

SINGLE-IMPACT FICHE – ORGANIC SYSTEMS

IMPACT: CARBON SEQUESTRATION

Data extracted in October 2021

Note to the reader: This fiche summarises the impact of organic systems on CARBON SEQUESTRATION. It is based on 8 peer-reviewed synthesis research papers¹. Each synthesis paper includes a number of individual studies, which ranges in this case from 9 to 102.

1. WEIGHT OF THE EVIDENCE

- **CONSISTENCY OF THE IMPACT:** The effect on CARBON SEQUESTRATION of organic farming systems, as compared to conventional systems are reported as:
 - per unit of area: positive effects were reported for organic systems, with 7 (6 of high quality) synthesis papers for cropping systems and 2 for livestock/mixed systems and. Only one synthesis paper reported no significant effect for livestock/mixed systems. Positive effects are reported for soil organic matter content, soil organic stocks, and soil organic carbon sequestration rate. One meta-analysis reported that, beyond the effects of fertilization intensity, crop residue traits (leaf nitrogen content, leaf dry matter content, fine-root carbon and nitrogen) also play a significant role driving the effects of organic farming on soil organic carbon (SOC) stocks and carbon sequestration rates.
 - Uncertain* results were reported by 2 synthesis papers.
 - per unit of product: no results were available.

All synthesis papers but one include results of experiments conducted in Europe.

Table 1. Summary of effects. The effect with the higher score is marked in bold and the cell coloured. The numbers between parentheses indicate the number of synthesis papers with a quality score of at least 50%. Details on quality criteria can be found in the next section. Some synthesis papers reported effects for more than type of system.

Impact	Metric	Impacts per unit of agricultural land				Impacts per unit of product			
		Positive	Negative	No effect	Uncertain*	Positive	Negative	No effect	Uncertain*
Organic cropping systems									
Increase Carbon sequestration		7 (6)	0	0	2 (1)				
Organic livestock systems									
Increase Carbon sequestration		2 (2)	0	1 (1)	0				

* Number of synthesis papers that report relevant results but without statistical test comparison of the intervention and the control.

- **QUALITY OF THE SYNTHESIS PAPERS:** *The quality score summarises 16 criteria assessing the quality of three main aspects of the synthesis papers: 1) the literature search strategy and studies selection; 2) the statistical analysis; 3) the potential bias. Details on quality criteria can be found in this document [→](#).*

¹ Research synthesis papers include a formal meta-analysis or systematic reviews with some quantitative results

As shown in the “Quality score” in **Table 2**, the quality the 7 synthesis papers retrieved ranged from 63% to 69%. The least frequently satisfied quality criteria were: “Search string”, “Number of studies of each step”, “Individual effect sizes”, “Individual studies weighted”, “Heterogeneity of results analysed” and “Publication bias analysed”.

2. IMPACTS

The main characteristics and results of the 8 synthesis papers¹ are summarized in **Table 2**. The references are ordered chronologically with the most recent publication date first.

Table 2. Main characteristics of the synthesis papers reporting impacts on carbon sequestration. All detailed results of each synthesis study are reported in the summary reports [↗](#).

Reference	Population	Geographical scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
Aguilera, E; Lassaletta, L; Gattinger, A; Gimeno, BS. 2013	Field studies (i.e. excluding laboratory and experimental greenhouse studies) conducted under Mediterranean climatic conditions in croplands (including arable crops, orchards and horticulture, but excluding permanent grassland and forests) assessing the performance of organic systems in comparison to conventional systems. In study organic croplands organic practices were applied for at least three consecutive years prior to sampling.	Global (Mediterranean climate)	79	Organic cropping systems	Conventional systems	SOC content and C sequestration rate.	Carbon sequestration is effectively promoted by organic farming practices in Mediterranean cropped soils. This relative increase of SOC sequestration over conventional practices is more marked in intensive cropping systems, where the difference in carbon inputs are higher.	75%
Garcia-Palacios, P; Gattinger, A; Bracht-Jorgensen, H; Brussaard, L; Carvalho, F; Castro, H; Clement, JC; De Deyn, G; D’Hertefeldt, T; Foulquier, A; Hedlund, K; Lavorel, S; Legay, N; Lori, M; Mader, P; Martinez-Garcia, LB; da Silva, P; Muller, A; Nascimento, E; Reis, F; Symanczik, S;	Long-term studies (at least 3 consecutive years) assessing the performance of organic systems in comparison to conventional systems.	Global	101	Organic systems	Conventional systems	Top soil organic carbon stocks, top soil organic carbon sequestration rates and soil respiration.	Organic farming positive effects on soil respiration, SOC stocks, and SOC sequestration rates were significant, even in organic farms with low manure application rates.	94%

Reference	Population	Geographical scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
Sousa, J; Milla, R. 2018								
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	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.	Global	74	Organic systems (all systems, mixed farming systems with zero-input from external)	Nonorganic systems (both conventional and integrated systems)	SOC concentration, SOC stock, and C sequestration rate	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.	75%
Kopittke, PM; Dalal RC; Finn D; Menzies NW 2016	Long-term studies (minimum 5 years) assessing the performance of organic systems in comparison to conventional systems.	Global	102	Organic systems	Conventional systems	Stock of Organic C in soil (kg m ⁻²)	Organic systems increase soil carbon stock by 8%, compared to conventional systems. However, the result is rated as uncertain, due to the lack of statistical tests.	44%
Mondelaers, K; Aertsens, J; Van Huylenbroeck, G. 2009	Studies assessing the performance of organic systems in comparison to conventional systems.	Global	9	Organic systems	Conventional systems	Organic matter content in soil (%).	Organic matter content in organic plots is significantly higher than in conventional plots.	50%
Smith, OM; Cohen, AL; Rieser, CJ; Davis, AG; Taylor, JM; Adesanya, AW; Jones, MS; Meier, AR; Reganold, JP; Orpet, RJ; Northfield, TD; Crowder, DW 2019	Previous meta-analyses including studies assessing the performance of organic systems in comparison to conventional systems.	Global	9	Organic systems (annual and perennial crops)	Conventional systems	SOC, C stock (kg /ha)	Higher mean soil carbon content in organic systems than in conventional systems. Similar level of variability.	56%
Tuomisto HL; Hodge ID; Riordana P; Macdonald DW 2012	Field studies, modelling studies and Life Cycle Assessment studies of organic systems in comparison to conventional systems in Europe.	Europe	71	Organic systems	Conventional systems	Soil organic matter per unit of area	The results indicate that organic farming generally leads to significantly higher soil organic matter content, but some conventional farming systems do have the potential to	69%

Reference	Population	Geographical scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
							achieve similar or even higher soil organic matter levels when they include the application of manures.	
Ugarte, CM; Kwon, H; Andrews, SS; Wander, MM. 2014	Field-based studies and on-farm research conducted in the continental United States assessing the performance of organic systems in comparison to conventional systems.	Continental USA	55	Organic systems	Conventional systems	Soil organic carbon content	The meta-analysis of studies using shallow sampling methods (0 to 20 cm [0 to 7.8 in]) suggested that organic cropping systems are able to increase SOC relative to that found under conventional monocultures with intensive reliance on external inputs.	44%

3. KNOWLEDGE GAPS

Aguilera, E, 2013	According with this analysis of the available data, C input is the main driver of the changes in SOC produced after the adoption of RMPs. However, information on C input was only provided in 42.2% of the data sets studied, and in most cases this information was incomplete. Thus, usually only the amount of C applied in the external C input was provided, while the internal sources of C were ignored.
Garcia-Palacios, 2018	1)Future studies looking at the role of root residue traits for SOC responses to OF; 2) Studies measuring the dynamics of crop residue decomposition in farms subjected to contrasting management practices are particularly needed; 3) Functional traits of cultivars need to be included in future studies addressing the ecosystem - level implications of intraspecific trait variability in agroecosystems; 4) More research is needed to address whether the influence of farming practices on SOC storage is driven by changes in crop litter lability and/or in microbial carbon use efficiency and community composition.
Gattinger A, 2012	The data mainly cover top soil and temperate zones, whereas only few data from tropical regions and subsoil horizons exist.
Kopittke, PM, 2016	1)The depth of sampling varied widely. These differences in sampling depths would influence the results obtained. 2)the bias of the published literature to report outcomes where significant changes are observed, with studies finding no significant differences less likely to be published.

4. SYSTEMATIC REVIEW SEARCH STRATEGY

Keywords	<p>TOPIC: ("organic farm*" OR "organic agriculture" OR "organic system*" OR "organic product*") AND TOPIC: ("meta-analy*" OR "systematic* review*" OR "evidence map" OR "global synthesis" OR "evidence synthesis" OR "research synthesis")</p> <p>TOPIC: ((organic near/4 farm*) OR (organic near/4 agric*) OR (organic near/4 produc*) OR (organic near/3 livestock) OR (organic near/3 animal)) AND TOPIC: ("animal*" OR "livestock" OR "ruminant*" OR "small ruminant*" OR "cattle" OR "dairy cattle" OR "dairy" OR "beef cattle" OR "sheep" OR "ewe*" OR "lamb*" OR "swine" OR "pig*" OR "porcine*" OR "goat*" OR "rabbit*" OR "poultry" OR "chicken*" OR "broiler*" OR "turkey*" OR "hen*" OR "horse*" OR "mule*" OR "milk" OR "egg" OR "beef" OR "cheese" OR "meat" OR (animal near/2 protein*) OR "yogurt" OR "bacon" OR "pork") AND TOPIC: ("meta-analy*" OR "systematic* review*" OR "evidence map" OR "global synthesis" OR "evidence synthesis" OR "research synthesis")</p>
Search dates	No time restrictions
Databases	Web of Science and Scopus, run for the first time in July 2020 and updated in September 2021 and October 2021.
Selection criteria	<p>Four main criteria led to the exclusion of a synthesis paper: (1) the paper does not deal with organic systems; (2) the paper does not assess the impacts of organic systems in comparison to another cropping system; (3) the paper report results on the effect of specific farming practices (e.g. organic fertilisation, green manure, alternative pest control techniques, etc.) which are part of organic systems, instead of the effect of the whole farming system; (4) the paper is neither a meta-analysis nor a systematic review including quantitative results. Synthesis papers that passed the relevance criteria were subject to critical appraisal carried out on paper-by-paper basis. From the 220 potentially relevant synthesis papers, 140 were excluded after reading the title and abstract, and 50 after reading the full text according to the above-mentioned criteria. Finally, 30 synthesis papers were selected for organic farming systems, from which 8 were relevant for this impact.</p>