CARBON STORAGE IN THE SOIL UNDER DIFFERENT LAND USES IN THE SOUTH OF PORTUGAL

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Abstract

The semi-arid climate areas are strongly affected by climate change but land management options knowledge for these areas is scarce and usually focused on one single type of land use when mitigation is evaluated. The aim of this study was to evaluate the amount of carbon stored in the soil in three main land uses traditionally encountered in the semi-arid areas of the South of Portugal (natural forest vegetation, agroforestry and agricultural) after a period of 100 years of land use. The results of this experiment showed that after 100 years the trees established in the plots increased the carbon storage per hectare in the soil, mainly due to the high inputs of organic matter to the soil coming from the tree leaves and roots. Therefore, in similar edaphoclimatic conditions to those of this study it could be recommended the implementation of agroforestry systems such as montado as a land use to mitigate the effect of the climate change, allowing agricultural production.

Keywords: agroforestry; forest; agricultural; climate change

Introduction

Human activities related to land use have a high impact on climate change because the land use sector represents almost 25% of total global emissions (UN 2018). Currently, the effect of land use on climate change is a concern in the context of international policies, being necessary policies and incentives that promote land uses that act as mechanisms for mitigation and adaptation to climate change. Portugal has an agroforestry system called montado where *Quercus suber* L. and *Quercus rotundifolia* L. are combined with agricultural and/or pastoral activities (Pereira and Tomé 2004). Montado is highly valued by its capacity to mitigate climate change, mainly due to the higher potential to sequester carbon in both above and below (soil) ground biomass compared with the conventional agricultural systems (Pinto-Correia et al. 2011). Recent studies shown that *Quercus suber* L. stands from the entire Portugal are responsible for storing 14 748 500 t CO_2, from which 14 030 787 t CO_2 are derived from the area placed below theTagus River, where montado is the main land use (Branco et al. *2010). Soil carbon represents the 85% of the carbon stocks of terrestrial ecosystems, which makes the evaluation of land use systems impacts on soil carbon highly relevant.*

The aim of this study was to evaluate the amount of carbon stored in the soil of three main land uses traditionally encountered in the semi-arid areas of the South of Portugal (natural forest vegetation, agroforestry and agricultural) after a period of 100 years of land use.

Materials and methods

The experiment was carried out in the Perímetro Florestal of Contenda located in the Baixo Alentejo province, South of Portugal (WGS84 coordinates: 38.058 N, -7.040 W) and covered a total area of 5270 ha. Three plots of the Perímetro Florestal of Contenda were selected to compare the effect of the land use on the soil carbon stocks after a period of 100 years. The selected plots were: i) a plot with natural forest vegetation, dominated by uneven aged *Quercus rotundifolia* L. trees established through natural regeneration, ii) a plot with an agroforestry land use (montado), in which uneven aged *Quercus rotundifolia* L. trees were established and are currently at a low density (66 trees ha^{-1}) and combined with an extensive grazing with sheep, iii) a plot with an agricultural land use in which during the last six years the soil was tilled to sow a mixture of grasses (triticale, oat and wheat) and legumes (clover) for livestock feeding.

All plots included in this study are characterized by the presence of a water line. For this reason, three composite soil samples were collected in each plot at three distances from the water line (5, 10 and 15 m) to eliminate the effect of the water line in the statistical comparison of the land uses. The soil samples were collected at a soil depth of 25 cm in March 2017 using a cylinder of a known volume. In the plots with natural forest vegetation the soil samples were collected under the trees and in the agroforestry plots the soil samples were collected under the trees and in those areas not affected by the trees.

In the laboratory, roots of each soil sample were separated by hand, dried, and weighed. The soil root biomass was calculated using the known volume value of the cylinder. Soil samples were air dried and passed through a 2 mm sieve. Material that did not pass through the 2 mm sieve was separated, weighed and then discarded. The weight of the discarded fraction was used to convert the eventual data derived from the 2 mm sieved fraction back to field condition (Rodríguez-Murillo 2001). The percentage of carbon in the soil was analysed using a LECO CNS Elemental Analyzer. The percentage of carbon was used to calculate the carbon storage per hectare (Mg C ha^{-1}) in the soil according to Mosquera-Losada et al. (2015) and Ferreiro-Domínguez et al. (2016).

Data were analysed using ANOVA and differences between averages were shown by the LSD test, if ANOVA was significant. The statistical software package SAS (2001) was used for all analyses.

Results

In Figure 1 it can be observed that the carbon storage (Mg ha^{-1}) in the soil was significantly higher in the plot with natural forest vegetation and under the trees in the agroforestry plot compared with the plot with an agricultural land use and the open area of the agroforestry plot ($p<0.001$).

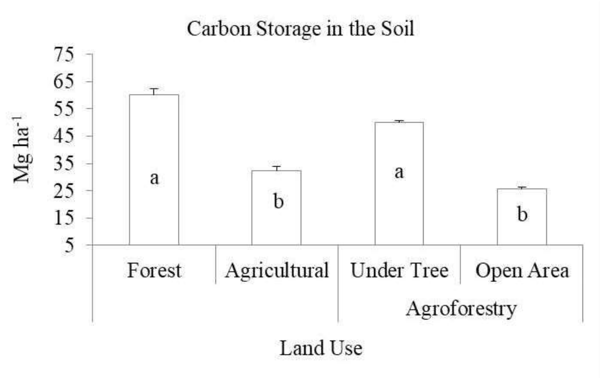

Figure 1: Carbon storage (Mg C ha^{-1}) in the soil under each land use (natural forest vegetation, agricultural and agroforestry). Different letters indicate significant differences between land uses. Bars indicate the standard error of the mean.

Root biomass was significantly affected by the land use ($p<0.01$). A higher root biomass was found in the plot with natural forest vegetation and under the trees in the agroforestry plot than in the agricultural plot and in the open area of the agroforestry plot (Figure 2).

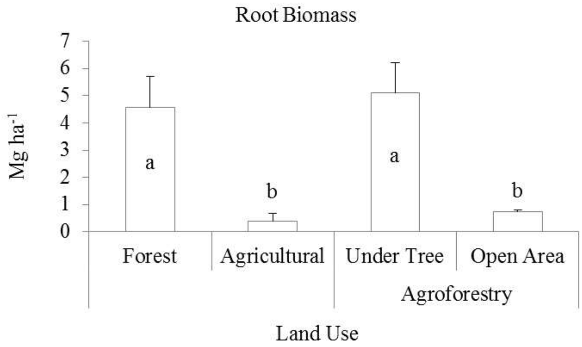

Figure 2: Root biomass (Mg ha^{-1}) under each land use (natural forest vegetation, agricultural and agroforestry). Different letters indicate significant differences between soil fractions in each land use. Bars indicate the standard error of the mean.

Discussion

The levels of carbon storage per hectare in the soils under natural forest and agricultural land use were similar to the levels reported by Sil et al. (2017) for broadleaved forest areas (60.51 Mg ha^{-1}) and agricultural areas (24.52 Mg ha^{-1}) of Portugal. In the case of the agroforestry plot, the mean levels of carbon storage per hectare, taking into account both the area under the trees and the open area, were similar to the levels found by Howlett et al. (2011) in a dehesa cork oak silvopasture of central-western Spain (29.9 Mg ha^{-1}).

The carbon storage in the soil was higher in the plot with natural forest vegetation and under the trees in the agroforestry plot compared with the plot with an agricultural land use and the open area of the agroforestry plot. The higher carbon stock associated to the presence of trees in the plots could be explained by the high inputs of organic matter to the soil from the tree leaves but also from the roots of trees and herbaceous species established in the understory (Mosquera-Losada et al. 2015) because the root biomass was higher in the plot with natural forest vegetation and under the trees in the montado than in the plot with an agriculture land use and in the open area of the montado. Moreover, in the case of the montado, trees generate micro-sites under their canopies which may favour the establishment of new herbaceous species (Rois et al. 2006), increasing the fine root biomass under the trees and therefore the carbon stocks compared with the open area. Sheep grazing in the montado could have also increased the carbon stock under the trees compared with the open area. Animals are generally close to the trees looking for feed and shade which can increase the soil nutrients around trees (from excreta) and therefore the development of fine roots in the trees mainly in winter when soil water is available (López et al. 2001). The important role of fine roots located in the upper few centimetres of the soil on the carbon storage in the soil have been previously described by several authors (Dresner et al. 2007; Mosquera-Losada et al. 2015; Ferreiro-Domínguez et al. 2016). Moreover, the shade generated by the trees probably decreased the mineralisation rate of the soil organic matter which favoured the carbon stock under the trees compared with the open area in the montado and the plot with agricultural land use in which the mineralisation rate of the soil organic matter could be high due to the soil tillage process carried out. These results demonstrate the important role of trees in carbon storage in the soil and therefore their potential mitigation role fighting against climate change climate. Moreover, this carbon can remain unalterable in the soil over very long periods of time as long as the tree management is adequate.

Conclusion

The presence of trees increases the carbon storage in the soil at long term, mainly due to the high inputs of organic matter to the soil from the tree leaves and roots. Therefore, in similar edaphoclimatic conditions to those of this study it could be recommended the implementation of agroforestry systems such as the montado as a land use to mitigate the effect of the climate change, allowing agricultural production.

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