THE INFLUENCE OF DEFORESTATION ON SOIL WATER CONSERVATION IN A PINE FOREST IN TENERIFE (CANARY ISLANDS, SPAIN)

M. Tejedor, C. Jiménez, C. Monteverde and J. Parra
University of La Laguna, Department of Soil Science and Geology, Faculty of Biology, Avda. Astrofísico Francisco Sánchez s/n, 38204 La Laguna, Tenerife, Canary Islands, Spain, e-mail: martesa@ull.es

Abstract

The present work studies the effect of deforestation on soil water conservation in a pine forest in Tenerife (Canary Islands, Spain). We compare two adjoining plots, with originally similar environmental characteristics but now differentiated by the presence or absence of canarian pines (*Pinus canariensis*) following the removal from one of the plots of trees for use as timber. In both areas soil moisture was monitored monthly every 10 cm to a depth of 1 metre over a period of three years. Also analysed were the spatial variability of the soil water in the pine forest and the influence of the type of vegetation thereon. The results obtained show differences in the soil moisture content distribution throughout the year. The importance of water uptake from condensation is also apparent. The increase in seasonal contrasts and the prolongation of the dry period caused by deforestation influence the soil moisture regime, which changes from udic under the pine trees to xeric in the deforested zone.

Additional Keywords: Land use, soil moisture regime, Soil Taxonomy, condensation

Introduction

The direct and indirect influence of vegetation on the soil water cycle has received extensive consideration in the literature (Zinke 1962; Huber and Oyarzun 1990; Domingo *et al.* 1994; Putuhena and Cordery 1996; Calvo and Gómez 2002). Some works have focused on the type of species, the age, height and degree of cover of the vegetation, while others have considered the stemflow effect of the trunks and the consequences this has for water concentration at the tree base and for the spatial variability. Others, meanwhile, have focused on the importance of the water falling on the undergrowth from tree branches and leaves or on the impact of rainwater interception and condensation phenomena. Fewer papers have addressed specifically the influence exerted by changes in plant cover on soil moisture regimes from the Soil Taxonomy classification point of view (Soil Survey Staff 1999), even though the type of cover is often mentioned in discussing the regimes of a specific region.

In the Canary Islands, where the use of groundwater is essential, studies contributing to better knowledge of aquifers and aquifer recharge is of great interest. In the present paper we analyse the effect of deforestation of a Canarian pine forest in Tenerife on soil water reserves and on the soil moisture regime. We examine also the spatial variability of the soil moisture in the pine forest and how this is influenced by the distance to the trees.

Materials and Methods

Study area
The island of Tenerife, Canary Islands, Spain (highest point, 3718 m.a.s.l.) has a wide variety of microclimates, depending on altitude, orientation, orography, the effects of the trade winds and influence of the sea. Moisture from the trade winds condenses extensively on the northern side at heights between 900-1400 m.a.s.l. (our study zone is situated at the latter figure). The total amount of water produced by condensation can be several times greater than the level of rainfall (Kämmer 1974; Santana 1990; Marzol 1981, 1993).

Two adjacent zones at 1300 m.a.s.l. were selected for the study. The first had canarian pine with virtually no underbrush, a tree density of 0.045 individuals/m^2, a basal area of 80 m^2/ha and over 75% cover. The second, smaller in size, was replanted with eucalyptus trees (*Eucaliptus globulus*) which were felled for wood shortly before the experiment commenced. During the study period, this second zone became covered with herbaceous plants and species of tree-heath (*Erica arborea*), none of which exceeded 1 metre in height. The average annual air temperature was 14.2°C and annual rainfall of approximately 700 mm with a seasonal distribution of 47% in winter, 24% in spring, 3% in summer and 26 % in autumn. The soils were Dystric Hapludands/Haploxerands (Soil Survey Staff 1999), silty loam in texture and rich in organic matter, which is fully deeply incorporated (more than 6% at a depth of 1 metre). They were formed by a mixture of pyroclasts and basaltic scoria. In some parts, particularly those covered with the herbaceous plants, the scoria is found at less than one metre from the surface. The modification of the vegetation has led to differences in the surface horizon: in the soil under pine cover the O

horizon is more or less compact, with accumulation of organic matter, pine needles. This horizon is not present in the soil covered by herbaceous plants.

Methods

In both study zones, sampling for soil moisture was conducted monthly over a period of three years (October 2000-December 2003) every 10 cm to a depth of 1 metre. However, in the deforested plot the maximum sampling depth tended to be around 80cm due to the presence of a layer of scoria. Three random replications were made on each date and for each plot. Sampling never took place within 48 h of rainfall. The samples were taken using an Eijelkamp probe and moisture content was determined by the gravimetric method. The monthly moisture content in both zones was compared using the Wilcoxon non-parametric test, given that the data distribution did not meet the requirements for parametric analysis.

To study the spatial variability of the soil moisture and the influence exerted by the pine forest, a 20x20 plot was selected and the position of each tree was mapped. A 10x10 sub-plot was also selected in which 40 points were chosen at random and the distance was recorded between each point and the three nearest trees (*distance 1*, *distance 2* and *distance 3)*. In March 2004 each point was sampled every 10 cm between 10-60 cm depth. During the previous three years, the greatest differences between the pine and herbaceous soils had been observed in the same month and in the same depth segment. Unilateral Spearman correlations and Principal Components Analysis were used for the statistical analysis. The statistics packages used were SPSS 11.0.1 (SPSS Inc. 2001) and Canoco for Windows 4.0 (ter Braak and Smilauer 1998).

Results and Discussion

The results of the Principal Components Analysis (Figure 1) show a clear distribution pattern for the soil moisture in the pine-forest plot studied. Most of the variation (55.4%) is linked to the distance to the nearest tree, which is inversely related to the soil moisture content. This result is corroborated to 95% significance in the unilateral Spearman correlation, with a negative sign between soil moisture content and distance to the nearest tree (Table 1). As is logical, analysis of the distances to the second and third trees (22.0% and 8.7% of variance respectively) corroborates that the influence on soil moisture diminishes as the distance increases. In this heterogeneous distribution pattern of the soil water, trickle from the trunks appear more influential than water translocation or direct precipitation not intercepted by the undergrowth. The high dispersion with respect to the factors indicates that although the trend is clearly defined, the extent of the influence of the trees is limited. In the case of the pine forest, the area of influence of each tree overlaps with that of near neighbours and the moisture gradient effect is thus cushioned by the presence of other gradients.

Table 1. Descriptive parameters of spatial variation and Spearman correlations between cumulative soil moisture and distance 1, distance 2 and distance 3 (no: non-sig.,*: 95% sig.)

	Mean (mm)	St. dev	St. error
Cumulative soil moisture content	118.5	12.9	3.6
	distance 1	distance 2	distance 3
Spearman correlations	-.364 *	-.122 no	-.314 *

Having seen the representativeness of the sampling over the three years, we will now consider the analysis. Figure 2 shows the evolution of cumulative moisture content at a depth of 80 cm in the plot under pine forest and the zone covered by herbaceous plants for all the sample dates. The annual tendency in the soil water content seen over the three years is maintained: higher content in the deforested plot during rainy periods and during the two or three subsequent months, lower content during summer and autumn. These differences are statistically significant during January, February, March, April, May and August.
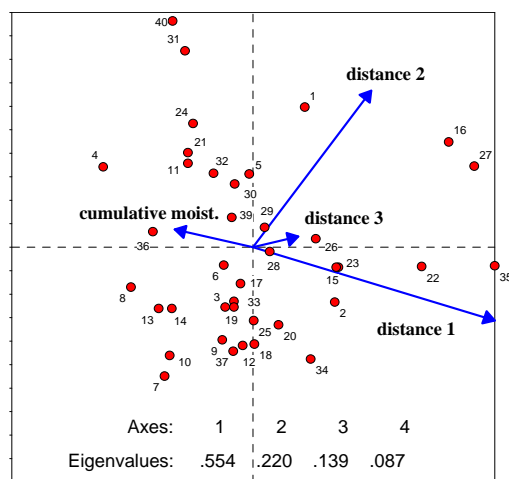
**Figure 1. Principal Components Analysis. Influence of distances to nearest trees
on cumulative soil moisture content**

Analysis of the seasonal distribution of cumulative soil water throughout the year produced the following results. Pine forest: 29% in winter, 28% in spring, 19% in summer and 24% in autumn. Deforested zone: 31% in winter, 28% in spring, 15% in winter, and 26% in autumn. The regular soil moisture distribution in the pine forest, which differs greatly to that corresponding to rainfall, indicates the presence of additional non-rainfall sources of water, due -we believe- of the effect of condensation. The importance of this effect is not so much the amount of water but its year-round distribution (Parra 2001), particularly during months of little rain. It is worth noting that in August the amount of water is significantly higher in the pine forest soil, where condensation is greater. The condensation effect is still seen in the deforested soil, which is more heavily influenced by rainfall. This effect may be due to the fact that the selected site is surrounded by pine forest and during the study period became populated with herbaceous plants, which also propitiate condensation of fog. In addition to the important influence of the condensation, the role played by the different types of cover in reducing moisture loss through evaporation and, secondly, the water consumed by the vegetation are also factors to be taken into account.
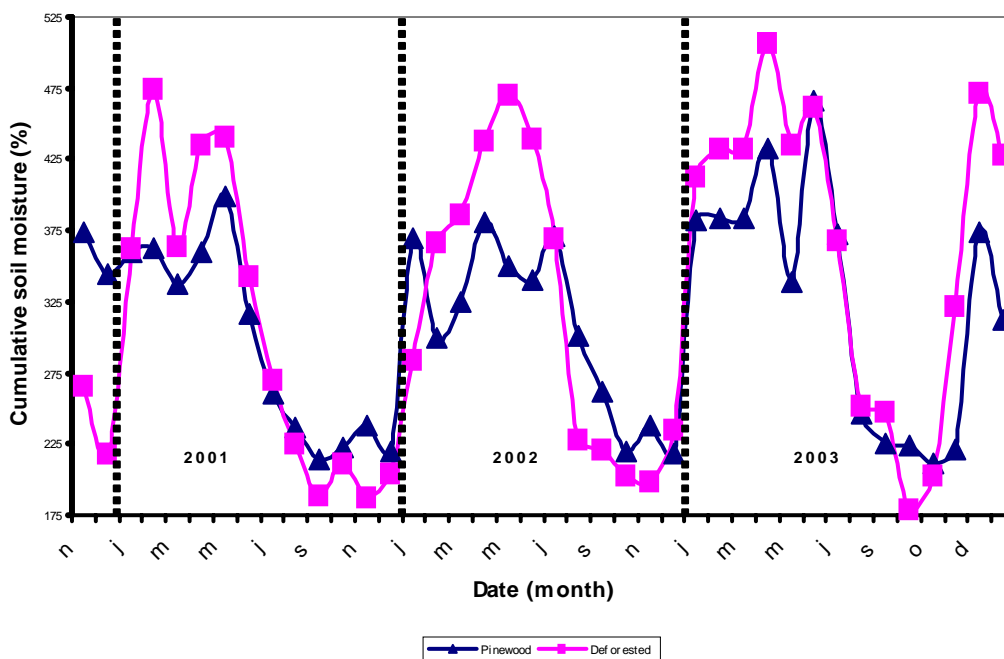

Figure 2. Evolution of cumulative moisture content. Effective soil depth: 80 cm

The differences in water balance influence the soil moisture regimes (Soil Survey Staff 1999). These regimes are defined in the Soil Taxonomy on the basis of the presence or absence of water at pressures below 1500 kPa, over a given number of days per year and at a given depth segment. Deforestation has propitiated seasonal contrasts and

an increase in the number of days on which the soil is totally dry (over 90 days). Given this circumstance and the fact that the soil temperature regime is isomesic in the case of the pine forest (Tejedor *et al.* 2003) and mesic for the deforested zone (Rodríguez Paz 2004), we could tentatively define an udic regime for the pine soil and a xeric regime for the deforested soil, to be confirmed in further studies.

References

Calvo de Anta, R., Gómez Rey, M.X. (2002). Distribución espacial del ciclo del agua en suelos forestales con *Pinus radiata* de Galicia (NO de España). *Edafología* 9(1), 61-84.

Domingo, F., Puigfabregas, J., Moro, M.J., Bellot, J. (1994). Role of vegetation cover in the biogeochemical balances of a small a forested catchment in southeastern Spainh. *Journal of Hydrology* 159, 275-289.

Huber, A.W., Oyarzun, C.E. (1990). Variaciones anuales en precipitación, escurrimiento e intercepción en un bosque adulto *de Pinus radiata*. *Turrialba* 40, 503-508.

Kämmer, F. (1974). Klima und vegetation auf Tenerife besonders in Hiblick auf Nebelniederschlag. *Scripta Geobotanica*. Vol. 7 Edit Erich Goltze KG. Göttingen.

Marzol, M.V. (1981). El clima de montaña de la isla de Tenerife. Variaciones en el gradiente térmico. VII Coloquio de Geografía, Pamplona. Tomo 1. p 163-168.

Marzol, M.V. (1993). El Clima: Rasgos generales. Geografía de Canarias. Consejería de Obras Públicas, Vivienda y Aguas, Gobierno de Canarias. p101-116.

Parra López, J. (2001). Estimación del régimen hídrico del suelo de dos zonas de la Isla de Tenerife. Trabajo de fin de carrera. Escuela Técnica Superior de Ing. Agrónomos y Montes. Universidad de Córdoba.

Putuhena, W.M., Cordery, I. (1996). Estimation of interception capacity of the forest floor. *Journal of Hydrology* 180, 283-299.

Rodríguez Paz (2004). Comunicación personal.

Santana, L. (1990). La importancia hidrológica de las nieblas en las cumbres del Parque Nacional de Garajonay, en P.L. Pérez de Paz (e d.) "Parque Nacional de Garajonay, Patrimonio Mundial". Exmo. Cabildo Insular de La Gomera, ICONA. p66-71.

Soil Survey Staff. (1999). Soil Taxonomy; a basic system of soil classification for making and interpreting soil surveys. 2ª Edition. United States Department of Agriculture. Natural Resources Conservation Service, Agricultural Handbook, 436. U.S. Gov. Print. Office, Washington, DC.

Tejedor, M., Jiménez, C., Rodriguez Paz, M., Hernández Moreno, J.M. (2003). Soil Temperature Regimes on the island of Tenerife. Altitudinal sequence. 2003 Annual Meeting Changing Sciences for a Changing World: Building a Broader Vision. Denver Colorado.

Ter Braak, C.F.J., Smilauer, P. (1998). Canoco Reference Manual and User's Guide to Canoco for Windows: Software for Canonical Community Ordination, Version 4. Microcomputer Power, Ithaca, NY.

Zinke, PJ. (1962). The pattern of influence of individual forest trees on soil properties. *Ecology* 43, 130-133.