

Supplementary information

Fig. S1 Absolute (a) and relative (b) values (calculated as the difference in mean OC-derived CO₂ between N+B and N, N+B and CK) of biochar plus SOC (OC)-derived CO₂ emission from a calcareous soil in response to ammonium sulphate plus maize-straw-derived biochar (B+N) addition during a 70-d incubation. BC-induced represents the relative change of OC-derived CO₂ emission from the B+N treatment compared with the N treatment. BC-induced represents the relative change of OC-derived CO₂ emission from the B+N treatment compared with the CK treatment. CK stands for unamended control; N stands for Nitrogen treatment (ammonium sulphate addition); N+B stands for combined Nitrogen (ammonium sulphate) and Biochar (maize-straw-derived biochar) treatment.

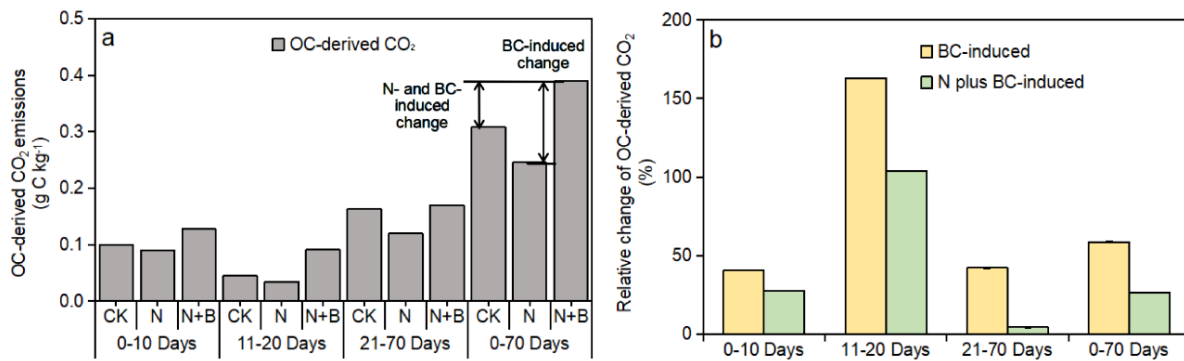


Table S1 Nitrogen-fertilization-induced SOC loss in cropland. SOC, soil organic carbon.

Location	Degree of SOC losses increased by N fertilization (%)	Soil type	Fertilizer N rate	Method	References
Russia	1	Luvic Chernozem	—	C difference method	Blagodatskaya et al., 2007
Finland	29 ^a -15 ^b	Peatland	59.5 kg N ha ⁻¹ (Slow-release fertilizer)	¹³ C natural abundance	Biasi et al., 2008
China	6.5	Aquic inceptisol	150 kg N ha ⁻¹ (Urea)	C difference method	Ding et al., 2010
United States	-29 ^c	Kalamazoo, Oshtemo, Typic Hapludalfs	134 kg N ha ⁻¹ (Urea-ammonium-N)	C difference method	Grandy et al., 2013
	-37 ^c		291 kg N ha ⁻¹ (Urea-ammonium-N)		
	-37 ^d		134 kg N ha ⁻¹ (Urea-ammonium-N)		
	-25 ^d		291 kg N ha ⁻¹ (Urea-ammonium-N)		
	-42 ^e		134 kg N ha ⁻¹ (Urea-ammonium-N)		
	-58 ^e		291 kg N ha ⁻¹ (Urea-ammonium-N)		
	-55 ^f		134 kg N ha ⁻¹ (Urea-ammonium-N)		
	-39 ^f		291 kg N ha ⁻¹ (Urea-ammonium-N)		
Germany	-4	Stagnic Luvisol	150 kg N ha ⁻¹ (Ammonium-N)	C difference method	Chen et al., 2014
Germany	-27	Luvisol	75 kg N ha ⁻¹ (Ammonium chloride)	C difference method	Zang et al., 2016
	-35		150 kg N ha ⁻¹ (Ammonium chloride)		
	-42		300 kg N ha ⁻¹ (Ammonium chloride)		
Germany	-28	—	160 kg N ha ⁻¹ (Ammonium chloride)	C difference method	Kumar et al., 2016
China	10	—	100 kg N ha ⁻¹ (Urea)	C difference method	Qiu et al., 2016
China	21	Fluvic Cambisol	300 g N kg ⁻¹ (Chemical N)	C difference method	Meng et al., 2017
	20		600 g N kg ⁻¹ (Chemical N)		
United States	-15 -29	Mollic Haploxeralf	—	C difference method	Li et al., 2018
China	-36	Stagnic Anthrosol	160 kg N ha ⁻¹ (Urea)	C difference method	Zhu et al., 2018
	116				
	119				
China	49	Eum-Orthic Anthrosol	160 kg N ha ⁻¹ (Urea)	¹³ C natural abundance	Yu, 2018
	29		160 kg N ha ⁻¹ (Urea) + Nitrification inhibitor		
	43		220 kg N ha ⁻¹		
	54		220 kg N ha ⁻¹ (Urea) + Nitrification inhibitor		
China	-22	Alfisol	154 mg N kg ⁻¹ (Ammonium nitrate)	C difference method	Wang et al., 2018
	-28		154 mg N kg ⁻¹ (Urea)		

Italy	1 -14	Typic Dystrudept	50 mg N kg ⁻¹ (Urea)	C difference method	Fiorentino et al., 2019
Trinidad and Tobago	-3	Fluvo-Aquic	100 kg N ha ⁻¹ (Ammonium chloride)	¹³ C natural abundance	Bramble et al., 2020
	-18		4000 kg N ha ⁻¹ (Ammonium chloride)		
	-2 ^g	Mollic Fluvaquents	100 kg N ha ⁻¹ (Ammonium chloride)	C difference method	
	-13 ^g		4000 kg N ha ⁻¹ (Ammonium chloride)		
	-4 ^h		100 kg N ha ⁻¹ (Ammonium chloride)	¹³ C natural abundance	
	-16 ^h		4000 kg N ha ⁻¹ (Ammonium chloride)		
	-5 ⁱ		100 kg N ha ⁻¹ (Ammonium chloride)		
	-18 ⁱ		4000 kg N ha ⁻¹ (Ammonium chloride)		
	1 ^g	Typic Kanhaplaquults	100 kg N ha ⁻¹ (Ammonium chloride)	C difference method	
	-22 ^g		4000 kg N ha ⁻¹ (Ammonium chloride)		
	-14 ^h		100 kg N ha ⁻¹ (Ammonium chloride)	¹³ C natural abundance	
	-43 ^h		4000 kg N ha ⁻¹ (Ammonium chloride)		
	1 ⁱ		100 kg N ha ⁻¹ (Ammonium chloride)		
	-16 ⁱ		4000 kg N ha ⁻¹ (Ammonium chloride)		
China	-13 -20 -15 -13	Inceptisol	75 kg N ha ⁻¹ (Urea) 150 kg N ha ⁻¹ (Urea) 225 kg N ha ⁻¹ (Urea) 300 kg N ha ⁻¹ (Urea)	C difference method	Jiang et al., 2021
Mean ± SE	-6.9±4.9				
95% confidence intervals	-16.6~2.8				

Note: ^awithout and ^bwith lime application; samples collected on ^cJune 17, ^dJuly 09, ^eAugust 05 and ^fSeptember 03; g, h and i representing three lime rates of 0, 1.36 and 7.94 Mg ha⁻¹ respectively.

Table S2 Nitrogen-fertilization-induced carbonate loss in cropland. SIC, soil inorganic carbon; STC, soil total carbon. Nitrogen-fertilization-induced SIC loss was calculated as the difference of SIC loss between N-only addition and control treatments.

Location	SIC/STC (%)	SIC loss by fertilizer N (%)	Soil type	Fertilizer N rate	Method	References
Finland	13	88	Peatland	59.5 kg N ha ⁻¹ (Slow-release fertilizer)	¹³ C natural abundance	Biasi et al., 2008
Israel	74	268	Typic Calciorthid	1755 kg N ha ⁻¹ (Chicken manure)	¹³ C natural abundance	Tamir et al., 2011
China	66	4	—	45 kg N ha ⁻¹ (Urea)	C difference method	Li et al., 2014
		7		90 kg N ha ⁻¹ (Urea)		
		11		135 kg N ha ⁻¹ (Urea)		
		14		180 kg N ha ⁻¹ (Urea)		
China	50	5	Eum-Orthic Anthrosol	0.2 g N kg ⁻¹ (Ammonium sulphate)	Soil sterilization with HgCl ₂	Meng et al., 2015
		9		0.3 g N kg ⁻¹ (Ammonium sulphate)		
		18		0.4 g N kg ⁻¹ (Ammonium sulphate)		
China	42	7	Eum-Orthic Anthrosol	0.3 g N kg ⁻¹ (Ammonium nitrate)	Soil sterilization at 550 °C	Meng et al., 2017
	42	30		0.3 g N kg ⁻¹ (Potassium nitrate)		
	42	36		0.3 g N kg ⁻¹ (Ammonium sulphate)		
China	69	9	Eum-Orthic Anthrosol	120 kg N ha ⁻¹ (Urea)	C difference method	Jin et al., 2018
		16		240 kg N ha ⁻¹ (Urea)		
China	38	32	Eum-Orthic Anthrosol	160 kg N ha ⁻¹ (Urea)	¹³ C natural abundance	Yu, 2018
		29		160 kg N ha ⁻¹ (Urea) + Nitrification inhibitor		
		101		220 kg N ha ⁻¹		
		40		220 kg N ha ⁻¹ (Urea) + Nitrification inhibitor		
China		28	Fluvo-Aquic	200 kg N ha ⁻¹ (Urea)	C difference method	Dong et al., 2016
		21		400 kg N ha ⁻¹ (Urea)		
		23		600 kg N ha ⁻¹ (Urea)		
China	16	-24	Fluvisol	270 kg N ha ⁻¹ (Chemical N)	C difference method	Dong et al., 2017
	10	-50		270 kg N ha ⁻¹ (Chemical N) + 94 kg N ha ⁻¹ (Chicken manure)		
	30	-8		180 kg N ha ⁻¹ (Chemical N)		
	23	-7		180 kg N ha ⁻¹ (Chemical N) + 96 kg N ha ⁻¹ (Corn straw)		
Trinidad and Tobago	16	-12	Aquentic Eutrudepts	100 kg N ha ⁻¹ (Ammonium chloride)	¹³ C natural abundance	Bramble et al., 2020
		-17		4000 kg N ha ⁻¹ (Ammonium chloride)		
China	61	14	Fluvo-Aquic	495 kg N ha ⁻¹ (Chemical N)	C difference method	Tian et al., 2022
		13		495 kg N ha ⁻¹ (Chemical N)		
Mean ± SE		24.3±10.2				

95% confidence intervals	4.2-44.4				
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Table S3 Contribution of inorganic C in biochar to total CO₂ emission from the biochar only incubation

Biochar type	Biochar-derived CO ₂ (BIC/BTC) (%)	Soil pH	Incubation time (Days)	CO ₂ partitioning method	References
Oak	60 ^a	—	365	Sterile incubations	Zimmerman, 2010
	44 ^b				
	77 ^c				
	73 ^d				
	81 ^e				
Pine	50 ^a				
	76 ^b				
	62 ^c				
	46 ^d				
	68 ^e				
Cedar	97 ^a				
	76 ^b				
	53 ^c				
	95 ^d				
Bubinga	88 ^a				
	93 ^b				
	90 ^d				
Gamma grass	91 ^a				
	74 ^b				
	90 ^c				
	42 ^d				
Sugar cane	98 ^a				
	40 ^b				
	49 ^c				
	82 ^d				
Mixed hardwood	50	6.2	2	Acid washed biochar	Jones et al., 2011
Rice straw	29 ^f	5.9	300	Sterilization combined with ¹³ C labeling	Yang, 2013
	32 ^g	5.9	300		
Barley roots	57	5.9	40	Sterilization combined with ¹⁴ C labeling	Bruun et al., 2014
Mean ± SE	68 ± 3.9				
95% confidence intervals	60.0~75.4				

Note: biochar produced at ^a250 °C, ^b400 °C, ^c525 °C, ^d650 °C, ^e72 hr@650 °C, ^f350 °C and ^g500 °C.

References

1. Biasi, C., Lind, S.E., Pekkarinen, N.M., Huttunen, J.T., Shurpali, N.J., Hyvonen, N.P., Repo, M.E., Martikainen, P.J., 2008. Direct experimental evidence for the contribution of lime to CO₂ release from managed peat soil. *Soil Biology and Biochemistry* 40, 2660-2669.
2. Blagodatskaya, E.V., Blagodatsky, S.A., Anderson, T.H., Kuzyakov, Y., 2007. Priming effects in chernozem induced by glucose and N in relation to microbial growth strategies. *Applied Soil Ecology* 37(1-2), 95-105.
3. Bramble, D.S.E., Gouveia, G.A., Ramnarine, R., Farrell, R.E., 2020. Short-term effects of aglime on inorganic- and organic-derived CO₂ emissions from two acid soils amended with an ammonium-based fertiliser. *Journal of Soil and Sediments* 20, 52-65.
4. Bruun, S., Clauson-Kaas, S., Bobulka, L., Thomsen, I.K., 2014. Carbon dioxide emissions from biochar in soil: role of clay, microorganisms and carbonates. *European Journal of Soil Science* 65, 52-59.
5. Chen, R., Senbayram, M., Blagodatsky, S., Myachina, O., Dittert, K., Lin, X., Blagodatskaya, E., Kuzyakov, Y., 2014. Soil C and N availability determine the priming effect: microbial N mining and stoichiometric decomposition theories. *Global Change Biology* 20(7), 2356-67.
6. Ding, W., Yu, H., Cai, Z., Han, F., Xu, Z., 2010. Responses of soil respiration to N fertilization in a loamy soil under maize cultivation. *Geoderma* 155(3-4), 381-389.
7. Dong, W.X., Duan, Y.M., Wang, Y.Y., Hu, C.S., 2016. Reassessing carbon sequestration in the North China Plain via addition of nitrogen. *Science of the Total Environment* 563-564, 138-144.
8. Dong, X., Hao, Q., Li, G., Lin, Q., Zhao, X., 2017. Contrast effect of long-term fertilization on SOC and SIC stocks and distribution in different soil particle-size fractions. *Journal of Soil and Sediments* 17, 1054-1063.
9. Fiorentino, N., Sanchez-Monedero, M.A., Lehmann, J., Enders, A., Fagnano, M., Cayuela, M.L., 2019. Interactive priming of soil N transformations from combining biochar and urea inputs: A ¹⁵N isotope tracer study. *Soil Biology and Biochemistry* 131, 166-175.
10. Grandy, A.S., Salam, D.S., Wickings, K., Mcdaniel, M.D., Culman, S.W., Snapp, S.S., 2013. Soil respiration and litter decomposition responses to nitrogen fertilization rate in no-till corn systems. *Agriculture, Ecosystems and Environment* 179, 35-40.
11. Jiang, Z., Liu, Y., Yang, J., Zhou, Z., Gunina, A., 2021. Effects of nitrogen fertilization on the rhizosphere priming. *Plant and Soil* 462, 489-503.
12. Jin, S., Tian, X., Wang, H., 2018. Hierarchical responses of soil organic and inorganic carbon dynamics to soil acidification in a dryland agroecosystem, China. *Journal of Arid Land* 10, 726-736.
13. Jones, D.L., Murphy, D.V., Khalid, M., Ahmad, W., Edwards-Jones, G., Deluca, T.H., 2011. Short-term biochar-induced increase in soil CO₂ release is both biotically and abiotically mediated. *Soil Biology and Biochemistry* 43, 1723-1731.
14. Kumar, A., Kuzyakov, Y., Pausch, J., 2016. Maize rhizosphere priming: field estimates using ¹³C natural abundance. *Plant and Soil* 409, 87-97.
15. Li, L.J., Zhu-Barker, X., Ye, R., Doane, T.A., Horwath, W.R., 2018. Soil microbial biomass size and soil carbon influence the priming effect from carbon inputs depending on nitrogen availability. *Soil Biology and Biochemistry* 119, 41-49.
16. Meng, F., Dungait, J.A.J., Xu, X., Bol, R., Zhang, X., Wu, W., 2017. Coupled incorporation of maize (*Zea mays* L.) straw with nitrogen fertilizer increased soil organic carbon in Fluvic Cambisol. *Geoderma* 304, 19-27.
17. Meng, Y., Cai, M., Shi, Q.Y., Zhou, J.B., 2015. Effects of nitrogen fertilizer application on carbon dioxide emission from calcareous soil. *Chinese Journal of Soil Science* 46,

948-954.

18. Meng, Y., Li, X.S., Hao, P.Q., Zhang, Y.K., Zhang, Y.M., Zhou, J.B., 2017. Effect of different N fertilizer applications on CO₂ emissions from *Lou* soil in Central Shaanxi. *Journal of Agro-Environment Science* 36, 1901-1907.
19. Qiu, Q., Wu, L., Ouyang, Z., Li, B., Xu, Y., Wu, S., Gregorich, E.G., 2016. Priming effect of maize residue and urea N on soil organic matter changes with time. *Applied Soil Ecology* 100, 65-74.
20. Tamir, G., Shenker, M., Heller, H., Bloom, P.R., Fine, P., Bar-Tal, A., 2011. Can soil carbonate dissolution lead to overestimation of soil respiration? *Soil Science Society of America Journal* 75, 1414-1422.
21. Tian, Y., Wang, Q., Gao, W., Luo, Y., Wu, L., Rui, Y., Huang, Y., Xiao, Q., Li, X., Zhang, W., 2022. Organic amendments facilitate soil carbon sequestration via organic carbon accumulation and mitigation of inorganic carbon loss. *Land Degradation and Development* 33, 1423-1433.
22. Wang, H., Hu, G., Xu, W., Boutton, T.W., Zhuge, Y., Bai, E., 2018. Effects of nitrogen addition on soil organic carbon mineralization after maize stalk addition. *European Journal of Soil Biology* 89, 33-38.
23. Yang, M., 2013. Stability of rice straw-derived biochar and its mechanism in paddy soil. PhD thesis, Zhejiang University, Hangzhou, China.
24. Yu, W.J., 2018. Effects of application of nitrogen fertilizer on carbon emissions and their sources from calcareous soils. Master thesis, Northwest Agricultural and Forestry University, Yangling, China.
25. Zang, H., Wang, J., Kuzyakov, Y., 2016. N fertilization decreases soil organic matter decomposition in the rhizosphere. *Applied Soil Ecology* 108, 47-53.
26. Zhu, Z., Ge, T., Liu, S., Hu, Y., Ye, R., Xiao, M., Tong, C., Kuzyakov, Y., Wu, J., 2018. Rice rhizodeposits affect organic matter priming in paddy soil: the role of N fertilization and plant growth for enzyme activities, CO₂ and CH₄ emissions. *Soil Biology and Biochemistry* 116, 367-377.
27. Zimmerman, A.R., 2010. Abiotic and microbial oxidation of laboratory-produced black carbon (biochar). *Environmental Science and Technology* 44, 1295-1301.