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Muhammad, I., Sainju, U.M., Zhao, F., (...), Fu, X., Wang, J. 2019 Regulation of soil CO₂ and N₂O emissions by cover crops: A meta-analysis Soil and Tillage Research 192, pp. 103-112 10.1016/j.still.2019.04.020

Background and objective

Cover crops provide multiple agronomic and environmental benefits, such as enhanced soil carbon sequestration, aggregation, water infiltration, and reduced erosion and nutrient leaching compared with no cover crop. However, little is known regarding the effect of cover crop species, biomass quality and quantity, and method of residue placement on greenhouse gas (GHG) emissions. The objectives were to: 1) quantify the effect of cover crop characteristics and residue management on CO₂ and N₂O emissions in various regions with different soil and climatic conditions, 2) determine which cover crop management practice can reduce GHG emissions. Here, only results regarding the effect of green manures on GHG emissions are reported.

Search strategy and selection criteria

Peer-reviewed research articles published before June 2017 were searched in Google Scholar and Web of Science with the following keywords and phrases: "nitrous oxide emissions, carbon dioxide emissions, greenhouse gas emissions, cover crop, green manure, or catch crop". Only studies that reported both N₂O and CO₂ emissions, cover crops grown between harvesting and planting of cash crops, and cash crops with similar management practices, such as irrigation, fertilization, and tillage practices were selected for the study. Studies that lack mean values, replications, and standard error or standard deviation of the mean were discarded.

Data and analysis

All graphical results were conducted using GetData graph digitizer 2.26. The authors used a random model MetaWin 2.1 to compute the mean effect size and generate 95% bootstrapped confidence intervals (CIs).

Number of papers	Population	Intervention	Comparator	Outcome	Quality score
48	Arable crops	Cover crops (legume/non-legume; incorporated/surface/removed)	Bare soil with the same treatments than in the intervention	Metric: N ₂ O emission; Effect size: Logarithm of ratio of the considered metrics in the intervention to the considered metrics in the control	62.5

Results

- The response ratios were positive for CO₂ emissions for cover crops, suggesting that cover crops increased CO₂ emissions compared to no cover crops. The CO₂ emissions from legume and non legume cover crops or overall cover crops were similar.
- Cover crop species had variable effect on N₂O emissions. While the overall effect of cover crops was negative in N₂O emissions compared to no cover crop, the emissions was positive and greater with legumes, but negative and lower with non legume cover crops.
- Regarding cover crop residue management, whether placed at the surface or incorporated into the soil, they exhibited positive response ratios, indicating increased CO₂ emissions compared to no cover crop residue. Emissions were greater with incorporated residues than surface placed.
- Compared with no cover crop, N₂O emissions was greater for the incorporated residue, but lower for the surface-placed residue and similar to the removed residue from the soil. As with CO₂ emissions, incorporated residues emitted greater N₂O emissions than surface placed.
- Regression analysis showed that response ratios for CO₂ emissions were positively related to cover crop biomass, suggesting that CO₂ emissions increased with increasing cover crop biomass. Cover crop biomass explained 63% of variability in CO₂ emissions. In contrast, increased cover crop biomass reduced N₂O emissions. Increasing the biomass to 5.0 Mg ha⁻¹, however, had no significant effect on N₂O emissions. Increased C/N ratio of the cover crop residue reduced both CO₂ and N₂O emissions, as RRs decreased polynomially with increased C/N ratio (P < 0.10)

Factors influencing effect sizes

- Cover crop type : Higher N₂O emissions for legume cover crop than for non-legume cover crops and no cover crops.
- Cover crop residue management : Higher emissions of both CO₂ and N₂O with cover crop biomass incorporation into the soil than with surface-placement.

Conclusion

Emissions of CO₂ and N₂O varied with cover crop species, quality and quantity of biomass residue, and method of residue placement in the soil. Cover crops increased CO₂ emissions compared to no cover crop. Legume cover crops emitted more N₂O than non legume or no cover crops, with lower emissions for non legumes than no cover crop.