1166: Effect of trees in the soil nutrient concentration and pasture productivity in Mediterranean silvo-pastoral systems

(WG 14.1)

27/09/2016, Room 007BA, 14h

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Silvo-pastoral are mixed systems of trees and grass, which have been proposed as a means to extend the benefits of forest to farmed land (Whitmore et al., 2014). Agroforestry systems under semi-arid Mediterranean conditions, called montados in Portugal and dehesas in Spain, cover substantial areas in the world. They represent 33% of the total Portuguese forest area (David et al., 2013).

Given the increasing need for more food production, a greater understanding of the changes in soil properties under the various pasture management systems around the world is required (Schipper et al., 2014).
In the Southern Portugal (Alentejo province), the main tree species are Quercus ilex ssp. rotundifolia Lam. (holm oak) and Quercus suber L. (cork oak), managed mainly for the production of acorns to feed livestock and cork, respectively (David et al., 2007). They are mainly located in areas with a Mediterranean climate, with a strong seasonality and variability, whereby, vegetation has to withstand hot and dry summers as well as recurrent droughts (David et al., 2013). In these areas, evaporative demand is higher than annual rainfall and the dry season (summer) lasts for several months (Paço et al., 2009).

Several studies were performed to quantify the contribution of the two components (the trees and the pasture) to the water and nutrient balance of the ecosystem (Paço et al., 2009).
INTRODUCTION

In the dehesa systems, the presence of trees, although with a low density, has been recognized to positively affect soil physical and chemical properties (Joffre and Rambal, 1993). Further, Howlett et al. (2011) highlighted the relevant role of holm and cork trees within the pastures in increasing soil organic matter (SOM) storage relative to areas under native pasture alone.
INTRODUCTION

Managing soil cover with permanent crops has been a strategy for soil conservation by reducing water, soil and nutrient loss, and increasing the quality and soil fertility (Yadav et al., 2014). However, the knowledge about the influence of different soil managements on the distribution and characteristics of the soil nutrient pools in the dehesa systems is still insufficient to develop conservation strategies (Seddaiu et al. 2013). This difficulty also results from the characteristic variability of this ecosystem, accentuated by the presence of trees (David et al., 2013) and by the dynamics of animal grazing (Dahlin et al., 2005).
Complex interactions between livestock, trees and pasture occur in silvo-pastoral systems. Between trees and pasture, competition for soil resources (nutrients and water) occurs, becoming especially relevant when one of them is in scarce supply. Trees reduce light and water reaching the understorey layers according to tree density and canopy size. However, they may ameliorate extreme climatological features (reducing wind speed and evapotranspiration, and alleviating extreme temperatures), and improve soil properties (Benavides et al., 2008).
In order to implement the conservation task and recovery of resources through silvo-pastoral systems and contribute to long-term sustainability of this agroforestry system, it is necessary to know and correct potential limiting factors, and this requires agronomic knowledge, soil, pasture, tree and animal monitoring, as well as the implementation of the available new technologies.

**OBJECTIVES**

-A better understanding of the contribution of the components of *montado* ecosystem (trees, herbaceous vegetation and animals) on the soil nutrient and pasture productivity and quality.

-Evaluate and calibrate new technologies that simplify the monitoring of soil, pasture, trees and grazing animals.
MATERIAL AND METHODS

Site characteristics

The experimental field, with an area of about 2 ha, is located at the Mitra farm (38°32.2’ N; 8°01.1’ W), University of Évora, in Southern Portugal, where pastureland use of acid soils (pH=5.4 ± 0.3) is particularly important.
MATERIAL AND METHODS

Site characteristics

Altimetry map of the experimental field (it is evident the undulated relief characteristics of this region).
Site characteristics

The climate is Mediterranean, characterized by dry and hot summers, variable rainfall, and mild or moderately cold winters. The annual rainfall in the region is between 400 and 600 mm; rainfall occurs mainly between October and March and is practically non-existent during the summer.
MATERIAL AND METHODS

Ecosystem

Tree species (*Quercus ilex* asp. *Rotundifolia* Lam. –holm oak)

Sheeps (*Black Merino*)

Pasture (Biodiverse)
MATERIAL AND METHODS

24 sampling points (6 trees × 4 points/tree)
MATERIAL AND METHODS

Soil and pasture sampling

**Soil parameters (0-0.20m):**
texture, SOM, pH, N, P, K, Mg, Mn, SMC (0-0.20m and 0.20-0.40m);

**Pasture parameters:**
GM, DM, PMC, Ash, CP, NDF

Exclusion cages
MATERIAL AND METHODS

Sensors

Animal GNSS receivers  Monitoring animal grazing
Sensors

Optical “OptRx” sensor → Monitoring pasture NDVI
MATERIAL AND METHODS

Sensors

Grassmaster II probe → Monitoring pasture capacitance
Sensors

Thermal infrared camera → Monitoring pasture temperature
MATERIAL AND METHODS

Sensors

Ceptometer
(PAR- Photosynthetically active radiation sensors)

Monitoring tree leaf area index (LAI)
MATERIAL AND METHODS

Temporal evaluation

UTC (Under Tree Canopy) vs. OTC (Outside Tree Canopy)

Dec 2015
Mar 2016
April 2016
May 2016
June 2016
Statistical analysis

Statistical procedures were performed using “MSTAT-C” software.

Least square differences (LSD) test ("Fisher’s Least Significant Difference") were used to determine significant differences among means (under tree canopy-UTC vs. open pasture or outside tree canopy-OTC) when significant ANOVA results occurred.

Linear regression analysis was used to study the relationships between soil and pasture variables. The Pearson correlation coefficients “r” for the statistically significant (p <0.05) regression relations were then presented.
RESULTS AND DISCUSSION

Animal tracking

Evolution of grazing behaviour

(depending on the availability of pasture, climatic conditions (temperature, wind, rainfall...), safety and security, shadow, ...)

Mars 2016

April 2016

May 2016

June 2016
RESULTS AND DISCUSSION

SOIL PARAMETERS
(Texture and nutrients)

NS- Correlation is not significant; *-Correlation is significant at the 0.05 level; **-Correlation is significant at the 0.01 level;
RESULTS AND DISCUSSION

SOIL PARAMETERS

Clear influence (positive) of trees on SOM
RESULTS AND DISCUSSION

SOIL PARAMETERS
(Nutrients)

Clear influence (positive) of trees on soil nutrients

Effect of differential animal waste (feces and urine)?

**-Correlation is significant at the 0.01 level;
RESULTS AND DISCUSSION

Significant correlations between soil nutrients

\[ y = 0.0517x + 2E-05 \]
\[ R^2 = 0.9203 \]

\[ y = 82.197x^{2.2053} \]
\[ R^2 = 0.663 \]
RESULTS AND DISCUSSION

Significant correlations between soil nutrients

\[ y = 3710.7x^{0.2857} \]
\[ R^2 = 0.7251 \]

\[ y = 1032x^{0.693} \]
\[ R^2 = 0.6089 \]
RESULTS AND DISCUSSION

SOIL PARAMETERS

(Soil moisture content)

When rainfall decreases and increases the T, the SMC tends to be higher under the trees than in open pasture.

**NS-** Correlation is not significant; **-Correlation is significant at the 0.01 level**;
RESULTS AND DISCUSSION

SOIL PARAMETERS

(Soil moisture content)

When rainfall decreases and increases the T, the SMC tends to be higher under the trees than in open pasture and it happens earlier in the topsoil (0-0.20m)

**-Correlation is significant at the 0.01 level;
RESULTS AND DISCUSSION

PASTURE PARAMETERS

(Green matter)

Clear influence (negative) of trees on GM

NS- Correlation is not significant; *-Correlation is significant at the 0.05 level; **-Correlation is significant at the 0.01 level.
RESULTS AND DISCUSSION

PASTURE PARAMETERS
(Dry matter)

Clear influence (negative) of trees on DM

NS- Correlation is not significant; *-Correlation is significant at the 0.05 level; **-Correlation is significant at the 0.01 level;
## RESULTS AND DISCUSSION

### PASTURE PARAMETERS

(Pasture quality)

<table>
<thead>
<tr>
<th>Pasture parameters</th>
<th>UTC</th>
<th>OTC</th>
<th>Prob.</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASH, % DM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15/03/2016</td>
<td>13.9</td>
<td>10.2</td>
<td>0.0049</td>
<td>22.6</td>
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<td>0.0048</td>
<td>10.8</td>
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<td>8.0</td>
<td>ns</td>
<td>16.5</td>
</tr>
<tr>
<td>16/06/2016</td>
<td>9.7</td>
<td>7.4</td>
<td>ns</td>
<td>39.4</td>
</tr>
<tr>
<td><strong>CP, % DM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15/03/2016</td>
<td>14.8</td>
<td>12.8</td>
<td>0.0300</td>
<td>14.4</td>
</tr>
<tr>
<td>28/04/2016</td>
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<td>25.9</td>
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<td>25/05/2016</td>
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<td>8.6</td>
<td>0.0009</td>
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<tr>
<td>16/06/2016</td>
<td>8.5</td>
<td>6.7</td>
<td>ns</td>
<td>34.1</td>
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<td><strong>NDF, % DM</strong></td>
<td></td>
<td></td>
<td></td>
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<td>15/03/2016</td>
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<td>25/05/2016</td>
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<td>ns</td>
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<tr>
<td>16/06/2016</td>
<td>68.5</td>
<td>65.1</td>
<td>ns</td>
<td>10.3</td>
</tr>
</tbody>
</table>
## RESULTS AND DISCUSSION

**CORRELATIONS**

*(Soil vs. pasture parameters)*

Better soil quality ➔ lower productivity pasture!

<table>
<thead>
<tr>
<th>Soil parameters</th>
<th>GM, Kg ha⁻¹</th>
<th>DM, Kg ha⁻¹</th>
<th>PMC, %</th>
<th>ASH, %DM</th>
<th>CP, %DM</th>
<th>NDF, %DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay, %</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>SOM, %</td>
<td>-0.531**</td>
<td>-0.601**</td>
<td>-0.469*</td>
<td>0.540**</td>
<td>0.476*</td>
<td>0.359*</td>
</tr>
<tr>
<td>pH</td>
<td>ns</td>
<td>ns</td>
<td>-0.425*</td>
<td>0.306*</td>
<td>0.407*</td>
<td>ns</td>
</tr>
<tr>
<td>Nₜ, %</td>
<td>-0.441*</td>
<td>-0.533**</td>
<td>ns</td>
<td>0.560**</td>
<td>0.462*</td>
<td>0.319*</td>
</tr>
<tr>
<td>P, mg kg⁻¹</td>
<td>ns</td>
<td>-0.252*</td>
<td>-0.442*</td>
<td>0.418*</td>
<td>0.427*</td>
<td>ns</td>
</tr>
<tr>
<td>K, mg kg⁻¹</td>
<td>-0.352*</td>
<td>-0.450*</td>
<td>-0.331*</td>
<td>0.480*</td>
<td>0.386*</td>
<td>0.213*</td>
</tr>
<tr>
<td>Mg, mg kg⁻¹</td>
<td>-0.255*</td>
<td>-0.306*</td>
<td>-0.399*</td>
<td>0.305*</td>
<td>0.253*</td>
<td>0.465*</td>
</tr>
<tr>
<td>Mn, mg kg⁻¹</td>
<td>-0.453*</td>
<td>-0.424*</td>
<td>-0.488*</td>
<td>0.596*</td>
<td>0.582**</td>
<td>0.357*</td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION

PASTURE PARAMETERS
(Normalized difference vegetation index)

Gradual decrease in vigor during the vegetative cycle

NS- Correlation is not significant; **-Correlation is significant at the 0.01 level;
RESULTS AND DISCUSSION

PASTURE PARAMETERS

(Corrected meter readings)

These graphics mirrored the variation of GM!

NS- Correlation is not significant; **-Correlation is significant at the 0.01 level;
RESULTS AND DISCUSSION

CORRELATIONS

(Sensor vs pasture parameters)

Correlation between CMR (obtained by Grassmaster II probe) and pasture productivity (Green matter) under and outside tree canopy (UTC and OTC, respectively)

\[ GM = 2.0358\text{CMR} - 2666.4 \]
\[ R^2 = 0.9885 \]

\[ GM = 2.7433\text{CMR} - 5537.9 \]
\[ R^2 = 0.9757 \]
RESULTS AND DISCUSSION

PASTURE PARAMETERS

(Mean temperature: infrared camera)

- Negative influence of trees on temperature

**NS** - Correlation is not significant; * - Correlation is significant at the 0.05 level; ** - Correlation is significant at the 0.01 level;
Rainfall > Photosynthesis?

Sunlight > Temperature

> Light

LAI

> Photosynthesis?

Evaluate!

Acorns

Vegetal and animal residues

Animal waste

Water and nutrients competition?

Δ SMC

ACID

Open pasture (OTC) Under Tree Canopy (UTC) Open pasture (OTC)

++ SOM, P, K, N, Mg, Mg/Mn

> Productivity (GM, DM)

Differential seeding?

PH correction?

(Dolomitic limestone) (++Mg)

Mg/Mn equilibrium

> Pasture quality and productivity

Autumn, Winter and Spring

Holm oak

Tree plantations?

Shadow

P - Soil

E - Plants

C - Animals

△ SMC

(Serrano et al., 2016)
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