Dairy farms management and carbon storage in the soil fractions

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Abstract. The dairy sector is one of the main economic activities in the Spanish region of Galicia, located in the northwest of the country. In dairy farms, the type of farm management has a clear effect on climate change mitigation by modifying crucial processes such as carbon storage in the soil. This study aimed to evaluate the effect of the dairy farm management (extensive, intensive and organic) on carbon storage in each soil aggregate fraction in dairy farms of Galicia. A total of 21 dairy farms were selected of which 7 farms were based on intensive conventional production, 7 farms were based on extensive conventional production and 7 farms were based on organic production. In each farm, two plots were selected and for each plot, two composite soil samples were collected. In the laboratory, soil samples were fractionated in macroaggregates (250–2000 µm), microaggregates (53–250 µm) and silt + clay (< 53 µm) to estimate the carbon storage in each soil fraction. The results show that the organic farms implied a higher amount of carbon storage in the different soil fractions than the extensive and intensive farms, being the carbon storage in the smallest soil fractions very stable and maintained in the soil in the long-term.

Keywords: climate change, extensive, intensive, organic

1. Introduction

Galicia (NW Spain) is amongst the 10 first European dairy production regions with 38% Spanish milk production (MAPA, 2019). In this region, the dairy sector implies a turnover of 800 million euros and more than 25,000 people employed. However, dairy farms are a major contributor to the total greenhouse gas (GHG) emissions over the life cycle of milk and other dairy products which contribute to climate change (Rotz, 2018). In dairy farms, climate change can reduce milk production and income and increase costs due to additional food purchases (Harrison et al., 2017). Given this context, it is desirable to propose farming management strategies for environmental improvement in milk production.

Previous studies have shown that in the current situation of climate change the extensive farms imply a production more sustainable and secure with a key role in adaptation and mitigation to the climate change compared to the intensive farms (Entretantos, 2020). Moreover, the extensive systems are generally characterized to provide diverse ecosystem services such as a higher soil carbon sequestration than the intensive systems. However, the information is scarce when the carbon associated with the different soil aggregate fractions is evaluated and compared in extensive and intensive dairy farms as well as in dairy farms with organic production. In general, carbon can be stored in macroaggregates (250-2000 µm) in the short-term and microaggregates (53-250 µm) and smaller aggregate sizes (<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 dairy farm management type.

This study aimed to evaluate the effect of the dairy farm management (extensive, intensive and organic) on carbon storage in each soil aggregate fraction (250–2000 µm; 53–250 µm and < 53 µm) in dairy farms of Galicia.

2. Materials and Methods

The experiment was carried out in Galicia (NW Spain), being this region part of the Atlantic biogeographic region of Europe. Galicia is characterised by the high rainfall levels, with well over 1000 mm a year across almost the entire region, which together with the type of bedrock (mainly quartz) imply soils with high acidity.

In January 2020, a total of 21 dairy farms were selected of which 7 farms were based on intensive conventional production (IP), being the cattle feeding with annual pastures produced on the farms, 7 farms were based on extensive conventional production (EP) and 7 farms were based on organic production (OP) (Figure 1).

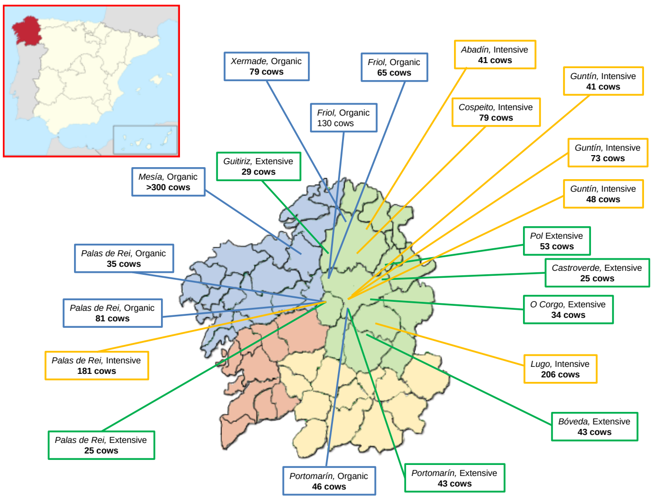

Figure 1. Dairy farms in the different Municipalities of Galicia (NW Spain) with the number of cows in each farm (yellow color: intensive conventional production, green color: extensive conventional production and blue color: organic production).

In each farm, two plots were selected and for 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 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 three soil aggregate fractions was analyzed using a LECOTM CNS Elemental Analyzer (LECO Corporation, USA).

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 the analyses.

3. Results and discussion

Figure 2 shows that the percentage of macroaggregates (250–2000 µm) in the soil was significantly higher in the organic dairy farms than in the other farms ($p<0.001$). Moreover, in general, the organic dairy farms implied a lower percentage of microaggregates (53–250 µm) and silt + clay fraction (< 53 µm) than the other farms ($p<0.0001$). These results could be explained by several physical and chemical factors. Regarding physical factors, it is important to be aware that organic farming implies a thickening of the plant roots which increases the presence of biopores in the soil surface layers, favoring the movement of small particles into the deep soil layers. Organic farming also enhances the soil microfauna compared to conventional farming (Gomiero et al., 2011) which can increase the macroaggregates formation in the soil. Moreover, the use of heavy equipment to till the soil and harvest the pasture in the dairy farms based on intensive conventional production could have increased the proportion of the smallest soil aggregate fractions in the intensive farms. In the case of the chemical factors, the higher percentage of macroaggregates in the organic dairy farms than in the other farms could be explained by the inputs of organic matter to the soil from the organic fertilisers used in the organic farms in which the organic fertilisers such as manure or composted agricultural wastes are key to maintain adequate ranges of soil fertility. In this context, it should be noted that the soil macroaggregates are plant residues that still have a recognizable cell structure (Kogel-Knabner et al., 2008). However, conventional dairy farms are generally characterized by the use of chemical fertilisers that increase the mineralization rate of the soil organic matter thus favoring the formation of the smallest soil aggregate fractions (Zhao et al., 2020).

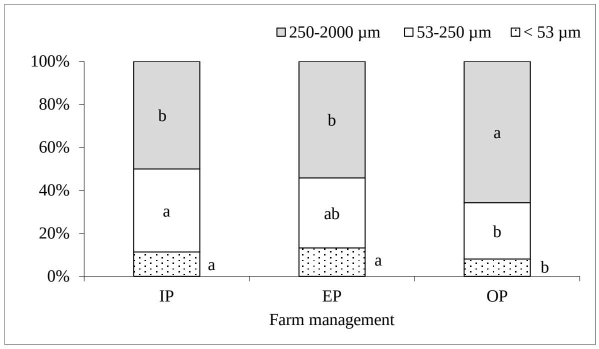

Figure 2. Percentage of each soil fraction (macroaggregates: 250–2000 µm; microaggregates; 53–250 µm and silt + clay: < 53 µm) under each dairy farm management (IP: intensive conventional production, EP: extensive conventional production and OP: organic production). Different letters indicate significant differences between types of dairy farm management.

In Figure 3 it can be observed that in the three types of dairy farms evaluated in this study, there was a higher percentage of carbon associated with the silt + clay fraction compared to the other soil fractions (250–2000 µm and 53–250 µm) ($p<0.001$). Moreover, the organic dairy farms generally implied a higher percentage of carbon in the three soil aggregate fractions than the conventional dairy farms ($p<0.001$). This result is very important in the case of the smallest soil aggregate fractions because the carbon associated with the microaggregates and the silt + clay soil fraction represents relatively old carbon that is in the soil over a long period (Puget et al., 2000). This carbon has a long residence time in the soil and is very stable (recalcitrant) to the variation of climatic conditions and management practices. Therefore, organic dairy farms rely on ecological processes and cycles adapted to local conditions which favor climate change mitigation, being climate change one of the biggest challenges of our times.

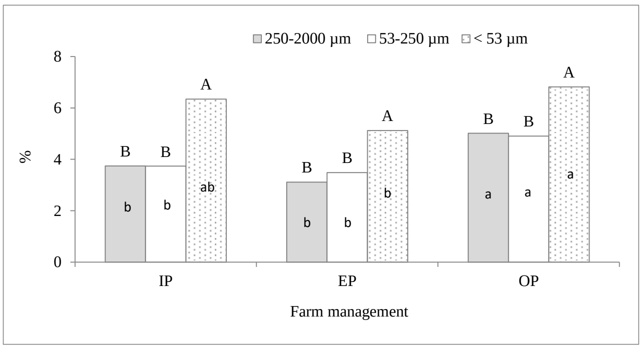

Figure 3. Carbon percentage in the three soil fractions (macroaggregates: 250–2000 µm; microaggregates; 53–250 µm and silt + clay: < 53 µm) under each dairy farm management (IP: intensive conventional production, EP: extensive conventional production and OP: organic production). Different lowercase letters indicate significant differences between types of dairy farm management in each soil fraction while different uppercase letters indicate significant differences between soil fractions in each type of dairy farm management.

4. Conclusion

Organic dairy farms increase the carbon associated with the smallest soil aggregate fractions, being this carbon maintained in the soil in the long-term. Therefore, in regions with edaphoclimatic conditions similar to those of Galicia conventional dairy farms could be adapted to organic production because the organic dairy farms produce healthy dairy products without the use of pesticides, synthetic fertilizers or antibiotics at the same time that the effect of climate change is mitigated.

Acknowledgments

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