

Soil Organic Carbon Changes for Croplands across China from 1991 to 2012

Wentian He ^{1, 2, 3}, Ping He ^{2, *}, Rong Jiang ^{2, *}, J.Y. Yang ⁴, C.F. Drury ⁴, W.N. Smith ³, B.B. Grant ³, Wei Zhou ²

¹ Institute of Plant Nutrition and Resources, Beijing Academy of Agriculture and Forestry Sciences, Beijing 100097, China; wentian_he@hotmail.com (W.H.)

² Key Laboratory of Plant Nutrition and Fertilizer, Ministry of Agriculture and Rural Affairs/Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China; zhouwei02@caas.cn (W.Z.)

³ Ottawa Research and Development Centre, Agriculture and Agri-Food Canada, 960 Carling Avenue, Ottawa, Ontario K1A 0C6, Canada; ward.smith@canada.ca (W.N.S.); brian.grant@canada.ca (B.B.G.)

⁴ Harrow Research and Development Centre, Agriculture and Agri-Food Canada, 2585 County Road 20, Harrow, Ontario N0R 1G0, Canada; jingyi.yang@canada.ca (J.Y.Y.); craig.drury@canada.ca (C.F.D.)

* Corresponding author: heping02@caas.cn (P.H.), rong_jiang@outlook.com (R.J.)

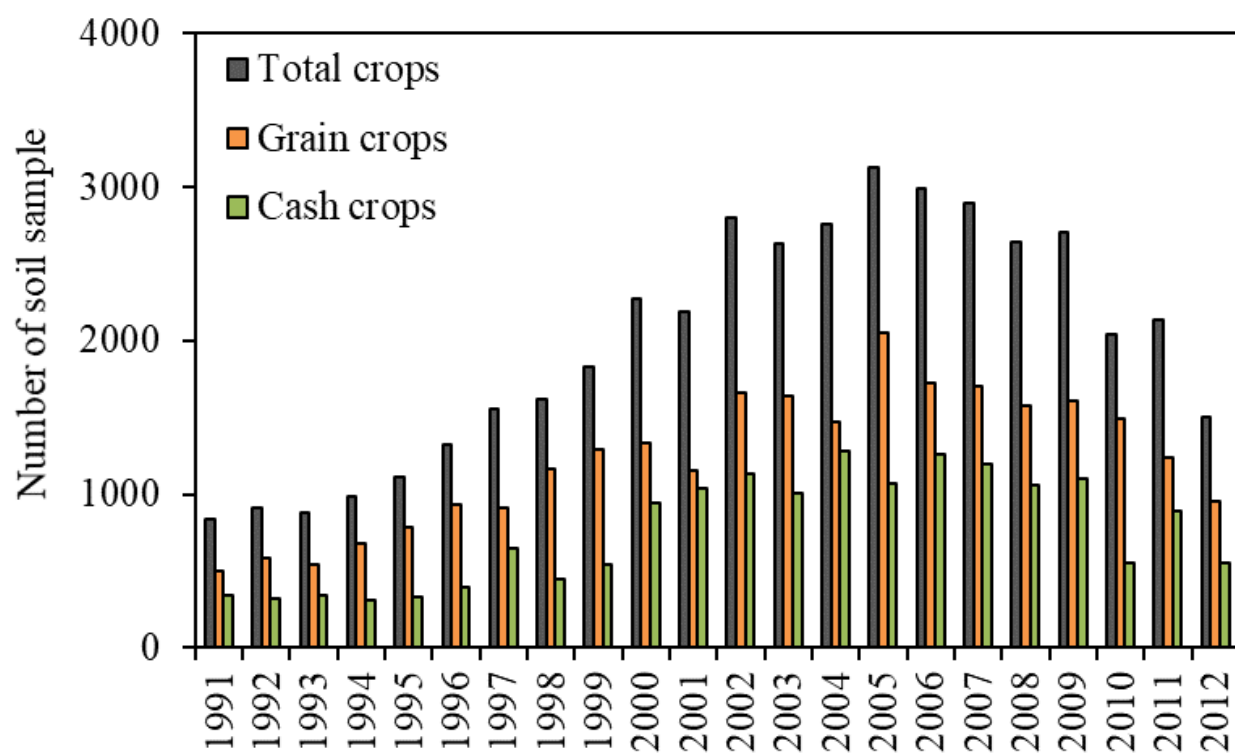


Figure S1. Number of soil samples from 1991 to 2012 in China's croplands.

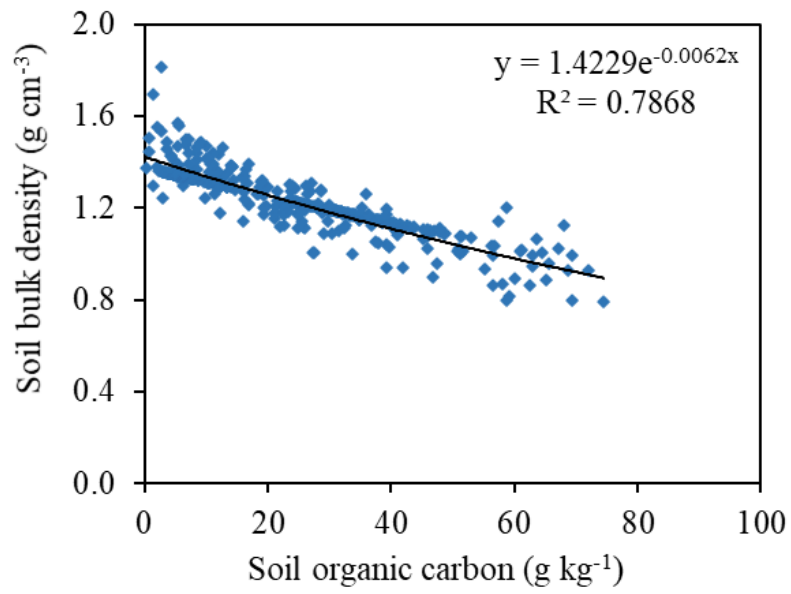


Figure S2. Correlation of bulk density with soil organic carbon (0-0.20 m depth) in China's croplands.

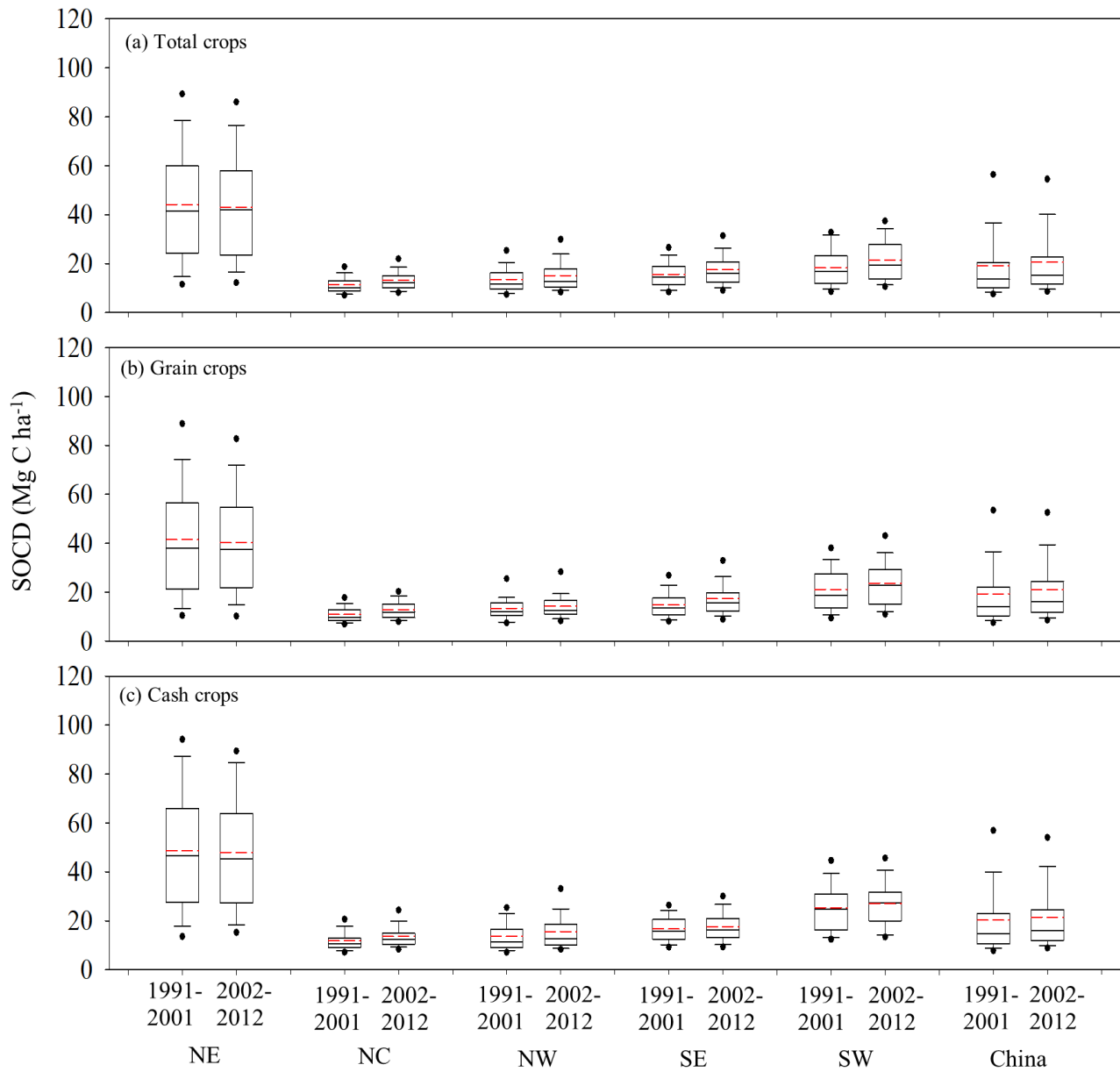


Figure S3. Soil organic carbon density (SOCD) for (a) total crops, (b) grain crops and (c) cash crops for different geographical regions in China's croplands between the 1991-2001 and the 2002-2012. NE (Northeast), NC (North Central), NW (Northwest), SE (Southeast) and SW (Southwest).

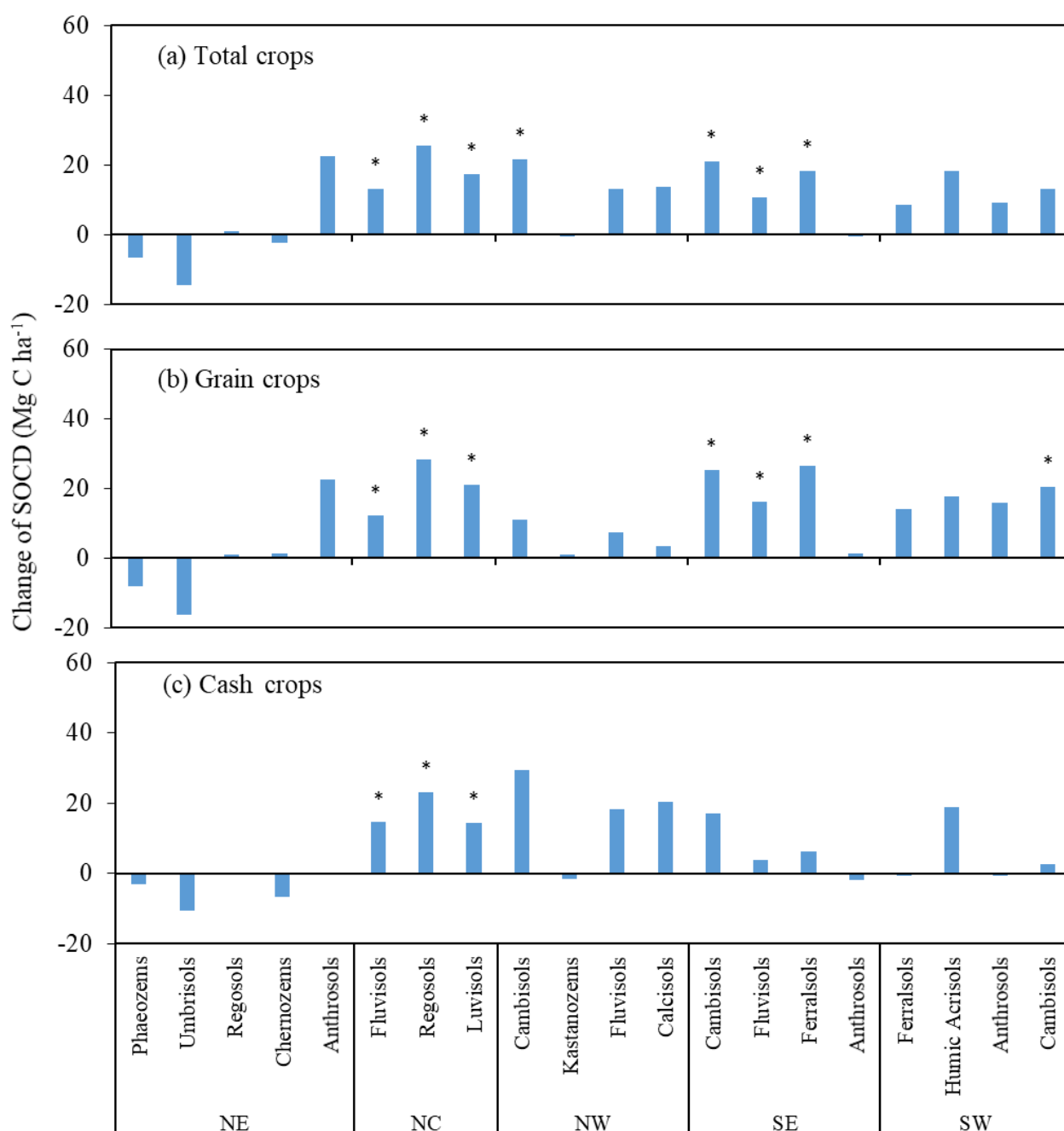


Figure S4. Changes of soil organic carbon density (SOCD) for resampling sites under different soil types for (a) total crops, (b) grain crops and (c) cash crops in China's croplands between the 1991–2001 and the 2002–2012. NE (Northeast), NC (North Central), NW (Northwest), SE (Southeast) and SW (Southwest).

* represents significant differences between the 1991–2001 and the 2002–2012.

Table S1. Estimated changes of soil organic carbon density (SOCD) for resampling sites between the 1991-2001 and the 2002-2012 from different geographical regions in China's croplands.

Crop type	Region ¹	SOCD (Mg C ha ⁻¹)	
		1991-2001	2002-2012
Total crop	NE	43.4±24.2a	42.8±22.5a
	NC	11.3±4.1b	13.2±4.7a
	NW	13.6±6.5b	15.2±7.0a
	SE	15.6±5.7b	17.5±7.1a
	SW	21.1±9.3b	23.6±9.6a
	China	19.4±15.8b	20.9±15.0a
Grain crop	NE	41.2±23.2a	40.6±21.7a
	NC	10.9±4.32b	12.79±4.1a
	NW	13.4±5.6a	14.3±5.7a
	SE	14.8±5.5b	17.3±7.4a
	SW	18.3±7.7b	21.4±9.2a
	China	18.8±15.5b	20.5±14.7a
Cash crop	NE	48.7±24.6a	47.9±23.0a
	NC	11.8±4.9b	13.7±5.3a
	NW	13.7±57.0b	15.6±7.6a
	SE	16.7±5.8a	17.6±6.6a
	SW	25.4±9.9a	27.1±9.2a
	China	20.3±16.3b	21.5±16.3a

¹ Regions used in this study are NE (Northeast), NC (North Central), NW (Northwest), SE (Southeast) and SW (Southwest); ² Different lowercase letters represent significant differences between the 1991-2001 and the 2002-2012.

Table S2. Estimated changes of soil organic carbon density (SOCD) under different soil types between the 1991-2001 and the 2002-2012 from different geographical regions in China's croplands.

Region	Soil type (WRB reference soil group)	SOCD (Mg C ha ⁻¹)					
		Total crops		Grain crops		Cash crops	
		1991–2001	2002–2012	1991–2001	2002–2012	1991–2001	2002–2012
NE ¹	Phaeozems	53.0	48.5	49.3	42.2	58.9	57.4
	Umbrisols	39.8	32.4	42.6	35.1	37.0	36.4
	Regosols	16.4	18.1	16.4	18.1	-	-
	Chernozems	37.4	34.1	25.8	26.4	57.4	44.2
	Anthrosols	30.9	42.4	30.9	42.4	-	-
NC	Fluvisols	11.6	13.8	11.8	12.6	14.0	15.4
	Regosols	11.1	14.2	11.3	13.0	11.6	14.5
	Luvissols	11.3	13.5	10.9	13.6	12.0	13.0
NW	Cambisols	10.1	11.9	11.0	11.1	9.3	11.8
	Kastanozems	15.9	15.5	13.7	15.3	18.5	15.2
	Fluvisols	12.3	14.4	13.6	17.2	13.0	13.7
	Calcisols	10.8	14.0	10.8	16.2	8.8	13.4
SE	Cambisols	13.4	16.4	15.4	16.0	11.9	15.3
	Fluvisols	13.1	15.7	12.2	16.1	13.6	13.6
	Ferralsols	15.7	20.2	15.5	20.7	18.6	21.0
	Anthrosols	16.0	15.8	14.8	15.4	18.5	17.3
SW	Ferralsols	25.0	27.3	19.2	25.4	28.2	27.5
	Humic Acrisols	22.3	28.6	21.9	25.9	27.3	30.3
	Anthrosols	23.5	25.1	18.9	21.0	32.6	32.3

¹ Regions used in this study are NE (Northeast), NC (North Central), NW (Northwest), SE (Southeast) and SW (Southwest).

Table S3. Comparisons of the estimated topsoil soil organic carbon stock (SOCS) in China's croplands.

Period	Cropland area (Mha)	SOCS (Tg C)	Changes in SOCS (Tg C yr ⁻¹)	Method ¹	References
1980-2000	118	-	15.6-20.1	Literature survey	[1]
1980-2000	155.8	3890	23.6	Literature survey	[2]
1985-2006	130	-	22.2-27.6	Literature survey	[3]
1980-2007	130	3950	9.6	The second NSS and field measurement	[4]
1980-2000	153.9	5370	13	Modelling (ANN model)	[5]
1981-2000	140-143	-	16	Modelling (DLEM model)	[6]
1980-2011	130	4277	18.1	The second NSS and field measurement	[7]
1991-2012	154.7	3221	23.7	Field measurement	This study

¹ NSS, National Soil Survey; ANN, Artificial Neural Network; DLEM, Dynamic Land Ecosystem Model.

References:

1. Huang, Y.; Sun, W. Changes in topsoil organic carbon of croplands in mainland China over the last two decades. *Chin. Sci. Bull.* **2006**, *51*, 1785–1803.
2. Xie, Z.B.; Zhu, J.G.; Liu, G.; Cadisch, G.; Hasegawa, T.; Chen, C.M.; Sun, H.F.; Tang, H.Y.; Zeng, Q. Soil organic carbon stocks in China and changes from 1980s to 2000s. *Glob. Change Biol.* **2007**, *13*, 1989–2007.
3. Pan, G.; Xu, X.; Smith, O.; Pan, W.; Rattan, L. An increase in topsoil SOC stock of China's croplands between 1985 and 2006 revealed by soil monitoring. *Agric Ecosyst Environ.* **2010**, *136*, 133–138.
4. Yan, X.Y.; Cai, Z.C.; Wang, S.W.; Smith, P. Direct measurement of soil organic carbon content change in the croplands of China. *Glob. Change Biol.* **2011**, *17*, 1487–1496.
5. Yu, Y.Y.; Guo, Z.T.; Wu, H.B.; Kahmann, J.A.; Oldfield, F. Spatial changes in soil organic carbon density and storage of cultivated soils in China from 1980 to 2000. *Glob. Biogeochem. Cycles* **2009**, *23*, GB2021.
6. Tian, H.; Melillo, J.; Lu, C.; Kicklighter, D.; Liu, M.; Ren, W.; Running, S. China's terrestrial carbon balance: contributions from multiple global changes factors. *Glob. Biogeochem. Cycles* **2011**, *25*, GB1007.
7. Zhao, Y.; Wang, M.; Hu, S.; Zhang, X.; Ouyang, Z.; Zhang, G.; Huang, B.; Zhao, S.; Wu, J.; Xie, D.; Zhu, B.; Yu, D.; Pan, X.; Xu, S.; Shi, X. Economics- and policy-driven organic carbon input enhancement dominates soil organic carbon accumulation in Chinese croplands. *Proc. Natl. Acad. Sci.* **2018**, *115*, 4045–4050.