Effect of the forage maize-pasture rotation on the soil carbon storage in Galicia (NW Spain)

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Abstract. Galicia is a region in NW Spain with high economic dependence on dairy cattle where livestock feeding is mainly based on the production of forage maize. In this region, one of the major challenges for the forage maize production systems is to maximize the economic return while minimizing environmental pollution mainly associated with greenhouse gas emissions such as CO_2. In this context, crop rotations influence not only crop growth, but also the soil chemical properties such as the amount of carbon storage in the soil. This study aimed to evaluate the effect of the forage maize-pasture rotation on the carbon storage in the whole soil and each soil aggregate fraction (250–2000 μm; 53–250 μm and < 53 μm) under different climatic conditions in Galicia. In September 2020, a total of sixteen plots were selected in the interior and coastal areas of Galicia. In each area, four plots with a forage maize-pasture rotation and four plots without rotation with pasture were selected to collect composite soil samples. In the laboratory, the total soil carbon and the carbon storage in the different soil fractions were estimated. In this study, the crop rotation increased the amount of carbon storage in the soil in the long term.

Keywords: climate change, agriculture, soil aggregate fractions

1. Introduction

In Galicia (NW Spain), the forest and agricultural sectors are very important from a socio-economic point of view, employing 10% of the region's workers. In this region, two-thirds of its area is classified as forest, being the livestock sector which generates most of the final agricultural income. Moreover, Galicia has a high economic dependence on dairy cattle, and livestock feeding is mainly based on the production of forage maize in periods of pasture shortage. However, it is important to be aware that agriculture is one of the most important contributors to climate change through emissions of greenhouse gases (GHG) and air pollutants (EEA, 2019). Therefore, in Galicia, one of the major challenges for the forage maize production systems is to maximize the economic return while minimizing environmental pollution, mainly associated with GHG emissions, to reach the climate targets set for 2030 and 2050 (reducing GHG emissions by at least 50% by 2050 compared to 1990 levels) (EU, 2020). In this context, farmers are increasingly using sustainable agricultural practices such as crop rotations to boost productivity while also reducing GHG emissions. Previous studies have shown that crop rotations may mitigate soil GHG emissions thanks to an increase in carbon sequestration, a reduction of mineral fertilizers and a decrease in the N losses due to the uptake of nitrate by catch crops both in the crop and intercrop period (Bosco et al., 2019). Moreover, crop rotations are included in the list of potential agricultural practices that the eco-schemes could support in the future common agricultural policy (CAP) to reach the Green Deal targets (EU, 2021). However, the effect of crop rotations on GHG emissions and therefore on the soil carbon sequestration is variable depending, among other factors, on climate conditions or composition and management of crop (Malhi and Lemke, 2007), being these factors little evaluated in regions such as Galicia. Moreover, the information is also scarce regarding the carbon associated with the different soil aggregate fractions in cultivation systems with and without crop rotation. In general, carbon can be stored in macroaggregates (250-2000 μm) in the short-term and microaggregates (53-250 μm) and smaller-size aggregates (<53 μm) in the long-term (Nair, 2011). However, the carbon associated with the different soil aggregate fractions can vary over time due to several factors, including the cultivation system.

This study aimed to evaluate the effect of the forage maize-pasture rotation on the carbon storage in the whole soil and each soil aggregate fraction (250–2000 μm; 53–250 μm and < 53 μm) under different climatic conditions in Galicia.

2. Materials and Methods

The experiment was carried out in Galicia (NW Spain), within the Atlantic biogeographic region of Europe. Galicia is characterised by high rainfall levels, with well over 1000 mm a year across almost the entire region and a thermal oscillation between the interior and coastal area (range of oscilation: 1-4 ºC).

In September 2020, sixteen agricultural plots were selected in the interior and coastal areas of Galicia. In each area, four plots with a forage maize-pasture rotation (R) and four plots without rotation with pasture (NR) were selected with the help of a dairy Cooperative that has more than 3.500 farms around Galicia. In each plot, two composite soil samples were collected at a soil depth of 0-25 cm. In the laboratory, soil samples were physically fractionated following the procedure described by Elliot (1986). The whole soil and the resulting three soil aggregate fractions, macroaggregates (250–2000 µm), microaggregates (53–250 µm) and silt + clay (< 53 µm), were dried overnight at 60 ºC and then ground for homogenization, and carbon analysis. The percentage of organic C in the whole soil and three soil aggregate fractions was analyzed using a LECOTM CNS Elemental Analyzer (LECO Corporation, USA). The carbon percentage was used to calculate the soil C storage per hectare (Mg C ha^{-1}) in the whole soil and soil aggregate fractions according to Ferreiro-Domínguez et al. (2016)

Data were analysed using a two way ANOVA and differences between averages were evaluated with the LSD test, in cases that the ANOVA was significant. The statistical software package SAS (2001) was used for the analyses.

3. Results and discussion

Figure 1 shows that in the coastal area of Galicia the carbon storage in the whole soil was higher in the plots with a forage maize-pasture rotation (R) than in the plots without rotation with pasture (NR) ($p<0.001$). The positive effect of the crop rotation on the carbon storage in the whole soil could be explained by the higher biomass production, and therefore inputs of organic matter to the soil, associated with the crop rotation compared to the cultivation practice without rotation. In this context, several studies have shown that the residues left by the plants in the cultivation systems with rotation contribute to the increase of soil organic matter which is responsible for the addition of carbon to the soil (Dos Santos-Canalli et al. 2020). However, it is important to be aware that in the interior area of Galicia, the levels of carbon storage in the whole soil of plots with a forage maize-pasture rotation (R) were similar to the levels found in the plots without rotation (NR) ($p>0.05$). The differences observed between the two areas of Galicia evaluated in this study could be explained by the higher soil degradation in the coastal area of Galicia than in the interior area, mainly due to anthropogenic factors such as forest fires which can decrease the levels of soil organic carbon by almost 50%, resulting in reduced stability of the aggregates (Varela et al., 2015). Therefore, in areas with degraded soils, the crop rotation can protect the soil surface and may even restorate the organic matter content and fertility of such soils (Ahmad et al., 2014).

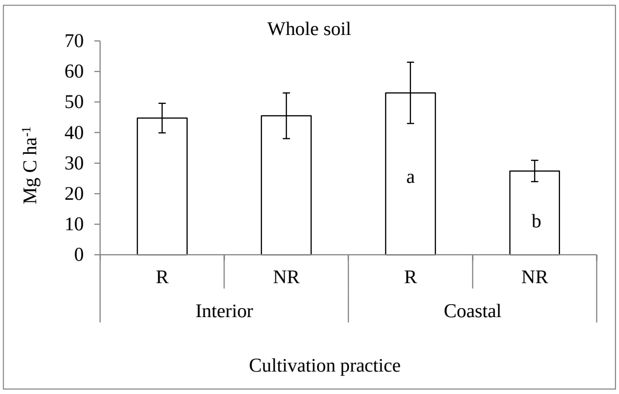

Figure 1. Carbon storage (Mg C ha^{-1}) in the whole soil under each cultivation practice (R: forage maize-pasture rotation NR: without rotation with pasture) in the interior and coastal area of Galicia. Different letters indicate significant differences between cultivation practices in each area of Galicia. Bars indicate the standard error of the mean.

In Figure 2 it can be observed that in both areas and cultivation practices, there was a lower percentage of carbon associated with the silt + clay (< 53 µm) fraction compared to the other soil fractions ($p<0.001$), probably due to the preferential stabilization of organic matter in macroaggregates as opposed to smaller size classes (Howlett et al., 2011). Moreover, crop rotation improves soil quality through the increase of biopores by plant roots (Dos Santos-Canalli et al. 2020), favoring the movement of small particles into the deep soil layers and therefore decreasing the carbon associated with the small particles in the soil surface layers.

On the other hand, in the coastal area, the forage maize-pasture rotation increased more the carbon associated with the microaggregates (53-250 µ) than the cultivation practice without rotation ($p<0.001$). This result is very important from a climate change mitigation point of view because carbon associated with the smallest soil aggregate fractions is very stable and is maintained in the soil in the long-term compared with the carbon linked to the macroaggregates. In this context, crop rotation could be considered as a promising way to adapt agricultural systems in temperate regions of the planet and contribute to food security under a changing climate.

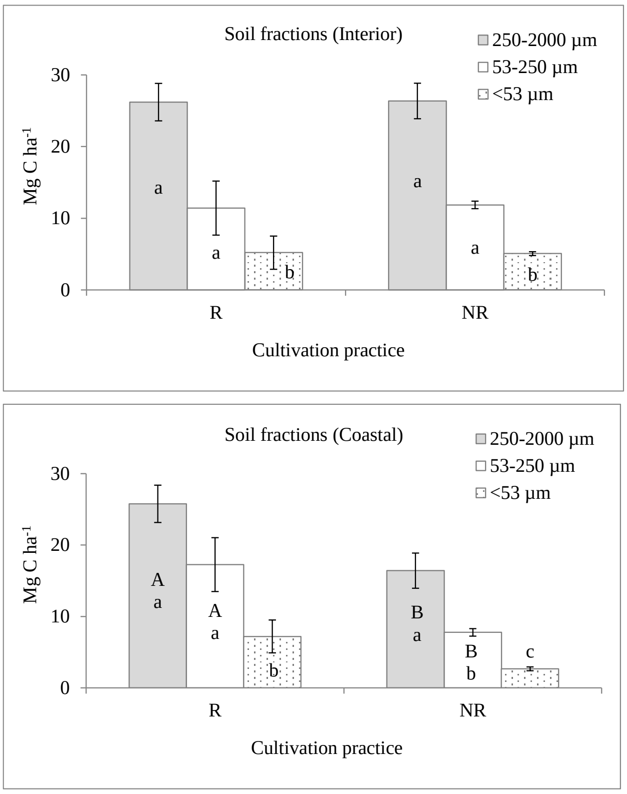

Figure 2. Carbon storage (Mg C ha^{-1}) in the three soil fractions (macroaggregates: 250–2000 µm; microaggregates; 53–250 µm and silt + clay: < 53 µm) under each cultivation practice (R: forage maize-pasture rotation NR: without rotation with pasture) in the interior and coastal area of Galicia. Different lowercase letters indicate significant differences between soil fractions in each cultivation practice while different uppercase letters indicate significant differences between cultivation practices in each soil fraction. Bars indicate the standard error of the mean.

4. Conclusion

In the coastal area of Galicia, crop rotation increased the carbon in the whole soil and the carbon associated with the microaggregates. Therefore, in degraded soils, the crop rotation in the agricultural systems could be used as a climate change mitigation strategy

Acknowledgments

This study has been supported by Xunta de Galicia, Consellería de Cultura, Educación e Ordenación Universitaria ("Programa de axudas á etapa posdoutoral modalide B DOG nº 213, 08/11/2019 p.48018, exp: ED481D 2019/009").

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