Geomorphology 214 (2014) 10–21

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Simulation of medium-term soil redistributions for different land use and landscape design scenarios within a vineyard landscape in Mediterranean France

Mélodie David [a,b], Stéphane Follain [c,*], Rossano Ciampalini [a,d], Yves Le Bissonnais [a], Alain Couturier [e], Christian Walter [f,g]

[a] INRA, UMR LISAH, 2 place Pierre Viala, F-34060 Montpellier Cedex 1, France
[b] GEODE UMR 5602, Maison de la Recherche, Toulouse, France
[c] Montpellier SupAgro, UMR LISAH, 2 place Pierre Viala, F-34060 Montpellier Cedex 1, France
[d] INRA — US1106 InfoSol, Centre de recherche Val de Loire, CS 40001, F-45075 Orléans Cedex 2, France
[e] INRA, UR0272 Science du sol, Centre de recherche Val de Loire, CS 40001, F-45075 Orléans Cedex 2, France
[f] INRA, UMR 1069 SAS, 65 rue de St Brieuc, F-35000 Rennes, France
[g] AGROCAMPUS OUEST, UMR 1069 Sol Agro et hydrosystème Spatialisation, F-35000 Rennes, France

ARTICLE INFO

Article history:
Received 13 December 2013
Received in revised form 27 February 2014
Accepted 5 March 2014
Available online 15 March 2014

Keywords:
Soil resources
Landform modelling
Landscape design
Land use change
Soil erosion
Mediterranean vineyard

ABSTRACT

Inappropriate agricultural land management practices cause irreversible soil losses in many parts of Europe. Soil degradation is predicted to increase in the next future as an effect of climate and cropping system changes. The most concerned areas are expected to be those already severely affected by erosion, as is the whole of the Mediterranean. Medium-term soil erosion models could be useful tools to analyse, understand and simulate complex interactions between geomorphic processes and human pressures for better assessment of medium-term soil redistributions associated with land use and landscape design change. The aim of this study was to compare the effects of various agricultural land uses and landscape design strategies on water and tillage erosion. The first step was to develop land use and landscape design scenarios of an agricultural Mediterranean landscape. Then, all of the scenarios were compared in terms of the soil redistribution using the LandSoil model. The results indicate that potential soil conservation associated with the adoption of sustainable land uses surpasses the potential conservation associated with certain landscape design. A detailed analysis of within-landscape soil redistributions suggests that land use is a major factor controlling sediment production, whereas landscape design is a major factor controlling hillslope connectivity.

1. Introduction

In many parts of Europe, soil resources are being irreversibly lost and degraded due to inappropriate land management practices (EEA, 2000). Pressures are generated by the concentration of human populations and activities in restricted spaces and by changes in climate and land use. Relevant human-induced changes include those created by farmers individually on the scale of fields or farms and those imposed by policymakers, ranging from farm plot to administrative divisions (Verburg et al., 2002; Rounsevell et al., 2005; Claessens et al., 2009). Climate-induced changes are those related to changes in the seasonal distribution of climate factors and the frequency of extreme events predicted by projections of future climate change (IPCC Core Writing Team et al., 2007).

Soil erosion is a primary cause of land degradation. Under the European Community baseline, the risk of erosion is expected to increase in approximately 80% of EU agricultural areas by the year 2050 as a result of climate change (EEA, 1999). This increase is expected to be the highest in areas where erosion has been already severe, as in the Mediterranean area (EEA, 1999). This vulnerability of Mediterranean landscape is due to productive, socio-economic and pedoclimatic conditions as a long history of anthropogenic pressure, frequent heavy rainfall events, perennial cultivation in areas of thin soil coverage, and a general deficiency of organic soil matter (Kosmas et al., 2002; Butzer, 2005; Hooke, 2006; Delibes-Mateos et al., 2009). Human activities may have a large influence on the risk of soil degradation (Blum, 2002; Tóth et al., 2008). A possible solution is therefore the promotion of sustainable land management practices that reduce erosion to a sustainable order.

Modelling is an appropriate method for simulating the space–time evolution of soil redistributions. Among numerical models, Coulthard (2001) and Willgoose (2005) have listed soil redistribution models

* Corresponding author. Tel.: +33 499 61 28 03; fax: +33 467 63 26 14.
E-mail address: follain@supagro.inra.fr (S. Follain).

http://dx.doi.org/10.1016/j.geomorph.2014.03.016
0169-555X/

that can be used to study the evolution of agricultural environments. Most of these models use mechanistic rules for diffusion and water erosion similar to those proposed by Kirkby (1985), and some of them also include a soil production function (Willgoose et al., 1991; Heimsath et al., 1997; Minasny and McBratney, 1999, 2001; Vanwalleghem et al., 2013). Some recent models such as SPEROS (Van Oost et al., 2000, 2005; Govers et al., 2006), LAPSUS (Schoorl et al., 2002; Debolini et al., 2013) and LandSoil (Ciampalini et al., 2012) are erosion models in which landforms and erosion evolve together and could be useful tools for simulating medium-term (10–100 years) soil erosion processes in relation to land use and landscape design changes. Such modelling, however, presumes not only the ability to produce quantitative models of soil redistribution in the landscape but also to produce realistic, explicit scenarios of land use and landscape design. Such scenarios can be used to explore alternative, plausible outcomes if basic assumptions about future developments are changed. This means that scenarios are pictures, internally coherent and plausible description of possible futures rather than predictions (IPCC et al., 1994; Millennium Ecosystem Assessment, 2003).

The aim of this study was to evaluate and compare the effects of various land use and landscape design scenarios on medium-term soil redistributions in a Mediterranean agricultural landscape. To achieve this goal, land use and landscape design scenarios were developed on the basis of a baseline scenario corresponding to the actual conditions of the Roujan long-term experimental research catchment, France. All of the scenarios were then analysed in terms of soil redistribution using the LandSoil model.

2. Materials and methods

2.1. The study area

The Roujan watershed (Languedoc-Roussillon, France, 43°30′N, 3°19′E; 91 ha in area; Fig. 1) was selected for this study because it has been monitored since 1992 for hydrological and sediment data and regularly characterised in terms of agricultural and landscape uses and management (ORE-OMERE, 2010). The Roujan watershed has a sub-humid Mediterranean climate (Emberger, 1955). The area is characterised by a mean annual rainfall of 634 mm and a mean annual Penman–Monteith reference evapotranspiration of 1097 mm. Annual rainfall records indicate a bimodal distribution, with major periods of rain during the spring and autumn and an extended dry period during the summer characterised by a long, dry season. The mean annual temperature is approximately 14 °C.

The watershed can be divided into four geomorphologic units (Fig. 1): (i) upslope, (ii) agricultural terraces on the backslope, (iii) footslope and (iv) toeslope. The elevation ranges from 75 m a.s.l. in the lowest part to 125 m a.s.l. at the top of the plateau, with slopes of ca. 2–20%. Heterogeneous Miocene marine and lacustrine sedimentary rocks underlie the region. These geologic strata are partially overlain by alluvial deposits that range from Pliocene to Holocene in age. The spatial distribution of the primary soils of the area is well correlated to the geomorphologic categorisation: (i) thin calcaric Regosols upslope, (ii) calcaric Regosols on the backslope; (ii) Calcisols on the footslope; and (iii) endogleyic Calcisols in the bottom part of the hillslope (WRB,

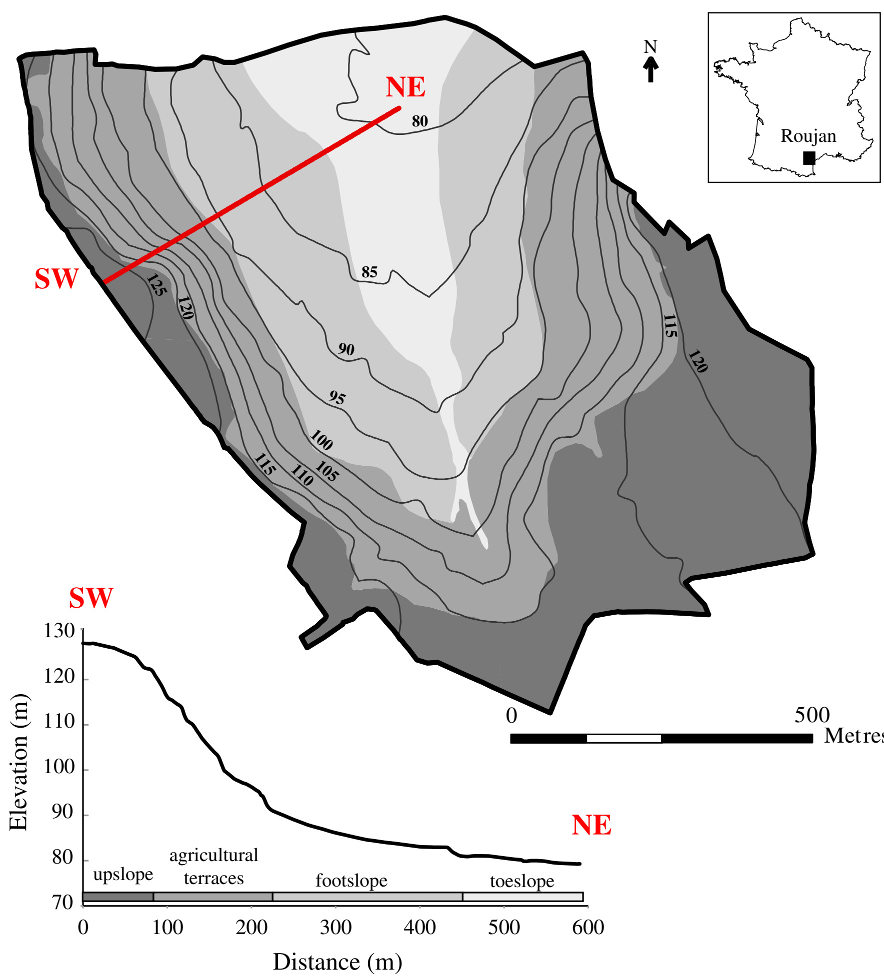

Fig. 1. Topographic map and geomorphologic section of the Roujan experimental catchment.