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Key Variables Explaining Soil Organic Carbon Content Variations in Croplands and Non-Croplands in Chinese Provinces

WU Lezhi[1], CAI Zucong[2]

(*1. Department of Geographical Science, Hubei Normal University, Huangshi 435002, China;*
2. College of Geographical Science, Nanjing Normal University, Nanjing 210046, China)

Abstract: Soil organic carbon (SOC) plays an important role in global carbon cycles. Large spatial variations in SOC contents result in uncertain estimates of the SOC pool and its changes. In the present study, the key variables explaining the SOC contents of croplands (CPs) and non-croplands (NCPs) in Chinese provinces were investigated. Data on SOC and other soil properties (obtained from the Second National Soil Survey conducted in the late 1970s to the early 1990s), climate parameters, as well as the proportion of the CP to the total land area (Pcp) were used. SOC content variations within a province were larger than those among provinces. Soil clay and total phosphorus content, ratio of annual precipitation to mean temperature, as well as Pcp were able to explain 75% of the SOC content variations in whole soil samples. Soil pH, mean temperature during the growing season from May to October, and mean annual wind velocity were able to explain 63% of the SOC content variations in NCP soils. Compared with NCP soils, CP soils had lower SOC contents, with smaller variations within and among provinces and lower C/N ratios. Stepwise regression showed that the soil clay content was a unique factor significantly correlated with the SOC content of CP soils. However, this factor only explained 24% of the variations. This result suggested that variables related to human activities had greater effects on SOC content variations in CP soils than soil properties and climate parameters. Based on SOC contents directly averaged from soil samples and estimated by regression equations, the total SOC pool in the topsoil (0–20 cm) of China was estimated at 60.02 Pg and 57.6 Pg. Thousands of years of intensive cultivation in China resulted in CP topsoil SOC loss of 4.34–4.98 Pg.

Keywords: soil organic carbon; land use; carbon loss; soil property; climatic variable

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1 Introduction

Soil organic matter (SOM) is one of the most important national resources (Albrecht, 1938), and a crucial factor in sustaining agricultural production for food security with inevitable population growths. SOM also plays an important role in global carbon cycles. The global soil organic carbon (SOC) pool is about 1550 Pg, which is twice the size of the atmospheric carbon pool of about 760 Pg (Lal, 1999; Batjes, 2002; Schuman *et al*., 2002). Small changes in the SOC pool can lead to significant changes in atmospheric CO_2 concentration, which greatly influences global warming. In history, the conversion of natural to agricultural lands has crucially led to the depletion of the SOC pool (Lal, 2004a). The net change in the SOC pool caused by cultivation depends not only on current management practices, but also on the management history of the soil (Kundu *et al*., 2007). In particular, after the irrational development and inappropriate long-term management of agricultural activities, the SOC pool has seriously decreased. European croplands (CPs) as far east as the Urals have been estimated to lose SOC at a rate of 300 Mt/yr (Janssens *et al*., 2003). A global analysis of soil carbon loss following

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Corresponding author: WU Lezhi. E-mail: wulezhi201@126.com

the cultivation of forests or grasslands has indicated a 20% reduction in the initial SOC, or approximately 1500 g/m^2 in the top 30 cm of soil (Mann, 1986). Davidson and Ackerman (1993) have estimated a 30% SOC loss from the entire soil column within 20 years after cultivation. Some cultivated soils have lost one-half to two-thirds of the original SOC pool with a cumulative loss of 30–40 MgC/ha (Lal, 2004b).

Based on data from the Second National Soil Survey, which was conducted from the late 1970s to the early 1990s, the SOC pool in China is estimated at 70–90 Pg in 1 m depth (Jin *et al*., 2001; Li *et al*., 2003; Wang *et al*., 2003). China has thousands of years of land cultivation history. The soil properties have been substantially altered such that a new soil order, i.e., anthrosols, has evolved (Gong, 1999). Lower SOC densities in CP than in non-cropland (NCP) soils indicate that the intensive cultivation has substantially reduced the size of the SOC pool in China (Cai, 1996; Wu *et al*., 2003; Song *et al*., 2005). Among CPs, paddy soils usually have higher SOC densities than upland soils (Cai, 1996; Pan *et al*., 2003). The carbon sequestration potential in CP soils can be roughly estimated if the total SOC loss is known. A proportion of SOC restoration to total SOC loss can be obtained by applying recommended management practices (Lal, 2004a). However, there are large uncertainties in the estimates of SOC losses because of intensive cultivation in China. The SOC loss estimated by Wu *et al*. (2003) is about 7.1 Pg in 100 cm soil depth. On the other hand, Song *et al*. (2005) estimate the SOC loss to be only 2 Pg in 30 cm soil depth.

Very large spatial variations in SOC content and storage result in uncertain estimates of SOC storage, SOC loss induced by land use change, and soil carbon sequestration potential at large spatial scales. Geographic information system (GIS) have been widely applied to estimating the regional and nationwide SOC pool and carbon sequestration potential in recent years (Arrouays *et al*., 2001; Vleeshouwers and Verhagen, 2002; Yu *et al*., 2007). Based on the GIS grid technique, every grid can represent individual spatial scopes and include geographic information, such as climate, soil, land use, and social activities. The geographic information in individual grids should be regarded as averaged values over the size of the grid regardless of the source (i.e., field investigation or statistical results) and variations within the grid. The GIS grid scope differs with spatial-scale resolutions. Hence, the sizes represented by the averaged values from the geographic information in the individual grids vary. Large variations in SOC and other soil properties exist even within a GIS grid. For instance, Li (2000) and Tang *et al*. (2006) have estimated the changes in the SOC pool in agricultural soils in China by applying the denitrification-decomposition (DNDC) model. This model is supported by a GIS with the county as the basic spatial unit. All parameters inputted into the DNDC model should be regarded as averages over a county, and SOC as the model output is also the average for a county. Therefore, for appropriate GIS application, the factors influencing SOC averaged over different spatial scopes need to be understood.

The current paper aimed to examine the critical variables explaining SOC content variations in NCPs and CPs at provincial scales in China. Another purpose was to estimate SOC loss in the topsoil caused by cultivation for agricultural production.

2 Data Sources and Processing

2.1 Soil data and processing

From 1979 to 1994, the Second National Soil Survey was conducted in China, and its result was overall and used popularly in scientific research till now. A series of books entitled the Soil Species of China, Volume 1 to 6, was published (SSSSC, 1993; 1994a; 1994b; 1995a; 1995b; 1996). These books have compiled the soil properties of 2473 typical soil profiles collected from 29 provinces in the mainland of China. This soil dataset has been widely applied to estimating SOC storages (Wang *et al*., 2003) and SOC loss caused by cultivation (Wu *et al*., 2003; Song *et al*., 2005). The same dataset was also used in the current investigation.

According to the descriptions of each typical soil profile in the book series, among the whole 2473 soil samples, 1511 soil samples were collected from CPs and 962 were from NCPs. NCPs are those covered with forests, grasses, *etc*. with little or no human impact. In the present study, the SOM content expressed in the books was converted into SOC content using a factor of 0.58 (Commission of Agricultural Chemistry, Soil Science Society of China, 1983). All soil properties, including the SOC content of the surface soil, were arithmetically averaged by province (hereafter referred to as SOCpa for the provincial averaged SOC content) and categorized as whole soil (WS), CP soil, and NCP soil samples. The SOC density (D_{soc}) and pool (P_{soc}) of topsoil were calculated using the methods of Schwager and Mikhailova (2002) as well as Song *et al*. (2005):

$$D_{soc} = SOCpa \times \gamma \times H \times (1 - \delta_{2mm}) \times 10^{-1} \quad (1)$$

$$P_{soc} = S \times SOCpa \times \gamma \times H \times (1 - \delta_{2mm}) \times 10^{-1} \quad (2)$$

where S is land area (ha); γ is the average soil bulk density (g/cm), adopted as 1.30 in NCP soils (Wang *et al*., 2000) and 1.36 in CP soils (Huang and Sun, 2006); H is the topsoil depth (defined as 20 cm in the present investigation), and δ_{2mm} is the average gravel fraction (> 2 mm, considered as 0.06 from the data of the Second National Soil Survey (Huang and Sun, 2006). The change in the SOC pool (ΔP_{soc}) caused by land cultivation was estimated as follows:

$$\Delta P_{soc} = S_1 \times \Delta D_{soc} \quad (3)$$

where ΔD_{soc} is the difference between the SOC densities of NCP and CP soils; S_1 is cropland area (ha). The total cropland area was 1.391×10^8 ha in China in the 1980s (Table 1).

2.2 Climate data and processing

The climate data of 669 meteorological stations, including daily temperature, daily precipitation and daily wind velocity, were obtained from the Chinese Natural Resources Database (Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, 2005). Considering that the Second National Soil Survey was conducted from the late 1970s to the early 1990s, the climate data used in the current investigation were arithmeticed as mean annual value from 1961 to 1980. Based on the location of each station, the climate parameters of temperature, wind velocity, and precipitation were averaged by province. The mean temperature and precipitation from May to October (defined as the growing season) and from November to April (defined as the non-growing season) were also calculated. The purpose was to determine the different effects of climatic parameters on the SOC content during the growing and non-growing seasons.

2.3 Areas of croplands

CP and total land areas were obtained from the *Chinese Natural Resources Series* (*Land*) (The Editorial Committee of Chinese Natural Resources Series, 1996). The proportion of the CP area to the total land area (Pcp) in each province was used to indicate the synthetic effect of cultivation on SOC content.

2.4 Statistic analyses

The variables that may be correlated with SOCpa content included soil properties, climate parameters, as well as land use and management. In the current investigation, the soil properties were limited to those available in the book series. The properties were soil pH, clay content, as well as total P and N content. Given that soil total nitrogen (N) is absolutely dominated by organic N, the SOCpa content is also significantly correlated with the total N averaged by province. Consequently, in the current investigation, the total N content was excluded from the correlation and stepwise regression analyses to prevent its interference with other variables. The climate parameters correlated with the SOCpa content were the mean annual temperature T, mean annual precipitation P, mean annual wind velocity W, as well as mean T and P in the growing and non- growing seasons (T_1, P_1, T_2, and P_2, respectively). The ratios P/T, P_1/T_1, and P_2/T_2 were also correlated with the SOC content. The Pcp reflected the intensity of cultivation in a region and was only correlated with SOCpa contents in the WS category. As aforementioned, all variables were averaged by province prior to statistic analyses.

Correlation and stepwise regression analyses were performed using SPSS 11.5. The purposes were to explore the variables that were correlated with the SOCpa content, and to determine the SOCpa content variations, respectively. Pearson correlation coefficients were used to test correlations at $p = 0.05$ of two-tailed tests. In the stepwise regression, the entrance level was set at $p = 0.05$, and removal level was at $p = 0.10$.

3 Results

3.1 SOC contents and variations at provincial level

Three soil sample categories were used in the current investigation, namely, WS, CP soil, and NCP soil samples. For the WS samples, the SOC content of the topsoil in China was mostly distributed from 2.5 g/kg to 40.0 g/kg, and its samples number was 91% of the total 2473 samples (Fig. 1). The nationwide arithmetic average of the SOC content was 18.29 g/kg, with a variation coefficient of 127%. The SOCpa content of the topsoil of WS samples ranged from 7.67 g/kg (Shandong Province) to 37.49 g/kg (Heilongjiang Province), with an

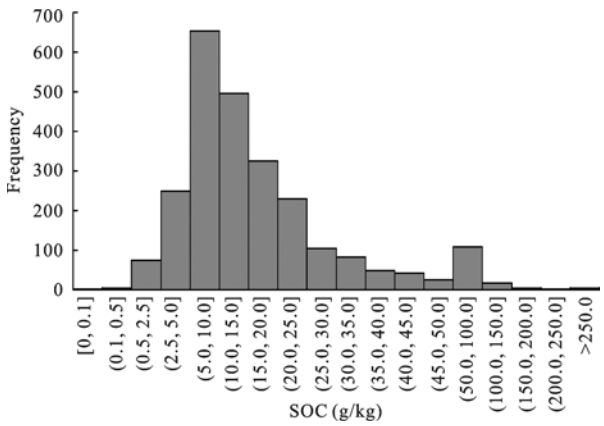

Fig. 1 Frequency distribution of SOC contents of 2473 soil samples in China

average of 17.92 g/kg (Table 1).

The variation coefficient calculated from the SOCpa content was 39.5%, which was much smaller than that calculated from individual soil samples (94.2%). Within a province, the variation coefficient of the SOC content calculated based on individual soil samples varied from 38.8% to 180%, with an average of 94.2%. This result clearly indicated that the SOC variations within a province were larger than those among provinces. The organic C/N ratio ranged from 7.71 to 13.34, with an average of 10.99. A significant linear relationship was found between the organic C/N ratio and SOCpa content (Fig. 2).

Table 1 Provincially averaged soil organic carbon (SOCpa) content and corresponding coefficients of variance (CV)

Province	WS		NCP		CP		Area of cropland (10^6 ha)
	SOCpa (g/kg)	CV (%)	SOCpa (g/kg)	CV (%)	SOCpa (g/kg)	CV (%)	
Fujian	22.95	60.2	31.42	45.0	14.47	44.6	1.65
Jiangxi	16.69	78.9	19.39	92.7	14.52	46.8	2.76
Zhejiang	17.82	79.4	27.38	95.6	15.53	51.1	2.62
Anhui	14.17	78.3	21.33	71.2	10.54	53.2	6.11
Jiangsu	12.44	52.9	24.05	61.5	11.88	47.1	5.48
Shanghai	17.43	38.8	23.78	51.7	17.18	40.3	0.39
Liaoning	12.53	97.3	16.32	103.0	10.06	69.7	4.51
Jilin	20.57	82.1	28.00	73.8	12.79	36.4	5.36
Heilongjiang	37.49	136.0	44.81	133.0	21.73	40.3	11.36
Hubei	17.59	102.0	21.18	111.0	13.36	41.2	4.44
Hunan	17.82	54.9	22.06	70.8	16.14	33.7	4.99
Hainan	13.80	51.6	15.05	52.9	12.91	49.8	1.02
Guangdong	16.34	73.0	21.03	90.2	14.3	43.1	4.48
Guangxi	20.78	73.9	26.82	75.7	15.67	38.1	4.34
Hebei	11.16	96.9	16.41	103.0	8.69	47.8	7.51
Henan	8.93	103.0	19.17	91.5	6.67	46.8	8.95
Shandong	7.67	90.5	14.24	68.2	6.72	84.4	9.14
Inner Mongolia	14.42	82.4	16.55	83.9	11.91	71.0	6.83
Beijing	17.55	114.0	35.62	75.7	8.51	72.0	0.53
Shanxi	18.88	128.0	27.92	103.0	6.45	37.4	6.14
Gansu	13.12	96.2	20.04	89.2	9.22	59.0	5.88
Shaanxi	8.98	90.2	12.59	99.6	7.53	63.5	5.59
Ningxia	8.15	114.6	8.76	131.0	7.15	56.9	1.84
Xinjiang	19.46	123.4	21.46	141.0	17.08	77.8	4.06
Qinghai	24.93	147.0	37.57	125.0	11.05	50.3	0.88
Yunnan	30.92	109.0	57.24	89.4	19.58	50.5	5.79
Guizhou	28.67	89.8	40.97	90.7	22.38	54.8	4.91
Sichuan	20.73	180.0	61.07	126.0	12.01	53.5	11.14
Tibet	27.74	109.0	31.92	114.0	20.82	62.4	0.38
National①	18.29	94.2	26.78	91.7	13.00	52.5	139.10
National②	17.92	39.5	25.63	48.6	13.00	35.4	

Notes: WS, whole soil samples; NCP, non-cropland soil samples; CP, cropland soil samples

① national average of SOC content calculated from individual soil samples and averaged CV of each province; ② national average of SOC content calculated from SOCpa and corresponding CV

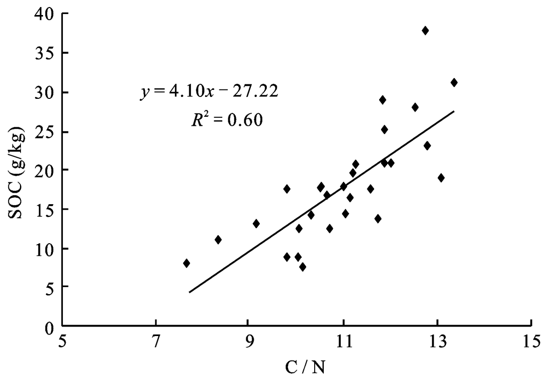

Fig. 2 Relationship between provincially averaged SOC contents and C/N ratios

The SOCpa content of NCP soils ranged from 8.76 g/kg (Ningxia) to 61.07 g/kg (Sichuan), with an average of 25.63 g/kg (Table 1). All the SOCpa contents of NCP soils were larger than those of CP soils in all the provinces. However, the differences between the SOCpa contents of NCP and CP soils greatly varied among the provinces (Table 1). For instance, in Sichuan, the SOCpa content of CP soils was only about 20% of that of NCP soils. In Hainan where the difference in SOCpa contents was smallest, the SOCpa content of CP soils was 14% less than that of NCP soils. Therefore, on the national average, the SOCpa was much larger in NCP than in CP soils; the SOCpa contents of CP soils ranged from 6.45 g/kg (Shanxi) to 22.38 g/kg (Guizhou), with an average of 13.00 g/kg (Table 1).

Similar with the SOCpa variations of WS, those of CP and NCP soils within a province were generally larger than those among provinces. For NCP soils, the variation coefficient of SOCpa was 48.6% (Table 1); within a province, the range was from 45.0% to 151.0%, with an average of 91.7%. For CP soils, the corresponding variation coefficients were 35.4% (Table 1), from 33.7% to 84.4%, with an average of 52.5% (Table 1). The SOC variations both within and among provinces were smaller in CP than in NCP soils. CP soils also had a smaller organic C/N ratio (9.72) than NCP soils (11.97).

3.2 Variables correlated with SOCpa content

The variables correlating with SOCpa content were substantially different among the soil samples. The Pearson correlation coefficient (Table 2) showed that for WS, the SOCpa content was significantly correlated with some climate parameters and soil properties. Among the climate parameters, P/T and P_1/T_1 positively correlated - with the SOCpa content. Among the soil properties, only the clay content significantly correlated with the SOCpa content. The SOCpa content had a significant negative correlation with the Pcp ($R^2 = 0.518$, $p < 0.01$). For NCP soils, only P/T and P_1/T_1 significantly correlated with the SOCpa content. No soil property significantly correlated with SOCpa in NCP soils. In contrast, the soil properties of CP soils more significantly correlated with the SOCpa content than did the climate parameters. The correlation analysis showed that clay content positively correlated and soil pH negatively correlated with the SOCpa content of CP soils. Among the climate parameters, only P_1/T_1 positively correlated with the SOCpa content.

Stepwise regression analyses showed that the variables that significantly explained SOCpa content variations differed among WS, CP soil, and NCP soil samples (Table 3). About 75% of the SOCpa content variation in WS was explained by soil properties (clay and total phosphorus content), climate parameters (P/T), as well as the Pcp. Only the clay content significantly explained the SOCpa content variation in CP soils, although only 24% of the variation was explained. The soil pH, T_1, and W only explained 63% of the SOCpa content variation.

Table 2 Pearson correlation coefficient among climatic variables, soil properties and SOCpa contents

Sample	Climatic variable					Soil property			
	T	P	W	P/T	P_1/T_1	Clay	TP	TK	pH
WS	–0.195	0.075	–0.225	0.533**	0.437*	0.405*	0.245	–0.061	–0.354
NCP	–0.085	0.103	–0.362	0.372*	0.495**	0.220	0.115	–0.076	–0.332
CP	0.101	0.318	–0.152	0.213	0.445*	0.532**	–0.009	–0.138	–0.507**

Notes: WS, whole soil samples; NCP, non-cropland soil samples; CP, cropland soil samples; T, mean annual temperature; P, mean annual precipitation; W, mean annual wind velocity; P/T, ratio of precipitation to temperature; P_1/T_1, ratio of precipitation to temperature from May to October; Clay, clay content; TP, total phosphorus content; TK, total potassium content. *, **, ***, significant at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively

Table 3 Regression equations of SOCpa contents and variables obtained by stepwise regression analyses

Sample	R^2	Linear regression model	
WS	0.75^{***}	$SOCpa = -0.51 + 0.79Clay + 39.37TP + 0.03P/T - 18.9Pcp$	(4)
NC	0.63^{***}	$SOCpa = 154.55 - 10.23pH - 2.26T_1 - 6.27W$	(5)
CP	0.24^{**}	$SOCpa = 2.87 + 0.46Clay$	(6)

Notes: WS, whole soil samples; NCP, non-cropland soil samples; CP, cropland soil samples; *T*, mean annual temperature; *P*, mean annual precipitation; *W*, mean annual wind velocity; *P*/*T*, ratio of precipitation to temperature; T_1, temperature from May to October; Clay, clay content; TP, total phosphorus content. *, **, ***¸ significant at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively

3.3 SOC loss by agricultural cultivation

SOC pools in CP and NCP soils were estimated based on SOCpa contents. The SOCpa contents of individual soil samples were directly averaged and estimated by the regression equations listed in Table 3. On the nationwide average, CPs accounted for 14.78% of the total land area of the mainland of China in the 1980s, and the proportions greatly varied among the provinces. Based on the SOCpa contents directly averaged from individual soil samples in NCP and CP soils and their land areas (Table 1), the SOC pools in the topsoil (0–20 cm) were estimated at 4.48 Pg in CP soils and 55.54 Pg in NCP soils. Based on the SOC contents estimated by regression equations, the corresponding values were 4.62 Pg and 52.98 Pg, respectively. Therefore, the total SOC pool of the topsoil in China was 60.02 Pg (directly calculated from soil samples) or 57.60 Pg (estimated by regression equations) in the 1980s.

Assuming that CP soils had the same SOC densities as NCP soils prior to cultivation, SOC loss due to cultivation was estimated from the difference between the SOC densities of NCP and CP soils using Equation (3). The SOC loss was estimated at 4.98 Pg based on SOCpa contents directly averaged from individual soil samples, and was 4.34 Pg based on regression equations.

4 Discussion

Based on the same dataset from the Chinese Second National Soil Survey used in literature (Wu and Cai, 2006), SOC content variations were demonstrated to increase with increased number of soil samples in the case where the variations were calculated from individual soil samples. However, the variations decreased with increased defined spatial scope when the variations were calculated from the averaged content of a defined spatial scope (Wu and Cai, 2006). The averaged coefficients of variance were 94.2%, 91.7%, and 52.5% within provinces for WS, CP, and NCP soil samples, respectively. The corresponding values among provinces were 39.5%, 48.6%, and 35.4%, respectively (Table 1). These results indicated that SOC variations within provinces were much larger than those among provinces. The SOC content is a function of climate parameters, soil properties, vegetation coverage, land management, and so on. The larger SOC variations within than among provinces suggested that the factors affecting SOC content were more homogeneous among than within provinces. Process-based models, such as CENTURY, ROTHC, and NCSOIL (Nicolardot *et al*., 1994; Parton and Rasmussen, 1994; Jenkinson and Rayner, 1997), have been developed based on knowledge of SOC dynamics at soil profile scales. The variables that explain SOC content variations based on individual soil samples are different from those that explain the variations averaged over a certain spatial scope. Considering that the SOC content and other soil properties available in GIS are, in fact, averaged over GIS grids, the key variables that explain variations in averaged SOC contents need to be understood to apply appropriately GIS information to a process-based model.

NCP soils in the current investigation were not real natural soils, but soils that were less affected by human activities, compared with CP soils. The Pearson correlation coefficients showed that the SOCpa of NCP soils only correlated with two climate parameters, i.e., P/T and P_1/T_1. No soil property significantly correlated with SOCpa (Table 2). These results indicated that climate parameters, especially *P* and *T*, more significantly influenced the SOC content at the provincial scale level than did the soil properties. Stepwise regression analyses showed that SOCpa content decreased with increased soil pH, *W*, and *T* during the growing season. These three variables explained 63% of the SOCpa variation (Table 3), suggesting that the number of variables for explaining the SOCpa variation in NCP soils were much less than those influencing SOC content.

All CP soil samples in the present study were collected from actual croplands. Thousands of years of intensive cultivation had reduced SOC content variations in CP soils both within and among provinces (Table 1). This reduction indicated that after cultivation, more SOC was lost by soils with high original SOC contents than those with low ones. In contrast with NCP soils, stepwise regression analyses showed that SOCpa in CP soils had a significant positive correlation only with the soil clay content. The correlation between SOCpa and soil clay contents has been previously described (Oades, 1988; Hassink, 1997; Carter, 2002). However, the soil clay content explained only 24% of the SOCpa variation in CP soils (Table 3). This finding suggested that the climate parameters and soil properties used in the stepwise regression analyses were not the key variables influencing the SOCpa content in CP soils. The key variables were also not among the variables selected for the current investigation. The unapplied variables are most probably those related with human activities, because organic input and output are partially controlled by crop rotation, as well as management practices such as those for crop residue, organic and chemical fertilizer application, irrigation, *etc*. These human activity-related variables greatly vary among the Chinese provinces, and may have affected SOCpa contents in CP soils more dominantly than climate and soil properties. Hence, variables related to human activities must be considered in future studies on SOCpa content variations in CP soils in China.

Thousands of years of intensive cultivation not only altered the key variables that explained SOCpa variations in CP soils, but also generally reduced the SOC content. On the national average, the SOCpa of CP soils (13.00 g/kg) was only 50.7% of that of NCP soils (25.63 g/kg). Assuming that the SOCpa content of CP soils was the same as that of NCP soils, 49.3% of SOC in the topsoil was lost due to the intensive cultivation for crop production, which is comparable to those observed elsewhere in the world (Lal, 2004a; 2004b). Based on these data, the total loss of SOC was estimated at 4.98 Pg. Using the regression equations in Table 3 to estimate the SOCpa contents of NCP and CP soils, the total SOC loss was 4.34 Pg. Using the same SOC dataset, Wu *et al*. (2003) have estimated that CP soils to 1 m depth have lost about 7.1 Pg of SOC. Song *et al*. (2005) have estimated that CP soils to 30 cm depth have lost about 2 Pg of SOC. The present estimates fell within the previously estimated ranges. There were also uncertainties in the estimates; the lack of area weight of each soil profile was one of the main sources of uncertainties. However, from these estimates, the carbon sequestration potential in CP soils can be roughly estimated to be as much as 3 Pg in the topsoil, assuming that lost SOC can be restored by 50% via good management practices (Lal, 2004a).

Although the nationwide average CP area, which varied from province to province, accounted for only 14.78% of the total land area in China in the 1980s, the thousands of years of intensive cultivation very significantly affected the Pcp in terms of SOCpa variations in WS (Table 2 and Table 3). Stepwise regression analyses showed that a larger Pcp corresponded to less SOC content within provinces. Soil clay content, total phosphorus content, Pcp, and P/T explained 75% of the SOCpa variations in WS.

5 Conclusions

In summary, the variation coefficient of SOC content increased with increasing the number of soil profiles while individual soil profile was taken as a basic statistical unit, and decreased with spatial scale up while average of SOC content in the defined scale was taken as a statistical unit. The majority of SOC content variations averaged within a province in WS and NCP soils were explained by very limited variables. This finding indicated that the number of variables that explained such variations were fewer than those influencing the SOC content. The variables that explained the variations in the SOC content varied with the land use types. For CP soils, only the soil clay content significantly explained 24% of the variation in SOCpa content. Human activity-related variables should be considered in explaining SOCpa variations in CP soils.

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