SINGLE-IMPACT FICHE
SOIL AMENDMENT WITH BIOCHAR

IMPACT: SOIL ORGANIC CARBON

Data extracted in February 2021

Note to the reader: This fiche summarises the impact of soil amendment with biochar on SOIL ORGANIC CARBON. It is based on 6 peer-reviewed synthesis research papers[1], each of them including from 18 to 65 individual studies.

1.WEIGHT OF THE EVIDENCE

- CONSISTENCY OF THE IMPACT:
  Soil amendment with biochar, compared to no-biochar-amendment, led to a positive effect (increase in Soil organic carbon) in 5 out of 7 results, while 1 result reported no effect and 1 reported uncertain effect. These last results were extracted from 2 meta-analyses targeting native soil organic carbon (i.e. the fraction of C present in soil before biochar amendment) (see **Table 1**).

  From the 6 reviewed synthesis papers, 2 include data collected in Europe and 4 did not specify geographical locations of experiments (see **Table 2**). One meta-analysis reported more than one effect.

Table 1. Summary of effects. The effect with the higher score is marked in bold and the cell coloured. The numbers between parenthesis 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.

Impact	Metric	Positive	Negative	No effect	Uncertain
Increase soil organic carbon		**5 (5)**	0	1 (1)*	1 (1)*

*accounts only for native soil organic carbon (i.e. present in soil before amendment)

- 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* →.

As shown in the "Quality score" in **Table 2**, the quality level ranges from 50% to 94%. The least frequently satisfied quality criteria were "Number of studies at each step", "Individual effect sizes", "Dataset available" and "Publication bias analysed".

2. IMPACTS

The main characteristics and results of the synthesis papers are summarized in **Table 2**. Detailed results of each synthesis study are reported in the summary reports.

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

Table 2. Main characteristics of the synthesis papers reporting impacts of soil amendment with biochar Soil organic carbon. The references are ordered chronologically with the most recent publication date first.

Reference	Population	Geographical scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
Albert, HA; Li, X; Jeyakumar, P; Wei, L; Huang, LX; Huang, Q; Kamran, M; Shaheen, SM; Hou, DY; Rinklebe, J; Liu, ZZ; Wang, HL 2021	Vegetables, grass, legume, maize, wheat, rice, and bamboo.	Global	65	Soil amendment with biochar	No amendment	Soil organic carbon content	Biochar significantly increased soil organic carbon.	75%
Payen FT, Sykes A, Aitkenhead M, Alexander P, Moran D, MacLeod M. Soil organic carbon sequestration rates in vineyard agroecosystems under different soil management practices: A meta-analysis. Journal of Cleaner Production. 2020 Dec 29:125736. 2021	Vineyards	Global	50	Soil amendment with biochar	No amendment	Soil organic carbon (SOC) stocks to a depth of 0.3 m (MgC /ha)	Biochar amendment was associated with a positive SOC stock change, SOC change rate in time and annual SOC sequestration rate, relative to conventional management.	94%
Bai, XX; Huang, YW; Ren, W; Coyne, M; Jacinthe, PA; Tao, B; Hui, DF; Yang, J; Matocha, C 2019	Pot and field experiments	Global	56	Soil amendment with biochar	No amendment	Soil organic carbon stocks (10-30 cm)	On average, biochar applications represented an effective approach for significantly increasing SOC content (39%).	69%
Liu, SW; Zhang, YJ; Zong, YJ; Hu, ZQ; Wu, S; Zhou, J; Jin, YG; Zou, JW 2016	Lab incubations, Pot trials, field trials	Global	50	Soil amendment with biochar	No amendment	Soil organic carbon content	When averaged across all studies, biochar amendment significantly enhanced SOC content by 40%.	75%
Wang, JY; Xiong, ZQ; Kuzyakov, Y 2016	Column, pot and field experiments on rice (paddy soils)	Global	21	Soil amendment with biochar	No amendment	Native soil organic matter, Total soil organic carbon	The authors conclude that priming on native soil organic matter induced by biochar addition is slightly negative, because of the preferential utilization of easily available substrates from incomplete pyrolysis. For all studies, the authors definitely conclude that biochar application has a positive C balance at least within 10 years.	56%

Reference	Population	Geographical scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
Maestrini, B; Nannipieri, P; Abiven, S 2015	Lab incubations, Pot trials, field trials	Global	18	Soil amendment with biochar	No amendment	Priming effect: the increase in CO_2 efflux derived from non-biochar C pool compared to CO_2 efflux in the control treatment (without biochar amendment).	Over 1 year biochar induces an average positive priming effect of 0.3 mg C g-1 soil on native soil organic matter and a priming effect of approximately the same size but opposite direction on fresh organic matter.	50%

3. KNOWLEDGE GAPS

Bai et al., 2019	The authors did not calculate SOC sequestration rates for biochar amendment due to the lack of some ancillary information (e.g., bulk density).
Liu et al., 2016	The authors did not take into consideration the data on environmental and management conditions or the auxiliary data on other soil properties (e.g., soil inorganic C and N) due to lack of relevant information in studies included. The limited range of study durations did not allow us to examine the effect of biochar aging on SOC in this meta-analysis. No studies ran more than 4 years, and only 21% of the observations included in this analysis showed results over a whole growing season with the presence of vegetation cover.
Maestrini et al., 2015	The authors believe that understanding the impact of tillage on priming effects induced by biochar is especially important in the context of biochar application. However this aspect was never investigated in the field.

4. SYSTEMATIC REVIEW SEARCH STRATEGY

Keywords	TOPIC: (biochar OR charcoal OR "black carbon") AND TOPIC: (soil OR agriculture OR farming) AND TOPIC: ("meta-analy*" OR "systematic* review*" OR "evidence map" OR "global synthesis" OR "evidence synthesis" OR "research synthesis") or

	TITLE-ABS-KEY: (biochar OR charcoal OR "black carbon") AND TITLE-ABS-KEY: (soil OR agriculture OR farming) AND TITLE-ABS-KEY: ("meta-analy*" OR "systematic* review*" OR "evidence map" OR "global synthesis" OR "evidence synthesis" OR "research synthesis")
Search dates	No time restrictions
Databases	Web of Science and Scopus, run in February 2021
Selection criteria	The main criteria that led to the exclusion of a synthesis paper were if the paper: 1) does not deal with agronomic application of biochar; 2) does not synthetize pairwise comparisons on the agronomic effect of biochar; 3) the control of the pairwise comparison is not no-biochar; 4) deals with soil application of mineral- or organic-enriched biochar; 5) does not report results with the same fertilisation conditions between intervention and control; 6) is either a simple review, a non-quantitative systematic review, a meta-regressions looking only at factors influences, without mean effect sizes; 7) deals with other than agricultural soils in cropping systems, e.g. forest restoration; 8) is not written in English. Synthesis papers that passed the relevance criteria were subject to critical appraisal carried out on paper-by-paper basis. The search returned 130 synthesis papers potentially relevant for the practice object of our fiche. Searches for other farming practices added another 2 potentially relevant synthesis papers. From the 132 potentially relevant synthesis papers, 57 were excluded after reading the title and abstract, and 34 after reading the full text according to the above-mentioned criteria. Because of the high number of studies available, we only considered the most recent meta-analyses dealing with the impact of soil amendment with biochar on bioavailability and plant uptake of toxic compounds, published since 2015. Finally, 41 synthesis papers were selected for soil amendment with biochar, from which 6 were relevant for this impact.