The *Montado* agroforestry system microclimatic specificity in the context of global change

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Abstract. The effects of oak trees on microclimatic parameters in *Quercus rotundifolia* Lam. woodland in the Alentejo, Southern Portugal, are reported. Results show that oak tree create a marked differentiation in the grass matrix, between open and undercanopy areas. Compared to open areas, it presents lower soil moisture beneath the oak canopy, lower soil temperatures and lower photosynthetically active radiation (PAR). Soil temperatures outside trees canopy were generally higher than undercanopy areas, reaching twice its values during the winter. The decrease of soil water content is more rapid in areas outside the trees canopy action, but the replenishment starts early and is faster in those areas. PAR intercepted by tree canopy is greater than 60%, and affects dramatically herbaceous production.
Different climatic conditions due to the presence of the tree, associated with greater variability in chemistry environment undercanopy, if combined with the IPCC forecasts for Mediterranean region, pose new challenges in the management of the *montado* areas.

Key words: *Montado*, *Quercus rotundifolia*, PAR, soil water content, soil temperature

Introduction

The main agroforestry system of Southern Portugal is an open *Quercus* woodland, called *montado*, which corresponds to a savanna like formation (Joffre and Rambal, 1993). The interactions between the trees and the under layer environment may have an important role in the management of these systems in a multiple use perspective. Although the study of these interactions is of utmost importance, some uncertainty subsist in Southern Portugal regarding the role of trees on microclimatic and soil characteristics, specially on soil water content, and on chemical characteristics and nutrient availability. The great economic and ecological importance of *montado* silvopastoral multi purposes system and the considerable concern about their long-term sustainability raised the relevance of studying the functioning of those oak woodlands ecosystems, and their influence on nutrient cycling in a way to understand how management practices affect his long-term sustainability.

Data and methods

The study was carried out in Southern Portugal at the Centro de Estudos e Experimentação da Mitra (CEEM), experimental *campus* of the University of Évora (38º32' N, 8º01' W, 243 m), during 2001-2002. The local climate is Mediterranean-type (Csa according to Köppen), characterized by winter-wet and summer-dry pattern. Mean annual rainfall is 665 mm, most of wich falling from autumn to early spring (90%) in less than 75 days of rain per year (INMG, 1991). Mean annual air temperature is about 15.4ºC, ranging from 8.6ºC in January to 23.1ºC in August. Air relative humidity is about 70%. The dry period is up to 5 months.
The landscape is gently undulating and the slope, at the study site, ranges from 5 from 3 to 8%. The geological substratum consists of granites and gneisses (Carvalhosa *et al.*, 1969). Soils are mostly Eutric Leptosols developed on gneiss (WRB, 2006), with a maximum soil depth of about 1 m. Soil texture is sandy to sandy loamy.
The vegetation consists of open pasture with scattered trees of *Q. suber* L and *Q. rotundifolia* Lam.. The oak stocking ranges from 35-45 trees ha^{-1} with an average canopy coverage of 21%. The herbaceous layer, with forbs and grasses, was invaded by shrubs, mainly *Cistus salviifolius* L..
Microclimatic parameters (photosynthetically active radiation, soil temperature and soil moisture), were monitored under the tree canopies and without their influence. Photosynthetically active radiation (PAR) was recorded by PAR sensors, placed at 0.30 m above soil surface, the upper limit of herbaceous layer. Average hourly soil temperature under trees canopy was recorded continuously using copper-constantan thermocouples of Delta-t, placed on soil organic surface layers, between surface organic horizon and mineral profile (0 cm), 2.5 cm, 5 cm, 10 cm, 15 cm and 20 cm. In the open, average hourly soil temperature was also recorded continuously with thermocouples placed at 2.5 cm, 5 cm, 10 cm, 15 cm and 20 cm. Soil moisture was monitored by 20 ThetaProbe sensors (ML2x, Delta-T Devices, Cambridge, UK). Ten sensors were installed in the soil under an isolated *Q. rotundifolia* tree (crown radius was 7.2 m) used for precipitation interception studies, and ten sensors were installed beyond the crown projection limits. In both cases half of the sensors were installed at 0.06 m depth, and the other half at 0.25m. Soil volumetric water content was averaged and stored at half-hourly intervals. All sensors were connected to a $DL2_e$ data-logger (Delta-T Devices, Cambridge, UK).

Results and discussion

Photosynthetically active radiation (PAR) was higher at the areas without the tree canopies than at those under their influence (Fig. 1). The PAR interception by the tree and shrub layers attained 95%. The pattern determined for the

radiation decrease is in accordance with that found by other authors (Belsky *et al*., 1993) in savanna formations.

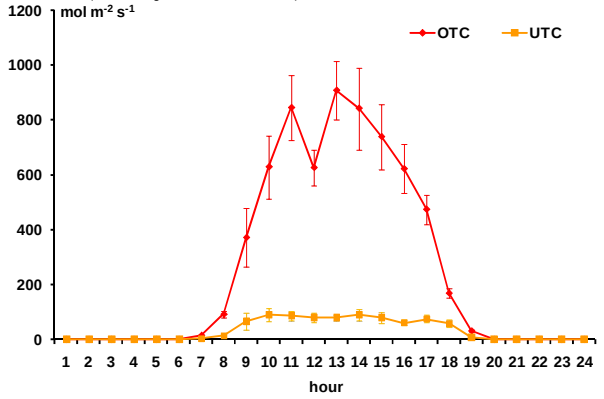

Figure 1. Average time course of photosynthetically active radiation (PAR, µmol m^{-2} s^{-1}), under tree canopy (UTC) and outside tree canopy (OTC), during March 2002.

Temperatures obtained during December 2001 and March 2002 at 2.5 cm and 10 cm depth were always higher in the areas without the canopies influence (Fig. 2). However, the differences found between the soil at these areas and at those under the canopies were still more accentuated during the summer months. A similar pattern was found by Rorison (1991), who compared north and south slopes and by Belsky *et al*. (1993) in its studies with *Acacia tortilis* and *Adansonia digitata*.

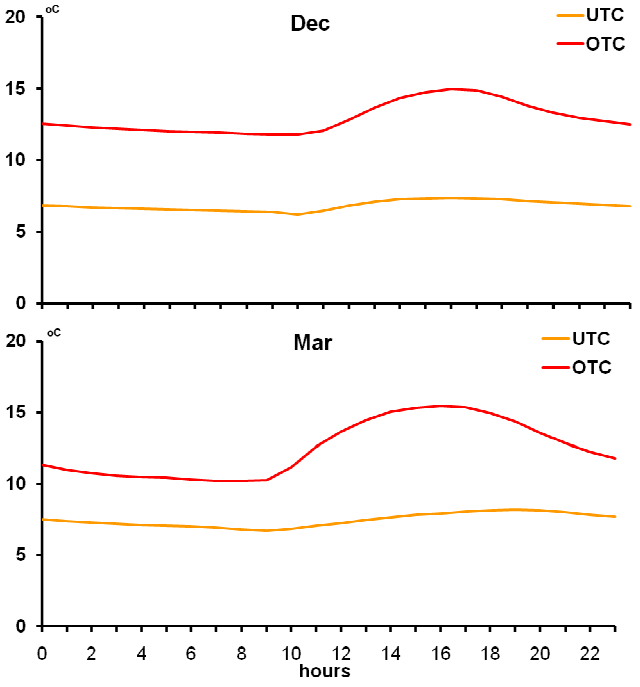

Figure 2. Average time course of soil temperature (°C) at 2.5 cm depth, under tree canopy (UTC) and outside tree canopy (OTC), during December 2001 and March 2002.

The pattern of soil moisture variation during the dry period was similar for both areas, although the highest values were always obtained for open areas (Fig. 3). The same behavior was observed as result of the first rains after summer drought. As result of this moistening both areas present the same soil water content at surface. There were no statistical significant differences in soil moistures values, between undercanopy and open areas, for all the measured periods.

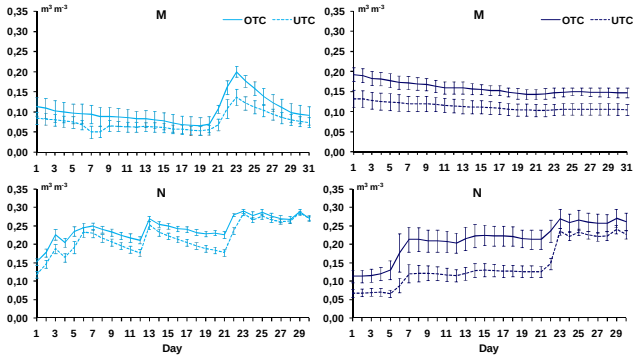

Figure 3. Average soil water contents undercanopy of *Q. rotundifolia* tree (UTC) and outside tree canopy (OTC) at 6 cm (——) and 25 cm (——), in March and November 2002.

Given the scenarios of wide variation in the distribution of precipitation and temperature, referred to the regions of Mediterranean climate (IPCC, 2007), the behavior of this mosaic ecosystem may be strongly changed. The differentiation between undercanopy and open areas, in soil carbon and nitrogen cycles, and in herbage production, will probably be exacerbated, questioning the sustainability of the *montado* ecosystem. The animal support capacity may decrease, and tree susceptibility to deseases may increase.

Conclusions

Quercus rotundifolia trees canopy changes dramatically the microclimatic environment of the under layer, namely PAR, soil temperature and soil moisture. This differentiation has as result, differences in herbaceous production, nitrogen mineralization and carbon storage, between undercanopy and open areas. The expected climatic change for Mediterranean region can tear down the present equilibrium of the *montado* ecosystem, questioning its sustainability

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