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Sustainable crop management through the use of biochar and manure based biofertilizers

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Abstract. The application of biochar to soil can contribute to reducing climate change through the development of the bioeconomy. However, biochar does not provide adequate amounts of nitrogen to the soil. Therefore, it is necessary to develop biofertilizers based on a mixture of biochar with a residual source rich in nitrogen such as manure from dairy farms. In this context, it is important to be aware that in Galicia (NW Spain) manure is very abundant because this region produces 40% of the raw milk from Spain. Moreover, these new biofertilizers could also be enriched with inoculums to improve soil health. BIOFER-CC is a Spanish project with the main aim to develop a crop-targeted biofertilizer based on the mix of commercial biochar with manure to sustainable improve soil health and enhance soil carbon sequestration while increasing crop production in annual (maize and pasture) and permanent crops (vineyard and chestnut trees) of high interest in the Galician region. BIOFER-CC includes a characterization of different commercial biochar and manure that will be used to prepare biofertilizers based on biochar and manure. The biofertilizers with the best properties will be tested on annual and perennial crops under greenhouse conditions to then be evaluated in the field. The biofertilizers will also be analyzed from a sustainable perspective that includes economic analysis (cost/benefit analysis), environmental (life cycle analysis (LCA) and carbon footprint) and social analysis (social LCA).

Keywords: climate change, bioeconomy, soil fertility, dairy farms, maize, pasture, vineyard, chestnut trees

1. Introduction

Climate change is one of the greatest risks that farmers have to face in Europe and worldwide, as crops and livestock are negatively impacted by rapid and steady global warming and also by the increased frequency of extreme climate events that harm the quantity, quality and stability of food production as recognized by the Green Deal and the different EU strategies. The main cause of climate change is the rapid increase of man-made Greenhouse Gas (GHG) emissions that are partly linked to agricultural activities. The agricultural sector is responsible for 10.3% of the EU´s total GHG emissions (EEA 2019) despite having declined by 20% between 1990 and 2015.

There is a large number of possible farm management practices that can potentially reduce GHG emissions by agriculture below current levels. These measures vary in cost-effectiveness and practicality, being optimization of fertilizer application rates, afforestation, and the use of soil amendments like biochar some of them.

The application of biochar to the soil is one of the “negative emissions technologies” (Intergovernmental Panel on Climate Change (IPCC 2019) 1.5SR). Moreover, the use of biochar has been recently approved as one of the amendments/fertilizer allowed for organic farming and it is mentioned in the last biofertilizer EU regulation 2019/1009. Biochar is an excellent organic amendment for the soil increasing the organic matter content of the soil, reducing the negative impact of the aluminium in very acidic soils like the Galician soils (NW Spain) and providing a fertilizer potential with slow and fast release of nutrients like nitrogen and phosphorus. However, the biochar does not supply adequate amounts of nitrogen. Therefore, new biofertilizers based on the mix of biochar with a rich nitrogen waste source such as dairy manure can be developed. These new biofertilizers can be also fortified with inoculums to enhance soil health.

BIOFER-CC is a project with the main aim to develop a crop-targeted biofertilizer based on the mix of commercial biochar with manure to sustainable improve soil health and enhance soil carbon sequestration while increasing crop production in annual (maize and pasture) and permanent crops (vineyard and chestnut trees) of high interest in the Galician region.

2. Materials and methods

BIOFER-CC is structured into three blocks and nine tasks, including laboratory, field and sustainability modelling activities (Table 1).

Table 1: Tasks of the BIOFER-CC project.

Block	Tasks
BLOCK I. Commercial biochar and manure characterization and biofertilizer screening	Task 1. Characterization of the commercially available biochar and dairy manure
	Task 2. Elaboration and characterization of the manure-biochar-based biofertilizer
	Task 3. Screening of the biofertilizer performance in greenhouse experiments
BLOCK II. Agronomic assessment. USC	Task 4. Sites characterization and crops establishment
	Task 5. Field monitoring of soil properties
	Task 6. Agronomic potential of the biofertilziers: crop assessment
BLOCK III. Sustainability assessment. USC	Task 7. Economic viability assessment
	Task 8.Carbon-footprint asessment
	Task 9. Social Life Cycle Assessment

2.1. Commercial biochar and manure characterization and biofertilizer screening

The first task aims to characterize the Spanish commercially available biochar and the manure of 100 different dairy cow farms considering their composition. In the second task, the manure-biochar-based biofertilizer based on the 4 best biochars and dairy cow manure selected from the previous task will be developed and characterized to produce two slow and two fast nutrient-release biofertilizer. The best slow and fast-performing biofertilizers obtained will be mixed (under controlled greenhouse conditions) with selected soils with high and low agronomic potential in pots, to characterize their effect on plant growth, nutrient availability for plants, dynamics of nutrient, organic compounds release, and biofertilizer-soil particle interactions (Task 3). For this purpose, a set of treatments cultivated with ryegrass will be performed.

2.2. Agronomic assessment

Field experiments will be developed in agricultural areas with annual (grass and maize in rotation) and perennial crops (vineyard and chestnut). The two biofertilizers selected in Task 2 as the most suitable for each type of crop will be agronomically tested in field conditions (Task 4). In the field, the biofertilizers will be applied to crops with and without inoculum, at different doses (50 and 100 kg N ha^{-1}) and with and without legumes. In Task 5 weather (temperature, precipitation and humidity) and soil (fertility, organic matter composition, footprint, moisture, root profile, microbial functionality and GHG fluxes) properties will be evaluated. The agronomic potential of the applied biofertilizers on crops (physiology of perennial crops, tree growth and crop production) will be also evaluated in Task 6

2.3. Sustainability assessment

In Task 7 the economic assessment will be based on the cost-benefit analysis of the biofertilizer development (Tasks 1 to 4) and the biofertilizer application (Tasks 5 to 6). Different possible supply and value chain scenarios will be discussed in workshops following a multi-actor approach methodology. A SWOT analysis of the modelled business plan and business environment will be elaborated and validated in the workshops. The carbon footprint assessment will be developed based on real and modelled data (Task 8). Finally, in Task 9, the social life cycle assessment (LCA) will be carried out through the development of a focus group that will be key to developing and validating the previous task results and understanding the main social benefits and challenges linked to the use of manure-biochar-based biofertilizer.

3. Results and discussion

BIOFER-CC will contribute to alleviate the existing important problems of agroindustry waste disposal and the shortcomings of fertilizers causing price rise challenges, through the development of one of the types of biofertilizers promoted in the EU biofertilizer regulation (EU 2019/1009) and the recently approved Royal Decree 1051/2022. The biofertilizer based on wastes (commercial biochars and manure) when adequately produced will provide nutrients and amend soils while enhancing soil health and agronomic productivity. However, there are currently many uncertainties around the effect of the biofertilizers based on the biochar matrix applied under real and local conditions in the Atlantic region of Spain, where just a very few number experiments were carried out at a laboratory scale. BIOFER-CC will contribute to closing this knowledge gap. Moreover, BIOFER-CC will also promote the benefits of biofertilizers by the addition of bioactive inoculum in soils and by testing the use of legumes in fields.

4. Conclusion

BIOFER-CC will provide a biofertilizer based on the mix of commercial biochar with manure to sustainably improve soil health, and enhance carbon sequestration while increasing crop production in annual and permanent crops of high interest in the region of Galicia.

5. Acknowledgements

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