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The impact of Climatic Change and land use on the hydrological response of Mediterranean soils; a study along a climatological gradient in Crete (Greece)

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Abstract

To help understand the impact of Climatic Change on the soils of the Mediterranean area, measurements of physical soil properties were carried out in a mountain zone in Crete (Greece), following a climatological gradient. Four experimental slopes were chosen, south facing and situated on limestone lithology. Soil hydrological properties including infiltration, runoff and sediment concentration, were measured and the percentage of waterstable microaggregation in the soil was calculated and used as an indicator of soil degradation. It was found that as well as climate, soil properties were highly affected by the extensive land use of the area, intensive grazing by goats and small scale wildfires.

1. INTRODUCTION

One of the approaches proposed by some authors [1-4] to evaluate the effects of Climatic Change on soil processes and erosion is to study soil properties and the erosion response of soils along climatological gradients. These climatological gradients have to be carefully selected, joining areas of comparable geology, soils, and vegetation characteristics but having different ranges of precipitation. In this way, it is possible to evaluate the effect of climate on the water-soil-vegetation system. The effect of land use is also important affecting the erosional behaviour of an ecosystem.

Following this approach, a climatological and altitudinal gradient was selected in Crete (Greece). This gradient was chosen to study the potential changes generated by changes in climate on soil properties like hydrological and erosional response as well as physical properties. This gradient was one of three gradients selected for study in a transect across the Mediterranean. The Crete transect differed from those in Alicante and Israel with respect to the high density of grazing. Four sites on Upper Cretaceous limestone were selected along this gradient (Table 1). The slopes are used as grazing land for goats, with the more intensive grazing at the highest site (Omalos) and the less intensive grazing at the lowest site (Afrata). The farmers frequently burn patches of shrub vegetation on the slopes to improve the pasture for grazing. In the whole area, old agricultural terraces at the foot slope positions have been abandoned.

Rainfall simulation experiments were carried out on the south facing slope of each site using a portable sprinkling rainfall simulator [6]. Rain was applied at an 55 mm h^{-1} during 55 minutes. At each slope a total of eight simulations on different soil surfaces and land uses categories were carried out. Soil samples were collected from comparable situations to analyze the water stable microaggregation. The waterstable microaggregation and the clay and silt proportion in the fraction <0.105 mm were determined. The methods used are described fully in the cited literature [4].

Table 1
Main characteristics of the four selected slopes (RFS: Rainfall simulation experiments)

Location	Altitude (m)	Aspect (degrees)	Slope (degrees)	Precipitation mm	Number of RFS
OMALOS	1100	200	25	1000	6
LAKI	800	180	35	800	8
RODOUPOS	400	175	18	350	6
AFRATA	100	165	12	200	8

2. RESULTS

2.1. Soil hydrological and erosional response

A clear decrease in soil erosion and other related parameters, such as the sediment concentration and the sediment yield, with the decreasing altitude and thus a more dry climate was found.

Table 2
Average values of the hydrological response of soils (OM: Omalos; LA: Laki; RO: Rodoupos; AF: Afrata)

	Runoff coefficient	Sediment concentra. (gr l^{-1})	Sediment yield (gr)	Erosion rate ($grm^{-2}h^{-1}$)	Bulk density (gr cm^{-3})	Porosity (%)	Soil moisture content (%)
OM	0.66	9.26	61.41	356.19	0.94	64.45	15.43
LA	0.68	1.95	15.74	97.59	0.90	65.70	17.69
RO	0.69	1.72	12.53	70.99	0.95	64.35	22.41
AF	0.37	1.40	6.00	33.40	0.91	65.80	10.04

Considering the average values for each slope (Table 2), Omalos, the highest and most humid site, shows the highest values of erosion rate, sediment concentration and sediment yield as well as a quite high bulk density. However, the highest runoff coefficient appears in Rodoupos, an intermediate site. In this case the runoff production was clearly influenced by the high soil moisture content at the moment of the experiments (Table 2), also Rodoupos shows the highest bulk density among the studied sites. The lowest and most arid site, Afrata, shows the lowest value of runoff coefficient, erosion rate and sediment yield and concentration.

Analyzing the values independently, according to the specific characteristics of the soil surface and land use, bare and burnt plots show the highest runoff coefficients, with the highest erosion rates in bare plots.

Abandoned terraces also present high values of runoff and erosion, but taking into account that the gradient of the slope at the terraces is very low, these values are always lower than in bare patches on the slope itself but higher than the vegetated patches on the same slope.

2.2. Soil aggregation

A positive influence of the clay content on the waterstable microaggregation, already pointed out by some authors has been found. Afrata, the lowest site, seems to have the best soil aggregation among the studied soils. The soils in Afrata present a more uniform aggregate size distribution for all the measured fractions and the highest value of waterstable microaggregation, besides the highest clay content in the soil. The lowest clay content is found in the Laki soils, an intermediate site, together with a lower value of waterstable microaggregation.

Figure 1 shows how the waterstable microaggregation and the clay content follow parallel trends while that in the runoff coefficient is the opposite direction. The waterstable microaggregation is higher in the plots with the highest clay content and the runoff coefficient is higher in plots with lower waterstable microaggregation and clay content.

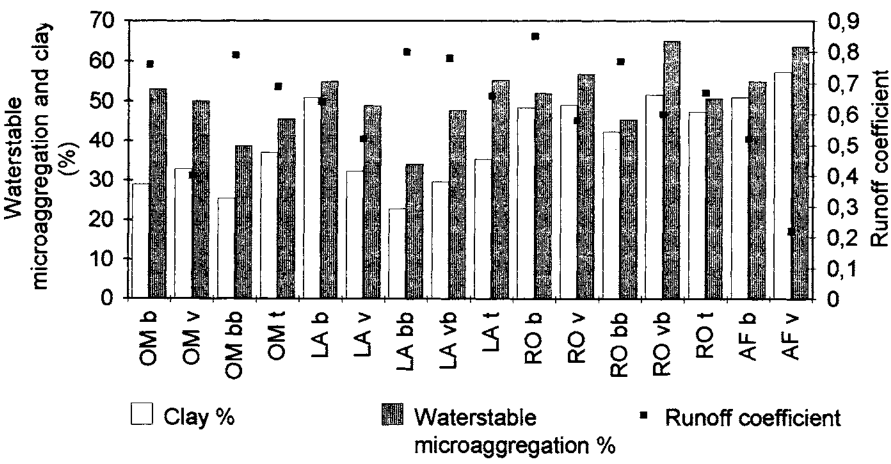

Figure 1. Clay content, waterstable microaggregation and runoff coefficients under different plot conditions (OM: Omalos; LA: Laki; RO: Rodoupos; AF: Afrata; b: bare patch; v: vegetated patch; bb: bare and burnt patch; vb: burnt patch with new vegetation; t: abandoned terrace).

3. DISCUSSION AND CONCLUSIONS

Soil structure and erosion rates seem to be the result of the combination of two main factors in this case: the climatological conditions and the land use. Omalos, the highest site, has nowadays more biomass production due to the very humid climatological conditions. As a consequence of that, the grazing is more intensive and the erosion rates higher. Due to the grazing the soil is trampled and this produces an increase of the bulk density of the top layer. The goats produce also a displacement of material that remains on the soil surface and this material is easily transported by the runoff water and so increasing the erosion rates. Afrata, the most arid site with less biomass production, less grazing, lower values of soil moisture and a high clay content and waterstable microaggregation shows the lowest erosion rate.

Specific soil surface conditions produce a different erosional response. Vegetated patches always show lower runoff coefficients and higher values of waterstable microaggregation than burnt and bare patches. Abandoned terraces at the medium sites have erosion rates higher than vegetated patches, but lower than expected, probably due to a high clay content and a low gradient.

In some cases, along studied gradients in Spain and Israel [2-4] high values of erosion have been found when the conditions become more arid, but in the case of Crete, the behaviour of the water-soil-vegetation system is clearly dependent on factors derived from the land use.

4. ACKNOWLEDGMENT

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