IMPACT: CARBON SEQUESTRATION

Reference 25

Gattinger A; Muller A; Haeni M; Skinner C; Fliessbach A; Buchmann N; Mäder P; Stolze M; Smith P; El-Hage Scialabba N; Niggli U. 2012 Enhanced top soil carbon stocks under organic farming PNAS 109 (44), 18226-18231. 10.1073/pnas.1209429109

Background and objective

It has been suggested that conversion to organic farming contributes to soil carbon sequestration, but until now a comprehensive quantitative assessment has been lacking The objectives were to test whether adoption of organic farming resulted in (i) an increase in overall SOC concentration, (ii) an increase in overall SOC stocks, and (iii) higher SOC accumulation over time (= C sequestration rates) compared with nonorganic management. Using metaregression, the effects of climatic conditions, soil characteristics, duration of contrasting farming management, external C and N inputs, and land use type modulated on the responses of SOC to the adoption of organic farming practices were investigated.

Search strategy and selection criteria

The majority of the collected research papers were published in scientific journals, but we also included eligible studies from conference proceedings, book chapters, and dissertations to enlarge the dataset, because those contributions also undergo a peer-review process. Data from pairwise comparisons on organic and nonorganic farming systems from peer-reviewed research papers that reported measured data on SOC concentrations, SOC stocks, and C sequestration rates. Following qualifying criteria to include studies: 1) the relevant organic farming principles were applied for at least 3 consecutive years; 2) pairwise farming system comparisons: organic and nonorganic farming management was performed under the same pedo-climatic conditions.

Data and analysis

We extracted the mean, SD, or significance level (P value) and sample size (n) of SOC data in each experiment for weighing the response of SOC change by variation (SD) and sample sizes (n). Where we could neither extract nor calculate SD from SEs, we reassigned the SD as 1/10 of the mean. A randomeffects metaanalysis was performed using the restricted maximum likelihood estimator using the Knapp-Hartung adjustment to account for the uncertainty in the estimate of (residual) heterogeneity (34–37). Datasets were analyzed with R Statistical Software using the "metafor" package (37) to calculate the effect sizes and their significance levels (Dataset S1). Metaregression. To investigate potential driver variables of the observed SOC differences, we used a mixed-effects metaregression. This was also run in R using the "metafor" package (37).

Number of papers	Population	Intervention	Comparator	Outcome	Quality score
74	Studies assessing the performance of organic systems in comparison to conventional systems. In study organic systems organic practices were applied for at least three consecutive years prior to sampling.	Organic systems (all systems, mixed farming systems with zero-input from external)	Nonorganic systems (both conventional and integrated systems)	Metric: 1) Soil organic carbon concentration; 2) Soil organic carbon stock; 3) Carbon sequestration rate; Effect size: Mean differences (MD) of SOC concentration, SOC stock, and C sequestration rate between organic and nonorganic systems.	75

Results

- In organically managed soils, SOC concentrations were 0.18 ± 0.06% points (mean ± 95% confidence interval) higher, SOC stocks were 3.50 ± 1.08 Mg C ha−1 higher , and sequestration rates were 0.45 ± 0.21 Mg C ha−1 y−1 higher than in nonorganically managed soils. These differences were all highly significant at P < 0.0001.
- The authors also performed a metaanalysis with our dataset grouped according to duration of farming system comparison (up to 10 y, 10–20 y, more than 20 y). Our results show this time dependency with the highest difference in sequestration rates for the first 10 years of organic management. Differences in sequestration rates are significant for the duration up to 10 y and 10–20 y, whereas differences in concentrations and stocks were always significant.
- To examine the potential impact of imported organic matter, we analyzed a subset of studies representing organic farming systems with zero net input separately. These represent mixed livestock–crop production farms with forage crops in the crop rotation, such that the livestock can be fed entirely from fodder produced on-farm. In such systems, no import of organic matter occurs. In this subset , SOC concentrations were 0.13 ± 0.09% points higher (P < 0.001), SOC stocks were 2.16 ± 1.65 Mg C ha−1 higher (P < 0.01), and C sequestration rates were no longer significantly different from nonorganically managed soils (0.27 ± 0.37 Mg C ha−1 y−1, P > 0.1).
- Taking only the subset also reporting measured bulk densities for the zero net input system trials led to SOC stocks that were not significantly higher under organic management (2.36 ± 2.99 Mg C ha−1), whereas C sequestration rates were 0.14 ± 0.14 Mg C ha−1 y−1 higher (P < 0.05) compared with nonorganic management.
- Taking all three conditions (measured inputs, measured bulk densities and zero net input systems), finally, led to SOC stocks that were 1.98 ± 1.50 Mg C ha−1 higher under organic management (P < 0.01) and sequestration rates that were 0.07 ± 0.08 Mg C ha−1 y−1 higher (P < 0.05).

Factors influencing effect sizes

- External C input : Differences in external C inputs, clay concentrations, mean annual precipitation, and mean annual temperature did influence differences in SOC concentrations and stocks.
- Clay concentrations in soils : Differences in external C inputs, clay concentrations, mean annual precipitation, and mean annual temperature did influence differences in SOC concentrations and stocks.

- Mean annual temperature : Differences in external C inputs, clay concentrations, mean annual precipitation, and mean annual temperature did influence differences in SOC concentrations and stocks.
- Mean annual precipitation : Differences in external C inputs, clay concentrations, mean annual precipitation, and mean annual temperature did influence differences in SOC concentrations and stocks.
- External C inputs : The sign of the influence of external C inputs is positive.

Conclusion

Metaanalysis of all three effect sizes revealed significantly higher SOC concentrations, SOC stocks, and carbon sequestration rates in soils under organic compared with nonorganic farming management.