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Does Reforestation Improve Soil Quality of Semiarid Degraded Lands? A Medium-term Assessment.

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Abstract

Reforestation has been advocated as an important tool to reduce erosion, to control runoff and, especially in the Mediterranean areas, to combat desertification. This paper describes results from a study of the effects of reforestation works on chemical soil properties (total organic carbon COT, nitrogen, phosphorus, potassium and sodium content, pH and electrical conductivity) and soil water retention characteristics at two scales. Major differences were found between sites in COT, Na, N, P and water content at wilting point. It reflects the greater influence of environmental conditions previous to reforestation. Within the sites, only slights differences in conductivity, pH and water content at wilting point were found, which indicate that the effects of reforestation on soil quality have not been significant after 35 year of the plantation.

Résumé

Le reboisement a été recommandé comme un instrument important pour réduire l'érosion, contrôler le ruissellement et, surtout dans les régions Méditerranéennes, combattre la désertification. Ce papier décrit des résultats d'une étude des effets des travaux de reboisement sur les propriétés chimiques du sol (le teneur total en carbone organique, azote, phosphore, potassium et de sodium, le pH et conductivité électrique) et caractéristiques de rétention d'eau du sol. Des différences principales ont été trouvées entre les sites dans le teneur en carbone organique, sodium, azote, phosphore et la teneur d'eau au point de flétrissement. Il reflète la plus grande influence de conditions de l'environnement avant de reforestation. Dans les sites, seulement différences légeres dans la conductivité, le pH et la teneur d'eau au point de flétrissement ont été trouvés, ce qui indiquent que les effets du reboisement sur la qualité du sol n'ont pas été significatifs après 35 ans de la plantation

Introduction

Reforestation has been advocated as an important tool to reduce erosion, to control runoff and to improve soils, and, especially in the Mediterranean areas, to combat desertification. The extended use of terracing in the 60s and 70s with the purpose of improving water supply has been severely criticized because of promoting erosion, reducing soil quality and disrupting natural landscapes. Several studies have shown the impacts of soil preparation techniques on physical and chemical soil properties (Ortigosa, 1991; Ternan et al.1996; De Witt and Brouwer, 1998) and their effects on vegetal cover (Chaparro et al. 1993). The removal of upper soil layers due to terracing causes a loss of organic matter and nutrients degrading soil structure and water retention capacity as well as soil productivity.

While the short-term effects of reforestation works are being increasingly known there is still a lack of knowledge of how these effects evolve. From the initial stage of

reforestation onward the impacts might be minimized, maintained or, even, increased depending on both development of plant cover and previous environmental conditions.
This paper describes results from a study of the effects of reforestation works on chemical soil properties (total organic carbon COT, nitrogen, phosphorus, potassium and sodium content, pH and electrical conductivity) and soil water retention characteristics at two scales. Microscale aimed to analyse terracing effects after 35 year while macroscale analysis focused on the influence of topography and former land uses before reforestation on soil evolution.

Study area and experimental design

The study was carried out in the Cárcavo catchment (38º13' N; 1º31' W) in the NW of the province of Murcia. The catchment has an area of about 2732 ha. It mainly consists of limestone, marls and quaternary deposits. Locally gypsum is present. Relief is mainly formed by limestone and dolomite ridges with localized outcrops of Keuper marls in the northwestern. The lower parts consist of extended pediment surfaces that have been developed in the Miocene marls and Quaternary deposits. Ephemeral channels and gullies dissect the pediment surfaces. The climatic conditions are characterised by a strong aridity. Mean annual rainfall is about 279 mm and evapotransporation reaches 848 mm. Pediments are for a great part in use for agriculture, or have been subject to reforestation with pines (*Pinus halepensis*). Most other slopes are covered with semi natural pines or recent pine reforestation.
This area was subject to a Forest Hydrological Restoration Project that started in 1969 and its revision began in 1977. The reforestation was made by terracing and subsoiling with a stocking rate of 1100 seedlings ha^{-1}.
Two different sites were defined: a terraced hillslope and an adjacent no-terraced pediment (Figure 1). The experimental design was a split plot layout with 10 plots (2x5 m) in each of the sites. Each whole plot (hillslope or pediment) was split in subplots according to the microtopography induced by the reforestation works. The number of subplots was 3 and 5 in the pediment and terraced hillslope, respectively

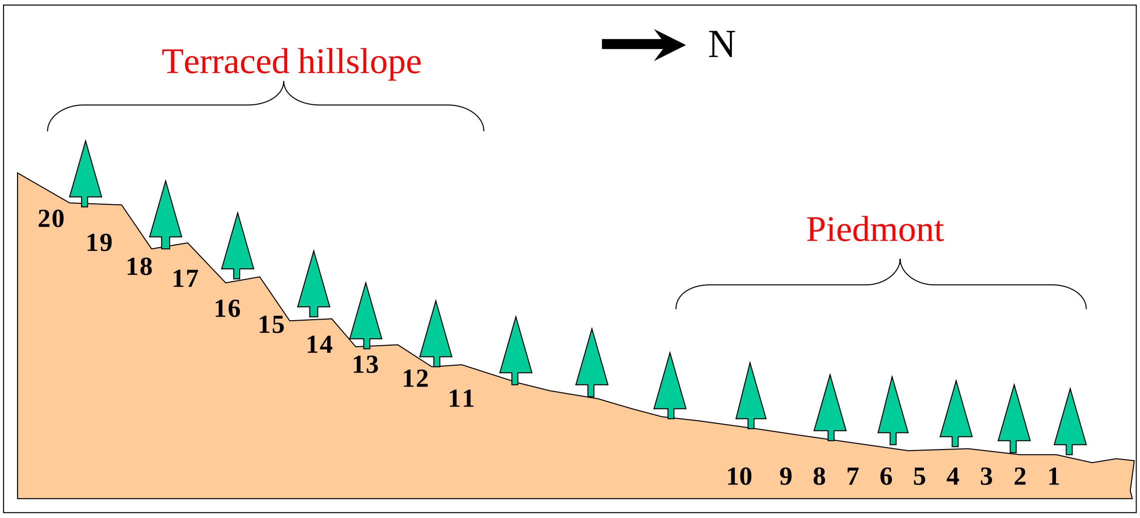

Figure 1: Experimental design at macroscale level

Soil samples of upper layer (10 cm) were randomly taken in each subplot after the removal of superficial vegetal litter. Total organic carbon (TOC), total N, available P,K and Na, pH and electrical conductivity were assessed to characterize the impact of soil chemical properties. Soil water content at –60 kPa and –1500 kPa was also measured. Differences between sites were analysed by a split-plot ANOVA with hillslope and piedmont as whole plots and the common subplots: line of plantation (LBT) and under crown (LBC). At microscale level, soil physical and chemical data were subjected to a mixed effect ANOVA with microenvironment as fixed effect and plot as random effect. Comparisons among microenvironments were made using least significant difference (LSD) test and tested for the significance at the 0.05 level of confidence.

Results and Discussion

Significant differences were found between terraced hillslope and piedmont in COT, Na, N, P and water content at wilting point. Interaction between sites and microenvironments was only slightly significant for conductivity (Tables 1 and 2).

Table 1. Split-plot ANOVA between sites as whole plot and microenvironments as subplot

VARIABLES	Interaction between sites		Interaction between sites and microenvironments	
	F	P	F	P
TOC	32.192	**0.001**	0.050	0.825
N total	3.924	0.063	0.048	0.830
P available	3.856	0.065	0.019	0.734
Na available	38.867	**0.001**	0.027	0.872
K available	0.734	0.403	0.009	0.926
Conductivity	0.088	0.770	4.036	0.060
pH	0.255	0.619	0.205	0.656
Water content at –60kPa	2.498	0.131	0.531	0.475
Water content at –1500kPa	21.840	**0.001**	1.922	0.183
Available water content	0.052	0.823	0.053	0.820

Table 2 Mean values (standard error) of physical and chemical soil properties in both macro-scale sites. Only variables in which a significant difference was found are shown

Site	COT ($g\ Kg^{-1}$)	N total ($g\ Kg^{-1}$)	P available ($mg\ Kg^{-1}$)	Na available ($mg\ Kg^{-1}$)	Water content at –1500 kPa cm^3cm^{-3}
Terraced hillslope	16.7 (1.02)	0.89 (0.09)	5.89 (0.36)	447.5 (11.5)	0.072 (0.003)
Piedmont	4.50 (0.62)	0.60 (0.13)	7.62 (0.42)	293.0 (10.6)	0.096 (0.002)

The higher soil organic matter content is hillslope site is a result of the fact that this area have maintained a natural vegetal cover (mainly a slow grow shrubland) since historical time while the piedmont site has been cultivated until recent time. Similar pattern is observed in total nitrogen content that is probably due to the high proportion of organic nitrogen.

The differences between microenvironments are only significant in conductivity in terraced hillslope site and in pH and water content at wilting point in piedmont site. Slightly significant differences were found in TOC and K content in hillslope and piedmont site, respectively.(Table 3).

According to the results it can be concluded that the environmental conditions at macroscale level previous to reforestation exert a greater influence on the soil quality than those induced by soil preparation techniques and vegetation growth at microenvironment scale. Within the sites, only slights differences in conductivity, pH and water content at wilting point were found, which indicate that the effects of reforestation on soil quality have not been significant after 35 year of the plantation.

It was highlighted the crucial role of soil characteristic in the effect of reforestation on soil quality and facilitate both the growth of planted species and secondary succession. Nevertheless the edaphic variability has frequently been neglected in the reforestation projects of degraded lands by using the same soil preparation techniques and selected species for the whole target regardless of the soil characteristics. The adoption of methods adapted to environmental heterogeneity of Mediterranean semiarid landscapes would increase the success of land restoration and reforestation programmes.

Table 3. One-way ANOVA between microenvironments in each of the sites studied

VARIABLES	Piedmont site		Hillslope site	
	F	P	F	P
TOC	0.77	0.926	2.198	0.089
N total	0.525	0.600	0.494	0.740
P available	0.562	0.580	0.206	0.933
Na available	0.236	0.792	1.492	0.226
K available	3.224	0.064	1.201	0.328
Conductivity	1.364	0.281	2.984	**0.032**
pH	4.594	**0.024**	1.241	0.312
Water content at –60kPa	2.410	0.118	0.899	0.475
Water content at –1500kPa	3.856	**0.040**	1.678	0.177
Available water content	0.891	0.428	0.628	0.646

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