Carbon benefits completely offset by nitrogen fertilization induced greenhouse gas emissions in Chinese main cropping systems

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Introduction:

The net exchange of CH_4 and N_2O emission and GHG emissions from manufacture and distribution of fertilizers and pesticides, irrigation and farm operations as the form of CO_2-eq between cropland soils and atmosphere composes the net global warming potential (**net GWP**) of the crop system, which provides a measure of the cumulative radiative forcing of various GHG relative to CO_2[1]. Large numbers of studies were carried out widely over China, for research soil GHG emissions and (or) calculated the GWP in different cropping systems, in recent two decades. However, we found these studies are incomparable because the different calculation components and parameters for calculating the hidden CO_2 emissions in the calculation of GWP. This shortcoming limits our overall evaluation of GWP in the Chinese main crop systems and thus impairs effective decision regarding mitigation. **The objectives of the present work were:** (*i*) to analyze the changes in SOC in the Chinese main cropping systems under conventional farming practices; (*ii*) to estimate the net GWP of the Chinese main crop systems; (*iii*) to explicit the main controlling factors on net GWP in different crop systems, and give some effective management tactics for reducing net GWP of the main crop systems over China.

Materials and Methods

Chinese main crop systems

(*i*) Winter wheat and summer maize system (WM) on the North and Southwest China;
(*ii*) Rice and winter wheat annual rotation system (RW) in the Central and East of China;
(*iii*) Double rice cropping systems (DR) in the Central and South of China;
(*iv*) Rice and rapeseed annual rotation system (RR) in the Central and Southwest China;
(*v*) Single rice per year (SR) in the Central and Northeast China;
(*vi*) Single spring maize per year in the Northeast (MNE) and (*vii*) Northwest of China (MNW).
(*viii*) Greenhouse vegetables (GV)
(*ix*) Open field vegetables (OV)

Data sources

We collected the data from published literatures, dissertations, books or research reports from The year 2000 to 2016. Under our criterion, 189 results for GHG studies were collected by reviewing about 600 literatures, including 37, 33, 26, 13, 18, 13, 8, 17, 24 for WM, RW, DR, RR, SR, MNE, MNW, GV and OV, respectively. At the same time, 317 publications for topsoil (0-20 cm) SOC changes were found, including 41, 40, 82, 10, 20, 45, 26, 30, 10, 13 for WM, RW, DR, RR, SR, MNE, MNW, GV, OV, and Chinese croplands (CC) respectively. The collected SOC density change in different cropping systems shown in right figure 1.

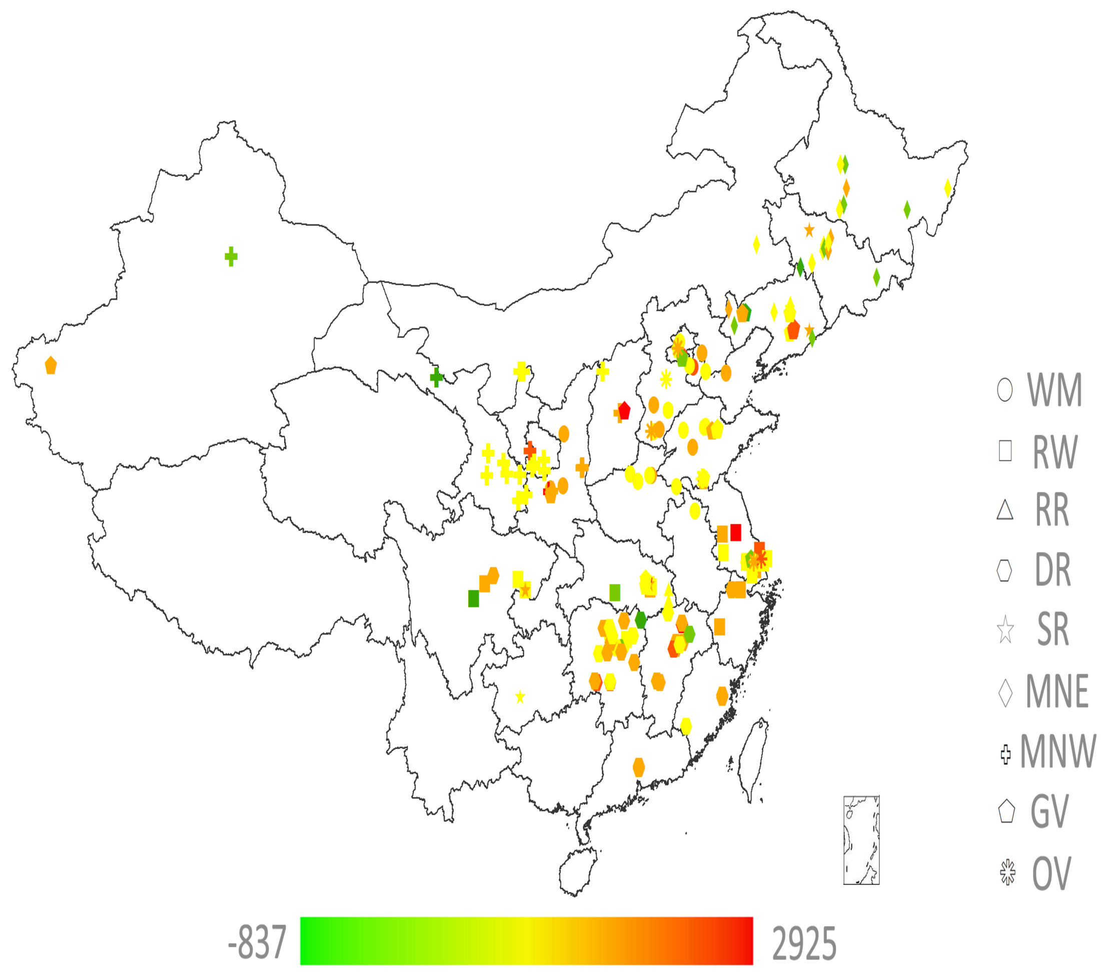

Figure. 1 The collected SOC density change in Chinese main cropping systems.

Net GWP estimates

Net GWP calculated by the following equation [2,3]:

$$\text{Net GWP (kg } CO_2\text{-eq ha}^{-1}\text{ yr}^{-1}) = 298 \times N_2O + 25 \times CH_4 + 8.3 \times \text{N rate} + 1.50 \times P_2O_5 \text{ rate} + 0.98 \times K_2O \text{ rate} + 1.30 \times \text{electricity rate} + 3.93 \times \text{fuel rate} + 18.0 \times \text{pesticide} - \delta SOC/12 \times 44$$

Results

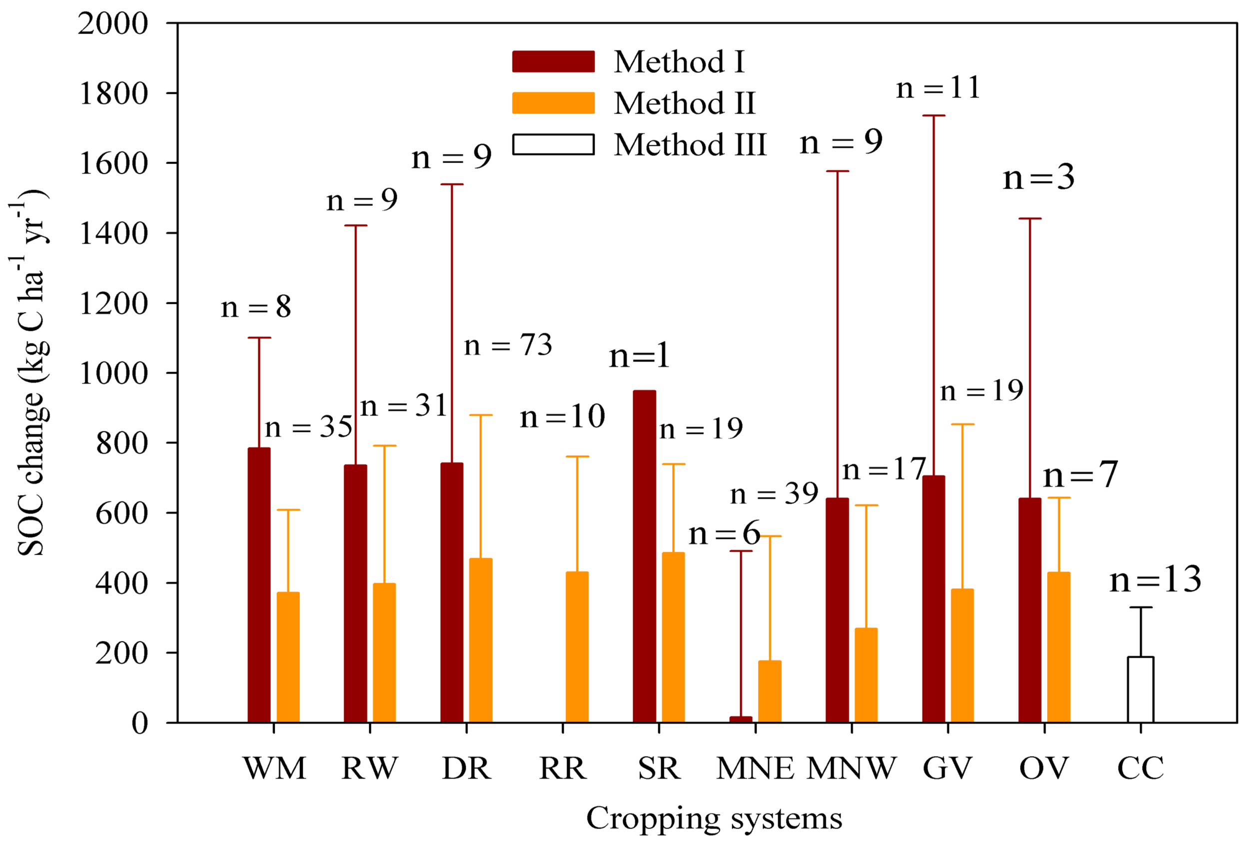

Fig. 2. The changes in SOC in Chinese main cropping system and entire China's cropland . Method I represent the data from short-term experiment (< 5 years), Method II represent the data from long-term experiment (= and >5 years), Method III represent data about SOC change in the entire Chinese cropland.

Conclusions

- Our result showed an overall increase of SOC in the topsoil (0–20 cm) of the China's main croplands.
- Nevertheless, carbon benefits from SOC sequestration were completely offset by N fertilization induced GHG emissions and CO_2-eq emissions from agricultural inputs and managements in Chinese main cropping systems.
- The Chinese main cropping systems are large sources of GHG because the high CO_2-eq emissions from chemical N fertilizer input, power for irrigation, and N_2O induced by N fertilization, and large CH_4 emission in four rice-based cropping systems.

Table 1 CO_2-eq emissions from N_2O and CH_4 emissions, fertilizer input, irrigation, fuel, pesticide and SOC change and final net GWP in Chinese main cropping systems under farmers' practices (kg CO_2-eq ha^{-1})

Crop system	N_2O	CH_4	Fertilizer input		Irrigation	Fuel	Pesticides	SOC change	Net GWP
			N	P_2O_5+K_2O					
WM	1666±779	-54±30	4094±1006	319±181	2218±675	425±147	134±48	-1360±873	7442±3739
RW	3044±1991	5417±3767	3740±817	452±167	2638±1386	371±150	172±80	-1456±1448	14378±9806
DR	797±625	11972±6780	2264±794	314±156	3040±1407	403±212	181±110	-1720±1507	17251±11591
RR	2601±1195	4259±2244	2750±1017	382±188	2962±793	292±279	188±18	-1578±1140	11856±6874
SR	899±779	4105±3296	1248±626	155±126	3299±2387	280±181	80±44	-1778±931	8288±8370
MNE	741±373	-17±15	1730±584	107±102	0±0	242±161	51±9	-645±1313	2209±2557
MNW	1480±1832	-84±77	2638±751	155±76	1414±1747	275±85	78±41	-986±1294	4970±5903
GV	7560±4376	-63±35	8640±4293	842±592	6740±5164	516±508	745±226	-1397±1731	23581±16925
OV	6364±4294	61±163	7169±4023	370±506	2455±1901	458¶	213±83	-1573±788	15517±11758

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Acknowledgements: This work was funded the National Basic Research Program of China (2014CB953801), the National Natural Science Foundation of China (41301237) and Young Talents Projects of Institute of Urban Environment, Chinese Academy of Sciences (IUEMS201402)