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Modelling net erosion responses to enviroclimatic changes recorded upon multisecular timescales

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Abstract

Land use change has been recognized throughout the Earth as one of the most important factors influencing the occurrence of rainfall-driven geomorphological processes. However, relating the occurrence of historical soil erosion rates is difficult because of the lack of long-term research projects in river basins. Also, complex models are not adequate to reconstruct erosion rate changes because they require significant input data not always available on long timescales. Given the problems with assessing sediment yield using complex erosion models, the objective of this study is to explore a parsimonious scale-adapted erosion model (ADT) from the original Thornes and Douglas algorithms, which aims at reconstruction of annual net erosion (ANE) upon multisecular timescales. As a test site, the Calore River basin (3015 km^2 in southern Italy) provides a peculiar and unique opportunity for modelling erosion responses to climate and land cover changes, where input-data generation and interpretation results were also supported by documented hydrogeomorphological events that occurred before and after land deforestation. In this way, ANE_{ADT}-values were reconstructed for the period 1675–2004 by using precipitation indexes, complemented by recent instrumental records, and by using land cover statistics from documented agrarian sources. Pulses of natural sedimentation in the predeforestation period have been related to Vesuvius volcanic activity and changes in rainstorm frequency. After deforestation, the basin system became unstable with sudden fluctuations in the hydrogeomorphological regime contributing significantly to increased erosion and, in turn, sediment transport sequences via river drainage towards the Tyrrhenian coast.
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Keywords: Rainfall erosivity; Land cover; Net erosion; Empirical model; Climate change; Calore River basin (southern Italy)

1. Introduction

Environmental changes have always been a topic of Earth's science and environmental research, but its importance increases during crucial changes and extremes (after Stehr and von Storch, 1995), often associated with land degradation driven by weather and external anthropogenic forcing (Riebau and Fox, 2005). However, while the major focus on causes of soil erosional degradation has been the relative significance of agricultural activities and practices, the possible impact of changing weather patterns and more sustained shifts in climate have also been implicated (Foster, 2001). Understanding how landscape components respond to forced conditions of land use change and to the climatic regime has implications for modeling the geomorphological processes hazard (Leeder et al., 1998;

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Coulthard et al., 2002) and for assessment of future planning (Higgitt, 2001; Verstraeten and Poesen, 2001). In this way, modeling has been a fascination for millennia, such as mean the words of Mulligan and Wainwright (2004) and Wainwright and Mulligan (2004, p. 8):

> "Modelling is described as an art because it involves experience and intuition as well as the development of (mathematical) skill."

especially in mountainous agricultural landscapes where land degradation is manifested in a variety of processes (Shrestha et al., 2004). Modelling is a crucial issue in assessing climate variability and land cover (Morgan et al., 1998; Renschler and Harbor, 2002; Ramos and Mulligan, 2003), which are very important factors affecting the environmental sustainability in these dynamic and sensitive landscape systems (Alexandrov, 1997; Thomas, 2001; Reinhard et al., 2003), highly controlled by a set complex of climatic, geomorphic, and ecologic processes (Krishnaswamy et al., 2000).

Amid current concerns over the consequences of recent enhanced climate variability of human and rainfall-induced agricultural and environmental impacts (Sivakumer, 2005), the modelling and reconstruction of the response of a river basin to past environmental changes is increasingly viewed as vital in the context of developing scenarios for future response (Rumsby, 2001). Much information regarding the geomorphological process, slope, and river response to climate change has been reported in numerous historical studies (Orbock Miller et al., 1993; Rumsby and Macklin, 1996; Brooks and Brierley, 1997; Wilby et al., 1997; Eden and Page, 1998; Arnaud-Fassetta and Provansal, 1999; Grove, 2001; Jacobeit et al., 2003; Hunt and Wu, 2004; Schmidt and Dikau, 2004). Many of them were concerned specifically with sediment and erosional processes from European archival data, such as in English catchments (David et al., 1998), German (Zolitschka, 1998), Welsh (Beavis et al., 1999), Irish (Huang and O'Connell, 2000), Spanish (Lasanta et al., 2001), Iceland (Lamoureux, 2002), Belgian (Van Rompay et al., 2002), Greek (Lespez, 2003), Turkish (Wick et al., 2003), Bavarian (Dotterweich et al., 2003), and French (Piégay et al., 2004). Although many of these studies form an attractive research field, the information derived from paleogeomorphological evidence [such as sedimentation traps in fluvial terraces (Prózynska-Bordas et al., 1992), in lakes (Slaymaker et al., 2003; Evans and Slaymaker, 2004), or in deglacierizing basins (Orwin and Smart, 2004)] are not continuous in time with less rigorous chronological control (Schulte, 2002; Bradley et al., 2003). Research developed in Italy have been carried out dealing with the influence of climatic modifications on the natural environment and on impacts of extreme events on human activities since A.D. 1000 (Camuffo and Enzi, 1992; Delmonaco et al., 2000) or earlier (Ramrath et al., 2000). An overview of paleoclimatic investigations on sediments from volcanic lakes in central Italy is given by Follieri et al. (1993). All these studies suggest that the Little Ice Age (LIA), variously assessed as AD 1300–1900, is not expected to be hydrogeomorphologically homogeneous and sustained over large geographical areas (see also Bradley and Jones, 1993; Ogilvie and Jonsson, 2001; Soon and Baliunas, 2003 for climate forcing). Thornes (1995) and Viles and Goudie (2003) agreed, declaring that in-depth research in a regional context would likely to provide meaningful answers questions of magnitude impact by combinations of modes of internal and forced climate variability (Goosse et al., 2005). For this topic, dynamically or stochastically driven models (see Nearing, 2004, for a synthesis) can be used. However, these models still have limitations for predicting basin sediment yield (de Vente et al., 2005), especially over long timescales, requiring a powerful computer, extensive computer run time (Toy et al., 2002), and validation that is difficult because scarcity of measurements (Instanbulluoglu et al., 2004).

To deal with these problems in this paper, I propose an integrative methodology incorporating bioclimate documentary data in a regression-derived erosion model offering the opportunities to account for parsimonious interpretation between input data and a basin-response erosion variable. This model is to revise the Douglas (1967) and Thornes (1990) empirical algorithms to an adapted-Douglas–Thornes (ADT) nonlinear model (ANE_{ADT}) by replacing the RUSLE erosivity factor with runoff data and by updating a vegetation-protection climatic function with improved net erosion time-series estimates. For (ANE_{ADT})-model calibration a SIMN-dataset (1957–1972), with a total of 20 samples was used, providing a unique opportunity to explore geomorphological processes in the Calore River basin (CRB) of southern Italy. The use of an ANE_{ADT} time-series model is motivated by its potential for capturing the significant and changing environment (including climate, vegetation cover, and erosive-resistance climate changes) with easily available data. Results show an important increase of sediment rate from 1811 to 1860, with higher fluctuations of the erosion peak from preceding and successive periods.

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