EJP SOIL ΣOMMIT

Policy Brief

APRIL, 2025

Trade-offs between carbon sequestration in agricultural soils and non-CO_2 emissions

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- Efforts to increase C sequestration in agricultural soils might be offset by non-CO_2 emissions
- Strategies promoting synergetic mitigation effects should be promoted
- Strategies' ~~I~~impacts depend on pedo-climatic conditions and long-term data are needed
- Trade-offs evaluation tools are useful to identify the best strategies

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INTRODUCTION

The agricultural sector is the largest global contributor to anthropogenic non-CO_2 greenhouse gas (GHGs) emissions, mainly ~~due to~~ methane (CH_4) deriving ~~emissions~~ from livestock and rice cultivation, and nitrous oxide (N_2O) ~~emissions~~ from fertilized soils. Although the absolute quantities of CH_4 and N_2O emitted by soils are smaller ~~compared with~~ thant ~~of~~ CO_2, the global warming potential (GWP) of these two gases is~~are~~ respectively 34 and 298 times ~~greater~~ higher than CO_2. For this reason, to be effective, strategies for climate change mitigation in the agricultural sector should consider both the effects on organic C sequestration in soil (SOC) and those on non-CO_2 emissions. In fact, even small increases in their fluxes could potentially hamper climate change mitigation efforts (trade-offs).

In this policy brief, we convey the lessons learned on this topic from ΣOMMIT, an integrated and interdisciplinary research project funded by EJP Soil (Figure 1). The effectiveness of soil management strategies in optimizing the trade-off between C sequestration in soil and the N_2O emissions was evaluated for representative European pedo-climatic conditions, along a transect including Mediterranean, Continental, Alpine, Atlantic and Boreal environmental zones. Strategies related to cropping systems, tillage, irrigation, nitrogen (N) and organic matter (OM) inputs were explored through a multidisciplinary approach, including long-term field experiments, laboratory in-depth analysis, meta-analysis, modeling and upscaling.

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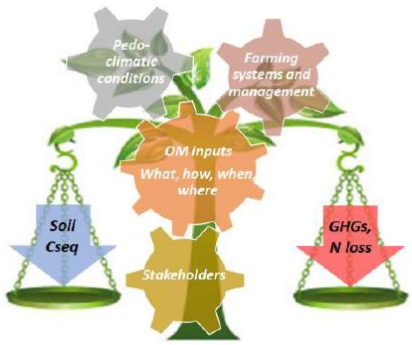

Figure 1 / © ΣOMMIT integrated and interdisciplinary research approach.

Moreover, stakeholders were involved through surveys and open days to evaluate the strengths and limitations of soil management strategies in specific contexts.

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KEY MESSAGES FOR POLICY MAKERS

Recommendation One:

Promote soil management strategies that simultaneously enhance carbon sequestration and reduce non-CO_2 greenhouse gas emissions, creating a "**win-win**" scenario with synergistic benefits for climate change mitigation. Examples of such strategies include: i) replacing mineral nitrogen fertilizers with organic alternatives, such as compost, applied at optimal rates, ii) reduced tillage practices, iii) adoption of cover crops, and iv) agroforestry techniques.

Recommendation Two:

The varied responses to fertilization strategies, which have been observed at different long-term research sites, suggest that agricultural mitigation measures need to consider **land-use** patterns tailored to **local soil type and climate**. For a comprehensive understanding of the impact of soil management strategies at the European level, a more concerted use of existing **long-term field experiments** (LTEs) and the installation of new ones in different pedo-climatic European regions are essential factors.

Recommendation Three:

The European Union-level policy approach currently under development (i.e., the Union certification framework for permanent carbon removals, carbon farming and carbon storage in products~~EU Regulation 2024/3012~~) should take into account the impact of agricultural management practices on C sequestration in soil while considering the ~~resulting~~ associated trade-offs in **CH_4 and N_2O emissions**. Evidence-based decisions and robust scenario planning could be supported by the use of a novel composite trade-off evaluation system (the SOMMIT index) freely available online.

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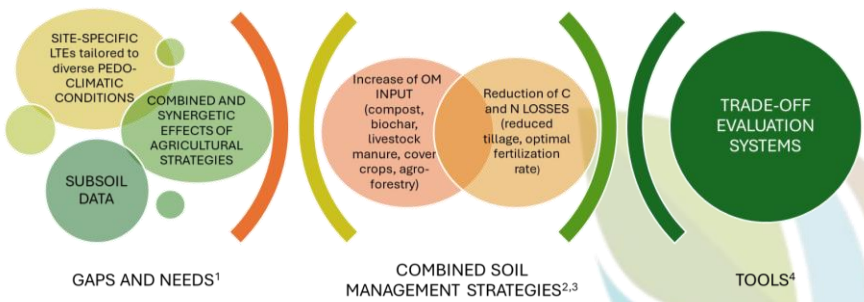

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Figure 2 / © Conceptual scheme of ΣOMMIT methodology and trade-off evaluation system.

SUPPORTING POLICY

The EU Regulation 2024/3012 establishes, for the agricultural sector, a Union certification framework for **temporary carbon removals** achieved by the application of sustainable management practices (***Carbon farming, CF***). In the art. 4, it is stated that the quantification methodology of temporary net carbon removals accounts also for the increase/decrease in **direct and indirect** ~~**greenhouse gas** (~~**GHG** emissions, i.e., CO_2 and ~~**N_20**~~**N_2O**,~~)~~ ~~emissions~~ deriving from the CF activity (e.g., fuel for agricultural practices, land use change, fertilisers).

More detailed methodologies for carbon removals quantification, for each agricultural practice, will be described in the **delegated acts** of the Regulation that are expected to be issued at the end of 2025. The present policy brief may contribute to the ongoing discussion about the above-mentioned delegated acts.

METHODOLOGY

The ΣOMMIT results were obtained based on the following methodology (Figure 2):

1. Identification of the knowledge gaps in trade-off analyses.
2. Compilation, synthesis and meta-analysis of available data.
3. Set up of targeted measurements through LTEs.
4. Modelling and upscaling.
5. Developing a composite trade-off evaluation system (the ΣOMMIT index).
6. ~~Involv~~Involvement of~~e~~ experts' opinion in the evaluation system.

KEY RESULTS

The literature review concluded that more **dedicated research** is needed for the soil management strategies that simultaneously examines SOC stocks, GHG emissions, and N losses by leaching. Furthermore, we identified a lack of information on the impact of pedoclimatic conditions, specifically on the longer-term, on trade-offs and synergies. Moreover, since soil management strategies are often **combined** and their interaction may affect the trade-offs and synergies, the impact of different soil management practices should be assessed simultaneously.

The identification of optimal agricultural management strategies that balance trade-offs among **SOC** changes, **N_2O** emissions, **nitrate** leaching, and crop **yield** can be supported by ~~T~~the ~~ΣOMMIT project designed a trade-off evaluation system, the~~ **ΣOMMIT index** (Figure 3)~~ to identify optimal agricultural management strategies, by balancing trade-offs among **SOC** changes, **N_2O** emissions, **nitrate** leaching, and crop **yield**~~. The index is suited for capturing the **complexities** of agricultural systems, characterized by ~~interdependencies among~~ multiple interacting factors. A dashboard ~~has~~ is freely available ~~been released~~ at https://github.com/kofm/sommit-dashboard. ~~where u~~Users can filter environmental parameters (e.g., moisture and temperature regimes, soil class and texture) and key management variables

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(e.g., N inputs, OM management and crop types), to explore targeted **agronomic scenarios** and perform **what-if** analyses. The filtered scenarios appear as a cloud of points, with color intensity reflecting the ΣOMMIT index value, while a side panel provides detailed information on each selected case. Graduate bars show each performance metric - SOC change, N_2O emissions, nitrate leaching and crop yield. This visual format makes the trade-off analysis easy to interpret, allowing users to quickly identify patterns and similarities between scenarios. The tool also allows users to switch between different narrative perspectives and priorities, from a farmer-centered approach to an EU policy agency view. ~~By allowing side-by-side comparisons of filtered cases and clearly highlighting synergies and trade-offs, the dashboard can help policymakers make evidence-based decisions and robust scenario planning.~~

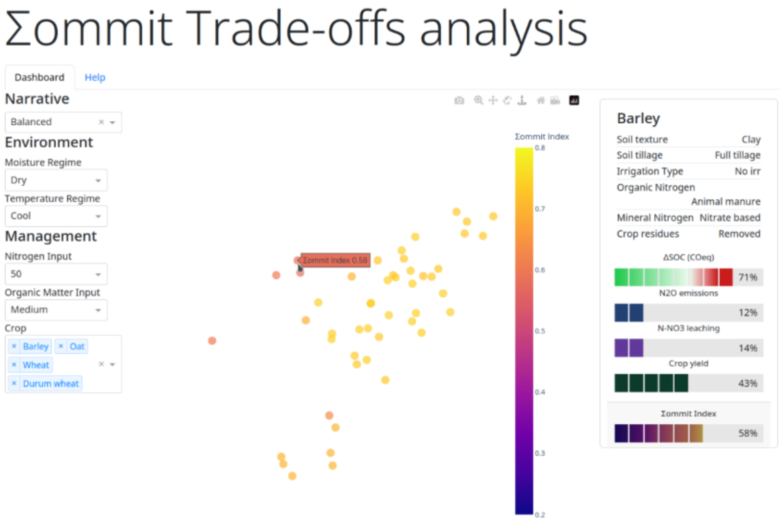

Figure 3 / Example of dashboard output of the ΣOMMIT index, available at GitHub - kofm/sommit-dashboard. Colour intensity reflects the ΣOMMIT index value: lighter shades indicate better performing cases.

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