Changes in climatic conditions, vegetation cover and erosion during the Holocene in southeast Spain

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ABSTRACT

The present-day landscape in Southeast Spain is the result of a long occupation history. To have a better understanding of the impact of human societies on soil degradation, we analysed the main shifts in vegetation cover, climate and human occupation for the last 12000 years. Our analyses use recently published information from continental and marine pollen series. The data suggest that climatic factors appear to be important driving factors of vegetation degradation induced by an increased aridity that is already recorded at about 5000 years ago.

Keywords: Holocene, human occupation, soil erosion, vegetation cover, desertification, southeast Spain

INTRODUCTION

The Mediterranean region is commonly reported as the European regions that is most affected by soil degradation. The degradation of Mediterranean soils has often been linked to inappropriate agricultural practices during the last decades. However, the Mediterranean region has been populated and cultivated since thousands of years by various civilizations, and the landscape is the product of a long land use history. This research aims to contribute to the understanding of long-term impact of humans on erosion processes. The main question that is driving this research is: '*Is the Mediterranean environment currently threatened by accelerated soil erosion following human occupation ?*

To address this research question, we reconstructed past changes in vegetation, climate and human occupation based on an extensive literature review. Long-term changes in climatic and land cover conditions were derived from pollen series from continental and marine cores from the Alboran Sea. The use of recently published data from high-resolution deep marine cores allows us to overcome some of the major drawbacks of the low quality and low-resolution deep-sea cores from the last decade. This data will be confronted with independently derived information on lake levels, human occupation and sediment fluxes.

METHODOLOGY

Our reconstruction is largely based on climate proxies derived from marine cores (ODP 976; Combourieu Nebout et al., 2009 and MD 95-2043; Fletcher et Sánchez Goňi, 2008; Fletcher et al., 2009) and continental cores. Terrestrial proxies are mainly composed by pollen sequences from Padul (Pons et Reille, 1988), Cabo de Gata (Estaban Amat, 1995), Sierra de Gádor (Carrión et al., 2002), Antas, Roquetas del Mar, San Rafaël (Pantaléon-Cano et al., 2003), Sierra de Baza (Carrión et al., 2007), and Carihuela Cave (Fernandez et al., 2007). In addition, terrestrial multi-proxies were retrieved from information on Zoñar Lake (Martin-Puertas et al., 2008), Laguna de Medina (Reed et al., 2001) and Siles Lake (Carrion, 2002). Additional information on the paleo-environment is derived from (i) terrace sequences from Aguas and Antas rivers (Schulte et al., 2002), (ii) past lake levels published by Thorndycraft et Benito (2006), and (iii) estimates of soil perturbation and regional sediment fluxes by van der Leeuw (1998). The archeological databases established by the Archaeomedes (van der Leeuw, 1998) and Aguas Projects (Castro et al., 1998) provide us information on occupation phases.

RESULTS AND DISCUSSION

Our compilation of published data from continental and marine paleo-environmental proxies confirms that the major climatic oscillations that are identified for Southeast Spain correspond with more global environmental shifts. This indicates that the environmental conditions in the western Mediterranean seem to be pulsed by more global climatic oscillations such as the successive phases of deglaciation in the Northern Atlantic (e.g. Frigola et al., 2008; Fletcher et Sanchez Goni, 2008) that are accompanied with rapid environmental response to short-lived Holocene climatic events (Combourieu Nebout et al., 2009). The effects of changes in precession and millennial-scale climatic variations on vegetation have been documented for the long pollen records from the Mediterranean region (e.g. Magri et Tdzedakis, 2000; Fletcher et Sanchez-Goni, 2008).

The general improvement of the vegetation towards optimum vegetation around 8000 to 5500 cal. years BP probably reflects climate change towards warmer and more humid conditions. Given the development of dense vegetation cover, it is very likely that this period is characterized by very low soil degradation, erosion and sediment production. This general warming trend ends at about 6000 cal. years BP. During this period, strong changes in vegetation were observed for a large number of terrestrial and marine paleo-environmental proxies across the western Mediterranean basin and Northern Africa. The expansion of semi-desert and the decline of Mediterranean forest were generally associated with an overall cooling and aridification (Fletcher et Sanchez-Goni, 2008). This likely caused important decrease of the vegetation cover leading to changes in soil surface properties (e.g. Reale et Shukla, 2000; Brovkin et Claussen, 2008). During this period of rapid changes in vegetation cover, the first human settlements were observed in the Vera Basin (Van der Leeuw, 1998). The anthropogenic impact of these first settlers is estimated to be rather low: these groups practiced seasonal transhumance and were characterized by very low population densities. The modification of the soil structuration that has been reported for this period seems to be primarily affected by climatically driven vegetation deterioration.

The first period with an important human occupation is often referred to as the Chalcolithic period (4950-4200 cal. years BP), and is defined by settling of sedentary populations. The population density remains still low. Agricultural activities are mainly concentrated in the Quaternary valleys, and are oriented for domestic use as shown by Castro et al. (1998) for the Aguas Basin. During this occupation period, a short but clear climate improvement is reported between about 4100 and 4700 cal. years BP. Besides of some records of important soil erosion and soil instability, it is suggested that the soils maintained generally good structural stability (van der Leeuw,1998).

The Argaric period (4200-3500 cal. years BP) is characterized by a prosperous occupation with strong modifications of the economic and agricultural practices. Notably, there is the development of networks of complementary economical production and the strong development of mining activities. During this period, the general aridification trend continues strongly. High erosion rates are observed, particularly during the Early Argaric (4200-3910 cal. years BP) in the Vera basin. However, field observations could not confirm that these patterns of erosion or degradation are directly associated with human settlements (van der Leeuw, 1998). The human pressure remains relatively low during this period, and it is possible that these soil perturbations are linked to an overall strong aridification and natural vegetation cover change.

The population density strongly increased during the colonization phases of the Phoenician I (2850-2150 cal. years BP) and Vizigothic-Byzantic (550-718/750 cal. years BP) period. The general cooling and aridification trend reported earlier on persisted during these occupation phases. However, some clear alternation of increases (e.g. at the onset of the third millennium BP, and at the Late roman period/Dark Age) and decreases (e.g. Warm Roman period) in aridity are reported. Important phases of rapid erosion of uplands and midlands with some accretion in the lowlands are documented for this period (van der Leeuw, 1998: from 2850 cal. years BP to about 718/750 cal. years AD). Although the economic and agricultural strategies adopted during these periods involved an important exploitation of natural resources, it is considered that the impact of these societies on the landscape has been short-lived and reversible. Based on various paleo-environmental proxies gathered at the local and regional scale, it has been suggested that the changes in climate and vegetation cover strongly correlate. The strong increase of pollen of temperate forest species in the marine ODP 976 core around the start of the Roman occupation is frequently cited to provide some evidence that the environment has a certain resilience to recover from human impact. Following this line of thoughts, the shifts in the vegetation cover that are observed for the period before 2000 BP could then be primarily climate induced. This is in agreement with the observations of Desprat et al. (2003) who argue that climate is the major cause for forest reductions in northwest Iberia during the 3000 last years, and that major human occupation periods such as the Roman occupation period show some stability in forest communities.

The last centuries experienced important fluctuations in population numbers, land cover and land use. The unrest associated with the Christian conquest (end of 15th Century) led to drastic decrease of the population, abandonment of the agricultural land and its irrigated terrace systems (van der Leeuw, 1998). Shortly after (16th to 19th Century), there is an important demographic growth that is largely associated with the boom of the metallurgic activities. The rapid increase of the population resulted in an acute need for agricultural land, and remote mountainous sites were terraced and converted to agricultural parcels. The Reconquista Period is often cited as the beginning of an era with high soil erosion that continued until the 1950s. The rapid development of badlands morphology is also reported to have occurred in this period. According to some authors, the intense cultivation of fragile soils pushed the system over an ecological threshold into the extreme degraded landscape as it appears today. It is important to mention that this period partially coincides with the Little Ice Age in Southern Spain (16th till 19th Century), an era characterised by lower temperatures and increased rainfall. Historical records of flooding frequency and sedimentation indicate that sediment production was enhanced during this period with important build-up of terrace sequences in the lower valleys. During the last decades, there is an important abandonment of agricultural land. This had major consequences for restoration of vegetation and soils. It is clear that further research is necessary to determine the resilience of this degraded landscape on the long-term.

CONCLUSIONS

Our review of published paleo-environmental proxies indicates that recurrent events of Holocene decline in forest cover are correlated with periods of increased dryness and changes in temperature. This allows us to infer that past changes in vegetation composition are largely induced by climate fluctuations. Various continental proxies seem to indicate that the major anthropogenic impact on soil degradation post-dates the Phoenician period. It is clear that independently derived measures of past erosion rates for Southeast Spain are necessary to disentangle natural from anthropogenic controls on erosion rates.

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