CONSEQUENCES OF DEHESA LAND USE ON NUTRITIONAL STATUS OF VEGETATION IN CENTRAL-WESTERN SPAIN

Obrador Olán JJ, García López E, Moreno G*
I.T. Forestal, Centro Universitario, Universidad de Extremadura, Plasencia 10600 Spain
* Corresponding author: gmoreno@unex.es

ABSTRACT
A dehesa is a silvoarable system, which results in structure and species simplification of Mediterranean forests. Activities like livestock, forestry, agriculture and, recently, hunting are carried out in these places, in which three main structures are found: trees with native grasses (G), trees with crops (C) and trees with woody understorey (M). In order to find out the effect of dehesa land use on nutritional status, we have measured the nutrient content (N and P) of the vegetation (holm-oak and crop) in three farms located in Central Western Spain, considering in each one the three aforementioned dehesa types. Additionally, the effect of the tree on soil fertility was studied in order to map soil resources around the oak-trees, which will be useful to model the tree-understorey interactions and dehesa functioning.

Soil samples (first 20-cm depth) were taken at different distances from the tree (from 2 up to 20 m) in three trees per plot (9 plots: 3 farms x 3 land uses). In all samples, pH, soil organic matter (SOM), cationic exchange capacity (CEC), total N and available P were determined. Foliar nutrient content of holm-oak (N and P) was measured in mature leaves of nine trees per plot. Crop samples were collected at four distances (2, 5, 10 and 15 m) of the trunk of 9 mature trees per plot (only cropped plots).

Trees in C plots presented the highest values of leaf-N, which is related to fertiliser application and to organic material incorporation/mineralization. Trees in M plots showed the lowest values of leaf-N, indicating a competitive effect of the matorral. By contrast, highest values of P were found in M plots, indicating a positive interaction between trees and shrubs in P uptake. Differences between C and G plots were not significant.

In soils, values of all measured parameters, except pH, diminished according to the distance from the holm-oak, which indicates a marked and positive effect of trees on soil fertility. Regarding the land use, both N and P presented significant differences, being M and C, respectively, which had the highest contents, which does not coincide with the results from leaf nutrient contents. By contrast, N and P values in cereal had a similar behaviour to those of soil, indicating the high dependence of the crop on the nutrients of the first cm of the soil.

Keywords: soil fertility, leaf nutrients, dehesa management intercropped systems, tree-understorey interactions.
INTRODUCTION

Dehesas are the result of a simplification, in structure and species, of Mediterranean forest, where tree density is lowered, matorral cover is eliminated, and grass layer is favoured with crop culture in large periods of rotation. They are silvoarable systems of extensive utilisation, where autochthonous pastures and trees have a preponderant place (Montero et al., 1998).

Dehesas of holm-oak (Quercus ilex) and cork-tree (Quercus suber) occupy 28% of the total Spanish woody Quercus area, which reach 2500000 ha (Campos et al., 2003). Land uses in dehesas are, in order of importance, livestock, forestry, agriculture and hunting, though in certain circumstances and regions the order of importance of each production can be altered.

These land uses result in three main types of vegetation structure in dehesas: holm-oak tree (Quercus ilex subsp. ballota) relations with pasture, crop and matorral, hereafter defined and named as cropped plots (C, trees with cereal), grazed plots (G, trees with native grasses) and encroached plots (M, trees with matorral, that is, woody understorey). In the last decades, a dramatic loss of cultivation has been taking place. On the other hand, an increase in the dehesa encroachment has been recommended in order to increase the natural regeneration of holm-oak in dehesas (Pulido et al., 2001). Moreover, in some areas this is also envisaged as a way to increase the hunting opportunities. However, these recent changes could have some effects on the soil chemical fertility and on the nutritional status of the holm-oak trees, and thereafter on the trees and dehesa productivity.

Several authors have already studied different aspects of the nutritional status of dehesas, namely, the effect of the tree on the soil fertility by comparing soil nutrient content beneath and beyond the tree canopy projection (e.g. Escudero, 1985; Gallardo et al., 2000; Joffre, 1987), the nutritional status of the pasture (e.g. Esselink et al., 1991; Joffre, 1987; Calabuig and Gómez, 1992; Vázquez-Aldana et al., 1995; Pérez-Corona et al., 1995) and trees (Mediavilla and Escudero, 2003; Escudero et al., 1992). These works have shown the general low soil fertility of the dehesa soils and a major role of the holm-oak trees in the soil fertility, which is observed also in other agroforestry systems (Menenzes et al., 2002; Sierra et al., 2002; Halvorson et al., 1995; Knops and Koening, 1997; Dahlgren et al., 1997).

Nowadays, comprehensive models of dehesa functioning are needed in order to improve its management and profitability and in order to detect both possible short and long-term consequences of the recent changes in dehesa land use. Nevertheless, some specific lack of information has been detected on the nutritional status of dehesas. For instance, no work has focused on the comprehensive study of the soil, tree and understorey nutritional status. On the other hand, previous studies have compared the soil fertility between beneath and beyond the
trees, but none has quantified the vertical (depth) or horizontal (distance to tree) extension of tree influence. No study has been carried out to differentiate the specific sources of soil nutrient for tree and understory, that is, we do not know if there is some type of temporal and spatial soil nutrient partitioning between vegetation strata. Finally, all the aforementioned studies have been carried out in grazed dehesas, while the possible consequence of the soil management on soil fertility and nutritional status of vegetation has not been studied yet. In order to find out the consequences of dehesa land use on the nutritional status of soil and vegetation, the aims of this study were:

1. To estimate the nutritional status (N and P) of holm-oak trees under different land uses (cropped, grazed and encroached dehesa plots), in three farms of Central Western Spain.
2. To characterise the soil nutrient distribution around scattered holm-oak trees by studying soil nutrient content at five distances to the holm-oak trunk and three land uses.
3. To find out the nutritional status (N and P) of the crop at four distances to the holm-oak trunk in four farms, and with different fertiliser applications.

Results of this study will be used to build a biophysical model of dehesa functioning, with especial emphasis in tree-crop interactions, both negative (competition) and positive (facilitation). In this context other studies, regarding microclimate, rooting system, water dynamic, physiological tree status and production (cereal and tree) are being carried out.

METHODOLOGY

Study Area

Study area is located in Cuatro Lugares County (Central-Western Spain; 34°4’N, 6°13’W), which has a land area of 441 km², with around 50% of the surface occupied by dehesas (Plieninger and Wilbrand, 2001). The climate is Mediterranean (579 mm y⁻¹ of rainfall, and 16°C of annual mean temperature) with dry and hot summers and cool, rainy winters.

Soils, following FAO (1998) were chromic Luvisols (CL farm) and chromic Acrisols (ST farm), developed over tertiary sediments. Both types of soils had a light-brown and silty-sand surface horizon, one or several very red argic horizons, and a very sandy deep horizon (below 100 cm). The soils also showed bad internal drainage, which produces variegated colours and/or pseudo-gleyic properties, abundant gravel of quartzite (frequently between 10-40 cm depth), low soil chemical fertility, and CaCO₃ accumulation between 150 and 200 cm depth. Where the sediments have been eroded emerge the slates on which eutric Leptosols have been developed (DB farm). Soil slope varies between 2 and 4%.
The more common activities in the study area are cattle raising with native pasture and cereal intercrops. More marginal activities are firewood production and hunting. Tree density is from 5 to 50 tree per ha, depending of its main use (lower densities in intercropped areas and higher densities in areas reserved for hunting). Common native grasses are *Trifolium campestre*, *Medicago polymorpha*, *Anthemis arvensis*, *Geranium molle*, *Erodium cicutarium*, *Taraxacum obovatum*, *Lolium rigidum* and *Silene psamitis*, and more common shrub species are *Genista hirsuta*, *Cistus ladanifer*, *Retama sphaerocarpa* and *Lavandula stoechas*.

**Experimental layout**

In this county, three farms were selected: Cerro Lobato (*CL*); Sotillo (*ST*), and Dehesa Boyal de Talaván (*DB*), each one with three different land uses: cropped plots (*C*, holm-oak tree with cereal, wheat and oats), grazed plots (*G*, trees with native grasses) and encroached plots (*M*, trees with matorral, that is, woody understorey); as overall 9 plots were studied.

In order to find out the effect of dehesa land use on the nutritional status of trees, in each farm we randomly selected 9 trees in *C* and *G*, and 6 in *M*. Foliar samples composed of 4 subsamples (one per orientation) of mature leaves were collected in August 2002.

To study the effect of land uses in dehesas and the tree effect on soil fertility, three holm-oaks were randomly selected in each plot. Soil samples were taken out at 5 distances from the trunk: 2 m (under the tree), 5 m (tree periphery), 10, 15 and 20 m (beyond the tree canopy projection). With the help of a stainless steel drill, five subsamples of composed samples were taken in a depth of 0-20 cm, in March-April 2002.

To study the nutritional status of crops, we randomly selected 9 trees per farm in *CL*, *DB* and *ST*, where the fertiliser applications (formula 7-12-7) were 200, 160 and 0 kg, respectively. For sampling, two orientations and four distances (2, 5, 10 and 15 m from the tree trunk) were considered. Each 6 plants were oven-dried at 75°C until constant weight, ground finely in a stainless steel sail grinder and sieved to be analysed.

Table 1 summarises the chemical analysis carried out on both soil and plants samples.

**Statistical analysis**

Non-linear regressions have been applied to obtain the relationship between soil nutrient contents and distance to the tree trunk. The applied model was the logistic decrease:

\[ y = A - \frac{B}{1 + C \times \exp(-D \times DISTANCE)} \]

Results are expressed in term of percentage of variability explained (R\(^2\)).
Differences between land uses (C, G and M plots) and distance to the tree trunk (as independent variables) were assessed by two-way ANOVAs for each chemical parameter (pH, SOM, CEC, available-P and total-N) as dependent variables. Results are expressed as F values (and degree of freedom) and significance level (p value).

Statistical analysis was carried out in SPSS for Windows (SPSS Inc, 2001).

RESULTS

Soil nutritional status

Soil pH did not show differences due to holm-oak influence (Figure 1), which was backed up by the statistical analyses (F_{4,103}=0.28, p=0.89). This result contrasts with that obtained by Escudero (1985) in more northern dehesas. Differences among land uses (Figure 2) were not significant (F_{2,78}=1.47, p=0.24). The studied soils are defined as acid (mean value of 5.35; range of pH is 6.49-4.35), which could affect the availability of some nutrients or the decomposition velocity of the organic matter (Ulrich and Summer, 1991).

SOM clearly diminished with distance to the tree trunk (Figure 1), indicating a marked effect of tree organic contribution on the soil system (through litterfall and root decay). Statistical analysis (F_{4,103}=24.3, p<<0.01) showed highly significant differences between values of beyond and beneath the trees. The decrease of SOM with distance followed a logistic curve (Figure 3), which shows that the influence of the tree disappears from only a few meters beyond the canopy projection. SOM was higher in M than in C and G plots (Figure 2), but differences among plots (land uses) were not significant (F_{2,78}=0.80, p=0.45).

In general, SOM contents were low, according to the range of values reported by Montoya and López (1998) for Spanish forests. On average, SOM contents were in the 30 percentile considering the values reported by Vanmechelem et al. (1997) for the whole of European soils. The SOM plays an important role in the physical, chemical and biological properties of the soil; for instance, the amount of nutrient in the soils of dehesa (total N) depends on organic matter quality and quantity (Gallardo et al., 2000). The low values of SOM of the studied dehesas are partly explained by the semiarid conditions, but it could also reflect a certain level of soil degradation.

N soil concentrations also diminished with the distance from the holm-oak trunk (Figure 1). Statistical analysis (F_{4,103}=10.1, p<<0.01) showed significant differences between the two first distances (2 and 5 m; beneath the tree) and the other ones (beyond the tree). Total N followed a similar tendency to SOM, although with a less sharp decline (Figure 3). A similar
spatial heterogeneity of soil nitrogen in dehesas has been found by Escudero (1985), Puerto et al. (1987) and Gallardo and Merino (1998). The amounts of total-N were moderate under the tree and low beyond the tree canopy, according to the ranges reported by Montoya and López (1998). Considering the whole of European soils (Vanmechelen et al., 1997), our soils fall around the 30 percentile, that is, the total N content in these soils can be qualified as moderately low.

There were significant differences as regarding land use (Figure 2; $F_{2,78}=3.70$, $p=0.03$), with higher concentrations in $M$ plots (mean value of $1.4 \text{ mg g}^{-1}$) than in $C$ and $G$ plots. This result agrees with the result for SOM; both N and SOM tendencies show a positive effect of the shrubs on the soil fertility (Fisher and Binkley, 2000).

Soil available P (P-Olsen) values at different distances of the holm-oak trunk (Figure 1) also showed a positive effect of tree on soil fertility. In fact, available P concentrations beneath trees were significantly higher than those out of tree canopy ($F_{4,103}=3.59$, $p=0.01$). The decrease at the limit of the canopy projection was sharper than for other analysed soil chemical parameters (Figure 3). These results coincide with those obtained in more northern dehesas by Escudero (1985).

There were significant differences among land uses in available soil-P ($F_{2,78}=5.90$, $p<0.01$); the highest concentrations were found in $C$ plots (Figure 2); which could be related to P fertiliser applications. In fact, grazed plots, which are also periodically cultivated (and then fertilised) had higher values of available soil-P than $M$ plots (which were not fertilised at least in the last two decades). Thus, soil P levels could be determined by biological (tree effect) and antropic causes. Both could explain the slightly high levels of available P (based on values reported by Domínguez Vivancos, 1997), in spite of the soil acidity, which contributes to lessen the availability of soil P (Fisher and Binkley, 2000).

Overall, the studied soils showed moderately low concentrations of N and moderately high levels of available-P, which is characteristic of young soils. Soils developed on old and nutrient-poor substrates are usually P deficient, whereas N may be deficient even in young soils (Vitousek and Farrington, 1997).

The CEC values found in the present study were between the 30 and 50 percentiles considering the values reported by Vanmechelem et al. (1997) for the whole of European soils. Values of CEC are basically related to organic matter and clay quality (mainly kaolinite) and quantity (below 20 % in the first 20 cm of the studied soils; unpublished data). The moderately low values of CEC in the studied soils must be explained by the low soil organic contents. CEC values diminished with the distance from the trunk (Figure 1).
Statistical analysis showed significant differences between distances ($F_{4,103}=7.67$, $p<<0.01$), with higher values beneath than beyond the trees, as a consequence of the levels of organic matter. However, CEC diminished much less than SOM with distance, because the clay content did not vary with the distance to the tree (data not shown). Similarly to SOM, there were no significant differences between soils of the three land uses (Figure 2; $F_{2,70}=0.15$, $p=0.86$).

The positive role of the holm-oak trees on soil fertility is explained by the annual input of organic matter to the soil through the litterfall (Gallardo and Merino, 1998; Escudero et al., 1992) and root decay (Jackson et al., 1996). Moreover, forests are particularly effective at scavenging and retaining atmospheric solutes due to their high surface area and aerodynamic resistance; this mechanism allows trees to thrive on poor soils and enabling soil improvement (Moreno et al., 2003).

**Crop nutritional status**

Mean concentrations of N in cereal plants diminished according to the increase in tree distance (Figure 4), indicating a positive effect of the tree canopy that is related to the holm-oak organic materials contribution and their incorporation into the soil due to agriculture machinery (Essenlik et al., 1991). Statistical analysis showed highly significant differences between the two first distances (2 and 5 m) and the rest ($F_{3,60}=22.07$, $p<<0.01$). The highest values of these concentrations imply that the materials that grow under the tree canopy have higher protein values, which rebound in a high quality of the pasture (Pérez-Corona et al., 1995). Nevertheless, on average the studied plants showed low levels of N in comparison with ranges reported by IFA (1992).

Figure 4 shows mean values and standard deviations of P concentrations in crop plants. Similarly to N, P concentrations diminished significantly as the distance to the oak trunk increases ($F_{3,60}=13.41$, $p<<0.01$). P levels ranged from normal (0.21) to very low (0.04) according to IFA (1992).

The concentration of N and P in crop plants changed in concordance with the aforementioned soil nutrient contents; both nutrients showed higher contents in the vicinity of the trees. This similarity between soil and herbaceous plants tendencies has been also shown by Puerto et al. (1987) and Escudero (1992). Our results indicate the high dependence of the crop on the nutrients of the first 20 cm of soil depth. This dependence coincides with the rooting system of these crops, which have most of the roots near the soil surface: 78% of the roots were located in the first 30 cm of soil (Obrador et al., 2003).
Holm-oak nutritional status

Figure 5 shows mean and standard deviation of N foliar concentrations in holm-oaks under three types of land use. Mean values of these concentrations (between 11.6 and 10.3 mg N g⁻¹) are in the range of those obtained in other studies for *Quercus ilex* in more northern dehesas (Escudero *et al.* 1992; Mediavilla and Escudero, 2003) and for evergreen *Quercus* in California (Knops and Koening, 1997). Nevertheless, these values are in the low extreme of the range reported by Stephan *et al.* (1997) for oaks all over Europe (9.94 – 32.62 mg N g⁻¹).

Statistical analysis showed high significant differences (*F*₂,₆₃=9.06, p<<0.01) among the three different land uses, with highest values for trees of *C* plots, followed by *G*. These results show a clear positive effect of the dehesa management practices (mainly cropping, *C*), due to nitrogen fertiliser application and mineralisation of the incorporated organic materials (Esselink *et al.*, 1991; Mansson and Falkengreen-Gregrup, 2003; Frank and Roeth, 1996; Gallardo *et al.*, 2000). The effect of the organic matter mineralisation is also revealed by the fact that the lowest concentrations of soil-N were found in *M* plots and the highest in *C* plots, while the opposite was found in the N contents in tree leaves.

Apart from comparing soil and tree N contents we can establish the following statements: shrubs compete strongly with trees for soil N and crop has no short-term negative effect on tree nutritional status. On the contrary, cropping activity leads to a higher leaf-N content in holm-oaks. These differences were found regardless of the fertilisation treatment, that is, trees in cropped plots of *ST* (unfertilised crops) also showed a higher leaf-N content than trees of *G* and *M* plots. This result indicates a positive effect of ploughing, probably an increase of the mineralisation rate. In order to find out the N contribution that the two principal N inputs (SOM and mineral N fertiliser) have in the dehesa system, a specifically designed experiment would be advisable.

Regarding P, trees in *M* plots showed the highest values (0.65 mg P g⁻¹), continued by trees of *G* plots (Figure 5). Statistical analyses showed significant differences between *M* plots and other two plots (*C* and *G*) (*F*₂,₆₃=7.90, p<<0.01). Observed values in *C* and *G* plots (0.48 and 0.54 mg P g⁻¹) were below those obtained in other studies carried out with the same species in more northern dehesas (Escudero *et al.*, 1992). Moreover, these values are even below the range reported by Stephan *et al.* (1997) for oaks all over Europe (0.56 – 2.22 mg P g⁻¹). P is considered in this county the most deficient nutrient; therefore, farmers apply higher quantities of this element in fertilisation doses.

The higher concentrations of P observed in leaves of *M* trees, must be explained in terms of a positive interaction between trees and shrubs. Most of the P could be in non-available forms
(mineral and organic) and roots could have some direct role in the mobilisation of this P. More root density and diversity, and more mycorrhizae are expected in $M$ plots than in $C$ and $G$ plots, so that the biological P mobilisation should be higher in $M$ plots than in the others (Jackson et al., 1999).

Moreover, tree roots in studied dehesas are located rather in deep layers, with a low root density in the first 20 cm of the soil (Obrador et al., 2003), and thus, most nutrients could be taken up from these deep layers and not as many from the first 20 cm of the soil. In fact, P has a very low dynamic in the soil, so that it could depend just as much on the root density than on the P soil content. This would also explain why trees in $M$ plots have the highest leaf-P contents while soils in $M$ plots have the lowest available P in the first 20 cm of soil.

**CONCLUSIONS**

A positive effect of the tree in the soil fertility has been shown through four parameters (organic carbon, total N, CEC and available P). Nevertheless, the level of these four parameters decreased sharply in the limit of the canopy projection, that is, the effect of the trees was almost limited to the tree cover. The effect was null (asymptotic values) beyond three meters to the canopy limit, although tree roots can spread horizontally to more than 25 m (Obrador et al., 2003).

The cultivation of dehesas increased the N concentration of holm-oak leaves as a direct consequence of organic matter mineralisation apart from the effect of mineral fertilisation. A positive effect of dehesa encroachment was also found, with increased SOM and total soil N contents. On the other hand, shrubs could positively affect the P content of holm-oak leaves, probably by helping the soil P mobilisation.

Results of N and P contents in crop plants revealed the high dependence of these plants on the nutrients of the first 20 cm of the soil, according to the superficial rooting system of the crop plants (Obrador et al., 2003). By contrast, P and N contents of tree leaves do not coincide with soil nutrient contents (first 20 cm of soil depth), indicating a certain dependence of the deep soil nutrient. Thus, crop plants and trees could acquire most nutrients from different parts of the soil, which would imply a nice example of niche complementarity in an agroforestry system.

**Acknowledgement**

This study was supported by European Union (SAFE project, contract QLV-2001-0560), Spanish Ministerio de Ciencia y Tecnología (MICASA project, contract AGL-2001-0850) and Consejería de Educación de la Junta de Extremadura (CASA project, contract 2PR02C012). Jesús Obrador and Eustolia García were awarded grants by ANUIES and Colegio de Posgraduados (México).
REFERENCES


Table 1. Methods of chemical analysis carried out with samples of holm-oak leaves, crop (total plant) and soil.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Parameter</th>
<th>Method</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant (oak and crop)</td>
<td>N total</td>
<td>Semi-micro Kjeldahl (modified to include nitrates)</td>
<td>Bremner, 1965</td>
</tr>
<tr>
<td></td>
<td>P total</td>
<td>Incineration and colorimetric</td>
<td>Bigham and Bartels, 1996</td>
</tr>
<tr>
<td>Soil</td>
<td>CIC</td>
<td>Ammonium acetic extraction</td>
<td>Bigham and Bartels, 1996</td>
</tr>
<tr>
<td></td>
<td>SOM</td>
<td>Walkley and Black wet combustion, modified by Walkley</td>
<td>Dewis and Freitas, 1984</td>
</tr>
<tr>
<td></td>
<td>Total N</td>
<td>Semi-micro Kjeldahl (modified to include nitrates)</td>
<td>Bremner, 1965</td>
</tr>
<tr>
<td></td>
<td>Available P</td>
<td>Olsen</td>
<td>Olsen and Dean, 1965</td>
</tr>
<tr>
<td></td>
<td>pH</td>
<td>CaCl₂ (1:2)</td>
<td>Bigham and Bartels, 1996</td>
</tr>
</tbody>
</table>
FIGURE CAPTION

Figure 1 - Mean values and standard deviations of soil pH, organic matter (SOM), total-N, Cation exchange capacity (CEC) and available-P at different distances to the holm-oak trunk. Data are average values of C (cropped), G (grazed) and M (matorral) plots. Different letters indicate significant differences.

Figure 2 - Mean values and standard deviations of soil pH, organic matter (SOM), total-N, cation exchange capacity (CEC) and available-P in dehesas soils with three different land uses: C (cropped), G (grazed) and M (matorral) plots. Different letters indicate significant differences.

Figure 3 - Relationships between the distance to the holm-oak and four chemical parameters of the dehesa soils in Central-Western Spain. NOTE: The logistic decrease curves \( y = A - \frac{B}{1 + C \times \exp(-D \times \text{DISTANCE})} \) have been normalised, and the corresponding parameters are:

<table>
<thead>
<tr>
<th>Chemical parameter</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOM</td>
<td>39,9</td>
<td>19,6</td>
<td>26,9</td>
<td>0,744</td>
<td>99,57</td>
</tr>
<tr>
<td>Total N</td>
<td>1,31</td>
<td>0,42</td>
<td>71,7</td>
<td>0,898</td>
<td>99,30</td>
</tr>
<tr>
<td>CEC</td>
<td>10,1</td>
<td>2,54</td>
<td>7994</td>
<td>1,668</td>
<td>98,81</td>
</tr>
<tr>
<td>Available P</td>
<td>14,0</td>
<td>5,06</td>
<td>2252</td>
<td>1,699</td>
<td>99,01</td>
</tr>
</tbody>
</table>

Figure 4 - Mean concentrations and standard deviations of N and P in cereal plants at different distances to the holm-oak trunk. Different letters indicate significant differences.

Figure 5 - Mean concentrations and standard deviations of N and P in leaves of holm-oak in dehesas with three different land uses: C (cropped), G (grazed) and M (matorral) plots. Different letters indicate significant differences.
FIGURE 1

- SOM (mg g$^{-1}$)
- N (mg g$^{-1}$)
- pH (CaCl$_2$)
- CEC (cmolc+ kg$^{-1}$)
- P (mg kg$^{-1}$)
FIGURE 2

- SOM (mg g\(^{-1}\))
- CEC (cmol c kg\(^{-1}\))
- N (mg g\(^{-1}\))
- P (mg kg\(^{-1}\))
- pH (CaCl\(_2\))

Different letters indicate significant differences among land uses.
FIGURE 4

![Figure 4](image)

FIGURE 5

![Figure 5](image)