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Land use can offset climate change induced increases in erosion in Mediterranean watersheds

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ABSTRACT

The aim of this paper is to assess the impacts of projected climate change on a Mediterranean catchment, and to analyze the effects of a suite of representative land use practices as an adaptation tool to reduce climate change-driven erosion and hydrologic extremes. Relevant climatic variables from the ERA-Interim global atmospheric re-analysis of the European Centre for Medium-Range Weather Forecasts (ECMWF) were downscaled for the study area, and perturbed with the anomalies of 23 global circulation models for three emission scenarios (B1, A1B and A2). Both a projected daily rainfall time series for the period 2010–2100, and a single precipitation event with a one-hundred year return period were used to assess the impact of climate change. The downscaled data were fed into a distributed hydro-sedimentary model (TETIS) with five land use configurations representative of future demographic tendencies, geographical characteristics and land management policies (e.g. European Union CAP). The projected changes showed a general decrease in runoff and sediment production by the end of the century regardless of land use configuration. Sediment production showed a positive relationship with an increase in agricultural land and a decrease in natural land under present day agricultural management. According to our simulations, some conservation practices in agriculture can effectively reduce net erosion while maintaining agricultural production. As such, they can play a critical role as an adaptation tool to reduce climate change impacts in the 21st century.

1. Introduction

The Mediterranean is one of the most sensitive regions to climate change in Europe (IPCC, 2014). Climate change projections for the southern Iberian Peninsula suggest a decreasing trend in annual average precipitation and an increase in heavy rainfalls by the end of the century (Barranco et al., 2014; Garcia et al., 2007; Rodrigo, 2010).Changes in total and extreme precipitation are projected to alter runoff production (Barranco et al., 2014), but the impact of changes on erosion and sediment yields at catchment scale has received less scientific attention (Bussi et al., 2014b).

Hydrological and environmental planning of Mediterranean watersheds requires an understanding of the future runoff and sediment yield response to climate and land use changes to enable adaptation to the potential impacts on freshwater resources and economic activities (e.g. agriculture). Sediment yields in Mediterranean catchments are mainly produced during high intensity precipitation events which may generate up to 40% of total erosion (Baartman et al., 2013; Rodriguez-Lloveras et al., 2015). At the same time, soil loss may be increased by inadequate land use and agricultural production techniques, deforestation, overgrazing, forest fires and construction activities (Boellstorff and Benito, 2005; Garcia-Ruiz, 2010; Puigdefábregas and Mendizabal, 1998). In these fragile Mediterranean environmental conditions, any soil loss higher than the estimated mean of 1.3 t ha^{-1} $year^{-1}$ (Cerdan et al., 2010) can lead to a stage of irreversibility within a time span of 50–100 years (EEA, 1999; Gobin et al., 2004). Climate change may contribute to increased soil erosion as a consequence of the higher frequency of heavy rainfalls projected by climatic models (Döll et al., 2015; Kundzewicz et al., 2014). However, the net sediment production will result from the combined impact of climate (dryness, heavy rainfall, total rainfall) and land use conditions (agriculture, forest, shrubs), and their spatial and temporal variability. Future water and sediment yield projections need to consider different socioeconomic pathway scenarios for both climate change and land management at watershed scale.

Simulating climate change impacts on hydrology and sediment production requires the generation of time series of projected climatic variables. General Circulation Models (GCMs) produce projected climatic variables under different socioeconomic and technological development scenarios. Several studies have used climate change projections from GCMs and regional climate models to model long-term changes in sediment transport in Mediterranean watersheds (Bussi et al., 2014a; Nerantzaki et al., 2015; Nunes et al., 2013). Most of these models provide projected climate variables at a coarse spatial resolution, which

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reduces precipitation intensities and disregards local patterns of variability. This is one of the most critical characteristics of precipitation in the Mediterranean region (Gonzalez-Hidalgo et al., 2009; Xoplaki et al., 2004), and it is therefore important to simulate it in detail. For this reason, downscaling methods have been used to obtain representative climatic variables at smaller scales, that take local relief and elevation characteristics into account (Christensen et al., 2007). Among these, statistical downscaling uses statistical modelling techniques to extrapolate and interpolate results generated by dynamic models (Benestad et al., 2008). These statistical downscaling techniques have been widely used for hydrological projections (Barranco et al., 2014; Hertig and Jacobeit, 2008; Segui et al., 2010), but their application to the analysis of watershed erosion and sediment yields is still limited (Michael et al., 2005).Downscaling methods have the capacity to preserve the observed statistical structure (mean and dispersion) of the projected climate parameters at local scale, and to include heavy rainfalls not well reproduced by GCM projections.

Climate change impacts on soil erosion and degradation can be reduced by adequate land use practices (Boellstorff and Benito, 2005), thus effectively offsetting climate-driven increases in erosion in Mediterranean areas. When exploring the best land use practices for climate change adaptation, it is necessary to project representative land use configurations, considering non-natural variables such as demographic and socioeconomic factors, which cannot be easily predicted (Aguirre Segura et al., 1997; Arnold et al., 1998; Barriendos, 1997).

The purpose of this paper is to analyze the effects of different climate change projection scenarios on runoff and sediment production in a Mediterranean catchment, and to investigate how these effects can be mitigated by different land use configurations and agricultural techniques. The dataset of daily climate projections was obtained from the ECMWF ERA-Interim project combined with the 4th IPCC General Circulation Models (GCMs). Land use scenarios were established considering geography, demographic trends, traditional agricultural use and techniques and plant phenology. Changes in hydrology and sediment yields were calculated by routing the projected meteorological time series (2010−2100) through the TETIS distributed hydro-sedimentary model simulated under different future land use and land cover scenarios.

2. Material and methods

2.1. Study area

The study area comprised a section of the upper catchment of the Guadalentin river (SE Spain, Andalusia) covering a surface area of 429 km^2 drained by the Rambla Mayor and Caramel Rivers (Fig. 1).

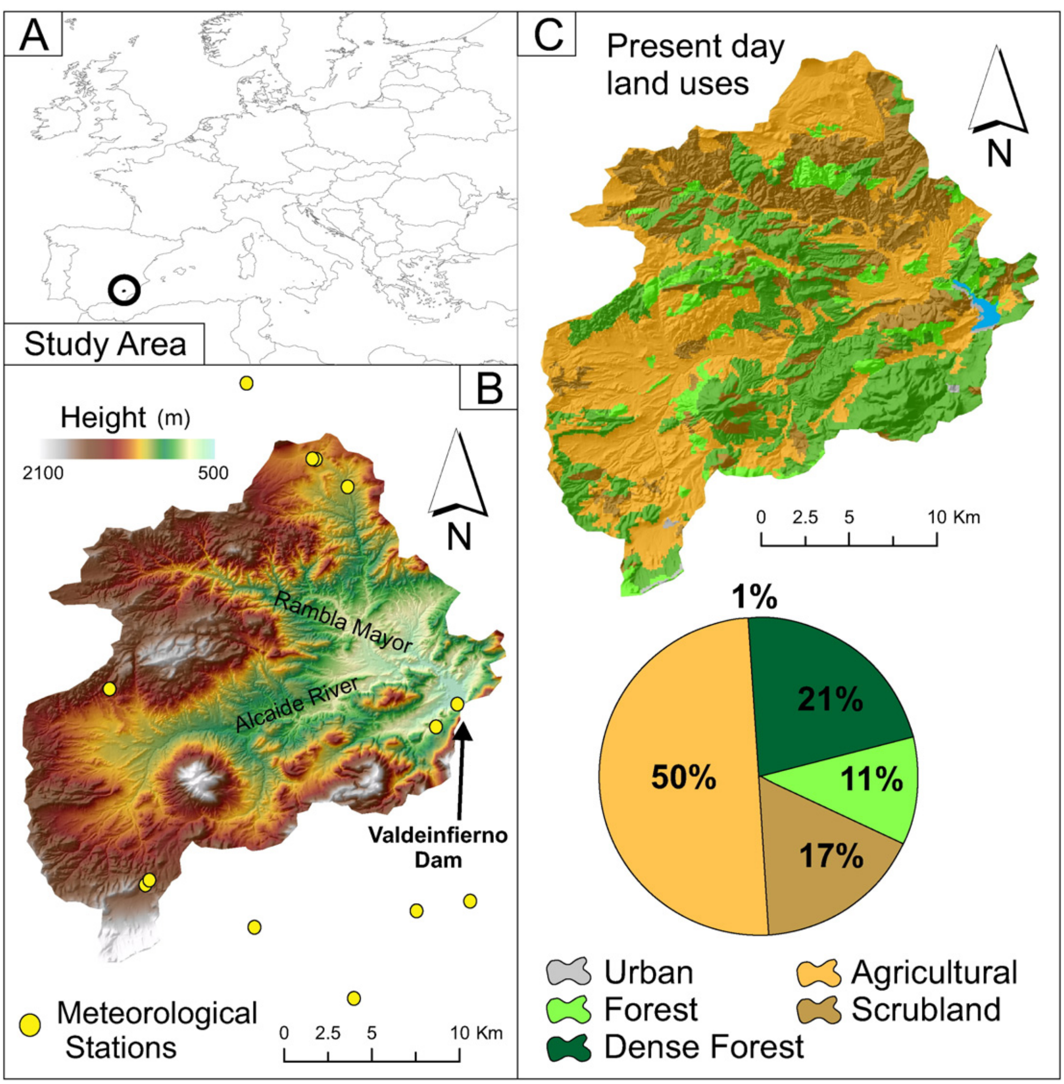

Fig. 1. (A) Location of the study area. (B) Topography of the basin and location of the meteorological stations. (C) Present day soil uses distribution and percentage.