INTER-ANNUAL VARIABILITY OF THE ECOGEOMORPHOLOGICAL SYSTEM AT HILLSLOPE SCALE UNDER SEMIARID MEDITERRANEAN CONDITIONS

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ABSTRACT

The induced changes by the pluviometric variability on the vegetation pattern and physico-hydrological soil properties at abandoned hillslope under semiarid climate conditions was analysed since 2002 till 2005, comparing both different situations, one humid (November'02) and another dry (November'05). The vegetation pattern was intensely disturbed and the biomass reduce by the lack of soil water available which caused the death of numerous vegetation individuals and the increase on bare soil patches and the surface wash. Those changes affected the soil properties: the texture became slightly sandier, the organic matter content felt and aggregate stability dropped. The soil water properties changed as a consequence of the variability of the pluviometry and they became more water-transferring. Moreover, the increase in surface stoniness reduced evaporation and the scarcer vegetation in lower transpiration; and as a consequence more water available on the soil profile. This will encourage vegetation recovery, which is a good example of how fast semiarid ecosystems are adapted to the dry periods.

Key words: Dry periods, vegetation pattern, soil degradation, hillslopes.

1. INTRODUCTION

The Mediterranean semi-arid regions are characterised by a regime of precipitation that is highly variable in space and time (Kosmas et al., 1994), with rainfall of extreme intensity,

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along with frequent drought periods and long dry episodes (Ceballos et al., 2002). This has short-term effects on the eco-geomorphological system that may be diverse and contradictory and induce an immediate response of the eco-geomorphological system to the modification of any one of its elements (Lavee et al., 1998). In fact, Märker et al. (in press) observe that periods of drought, like the one in Southern Italy in 2003, may cause changes in soil erosion and sediment transport processes, since surface conditions (vegetation pattern and surface soil properties) play a major role in the rates of water infiltration and evaporation from soil. The frequent periods of drought in the Mediterranean are the most effective way that soil surface characteristics are modified, due to drought's effect on pore space (shape, volume and continuity of pores), litter cover and surface roughness, and due to increased surface ponding, thus reducing surface run-off and increasing the soil surface area exposed to evaporation (Kosmas et al., 2000). All this has impact on the water balance and is a limiting factor on biological activity, such that a small variation or drop in the amount of water entering the system, as occurs in drought periods, may have consequences on the future of the system's dynamic (Lázaro et al., 2001; Ferre et al., 1994) and, in particular, on the vegetation that attempts to recolonize the abandoned field. Therefore, the consequences for water balance will depend on soil characteristics and meteorological conditions, which are particularly sensitive in semiarid Mediterranean environments of abandoned fields.

The objective of this paper is to show the immediate changes in the pattern of vegetation and in key physical, chemical and hydrological soil properties caused by a drought period from a eco-geomorphological perspective.

2. MATERIALS AND METHODS

2.1. Experimental site

The research was conducted at one hillslope of the Southwestern Montes de Málaga, a geological unit belonging to the Betic Cordillera, in the South of Spain. The hillslope's features were: N115º exposition, a 36 m difference in elevation, a rectilinear-convex shape and a mean slope of 36%. Its parent material is phyllites. The climate conditions of the environment are semi-arid Mediterranean: annual rainfall = 454 mm and mean annual temperature = 18.5ºC. Almond trees were grown on the hillslope until the mid-XXth century, since when it was abandoned and then recolonized poorly by bushy vegetation (*Genista umbellata*, *Lavandala stoechas*, *Lavandula dentata* and *Asparagus acutifolius*) and by an annual herbaceous layer that varies in extent, depending on the season (*Tuberarion guttatae* association).

2.2. Experimental design

In November 2002, we delimited an experimental opened-plot marked with several pins on a hillslope representative of the region and used a GPS Leica for its topographic elevation. The length of this plot was equal to the distance between the upper water-shed and the talweg (112 m.) and its width was five metres. We have followed the methodology applied by Calvo et al. (2005), Martínez-Murillo (2006), Boix et al. (2007). We divided the interior of the plot into open sub-plots measuring 3 metres long by 2.5 metres wide, defining three transects. Each of these sub-plots was photographed with a digital camera placed on a 4.5 metre-high portable metal structure, for subsequent photo-interpretation through the Geographical Information System ArcGIS 9.0. From the bottom of the hillslope and every nine metres (36 points in total), soil samples (disturbed and undisturbed, 5 and 15 cm deep) were collected in Nov '02 and Nov '05, both to determine its physical properties and for infiltration experiments and monitoring of soil moisture. In October 2002, a raingauge was placed on the hillslope as well, to measure the total volume of rainfall events. Every two weeks at the same sampling points, soil water content (SWC) was measured with a TDR-Tektronix 1502C at 5 and 15 cm depth to obtain the temporal and spatial variability inside the experimental opened-plot.

2.3. Measurements

Distinct variables between November 2002 and November 2005 were analysed: rainfall, the eco-geomorphological pattern (vegetation cover and soil surface) and the soil's hydrological, chemical and physical properties. The disturbed samples were used for laboratory analysis of the following soil properties: gravel content (G) (sieved at 2 mm.), texture (sands, S; silts, L; clays, Cl) (sieved and Robinson's method; Robinson, 1922), soil aggregate stability (AS) by wet sieving (Kemper and Rosenau, 1986; Smith et al., 1992; Madari et al., 2005; Eynard et al., 2005), Organic Matter content (OM) (AFNOR, 1987) and pH (pHmeter). In the undisturbed soil samples, we used 100 cm3 cylinders to determine porosity (P) and Bulk Density (BD). Soil hydrological properties were also analysed with this kind of sample: the capacity of water retention to saturation (SAT), Field capacity (FC) and Wilting point (WP), using a sand-box (pF<2.0) and a Richard membrane (pF>3.0). In the field, at the same points of soil sampling, infiltration experiments were conducted. Using a minidisk infiltrometer following the Zhang method (1997), we obtained the hydraulic conductivity (K) rates at pressures of -0.5 and -2.0 cm. The available water content (AWC) for vegetation (1) was worked out and expressed as follows:

$$(1)\ AWC = [\ (SWC-WP) / (FC-WP)\ ] \times 100$$

AWC: Available water content; SWC: Soil water content; WP: Wilting point; FC: field capacity.

Thus we obtained the AWC in the soil as a percentage of the total amount of useful water that the soil could hold in its porous system. Zero or negative values indicated the absence of AWC.

2.4. Statistics

A factorial analysis of the soil properties measured in 2002 and 2005 was conducted. Previously, ANOVA was used to examine significant changes in variables and to identify the most efficient linear combinations, which means that they explain the higher percentages of total variance (Davis, 1986). A factor analysis was applied to the soil data from 2002 and 2005. The factors defined by the analysis, represents the combination of two or more variables that are well related. The Kaiser criterion method was used to extract the number of factors, by which only factors of self-values higher than 1 are retained, which means that each factor extracts at least the equivalent of each original variable.

3. CONCLUSIONS

Drought periods trigger eco-geomorphological changes in semiarid Mediterranean ecosystems that results in contrasted vegetation and soil properties response.

Vegetation cover results in a reduction in herbs and a maintenance of shrubs. Soil surface cover is enriched by rock fragment cover and sand fractions are more abundant on the surface probably due to the increase in surface was. This is related to the fact that drought periods are characterised too by intense thunderstorms. Due to organic matter reduction and bulk density increase during the drought periods, there are changes in soil hydraulic conductivity that encourage the water transfer instead of water retention. Finally the rock fragment cover growth as a consequence of the surface was and lack of vegetation. This contribute to a greater soil water availability as direct evaporation is reduced by the rock fragment and transpiration reduced by the lack of vegetation. This higher soil water availability will contribute to a faster recovery of vegetation if the drought period will last.

The abandoned field site, under semi-arid climate conditions and on a geological substrate consisting of phyllites, the change in texture caused changes in water retention capacity at low pressures, near to air pressure, and in the hydraulic conductivity of the soil. However, precisely due to the increase in surface stoniness not embedded in the soil, the reduction in organic matter and the loss of aggregate stability, the water retention capacity of the soil dropped at high pressures (WP), as did hydraulic conductivity at pressures where meso-pores and, to a lesser extent, micro-pores act. In hydrological terms, the soil changed from being more water-retaining to water-transferring, i.e. it became much more dependent on rainfall events, especially on their intensity, although the scant vegetation cover had its water supply guaranteed because of the increase in water available for vegetation in the soil.