FARMING PRACTICE
COVER AND CATCH CROPS

IMPACT: CARBON SEQUESTRATION

Reference 4

McClelland, SC; Paustian, K; Schipanski, ME 2021 Management of cover crops in temperate climates influences soil organic carbon stocks: a meta-analysis Ecological applications, 31, 3, e02278 10.1002/eap.2278

Background and objective

Increasing the quantity and quality of plant biomass production in space and time can improve the capacity of agroecosystems to capture and store atmospheric carbon (C) in the soil. Cover cropping is a key practice to increase system net primary productivity (NPP) and increase the quantity of high-quality plant residues available for integration into soil organic matter (SOM). Cover crop management and local environmental conditions, however, influence the magnitude of soil C stock change. The purpose of our study was to quantify the effect of different management, climate, and soil factors on SOC response in cover crop systems. The authors used a comprehensive meta-analysis approach to address the following objectives: (1) estimate cover crop effects on SOC stocks (0–30 cm) in temperate climates; (2) estimate the relative importance of different cover crop management decisions and their interactions on SOC response; and (3) identify important environmental controls on SOC response under cover crops. The authors discuss the implications of our findings for cover crops as a negative emissions technology and how the integration of key management factors into decision support tools could improve confidence in SOC response estimates.

Search strategy and selection criteria

The authors searched the Web of Science and CAB databases for articles containing "cover crop" or "green manure" or "catch crop" AND "greenhouse gas" or "carbon" or "trace gas" or "nitrous oxide" or "methane" or "carbon dioxide." The search in both databases included all papers published until 6 July 2017 (inclusive). After duplication removal, our search yielded 4,280 publications. However, the literature search did not produce a robust data set for the evaluation of soil trace gas emissions response to cover crops. Thus, we only focus on the publications pertaining to soil C. (1) field-based experiments that contained a cover crop treatment or (2) outside the scope of the review. Publications included in the first category were from peer-reviewed journals that contained original data from field experiments. These publications included a cover crop (or catch crop or green manure) treatment. Studies in the first category also met the following criteria: 1. The cover crop was not harvested and was grown during fallow periods between cash crops, or, in the case of orchard and vineyard systems, in the rows between trees/vines. 2. The control treatment was (a) a treatment with no cover crop (fallow) or (b) a management system with no cover crop. 3. All other management practices between the treatment and control were similar, e.g., tillage, cash crop rotation, soil amendments. However, there were a few cases where tillage was done in the control and not the experimental treatments to maintain bare ground. We included these studies in our analyses. 4. The experiment occurred in a country within temperate latitude zones, i.e., latitudes from 23.5° to 66.5° north and south of the equator. 5. The response variable or variables measured was soil organic C or soil organic matter. 6. Means and sample size were reported for each treatment. 7. The publication included enough management details and data to be recorded. The authors excluded studies that did not meet the criteria above. Other studies in the second category included publication types such as book chapters and fact sheets. We also omitted publications where the cover crop was grown and sampled in a lab or greenhouse including incubation, mesocosm, or pot experiments.

Data and analysis

The inclusion of multiple effect sizes from the same study often with the same no cover crop control introduces dependency among effect sizes. Non-independent effect sizes violate the traditional independency assumption of univariate meta-analyses (Rosenthal 1984). To account for the dependency of effect sizes, we applied a multivariate approach using the rma.mv function in the metafor package (Viechtbauer 2010). A three-level structure meta-analytic model accounts for three different levels of variance in the model: sampling variance of individual effect sizes, variance between effect sizes from the same study, and, finally, variance between studies (Assink and Wibbelink 2016). Models fit with this function are superior to linear mixed-effect model approaches because traditional linear mixed-effect models mix additive and multiplicative variance components, whereas meta-regression models use additive variance components (Thompson and Sharp 1999, Viechtbauer 2010). We also applied the Knapp and Hartung (2003) adjustment to each of the models.

Number of papers	Population	Intervention	Comparator	Outcome	Quality score
40	Annual and perennial cropping systems	Cover crops	No cover crop	Metric: Soil organic carbon stock (within 30 cm depth); Effect size: Logarithm of ratio of the considered metrics in the intervention to the considered metrics in the control	87.5

Results

- Across the entire data set, cover crops demonstrated a strong, positive effect on SOC stock from 0 to 30 cm. The average relative increase of SOC stocks under cover crops was 12% (95% CI 7–16%), which is equal to an average increase in SOC under cover crops of 1.11 Mg C/ha (95% CI 1.07–1.16).
- SOC response under high cover crop biomass production (>7 Mg·ha−1·yr−1) was 30%, which was almost 20% greater than low (12%) or moderate (11%) cover crop biomass production.
- Grasses and mixtures had strong positive effects on SOC when grown as a continuous cover rather than as an overwinter or summer cover crop, respectively. The effect of legume cover crops on SOC response was greater under fall, summer, and continuous cover growing windows relative to overwinter.
- "Time since introduction" of a cover crop was a poor predictor of SOC response even after controlling for outliers (P = 0.23; marginal R2 = 0.004 and conditional R2 = 0.083). Thus, we were unable to make a robust estimate of the average annual SOC stock change from 0 to 30 cm under cover crops. A simple calculation dividing the overall mean (1.11 Mg C/ha) by the average time since introduction across the observations in the data set (5.2 yr) indicates an average annual SOC stock change of 0.21 Mg C·ha−1·yr−1 (95% CI 0.20–0.22). While not robust, this estimate provides a general indication of the expected annual SOC stock change with cover crops.
- NULL

Factors influencing effect sizes

- Growing window : Cover crop planting and termination date, i.e., growing window, was the most significant predictor of SOC response across all the individual moderators ($P = 0.003$). Continuous cover and autumn planted and terminated cover crops exhibited the highest influence on SOC response (36% and 27%, respectively) relative to overwintering (8%) and summer cover crops (7%).
- Cover crop biomass production : SOC response under high cover crop biomass production (>7 $Mg \cdot ha^{-1} \cdot yr^{-1}$) was 30%, which was almost 20% greater than low (12%) or moderate (11%) cover crop biomass production.
- Rotation type : Perennial crop rotations (35% increase in SOC) had 27% and 23% higher SOC response to cover cropping relative to both continuous annual and multi-crop annual systems
- Tillage : Systems managed with no-till had higher mean percent change than conventional tillage (16% vs. 9%, respectively), but there were no differences between no-till and reduced tillage or conventional tillage and reduced tillage
- Soil texture : Higher clay content soils (≥20% clay) demonstrated greater SOC response relative to lower (<20%) clay content soils ($P = 0.009$

Conclusion

Across the entire data set, cover crops demonstrated a strong, positive effect on SOC stock from 0 to 30 cm.