FARMING PRACTICE
SOIL AMENDMENT WITH BIOCHAR

IMPACT: GHG EMISSIONS

Reference 26

Ji, C; Jin, YG; Li, C; Chen, J; Kong, DL; Yu, K; Liu, SW; Zou, JW 2018 Variation in Soil Methane Release or Uptake Responses to Biochar Amendment: A Separate Meta-analysis Agric For Meteorol. 278:107625. 10.1007/s10021-018-0248-y

Background and objective

Agricultural soils play an important role in the atmospheric methane (CH_4) budget, where paddy soils can contribute significant CH_4 to atmosphere whereas upland soils may act as a source or sink of atmospheric CH_4, dependent on soil water conditions. Biochar amendments have effects on soil CH_4 production or oxidation processes in individual experiments, but the causative mechanisms are yet to be fully elucidated. 1) quantitatively and separately examine the response of soil CH_4 release or uptake to biochar amendment, and simultaneously to address earlier review limitations; 2) identify the key factors driving the response of soil CH_4 fluxes to biochar amendment.

Search strategy and selection criteria

We conducted a detailed review of the literature reporting the effects of biochar amendment on soil CH_4 fluxes prior to October 2017. This included a keyword search in Web of Science (ISI) and Google Scholar (Google Inc.), and papers published in the China Knowledge Resource Integrated Database (CNKI) with English abstracts. Different combinations of search keywords ("biochar" OR "charcoal" OR "black carbon" AND "methane" OR "CH_4" AND "soil") were used for data extraction. For each paired measurement, we gathered a range of original documented information by integrating mean and/or cumulative CH_4 fluxes, standard deviation (SD), and number of replicates from both biochar amendment and control treatments. Besides field studies, the studies under controlled experimental contexts (laboratory incubation or pot studies) were also introduced to fully evaluate the integrative effect of biochar on CH_4 fluxes across soils (Figure 1). For incubation or pot studies, however, only those highly simulating the field water capacity (30–85% WFPS) were included in this analysis to guarantee the ability to group the available soils into different original land-use types. Only studies with at least three replicates were included for this analysis.

Data and analysis

The categorical random effects model was used to calculate mean effect size for each grouping category with a weighted meta-analysis approach. Groups with less than two treatments were excluded from the analysis. Mean effect sizes of each category and the 95% confidence intervals (CIs) generated by bootstrapping (9999 iterations) were calculated with the mixed-effect model by R. o further address the differences among sub-grouping categories, between-group heterogeneity (Qb) was examined across all data for a given response variable.

Number of papers	Population	Intervention	Comparator	Outcome	Quality score
61	Paddy soils and upland soils	Soil amendment with biochar	No amendment	Metric: 1) CH_4 emission; 2) CH_4 uptake; Effect size: Logarithm of ratio of the considered metrics in the intervention to the considered metrics in the control	0.9375

Results

- When averaged across all studies, biochar amendment significantly decreased soil CH_4 release and uptake rates by 61% (confidence interval, CI – 81 to – 47%) and 84% (CI – 102 to – 69%), respectively.
- Responses of soil CH_4 release to biochar were significantly altered by pyrolysis temperature of biochar, shifting from a significant increase at pyrolysis temperatures below 400 °C (+25%, CI 18–44%) to the highest decrease at temperatures above 600 °C (– 112%, CI – 144 to – 97%).
- In upland soils acting as a sink of CH_4, biochar generated under high pyrolysis temperatures (501–600 °C or > 600 °C) resulted in a significant decrease in soil CH_4 uptake, whereas no pronounced response to biochar was observed when pyrolysis temperatures fell to within 400–500 °C (– 8%, CI – 21 to 12%).

Factors influencing effect sizes

- Soil type : When averaged across all studies in paddy soils, biochar amendment significantly decreased CH_4 release rates by 12% (CI – 26 to – 3%), largely attributed to incubation and pot studies. Biochar amendment significantly decreased CH_4 releases from upland soils by 72% (CI – 97 to – 44%). When averaged all studies on upland soils acting as a sink of CH_4, biochar amendment consistently decreased soil CH_4 uptake in both incubation and pot studies.
- Scale of experiment : Paddy soils showed the weakest negative response of CH_4 release (– 4%, CI – 6 to 11%) in field studies. Decreased CH_4 releases from upland soils was overwhelmingly contributed by incubation studies (– 226%, CI – 243 to – 191%). Biochar amendment consistently decreased soil CH_4 uptake in both incubation and pot studies, but slightly increased soil CH_4 uptake in field studies,
- Soil texture : For soils acting as a source of CH_4, soil CH_4 release were significantly increased in soils with fine texture (+34%, CI 8–62%), in contrast to negative responses (decrease) in soils with medium (– 170, CI – 214 to – 126%) or coarse texture (– 32%, CI – 78 to – 12%). For upland soils as a sink of CH_4, soil CH_4 uptake rates were significantly decreased following biochar amendment over all investigated soil textures and the strongest negative response occurred in soils with medium texture (– 129, CI – 144 to – 78%).
- Soil pH : Across all observations, experimental soils were divided into acid, neutral, and alkaline soils, corresponding to soil pH < 6.5, 6.6–7.5, and > 7.5, respectively. For soils acting as source of CH_4, biochar significantly decreased soil CH_4 release rates by 128% (CI 96–142%) in neutral soils, in contrast to a less decrease in alkaline soils or significant increase in acid soils. For upland soils acting as sink of CH_4, biochar amendment significantly decreased CH_4 uptake rates both in acid and neutral soils. The decrease in CH_4 uptake rates was the greatest in neutral soils (– 1640, CI – 185 to – 122%), against minor positive responses in alkaline soils (+11, CI – 3 to 27%).

- N-fertilisation : Biochar amendment significantly decreased soil CH_4 release rates by 115% (CI 99–131%) for unfertilized soils, as a contrast to a minor decrease in soil CH_4 release for fertilized soils (− 9%, CI − 14 to 1%). Similarly, the biochar-induced decrease in CH_4 uptake of upland soils was weakened by fertilizer application. Biochar combined with synthetic and organic N fertilizer led to a decrease by 39% (CI 26–47%) and 8% (CI 2–13%) in CH_4 release rates, respectively, whereas biochar combined with compound N fertilizer (N-P-K) incurred a significant positive response (+28%, CI 22–39%). Significant negative effects on soil CH_4 uptake for synthetic N (− 25%, CI − 41 to − 17%) but positive effects for organic N fertilizer (+20%, CI 18–23%).

Conclusion

The evidence provided here demonstrates that biochar amendment benefits CH_4 mitigation for paddy soils, and a more beneficial effect can be achieved in upland soils acting as sources of CH_4. However, for upland soils acting as sinks of CH_4, a significant negative response of soil CH_4 uptake to biochar would instead potentially intensify global warming by increasing the source strength of atmospheric CH_4. Biochar's potential to mitigate CH_4 emissions from paddies and uplands would be largely offset by its induced decreases in CH_4 uptake of upland soils.