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Potential of C storage and GHG emissions of cover crops optimisation strategies designed with stakeholders in three French agricultural regions.

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1. Introduction

Understanding the multifunctional role of soil in ecosystem functioning is crucial, and soil scientists have recently given more importance to quantifying the contribution of soils to climate change mitigation (Ellili et al., 2019), particularly in agricultural systems. Increasing SOC storage and reducing GHG emissions is the main objective of the 4 p 1000 initiative, which incites to introduce cover crops and optimizing agriculture system designs (Pellerin et al., 2019). To this end, several tools have emerged but no one explicitly assesses the spatial effect of alternative agricultural practices in small agricultural regions (Colomb et al., 2013). This scale allows considering interactions between SOC dynamics and natural and anthropogenic processes.

ABC'Terre approach has been designed since 2013 for that purpose and from 2018 to 2020 have been tested in several French agricultural regions. ABC'Terre approach consists in several steps aiming to support participatory cropping system design: 1) modelling ongoing crop rotations per soil and farm types in a region using the RPG Explorer tool (Levavasseur et al., 2016); 2) affect the carbon content to each soil type (Scheurer et al., forthcoming); 3) affect the crop management practices in each crop rotation x soil x farm types using expert local knowledge and decision rules; 4) assess the long term C stock dynamics using the AMG model (Clivot et al., 2019); 5) assess the GHG emissions per cropping system (Delesalle et al., 2019). The aim of this paper is to present the results of an ex-ante assessment of the effect of cover crops optimisation on C storage and GHG emissions in three French agricultural regions, different for climate, cropping systems and soil types.

2. Materials and Methods

The French agricultural regions were the Saint-Quentinois-Vermandois, the Ternois and the Thouarsais, located respectively in Northern and Central-Western France (Table 1). The method was in two steps. Firstly, in each region, 3 to 5 participatory workshops have been organised with farmers under the supervision of local advisors from the agricultural chambers to co-design less emitting practices. In all the three regions, cover crops were targeted during co-design as cover crops management is a common issue at stake, resulting in a total of 9 different cover crop optimisation strategies (Table 1). Secondly, an ex-ante assessment was performed of the impact of these strategies on C storage and GHG emissions using the ABC'Terre approach.

Table 1. Main characteristics of the three case studies and of the cover crops optimisation strategies co-designed. Sn indicates each cover crop optimisation strategy, SQV, Ten and Th designate the three regions. (*of agricultural area)

<table>
<tr><th>Case study region (% UAA, ha)</th><th>Main crops</th><th>Soil types</th><th>Average C stocks* (tC/ha)</th><th colspan="12">Cover crop optimisation strategies</th></tr>
<tr><td>Saint-Quentinois -Vermandois (59%, 44 kha)</td><td>Cereals, industrial crops (sugar beet, potato, vegetables)</td><td>Deep silty loams and chalky soils</td><td>47.0</td><td colspan="3">In silty loams: Increasing of the mustard biomass (from 2 to 3 t/ha), early destruction (SQV-S1)</td><td colspan="3">In silty loams: increasing of the mustard biomass (from 2 to 3 t/ha), late destruction (SQV-S2)</td><td colspan="3">In silty loams: S1 + vetch/rye after wheat. In chalky soils: adding a vetch/rye mixture after wheat (SQV-S3)</td><td colspan="3">In silty loams: S1 + legume-based mixture after winter cereals (SQV-S4)</td></tr>
<tr><td>Ternois (79%, 50 kha)</td><td>Cereals, industrial crops (sugar beet, potato, flaxseed)</td><td>Mainly deep silty loams</td><td>58.8</td><td colspan="6">Increasing the biomass (from 1.5 t/ha to 3 t/ha), late destruction before spring crops (Te-S1)</td><td colspan="6">S1 + legume-based mixture before spring crops (Te-S2)</td></tr>
<tr><td>Thouarsais (65%, 40 kha)</td><td>Cereals, oil crops (sunflower, soybean)</td><td>Clay loams, heterogene ous shallow soils</td><td>54.6</td><td colspan="4">Optimization of the biomass (from 1 to 2.5 t/ha) before spring crops + 25% of the cover crops between 2 cereals at 1.5 t/ha (Th-S1)</td><td colspan="4">Optimization of the biomass (1 t/ha to 2.5 t/ha) before spring crops + 50% of the cover crops (1.5 t/ha) between 2 winter cereals (Th-S2)</td><td colspan="4">Optimization of the biomass (1 t/ha to 2.5 t/ha) before spring crops + 100% of the cover crops (1.5 t/ha) between 2 winter cereals (Th-S3)</td></tr>
</table>

3. Results and discussion

As presented in Figure 1, in all the co-designed strategies where the cover crops are intensified, GHG gross field emissions but also mitigated emissions thanks to soil carbon storage are higher than in the ongoing situation. Strategies that introduce legume-based mixtures show even more GHG gross field emissions, due to their higher nitrogen soil restitution. When comparing the cover crops optimisation practices among the three regions, we can observe that in the Ternois and Thouarsais, the impact of the strategies designed by the local stakeholders is higher in terms of additional C storage and mitigated emissions. Nevertheless, these two regions have higher initial C stocks. So we can conclude that the local strategies designed have a higher impact on C storage. This can be explained by the fact that cover crop optimisation strategies act on different variables among the three regions, e.g. the part of area under optimisation strategy is lower in the SQV than in the other regions. These differences are also related to the willingness of local stakeholders to test innovative disruptive practices.
The method is data driven and its application is subject to several hypotheses on the initial soil C stock, the spatially-explicit modelling of cropping systems, along with the application of the optimization strategies, e.g. the random selection of the 50% cropping systems where practices have been optimised, questioning the reproducibility and reliability of the results. Thus, it is more reliable to compare the scenarios with the initial situation. Moreover, the uncertainty of the results is more acceptable at territorial level as underlined by Colomb et al. (2013).

4. Conclusion

Cover crops optimisation strategies designed with stakeholders have demonstrated to have a potential to mitigate GHG emissions and increase C storage in agricultural regions. This potential is different according to the management practices developed and their relevance with regards to the cropping system and soil characteristics of the region. The overall method can also support the implementation of local climate action plans in agricultural regions.

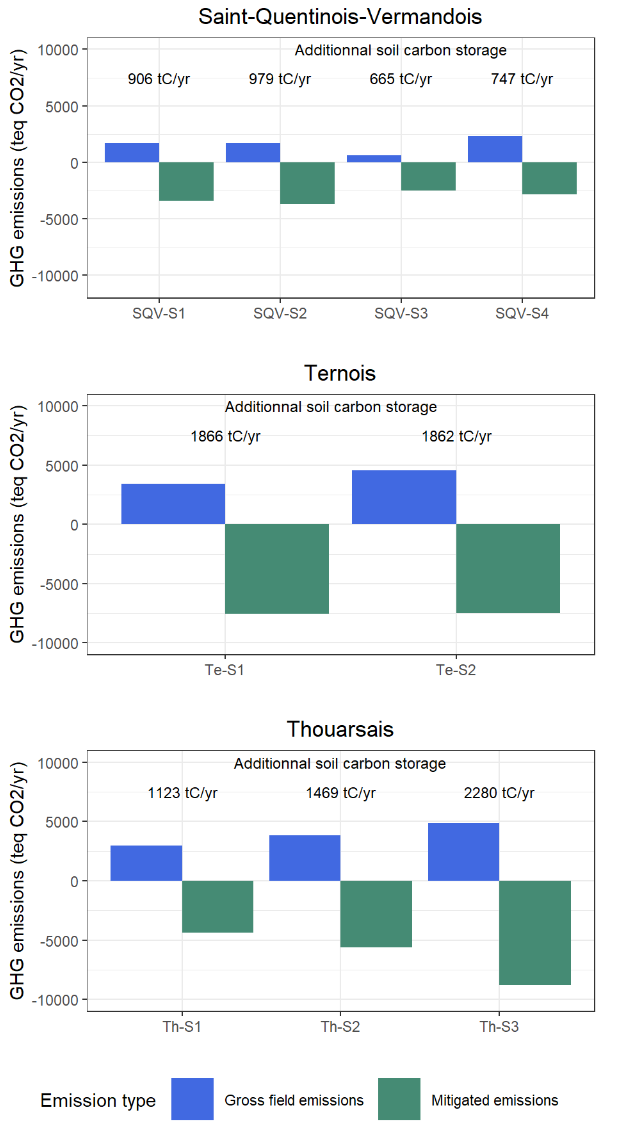

Figure 1: GHG gross field emissions, mitigated emissions and C storage over the three study regions compared to the ongoing situation (teq CO2/yr) for the cover crops optimisation strategy described in Table 1

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