SINGLE-IMPACT FICHE
SOIL AMENDMENT WITH BIOCHAR

IMPACT: CROP YIELD

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 CROP YIELD. It is based on 11 synthesis papers[1], including from 5 to 208 primary studies.

1. WEIGHT OF THE EVIDENCE

CONSISTENCY OF THE IMPACT

Soil amendment with biochar, compared to no-amendment, generally shows significant positive effect on crop yield (i.e. increase in crop yield) (**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.

- Out of 13 results, 10 were positive (increase in crop yield), 1 was negative and 2 showed non-significant effect.
- However, the results are affected by several factors, including biochar properties and soil properties. For example, the positive effects are more frequently reported in nutrient-poor and acidic soils, whereas the negative effect was reported for temperate pedo-climates, neutral and nutrients-rich soils.

Out of the 11 selected synthesis papers, 7 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 crop yield	Crop yield	Soil amendment with biochar	No amendment	10	1	2	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 11 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 crop yield. The references are ordered chronologically with the most recent publication date first.

Reference number	Population	Scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
Ref3	Rice paddy fields in Subtropical China	China	74	Soil amendment with biochar	No amendment	Crop yield	Biochar significantly increases rice yield.	75%
Ref6	Not specified	Global	153	Soil amendment with biochar	No amendment	Crop yield metrics: Total biomass, grain yield, aboveground biomass (shoot biomass) and/or underground biomass (root	The meta-analysis in the present study showed that the grand effect of biochar on plant productivity was estimated to be 16.0 ± 1.26%, regardless of biochar properties and soil conditions. However, the efficiency of biochar in improving plant growth could be greatly affected by the combined effect	69%

[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
						biomass)	of biochar properties and soil conditions.	
Ref9	Greenhouse vegetables	China	5	Soil amendment with biochar	No amendment	Crop yield	Biochar application to greenhouse vegetables tends to increase, but non-significantly, crop yield.	75%
Ref10	Not specified	Global	74	Soil amendment with biochar	No amendment	1) Total biomass (TB); 2) shoot biomass (SB); 3) Crop yield (CY); 4) plant height (PH); 5) and leaf area (LA)	Plant total biomass, shoot biomass, and root biomass increased by 25.4%, 22.1%, and 34.4%, respectively.	81%
Ref15	Biochar obtained from crop residues or straw	Global	129	Soil amendment with biochar	No amendment	Crop yield	With biochar application, the overall crop yield significantly increased.	62%
Ref21	Rice-wheat/corn rotation systems	Global	60	Soil amendment with biochar	No amendment	Grain yield	Biochar application appeared to be a good strategy to increase the yield in fertilized soils over a long period on a global scale.	88%
Ref22	Rice cultivation	Global	13	Soil amendment with biochar	No amendment	Crop yield	Biochar application resulted in a significant increase by 5.7% ($P < 0.05$) in rice yield.	88%
Ref23	Column, pot and field experiments on rice (paddy soils)	Global	40	Soil amendment with biochar	No amendment	Rice yield	Application of biochars derived from all feedstocks at pyrolysis temperatures of 450–500°C showed significant positive changes in rice grain yield.	56%
Ref27	Not specified	Global	208	Soil amendment with biochar	No amendment	Plant biomass	Biochar significantly increases plant biomass. Manure biochar particularly high potential for benefiting plant growth.	69%
Ref31	Temperate and Tropical soild	Global	111	Soil amendment with biochar	No amendment	Crop yield	Overall, biochar increased crop yield by a grand mean of 13%. However, biochar has, on average, negative or no effect (for field tests only) on crop yield in temperate latitudes, yet elicits a 25% average increase in yield in the tropics. The results show that biochar can be a useful tool to improve crop yield in nutrient-poor and acidic soils.	81%
Ref37	Woody plants in forest restoration land	Global	17	Soil amendment with biochar	No amendment	Crop yield	The meta-analysis on biochar responses of woody plants indicates a potential for large tree growth responses to biochar additions, with a mean 41 % increase in biomass. Responses are especially pronounced at early growth stages, and appear to be higher in boreal and tropical than in temperate systems, and in angiosperms than conifers.	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 crop yield	Crop yield	Soil amendment with biochar	No amendment	Ref3, Ref6, Ref10, Ref15, Ref21, Ref22, Ref23, Ref27, Ref31 and Ref37	Ref31	Ref9 and Ref31	

3. FACTORS INFLUENCING THE EFFECTS ON CROP YIELD

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

Factor	Reference number
Biochar application rate	Ref27
Biochar ash content	Ref6
Biochar C/N ratio	Ref21
Biochar Cation exchange capacity	Ref6
Biochar nutrients content	Ref31
Biochar pH	Ref6
Biochar total carbon and total organic carbon	Ref6
Crop type	Ref10
N fertilisation rate	Ref21
NA	Ref3, Ref3, Ref3, Ref3, Ref3, Ref3, Ref3, Ref3, Ref9, Ref9, Ref9, Ref9, Ref9, Ref9, Ref9, Ref9, Ref10, Ref10, Ref10, Ref10, Ref10, Ref10, Ref15, Ref15, Ref15, Ref15, Ref15, Ref15, Ref15, Ref15, Ref21, Ref21, Ref21, Ref21, Ref22, Ref22, Ref22, Ref22, Ref22, Ref22, Ref22, Ref22, Ref23, Ref23, Ref23, Ref23, Ref23, Ref23, Ref27, Ref27, Ref27, Ref27, Ref31, Ref31, Ref31, Ref31, Ref31, Ref37, Ref37, Ref37, Ref37, Ref37
Pedo-climatic zone	Ref31
Soil C/N ratio and Soil organic carbon	Ref6

Factor	Reference number
Soil cation exchange capacity	Ref27
Soil pH	Ref6, Ref23, Ref27 and Ref31
Soil texture	Ref6, Ref10 and Ref27
Soil total nitrogen	Ref6
Soil type	Ref21
Time of	Ref37
Time scale	Ref21
Tree species	Ref37
Type of experiment	Ref37

4. KNOWLEDGE GAPS

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

Ref Num	Gap
Ref10	A lack of long-term field experiments, especially those conducted in the Southern Hemisphere, may hamper our evaluation of ecosystem structure and functioning, including photosynthesis and plant productivity, in response to biochar amendment over a larger timescale.
Ref15	Although the short-term effect of biochar on soil GHG emissions and crop yield was analyzed, the sustainability of biochar for long-term application needs further research. Long-term trials, particularly under field conditions, are required to investigate the impact of biochar on reducing GHGI.
Ref27	The biochar effects synthesized in the current paper are mainly derived from experiments characterized by single-dose designs and relatively short-term time scales (months to a few years). Biochar effects with respect to longer-term and repetitive additions require further evaluation with future more relevant experimental data.
Ref37	Given the high heterogeneity in properties of chars and soils, it is critical that future studies provide more comprehensive details on properties of chars used, and the recent promulgation of characterization guidelines should assist in this regard.

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
Ref3	Liu L, Li H, Zhu S, Gao Y, Zheng X, Xu Y.	2021	The response of agronomic characters and rice yield to organic fertilization in subtropical China: A three-level meta-analysis	F Crop Res. 263:108049.	10.1016/j.fcr.2020.108049
Ref6	Dai, YH; Zheng, H; Jiang, ZX; Xing, BS	2020	Combined effects of biochar properties and soil conditions on plant growth: A meta-analysis	Sci Total Environ. 713:136635.	10.1016/j.scitotenv.2020.136635
Ref9	Gu, JX; Wu, YY; Tian, ZY; Xu, HH	2020	Nitrogen use efficiency, crop water productivity and nitrous oxide emissions from Chinese greenhouse vegetables: A meta-analysis	Sci Total Environ. 743:140696.	10.1016/j.scitotenv.2020.140696
Ref10	He, YH; Yao, YX; Ji, YH; Deng, J; Zhou, GY; Liu, RQ; Shao, JJ; Zhou, LY; Li, N; Zhou, XH; Bai, SH	2020	Biochar amendment boosts photosynthesis and biomass in C(3)but not C(4)plants: A global synthesis	GCB Bioenergy 12:605–17	10.1111/gcbb.12720
Ref15	Zhang, Q; Xiao, J; Xue, JH; Zhang, L	2020	Quantifying the Effects of Biochar Application on Greenhouse Gas Emissions from Agricultural Soils: A Global Meta-Analysis	Sustainability 12:3436. .	10.3390/su12083436
Ref21	Wu, Z; Zhang, X; Dong, YB; Li, B; Xiong, ZQ	2019	Biochar amendment reduced greenhouse gas intensities in the rice-wheat rotation system: six-year field observation and meta-analysis	Agric For Meteorol. 278:107625.	10.1016/j.agrformet.2019.107625
Ref22	Zhao, X; Pu, C; Ma, ST; Liu, SL; Xue, JF; Wang, X; Wang, YQ; Li, SS; Lal, R; Chen, F; Zhang, HL	2019	Management-induced greenhouse gases emission mitigation in global rice production	Sci Total Environ. 649:1299–306.	10.1016/j.scitotenv.2018.08.392
Ref23	Awad, YM; Wang, JY; Igalavithana, AD; Tsang, DCW; Kim, KH; Lee, SS; Ok, YS	2018	Biochar Effects on Rice Paddy: Meta-analysis	Adv. Agron. 148	10.1016/bs.agron.2017.11.005
Ref27	Liu, Q; Zhang, YH; Liu, BJ; Amonette, JE; Lin, ZB; Liu, G; Ambus, P; Xie, ZB	2018	How does biochar influence soil N cycle? A meta-analysis	Plant Soil 426:211–25	10.1007/s11104-018-3619-4
Ref31	Jeffery, S; Abalos, D; Prodana, M; Bastos, AC; van Groenigen, JW; Hungate, BA; Verheijen, F	2017	Biochar boosts tropical but not temperate crop yields	Environ. Res. Lett. 053001.	10.1088/1748-9326/aa67bd
Ref37	Thomas SC, Gale N. Biochar and forest restoration: a review and meta-analysis of tree growth responses.	2015	Biochar and forest restoration: a review and meta-analysis of tree growth responses.	New For 46:931–46.	10.1007/s11056-015-9491-7