# FARMING PRACTICE
# SOIL AMENDMENT WITH BIOCHAR

## IMPACT: GHG EMISSIONS

### Reference 15

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

### Background and objective

Agricultural disturbance has significantly boosted soil greenhouse gas (GHG) emissions such as methane ($CH_4$), carbon dioxide ($CO_2$), and nitrous oxide ($N_2O$). Biochar application is a potential option for regulating soil GHG emissions. However, the effects of biochar application on soil GHG emissions are variable among different environmental conditions. 1) quantify the response of soil GHG emissions to biochar application under different management strategies, biochar characteristics, and soil properties; 2) explore which environmental variables are the driving factors of the regulation of soil GHG emissions with biochar application; and 3) evaluate the response of soil global warming potential (GWP), greenhouse gas emission intensity (GHGI), and crop yield to biochar application under identical conditions.

### Search strategy and selection criteria

These selected publications were obtained from the China Knowledge Resource Integrated Database (http://www.cnki.net) and the Web of Science (http://apps.webofknowledge.com). The keywords included "biochar", "methane", "carbon dioxide", "nitrous oxide" or "greenhouse gases", and "crop yield". 1) treatments and the control group must be included in the same independent trials; 2) either crop yield or soil GHG emissions must be present in both treatments and control groups; 3) the data of soil GHG emissions must come from topsoil (0–20 cm); 4) the means, standard deviation (or standard error), and number of replicates must be presented or calculated from the reported data; 5) the number of trial design iterations must be higher than two.

### Data and analysis

One-way ANOVA was used to examine whether soil greenhouse gas emissions and crop yield differed significantly between biochar application and nonbiochar application. The software MetaWin 2.1 was applied to calculate the effect sizes of management, biochar characteristics, and soil properties on soil GHG emissions. All the graphs were obtained by using the software Origin 8.5. Eight variables (biochar application rate and time, biochar characteristics (type, pyrolysis temperature, carbon-to-nitrogen [C:N] ratio, and pH), and soil properties (soil texture and soil pH)) were retained to calculate the relative influence (%) of biochar application on soil GHG emissions on the basis of a boosted regression tree (BRT) model. Boosted trees were constructed by using the recommended parameter values: learning rate (0.01), bag fraction (0.50), cross-validation (10), and tree-complexity (5) [28]. Because there were continuous numerical variables, the Gaussian distribution of errors was used for all BRT fittings. All BRT analyses were performed with the gradient boost machinet (GBM) package in R version 3.3.3.

| Number of papers | Population | Intervention | Comparator | Outcome | Quality score |
|---|---|---|---|---|---|
| 129 | Biochar obtained from crop residues or straw | Soil amendment with biochar | No amendment | Metric: 1) $CH_4$ emission; 2) $N_2O$ emission; 3) $CO_2$eq emission; Effect size: Logarithm of ratio of the considered metrics in the intervention to the considered metrics in the control | 0.625 |

### Results

- Across all the sites, compared with nonbiochar application, biochar application significantly increased soil $CH_4$ emission by 15% (95% confidence interval, 2%–27%; $p < 0.05$) and soil $CO_2$ emission by 16% (11%–22%; $p < 0.05$). Biochar application significantly decreased soil $N_2O$ emission by 38% (27%–45%; $p < 0.05$).
- Biochar from wood waste significantly increased soil $CO_2$ emission (22%). Biochar made at 400–500 °C and 500–600 °C respectively increased soil $CO_2$ emission by 14% and 45%, while biochar made at >600 °C decreased soil $CO_2$ emission by 32%.
- In general, GWP and GHGI were decreased with biochar application in several independent experiments under identical conditions, with an average weighted response ratio of −23% and −41% respectively.

### Factors influencing effect sizes

- Biochar application rate : The results of boosted regression trees showed that the biochar application rate was an influential variable on soil GHG emissions (>15%). With the increase in biochar application rates, the effect sizes for soil $CH_4$ and $CO_2$ emissions significantly decreased (Figure 2; $p < 0.05$). Biochar application significantly increased soil $CH_4$ and $CO_2$ emissions by 20% and 15% with an application rate of <10 t ha−1. Soil $CO_2$ emission shifted from positive to negative (−36%) when the application rate exceeded 80 t ha−1. Biochar application appeared to significantly inhibit soil $CH_4$ emission in the first month (−33%). Soil $N_2O$ emission was significantly reduced with increasing rate of biochar application (15% to 65%; $p < 0.05$).
- Biochar incubation time in soil : With the increase in experimental time, soil $CO_2$ emission with biochar application decreased from 26% (the first month) to 1% (the second year). Soil $N_2O$ emission was significantly reduced with increasing time of biochar application (15% to 65%; $p < 0.05$).
- Soil texture : The increase ratios of soil $CH_4$ emission in loamy soil (10%) and clayey soil (12%) were higher compared with that in sandy soil (5%). In contrast, soil $CO_2$ emission significantly increased in sandy soil by 25%. Soil $N_2O$ emission in sandy soil (44%) was higher compared with that in loamy soil (30%) and clayey soil (25%).
- Soil pH : Soil pH had a greater influence on soil $CH_4$ and $N_2O$ emissions (>25%) and less of an effect on soil $CO_2$ emission (<5%). The response ratio of soil $CH_4$ emission to biochar input in soil with pH < 5.5 was negative (25%). Biochar application increased soil $CH_4$ emission by 11%, 30%, and 11% in weak acidic

soil (5.5 < pH < 6.5), neutral soil (6.5 < pH < 7.5), and alkaline soil (pH > 7.5). Moreover, biochar application significantly increased soil $CO_2$ emission in neutral soil (24%) and alkaline soil (17%).

## Conclusion

Biochar application enhanced the soil $CH_4$ and $CO_2$ emissions but reduced the $N_2O$ flux. However, with biochar application, the overall global warming potential (area-scaled) and greenhouse gas emission intensity (i.e. Yield-scaled) significantly decreased.