SINGLE-IMPACT FICHE
SOIL AMENDMENT WITH BIOCHAR

IMPACT: CARBON SEQUESTRATION

Data extracted in February 2021
Fiche created in May 2024

Note to the reader: This fiche summarises the effects of Soil amendment with biochar on CARBON SEQUESTRATION. It is based on 6 synthesis papers[1], including from 18 to 65 primary studies.

1. WEIGHT OF THE EVIDENCE

CONSISTENCY OF THE IMPACT

Soil amendment with biochar, compared to no-biochar-amendment, generally increases soil organic carbon pool (**Table 1**).

The table below shows the number of synthesis papers with statistical tests reporting i) a significant difference between the Intervention and the Comparator, that is to say, a significant statistical effect, which can be positive or negative; or ii) a non-statistically significant difference between the Intervention and the Comparator. In addition, we include, if any, the number of synthesis papers reporting relevant results but without statistical test of the effects. Details on the quality assessment of the synthesis papers can be found in the methodology section of this WIKI.

- Soil amendment with biochar, compared to no-biochar-amendment, led to a significant positive effect (increase in soil organic carbon pool) in 5 out of 7 synthesis papers.
- One result reported non-significant effect and one reported non-statistically tested results. These results were extracted from 2 meta-analyses targeting native soil organic carbon (i.e. the fraction of C present in soil before biochar amendment).

Out of the 6 selected synthesis papers, 3 included studies conducted in Europe (see **Table 2**).

Table 1: Summary of effects. Number of synthesis papers reporting positive, negative or non-statistically significant effects on environmental and climate impacts. The number of synthesis papers reporting relevant results but without statistical test of the effects are also provided. When not all the synthesis papers reporting an effect are of high quality, the number of synthesis papers with a quality score of at least 50% is indicated in parentheses. The reference numbers of the synthesis papers reporting each of the effects are provided in **Table 3**. Some synthesis papers may report effects for more than one impact or more than one effect for the same impact.

				Statistically tested			Non-statistically tested
Impact	Metric	Intervention	Comparator	Significantly positive	Significantly negative	Non-significant	
Increase carbon sequestration	Native SOC	Soil amendment with biochar	No amendment	0	0	1	1
Increase carbon sequestration	Total SOC	Soil amendment with biochar	No amendment	5	0	0	0

QUALITY OF THE SYNTHESIS PAPERS

The quality of each synthesis paper was assessed based on 16 criteria regarding three main aspects: 1) the literature search strategy and primary studies selection; 2) the statistical analysis conducted; and 3) the evaluation of potential bias. We assessed whether authors addressed and reported these criteria. Then, a quality score was calculated as the percentage of these 16 criteria properly addressed and reported in each synthesis paper. Details on quality criteria can be found in the methodology section of this WIKI.

2. IMPACTS

The main characteristics and results of the 6 synthesis papers are reported in **Table 2** with the terminology used in those papers, while **Table 3** shows the reference numbers of the synthesis papers reporting for each of the results shown in **Table 1**. Comprehensive information about the results reported in each synthesis paper, in particular about the modulation of effects by factors related to soil, climate and management practices, are provided in the **summaries of the synthesis papers** available in this WIKI.

Table 2: Main characteristics of the synthesis papers reporting effects on carbon sequestration. The references are ordered chronologically with the most recent publication date first.

Reference number	Population	Scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
Ref1	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%

[1] Synthesis research papers include either meta-analysis or systematic reviews with quantitative results. Details can be found in the methodology section of the WIKI.

Reference number	Population	Scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
Ref13	Vineyards	Global	50	Soil amendment with biochar	No amendment	Soil organic carbon 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%
Ref16	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%
Ref33	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%
Ref35	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%
Ref36	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 PyOM 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%

Table 3: Reference numbers of the synthesis papers reporting for each of the results shown in **Table 1**.

				Statistically tested			Non-statistically tested
Impact	Metric	Intervention	Comparator	Significantly positive	Significantly negative	Non-significant	
Increase carbon sequestration	Native SOC	Soil amendment with biochar	No amendment			Ref35	Ref36
Increase carbon sequestration	Total SOC	Soil amendment with biochar	No amendment	Ref1, Ref13, Ref16, Ref33 and Ref35			

3. FACTORS INFLUENCING THE EFFECTS ON CARBON SEQUESTRATION

Table 4: List of factors reported to significantly affect the size and/or direction of the effects on carbon sequestration, according to the synthesis papers reviewed.

Factor	Reference number
Bioachar feedstock	Ref35
Biochar application rate	Ref33 and Ref35
Biochar feedstock	Ref33
Biochar labile-C content	Ref36
Biochar pyrolysis temperature	Ref35
Crop rotation	Ref16
Experimental conditions	Ref33
Land use type	Ref33
N-fertilisation rate	Ref16
NA	Ref1, Ref1, Ref1, Ref1, Ref1, Ref1, Ref1, Ref1, Ref13, Ref13, Ref13, Ref13, Ref13, Ref13, Ref13, Ref13, Ref33, Ref33, Ref33, Ref35, Ref35, Ref35, Ref35, Ref36, Ref36, Ref36, Ref36, Ref36 and Ref36
Pedo-climatic conditions	Ref16
Soil depth	Ref16
Soil pH	Ref16 and Ref33
Soil type	Ref16
Time scale	Ref16, Ref35 and Ref36
Water management	Ref16

4. KNOWLEDGE GAPS

Table 5: Knowledge gap(s) reported by the authors of the synthesis papers included in this review.

Ref Num	Gap
Ref16	The authors did not calculate SOC sequestration rates for biochar amendment due to the lack of some ancillary information (e.g., bulk density).
Ref33	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.
Ref36	The authors believe that understanding the impact of tillage on priming effects induced by biochar is specially important in the context of biochar application. However this aspect was never investigated in the field.

5. SYNTHESIS PAPERS INCLUDED IN THE REVIEW

Table 6: List of synthesis papers included in this review. More details can be found in the summaries of the meta-analyses.

Ref Num	Author(s)	Year	Title	Journal	DOI
Ref1	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	Influence of biochar and soil properties on soil and plant tissue concentrations of Cd and Pb: A meta-analysis	Sci Total Environ. 755:142582.	10.1016/j.scitotenv.2020.142582
Ref13	Payen FT, Sykes A, Aitkenhead M, Alexander P, Moran D, MacLeod M.	2020	Soil organic carbon sequestration rates in vineyard agroecosystems under different soil management practices: A meta-analysis	J. Clean. Prod. Elsevier 125736	10.1016/j.jclepro.2020.125736
Ref16	Bai, XX; Huang, YW; Ren, W; Coyne, M; Jacinthe, PA; Tao, B; Hui, DF; Yang, J; Matocha, C	2019	Responses of soil carbon sequestration to climate-smart agriculture practices: A meta-analysis	Agric For Meteorol. 278:107625.	10.1111/gcb.14658
Ref33	Liu, SW; Zhang, YJ; Zong, YJ; Hu, ZQ; Wu, S; Zhou, J; Jin, YG; Zou, JW	2016	Response of soil carbon dioxide fluxes, soil organic carbon and microbial biomass carbon to biochar amendment: a meta-analysis	GCB Bioenergy 8:392–406.	10.1111/gcbb.12265
Ref35	Wang, JY; Xiong, ZQ; Kuzyakov, Y	2016	Biochar stability in soil: meta-analysis of decomposition and priming effects	NA	10.1111/gcbb.12266
Ref36	Maestrini, B; Nannipieri, P; Abiven, S	2015	A meta-analysis on pyrogenic organic matter induced priming effect	GCB Bioenergy. 7(4):577-90	10.1111/gcbb.12194

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