Simulation of Impacts of Agricultural Management Practices on Soil Carbon Stock

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Abstract: The impacts of agricultural practices on soil carbon stock under different cropping systems were simulated using DNDC Model. The cropping systems included in this study are maize-wheat, double rice, single rice, single corn, rice-wheat, wheat-cotton and single cotton. The agricultural practice, soil property data including soil organic content, clay content, pH, bulk, and sowing and harvest date, crop yield for more than 300 hundred sites were collected for the simulation. The soil carbon stock change was analyzed for different cropping systems. The simulated result is that the cropland is a carbon sink under current management practice. The total carbon stock increases 18.89 Tg C in 1994. The carbon stock changes under different agricultural practice were also simulated. The most import management practice is organic fertilizer application.

1. Introduction

Estimates of CO_2 fluxes can be made in two ways: (1) by direct measurement of CO2 flux, and (2) indirectly, through balance estimates of the net change in carbon stocks of the soil. Direct estimates of CO_2 emission or removal, through photosynthesis, and CO_2 efflux, through decomposition and respiration, are difficult to obtain. Carbon balance-based approach is seemed to be the most feasible alternative (IPCC, 1996), especially for the GHG inventory compilation.

Agricultural activities can affect soil carbon stock. There is a substantial literature on the impacts of tillage, fertilization, manure application, and crop rotation on soil organic matter. A process-oriented simulation model, DNDC, was developed for predicting the effects of agricultural practices on carbon and nitrogen dynamics (Li et al., 1992). DNDC model was calibrated and validated in many countries (Li 1994). It is also validated in China (Li C personal communication, Qiu & Wang in press). According to the results of simulated and measured soil carbon stock change, it was thought that DNDC could be applied to simulate the carbon stock change in China. This study was to use this model to estimate the net carbon change under current management practices and crop rotation.

2. Material and data

2.1 The model description and validation

DeNitrification and DeComposition (DNDC) model is a process-oriented simulation model of soil carbon and nitrogen biogeochemistry. The model contains 4 sub-models to simulate the soil climate, decomposition of soil organic carbon, denitrification, and plant growth. The essential inputs for the model are soil data (clay content, soil organic carbon content, soil bulk density soil pH), climate data (daily minimum, maximum air temperature, and daily precipitation), management practice data (crop rotation type and timing, the amount, type and timing of fertilizer application, amount and timing of irrigation, amount and timing of residue incorporation, timing and type of tillage). The output from the model includes daily emissions of N_2O and CO_2, and daily and seasonal fluxes to soil carbon pools. The model operates on a hourly to daily time step.

2.2 Data collection

2.2.1 Activity data

The planting area in 1994 for main type of cropping rotations was collected such as Wheat-corn, single corn, single rice, double rice, rice-wheat, cotton, and wheat-cotton. The selected cropping systems are accounted for 73 percent of total grain sowing area and 54% of total cropping area.

2.1.2 Agricultural practice data

The management practice in 1994 including tillage, irrigation, fertilization, weeding, pesticide usage, sowing data, harvest date and the yield for more than 300 hundred sites. Animal population, the proportion of manure returned to the soil and the grain yield were collected to estimate the organic fertilizer application amount. The manure excretion rate and manure property such as water content, carbon and nitrogen content for fresh and dried manure were also collected and listed in table 1. The amount of organic fertilizer application was calculated using formula 1.

Table 1 manure excretion and C/N content

Manure type	Excretion rate (kg/a)	Dried manure			Fresh manure			
		Organic carbon (C,%)	Total (N,%)	C/N	Water content (%)	Carbon content (C,%)	Total N (N,%)	C/N
Human	113.7	36.775	6.382	8.062	80.670	9.517	1.159	
Swine	1275	41.381	2.083	20.986	68.74	13.76	0.547	20.986
Cattle	4647	36.775	1.669	23.171	75.038	10.414	0.383	
Sheep	474	33.634	2.012	16.62	50.746	18.859	1.014	
Horse	3456	36.057	1.476	25.623	68.463	11.965	0.437	
Mules and Assess	2040	Asses：35.432 Mule：23.408	0.969 0.959	32.056 26.461	61.519 62.929	13.256 8.203	0.491 0.312	
Chicken	26	30.146	2.338	14.028	52.306	16.511	1.032	

Data source: Nutrition of Organic fertilizer in China

Input of organic fertilizer(kg/ha) $= \sum (N_i \times M_i \times C_i \times (100-W_i) \times R_i) / 10000 \times P_j/P_t$

（1）

where：

Ni：Animal population (head)；

Mi：The excretion rate of fresh manure by animal type i（kg）

Ci：The carbon content of dried manure by animal type i（%）

W_i：Water content of fresh manure by animal type i（%）

R_i： The proportion of animal manure applied to field by animal type i（%）. In this paper, the proportion of manure applied to field to excreted was assumed to be 67%（Wen Qixiao，1984）

P_j：Planting area of crop j（ha）

P_t：Total planting area in the county (ha)

2.2.3 Soil and climate data

According to the requirement of the DNDC model, the daily minimum, maximum temperature and daily precipitation in 1994 for the simulated sites were collected. Soil property data such as soil texture, clay content, soil bulk density, organic carbon content, and pH were also collected for the simulation.

3. Results analyses

3.1 Organic carbon applied the field

According to the formula 1, the amount of organic fertilizer application were calculated using formula 1(table2). The organic fertilizer application amount is varying widely under different cropping rotations and different locations. This amount mainly determined by the animal population, multiple cropping index and arable land area.

Cropping rotation	Organic fertilizer application (kg C/ha)
Wheat-corn	391-1854
Single corn	180-3363
Single rice	721-2691
Double rice	348-1589
Rice-wheat	566-1750
Cotton	170-1723
Cotton-wheat	328-568

Table 2. Organic fertilizer application under different cropping rotation (kg C/ha)

3.2 The carbon stock change under the current management practice

Because of the crop straw returned to soil, organic fertilizer application and the lower soil organic carbon content, the soil carbon contents in many of the croplands are increasing in China. The average carbon stock increase rate in 1994 was estimated to be279 kg C/ha for wheat-corn cropping rotation system, 342 kg C/ha for double rice cropping rotation system, 233 kg C/ha for single rice cropping rotation system. For single corn cropping system, it is a source of carbon. The average emission rate of single corn is estimated to be 90 kg C/ha(Table 3).

The change of carbon stock is clearly related to soil initial organic carbon content and rotation systems. Figure 1 shows that initial SOM content of agriculture land. Figure 2 shows the Carbon content change under current agricultural practices. In Northern East of China, the average soil organic matter content of the selected sites is 3.93%. Soil carbon stock decreased dramatically under different cropping systems due to the higher soil organic carbon content. The range for the carbon losing is 0.03-3.6 t C/ha/y. The average carbon stock decrease rate in Northern East for single corn was 856 kg C/ha/y. But in Northwestern area, the carbon stock for single corn cropping system was increased where the soil organic matter content is rather low (SOM=1.23%). The carbon stock increase range was 0.6-0.9 t C/ha/y.

In Huanghaihai region, the dominant cropping rotation is wheat-corn rotation system. The average soil organic carbon content of the selected sites of this region is 1.2%. The carbon stock in most of the sites simulated was increasing. The carbon stock increase range was 0.1-1.2 t C/ha/y. The average carbon stock increase in the region was estimated to be 0.28 kg C/ha in 1994 for wheat-corn rotation cropping system.

Table 3 Carbon stock changes by different cropping system

	Carbon stock change (kg C/ha/y)	Estimated sowing area (1000ha)	Estimated carbon stock change (Tg C/y)
Wheat-corn	279.45	16653	4.65
Single corn	-90.28	7499	-0.68
Double rice	342.9	17982	6.17
Single rice	233.4	7371	1.72
Rice-wheat	211.1	2511	0.53
Single cotton	1163.2	1850	2.15
Wheat-cotton	1442	3013	4.34
Total		56879	18.89

Note: - decrease, ＋increase

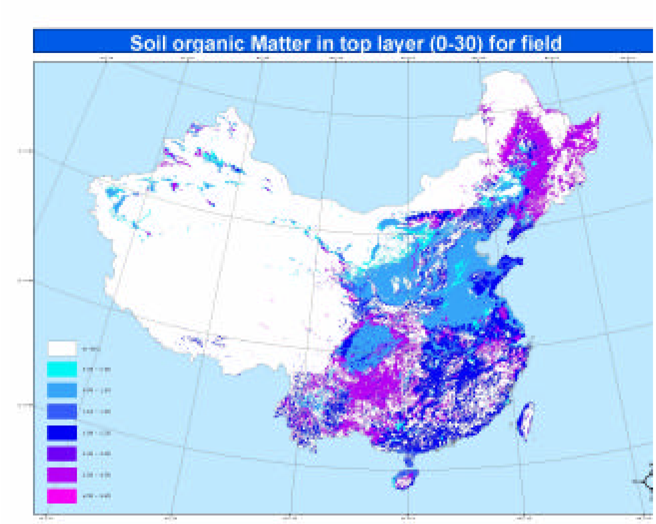

Figure 1 The initial SOC content of agricultural land

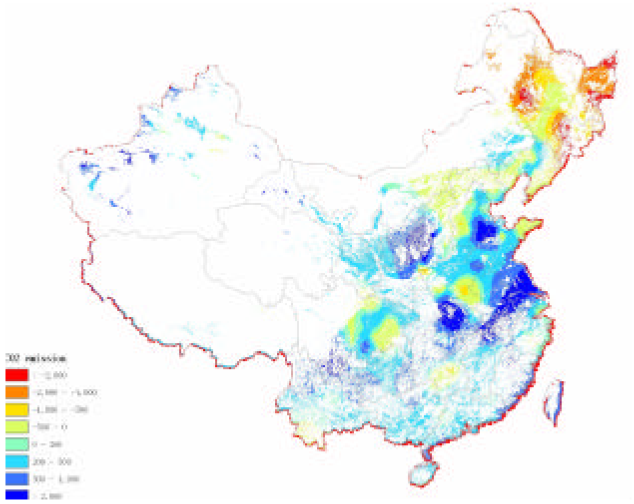

Figure 2 The carbon stock change in 1994

In double rice cropping system, soil carbon stocks in most of the simulated sites are increased. The average SOM content for the selected sites is 2.19 t C/ha. The average increase rate is 0.34 t C/ha/y. The SOM is higher in the double rice cropping system region, but the carbon stock increase rate is higher than in wheat-corn rotation system. The reason mainly is due to the microbial activity is decreased and the decomposition of SOM is slowed down under the flooded condition. CO_2 emission from soil respiration under flooded condition is only half of that emitted under aerobic condition (Xu et al., 1998). The simulated results for single rice cropping system are similar to the results for double rice cropping system. The average carbon stock increase rate for single rice is 0.23 t C/ha in 1994.

3.3 The carbon stock change under different management practice

The carbon stock changes under different agricultural practices and different rotation systems were simulated using DNDC. The simulated results were listed in table 4. The most important management practice, which affects the carbon stock, is organic fertilizer application. The carbon stocks were decreased in every rotation system if no organic fertilizer was applied compared with the current agricultural practices. If there is no mineral fertilizer applied, the carbon stock increase rate is decreased 28%, 29%, 37% 19%, 21% and 34% for wheat-corn, double-rice, single-rice, rice-wheat, single cotton and wheat-cotton, respectively. The carbon stocks were also decreased in every rotation system under no irrigation condition compared with the current agricultural practices. If there is no irrigation, the carbon stock increase rate is decreased 27%, 31% and 0.6% for wheat-corn, single cotton and wheat-cotton, respectively.

Table 4 Carbon stock change under different agricultural practices and rotation systems(kg C/ha/y)

	Current management practice	No organic fertilizer applied	No mineral fertilizer	No irrigation
Wheat-corn	279.45	-195.6	200.43	203.8
Single corn	-90.28	-1268	-370.3	-324.0
Double rice	342.9	-674.7	242.5	
Single rice	233.4	-556.2	146	
Rice-wheat	211.1	-333.5	170.3	
Single cotton	1163.2	864.3	917.6	804.1
Wheat-cotton	1442	-196.4	953.7	1432.7

Note: - decrease, ＋increase

4. Conclusion

The cropland is net sink of carbon in China in 1994. The total carbon stock increases 18.89 Tg C. The average carbon stock increase rate in 1994 was estimated to be 279 kg C/ha for wheat-corn cropping rotation system, 342 kg C/ha for double rice cropping rotation system, 233 kg C/ha for single rice cropping rotation system under current agricultural practices. For single corn cropping system, it is a source of carbon.

The change of carbon stock is clearly related to soil initial organic carbon content. In Northern East of China, the average soil organic matter content is higher and the soil carbon stock decrease rate was 0.03-3.6 t C/ha in 1994. But in Northwestern area, the carbon stock for single corn cropping system was increased where the soil organic matter content is rather low.

The carbon stock changes under different agricultural practice were also simulated. The most import management practice is organic fertilizer application.

The simulated results for single cotton and wheat-cotton rotation systems were unreasonable high. DNDC model was not validated on cotton field. This work should be done before using DNDC model to simulate the carbon stock change in cotton field.

References:

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