CAPTURE - Evaluating Cover Cropping as a Climate Action Strategy in Norwegian Cereal Production: Impact on Soil Organic Matter Fractions and N_2O Emissions

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Background and Main Objective

In the 1990s, Norway implemented the use of cover crops to mitigate the loss of nitrogen and phosphorous from fields into waterways. The extent of cover crop adoption has been closely tied to subsidy levels. In 2002, it reached its peak at 35,000 hectares but has since dwindled significantly and currently stands at only 1/10 of that amount. There is potential for expansion, with an estimated capacity of 80,000 hectares.

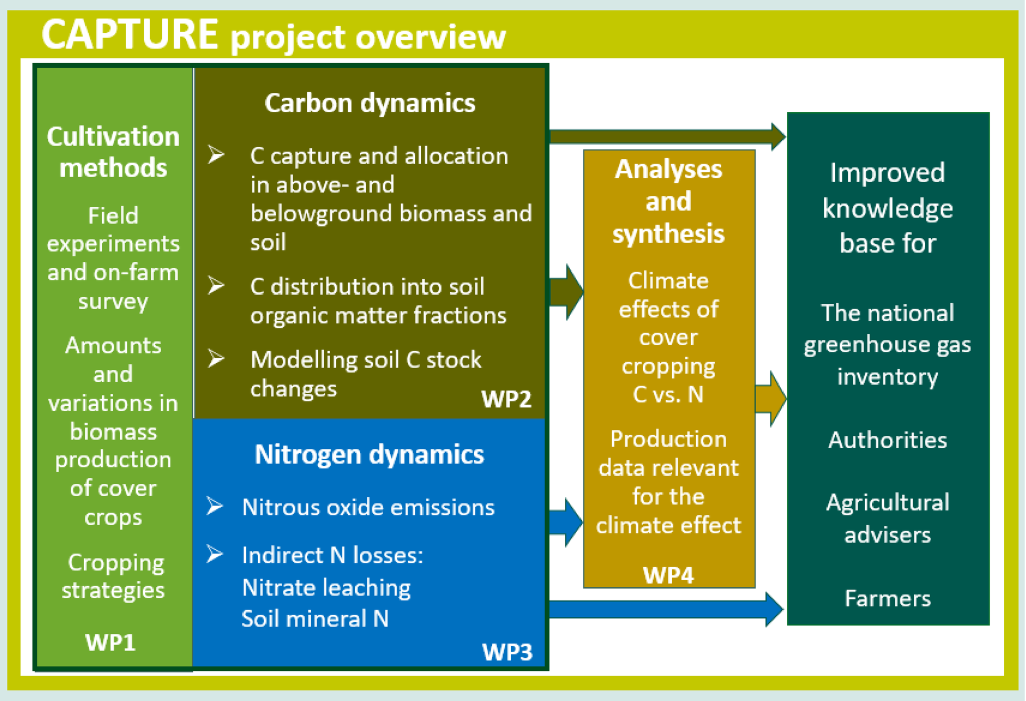

Fig.1. CAPTURE project structure and work packages.

In CAPTURE, we are assessing the net climate effect of various cover crops in Norway's primary cereal-producing regions **(Fig.1)**.

Hypotheses

Carbon Dynamics

- Cover crops significantly increase soil C in Norwegian cereal cropping systems on the short-term
- Cover crop species characterized by a low C/N ratio will facilitate a more effective accumulation of carbon within the mineral-associated organic matter (MAOM) fraction
- Cover crop species with higher root-to-shoot ratios (R/S ratio) will increase the carbon allocation to MAOM

Nitrogen Dynamics

- Cover crop species with low C/N ratios and species with high above-ground biomass are more prone to off-season nitrogen losses
- Fertilizing in the autumn accelerates cover crop growth and carbon capture but triggers additional N_2O emissions immediately after application
- Compared with the annuals, mixtures with both annual and perennial species retain nitrogen better than those with only annuals.

Experimental setup and methods

The experimental field is located in Ås, Southeast Norway (59°39'49''N; 10°45'40''E; Artificially drained Umbric Epistagnic Retisol), a region known for its cereal production. Here, we've set up dedicated plots, to study the impact of cover crops on a) carbon sequestration and b) N_2O emissions, next to each other.

Carbon sequestration – 13C Pulse labelling of cover crops

The study of soil carbon sequestration potential focuses on four species, namely Italian ryegrass [IR] (high R/S, C/N ratio), phacelia [PH], oilseed radish [OR] and summer vetch [SV] (low C/N ratio). They were grown in monoculture (in 4 replicates), and were pulse labelled (5-6 pulses) with $^{13}CO_2$ during the growing season (Fig.2).

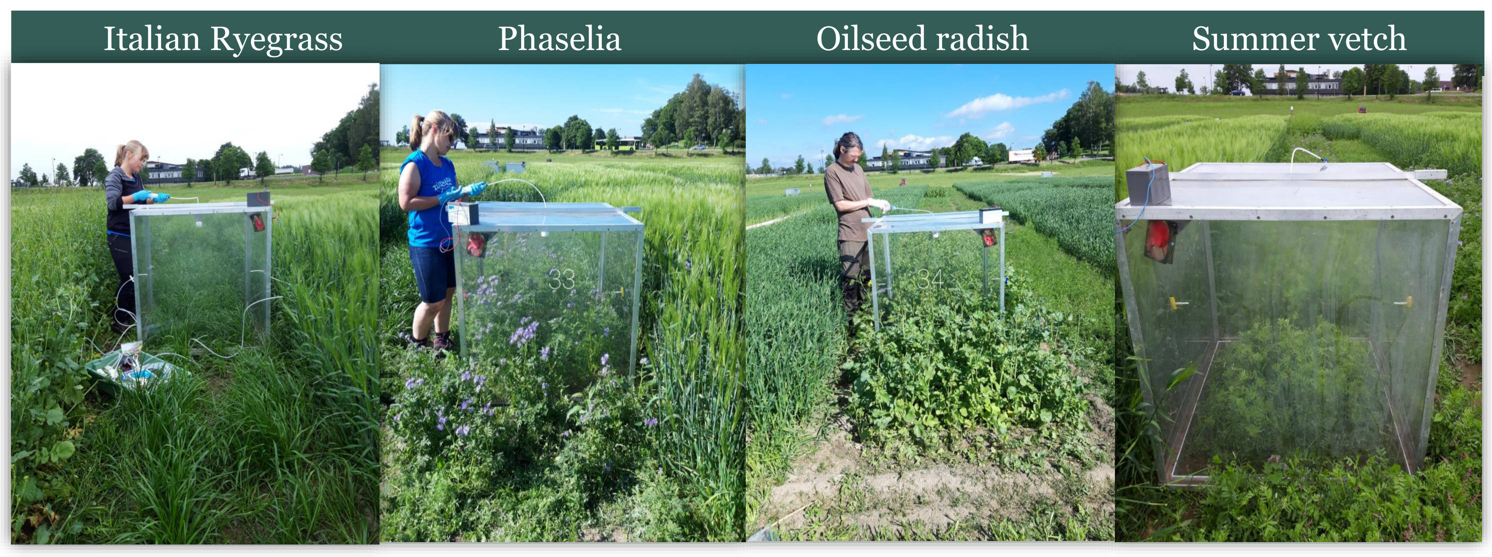

Fig.2. ^{13}C-pulse labelling events with 1 m^3 transparent chambers (summer 2021)

At the end of the growing season, plants and soil were sampled to analyze how the ^{13}C was allocated, not only in the plants and the bulk soil but also in the particulate organic matter (POM) fraction and in the mineral organic matter fraction (MAOM) of the soil (Fig.3).

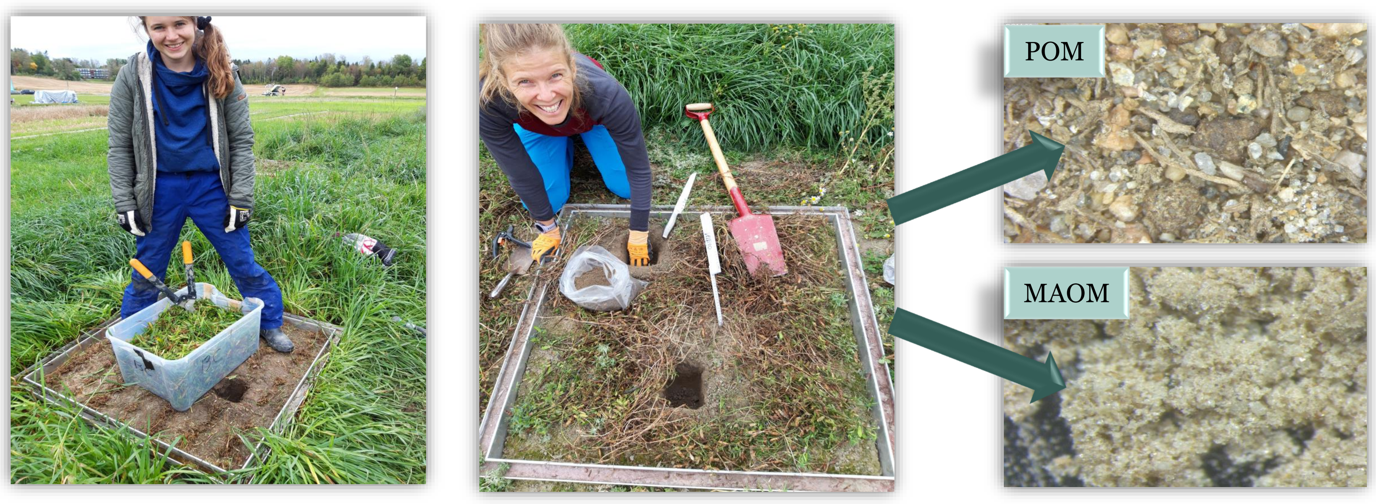

Fig.3. Plant and soil sampling at the end of the growing season of 2021, POM and MAOM fractions.

Carbon persistence – Reciprocal study

After the harvest in 2021, the above-ground biomass of the pulse-labeled plots and the control, natural abundance plots were exchanged and incorporated into the top layer of the soil. This allows us to follow the fate and decomposition of the shoot and root-derived C in the later years. The consecutive soil samplings of 2022 and 2023 (autumn) help us to study the C persistence of the root and shoot of the various cover crops.

N_2O emissions

On the neighboring plots, barley was planted in the spring (2021) followed by the sowing of cover crops in the summer according to the common agricultural practices.

Here, N_2O emissions were measured at least weekly by manual chambers and by a field flux robot after the harvest of barley (Fig.4).

Fig.4 *N_2O measurements with manual chambers (left) or robot (right)*

Preliminary results

C allocation

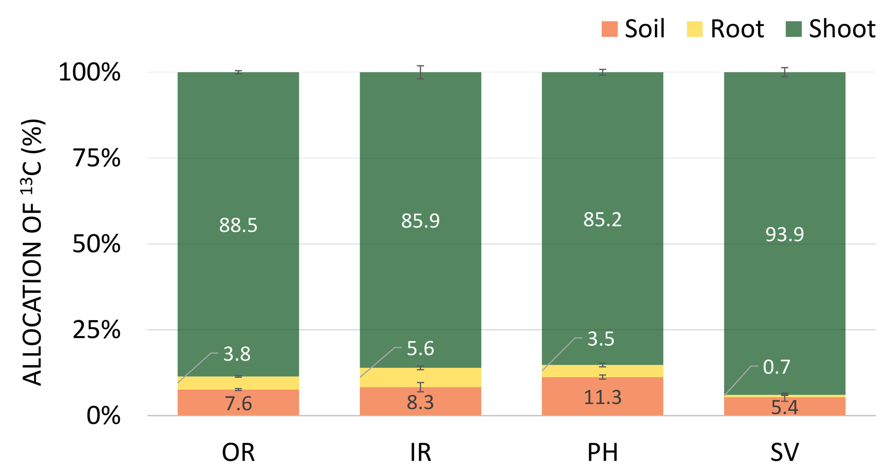

Fig.5. Allocation of 13C to different plant fractions and soil.

From the results of the harvest of 2021, we see that all of the examined cover crops allocated the majority of the C to the aboveground biomass, and less to the roots and exudates. PH had the highest, and SV had the lowest ^{13}C percentage in the total belowground fractions (Fig.5).

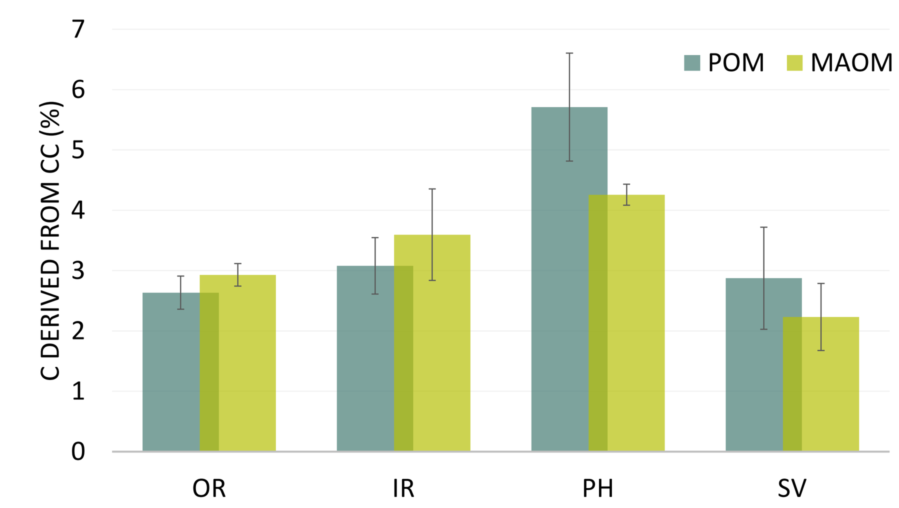

Fig.6. ^{13}C pools in the different soil organic matter fractions

As expected, at the end of the 2021 growing season the POM fraction was more enriched in 13C than the MAOM. However, when comparing the actual C derived from the cover crops, we see it varies from species to species, with the highest percentage for both fractions in the case of PH (Fig.6).

C persistence

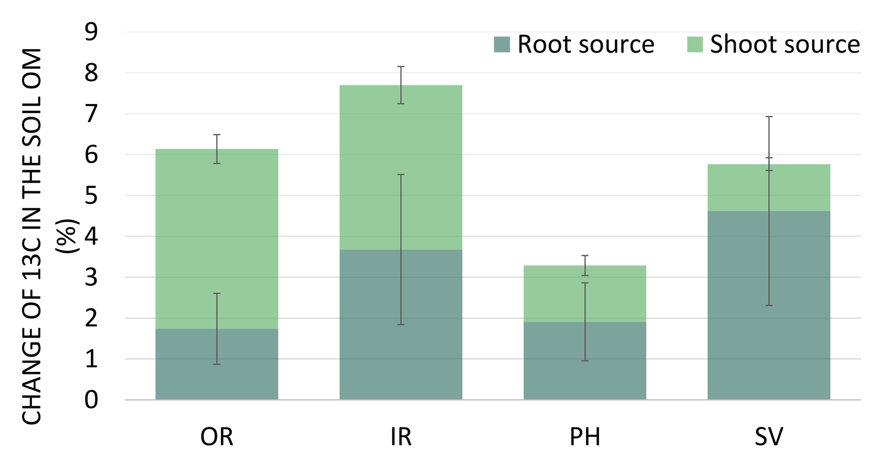

Fig.7. Persistence of 13C as a function of root or shoot source

With the two-pool model, we can calculate the change in 13C in the soil organic matter in relation to our reference plot. After one year (in 2022), the largest share of root-derived carbon was found in the soils grown with SV, while for shoot-originated carbon, the largest share was found in the case of OR. (Fig.7).

N_2O emissions

The highest N2O emissions were measured during freezing-thawing off-season, with clear effects of cover crop type. Due to the high variation in fluxes over the course of the year, it is difficult to estimate an annual emission budget (Fig.8).

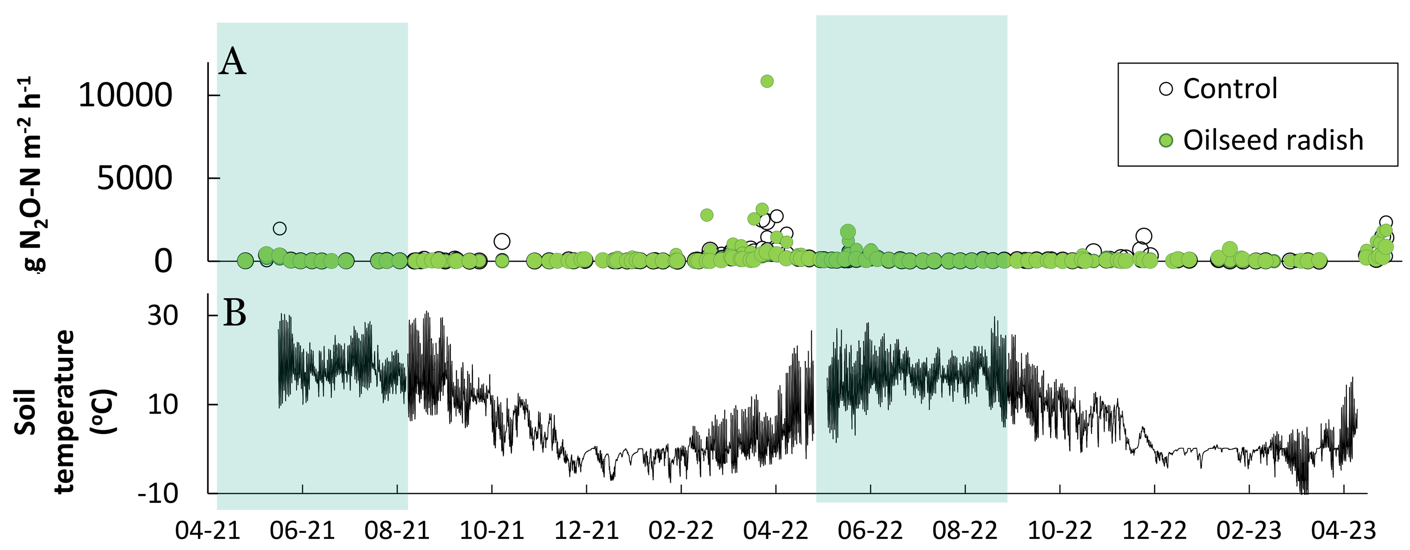

Fig.8. A: Daily averages of N_2O fluxes measured. B: Average soil temperature at 2 cm depth measured in control plots. Colored area represents the growing season of barley

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