valley, Spain, during the second half of the 20th century. As was common in the Spanish Pyrenees, the Ijuez Valley underwent a shift from high land-use pressure to almost complete abandonment during the 20th century, with a general increase in vegetation cover following abandonment. The main objective of this study is to assess the influence of changes in land cover on the occurrence of shallow landslides, through the example of the Ijuez Valley.

With this objective, I developed a GIS database based on the analysis of sequential aerial images to map the location of shallow landslides and land cover, and the derivation of topographic parameters from a digital terrain model (DTM). Annual landslide occurrence rates and 'extinction rates' (the rate at which evidence of past landslide activity is lost) could be

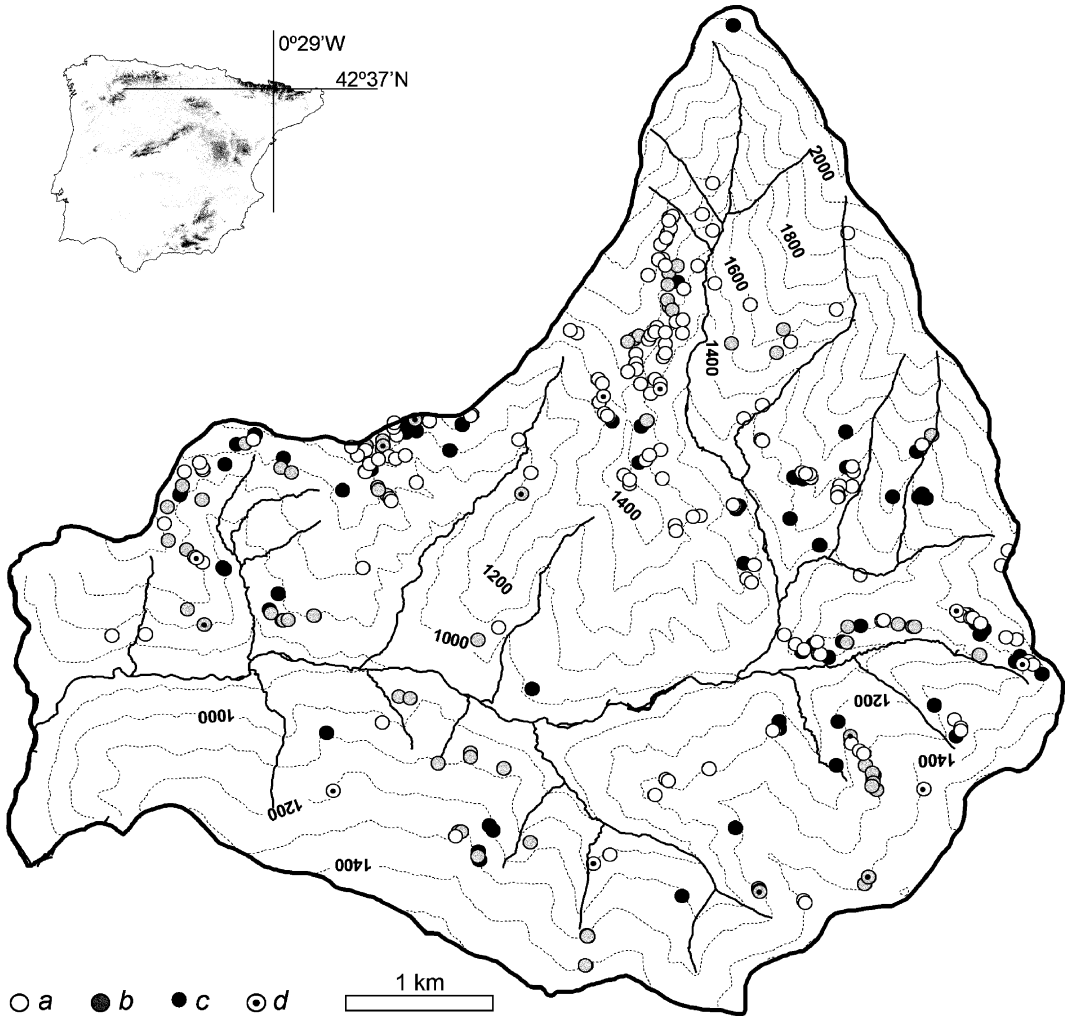

Fig. 1. Location of the study area (Ijuez Valley) in the Iberian Peninsula and distribution of shallow landslides at different times: a) occurred prior to 1957; b) occurred between 1957 and 1977; c) occurred between 1977 and 2002; d) extinct landslide scars. Contour interval is 100 m.