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Topsoil organic carbon storage of China and its loss by cultivation

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Abstract. Topsoil is very sensitive to human disturbance under the changing climate. Estimates of topsoil soil organic carbon (SOC) pool may be crucial for understanding soil C dynamics under human land uses and soil potential of mitigating the increasing atmospheric CO_2 by soil C sequestration. China is a country with long history of cultivation. In this paper, we present an estimate of topsoil SOC pool and cultivation-induced pool reduction of China soils based upon the data of all the soil types identified in the 2nd national soil survey conducted during 1979–1982. The area of cultivated soils of China amounted to 138×10^6 ha while the uncultivated soils occupied 740×10^6 ha in 1980. Topsoil SOC density ranged from 0.77 to 1489 t Cha^{-1} in uncultivated soils and 3.52 to 591 t Cha^{-1} in cultivated soils with the average being 50 $\pm$ 47 t Cha^{-1} and 35 $\pm$ 32 t Cha^{-1}, respectively. Geographically, the maximum mean topsoil SOC density was found in northeastern China, being of 70 $\pm$ 104 t Cha^{-1} for uncultivated soils and of 57 $\pm$ 54 t Cha^{-1} for cultivated soils, respectively. The lowest topsoil SOC density for uncultivated soils was found in East China, being of 38 $\pm$ 33 t Cha^{-1} and that for cultivated soils in North China, being of 30 $\pm$ 30 t Cha^{-1}. There is still uncertainty in estimating the total topsoil SOC of uncultivated soils because a large portion of them was not surveyed during the 2nd Soil Survey. However, an estimate of total SOC for cultivated soils amounted to 5.1 Pg. On average, cultivation of China's soils had induced a decrease of SOC density of 15 t Cha^{-1} giving rise to an overall pool reduction at 2 Pg. This is significantly smaller than the total SOC pool decline of 7 Pg due to cultivation of natural soils in China reported by Wu et al. (Glob. Change Biol. 2003, 9: 305–315), who made a pool estimation of whole soil profile assuming 1 m depth for all soils. As the mean topsoil SOC density of China was lower than the world average value given by Batjes (J. Soil Sci. 1996, 47: 151–163), China may be considered as a country with low SOC density and may have great potential for C sequestration under well defined management. However, the dynamics of topsoil C storage in China agricultural soils since 1980's and the effects of modern agricultural developments on C dynamics need further study for elucidating the role of China agriculture in global climatic change.

Introduction

Soil organic carbon (SOC) storage in terrestrial C cycling under global climate change has become one of the foci of global soil studies (Lal 1999; Schlesinger 1999, 2000; Kirschbaum 2000; Amundson 2001; Rustad et al. 2001). Estimating the carbon pool and potential sink effect of soils may be crucial for a country or a region to commit to the Kyoto Protocol and Global Climate Change Framework Agreement (Smith et al. 2000a, b) as carbon sequestration by soils has been considered as a practical measure for mitigating the rise in atmospheric CO_2 (Lal 1999; Schlesinger 1999, 2000). World soils preserved approximately 1500 Pg SOC in the upper 1 m of soil cover (Batjes 1996; Lal 1999), changes in climate and land use may have significant effects on SOC dynamics, particularly with respect to its turnover rate (Rustad et al. 2001; West and Marland 2002). Changes in SOC of agricultural soils have been reported by Eve et al. (2002). Assessment of pool size and turnover of SOC at different scales (Batjes 1996, 2002; Fearnsid and Barbosa 1998; Batjes and Dijkshoorn 1999; Houghton et al. 1999; Bhattacharya et al. 2000; Bhatti et al. 2002a, b; Vleeshouwers and Verhagen 2002; West and Marland 2002) have been very well documented while addressing the role of soil carbon dynamics in global change. However, there have been few studies of total topsoil SOC pools of cultivated soils at national or global level.

Efforts have been made worldwide to enhance soil C sequestration to offset CO_2 emission from the industrial sector (Lal et al. 1999; Schlesinger 1999, 2000; Lal 2002a). Increasing attention had been paid to SOC dynamics and its potential for C sequestration in croplands for the last decade (Dadal and Mayer 1986; Rounsevell et al. 1999; Smith et al. 2000a, b; Jacinthe et al. 2001; Uri 2001; Hao et al. 2002; Schuman et al. 2002). Such issues have been raised especially for China with its intensely cultivated soils under extensive soil degradation in a process of fast industrialization (Lal 2002b). China is a country with a long history of cultivation of diverse soil types. While the industrial C emission of China has been rising, C loss from China soils due to intensive agricultural land use has also raised serious concerns (Lindert et al. 1996; Li 2000; Lal 2002b; Wu et al. 2003). Various estimates of the total SOC pool of China's soils range from 50 to 200 Pg (Wang and Zhou 1999; Ni 2001; Pan et al. 2003b). However, the topsoil SOC pool size and its dynamics have been poorly studied (Pan et al. 2003b). Supposing that topsoil SOC stock may account for 80–90% of the stock variations to be observed over decades, Arrouys and Balesdent (2002) worked out an estimate of topsoil SOC pool size of French soils to the upper 30 cm by using 19,000 references available in a national database. Pan et al. (2003a) accomplished an estimate of topsoil SOC pool of China's paddy soils by using the sampling depth records of the topsoil thickness. Nevertheless, there had been no data on the SOC pool of croplands of China and its change due to cultivation.

In this paper, we analyzed the data of all the China's soil types and estimate the total topsoil SOC pool in an attempt to present the pool size and its cultivation-induced change. We aimed to address the role of agriculture in SOC storage dynamics and the necessity to approach a carbon sequestration strategy for China's sustainable agriculture in mitigating the atmospheric CO_2 rise.

Data and methods

Data source

All the data was obtained by the 2nd State Soil Survey conducted in 1979–1982, which are available in a series of China Soil Types of Volumes 1–6 (SSSSC 1993; 1994a, b; 1995a, b; 1996a, 1996b; 1997; 1998). The original soil data of the overall 2456 soil types identified by the soil survey was grouped into uncultivated and cultivated soils according to the sampling records. Soil sampling was done generally at a scale of 1:200 ha and locations were shown in Figure 1. As required by the 2nd State Soil Survey, the SOC content, thickness and bulk density of topsoil of typical uncultivated soil profiles and of most heavily cultivated soils were determined. As a whole, the data set comprised 34,411 whole soil profiles and 523,894 topsoil samples. In this data set, 2553 soil profiles were documented with their land use conditions, of which 923 soil profiles and 165,122 soil samples from uncultivated and 1630 soil profiles and 358,772 soil samples from cultivated soils, respectively. The numbers of soil area were respectively 740×10^6 ha and 138×10^6 ha for uncultivated and cultivated soils though a large portion of uncultivated soils was not surveyed.

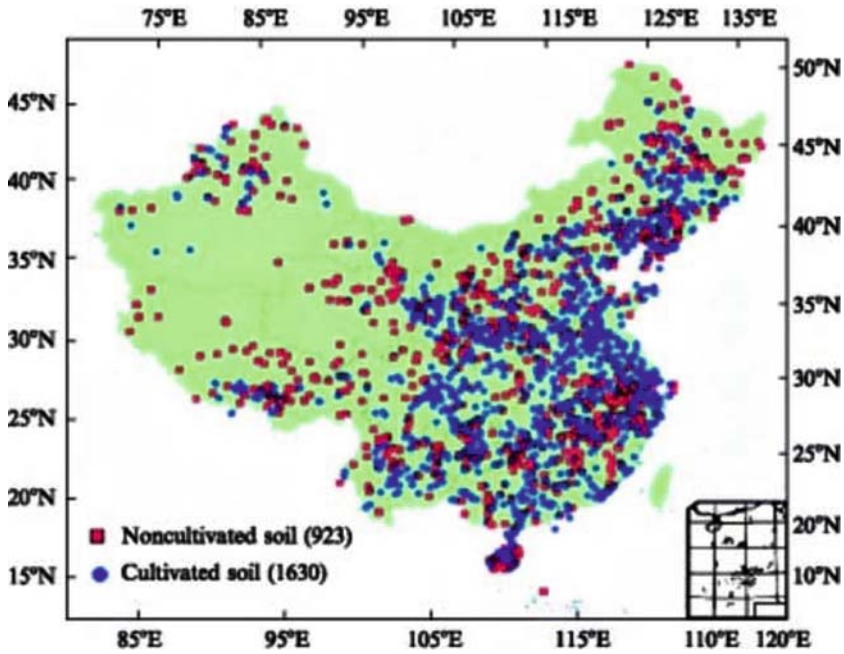

Figure 1. Sampling locations of the typical profiles of the 2456 Soil Series during the 2nd State Soil Survey of China 1979–1982 (Cited from Wu et al., 2003).

Calculation of SOC pool estimate

The SOC pool was calculated to the recorded depth of A horizon (or Ap and P horizon in case of paddy soils) or to a depth of 30 cm in case of A horizon thickness exceeding 30 cm. The SOM content from the original data was converted to SOC by multiplying a constant of 0.580, since the determination was done by conventional wet combustion (SSSSC 1996b). Thus, the topsoil SOC density can be obtained by the following equation:

$$D_{oc} = \mathrm{SOC} \times \gamma \times H \times (1 - \delta_{2\,mm}/100) \times 10^{-1} \quad (1)$$

where D_{oc} and SOC are the amount (t ha^{-1}) and content (g kg^{-1}) of SOC, respectively, γ is the bulk density (g cm^{-3}), H is the recorded thickness (cm), and $\delta_{2\ mm}$ is the fraction (%) of $>$2-mm fragments in soil. In cases where data were missing, bulk density value γ in the equation was estimated by regression analysis between the available data of bulk density and SOC content for a given layer (Figures 2 a and b).

While the total SOC pool (P_{oc}) of soils can be estimated by:

$$P_{oc}(tC) = \sum_{i=1}^{n} S_i \times \sum_{j=1}^{n} \mathrm{SOC}_j \times \gamma_j \times H_j \times 10^{-1} \quad (2)$$

where j is the sublayer number of topsoil and S_i is the number of area (ha) of a given soil types i. The calculation was carried out separately for the cultivated and uncultivated soils. The cultivation-induced C change was deduced by subtracting the SOC amount of uncultivated soil by that of cultivated soil for individual soil types.

Results and discussion

Relationship between SOC content and bulk density

The regressions between soil bulk density and SOC content depends on soil types (Callsen et al. 2003; Pan et al. 2003a). Of the data available, 3645 topsoil samples of uncultivated soils and 4765 of cultivated ones had records of means or single measurements of both SOC content and bulk density (γ). The regression between γ and SOC (Figures 2 a and b) are found as follows: For the uncultivated soils:

$$\gamma = 1.3565 \times e^{-0.0046*\mathrm{SOC}} \qquad (R^2 = 0.7260, p < 0.001) \quad (3)$$

and for the cultivated soils

$$\gamma = 1.3770 \times e^{-0.0048*\mathrm{SOC}} \qquad (R^2 = 0.7870, p < 0.001) \quad (4)$$

The regression Eqs. (3) and (4) were used to estimate the missing bulk density values for the uncultivated and cultivated soils, respectively.

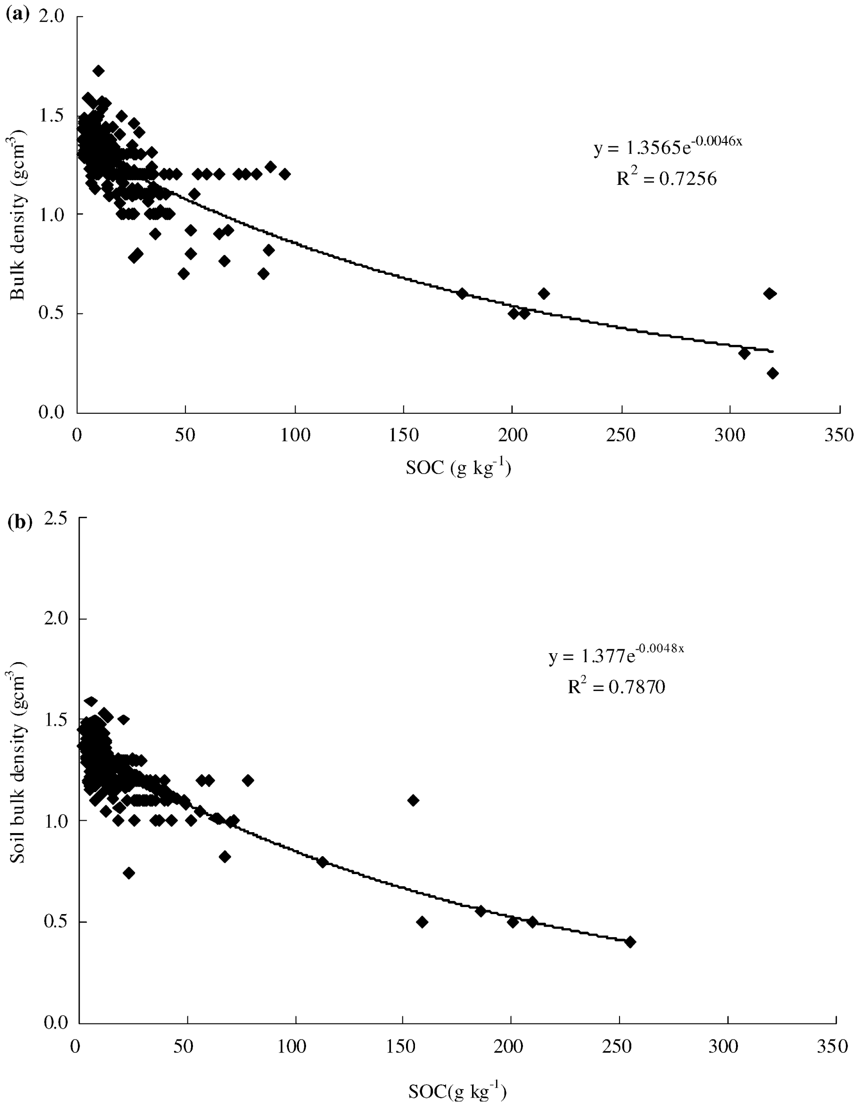

Figure 2. Correlation of bulk density with SOC for uncultivated soils (a) and for cultivated soils (b).

Topsoil SOC amounts

The calculated topsoil SOC density for individual soil types varied in a wide range from 0.77 to 1489 t Cha^{-1} for uncultivated soils and from 3.52 to 591 t Cha^{-1} for cultivated soils. The frequency distribution patterns of SOC of

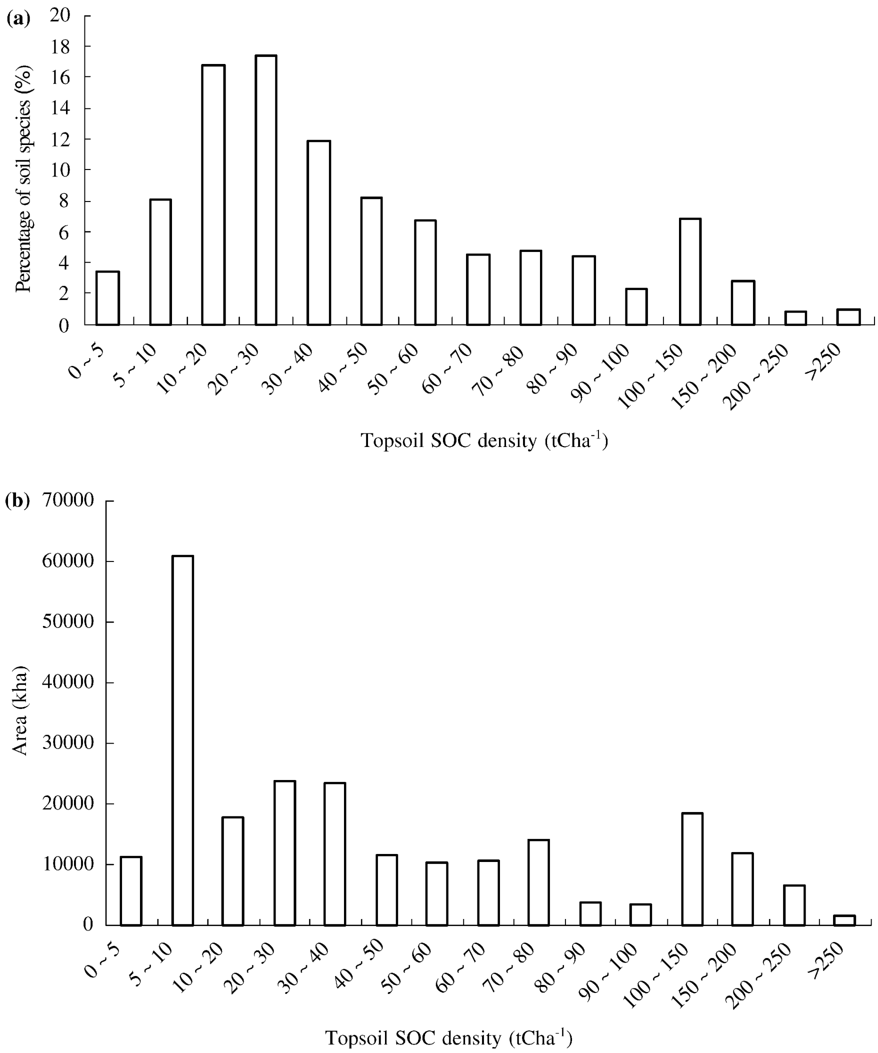

Figure 3. Frequency distribution of topsoil SOC density in the term of (a) percentage of number soil species (%) and (b) area (kha) among uncultivated soils.

1281 uncultivated soils and that of 1383 cultivated soils are shown in Figures 3 and 4, respectively. Over 60% of the cultivated soils corresponding to an area of 82 Mha possessed an averaged SOC amount in range of 10 to 40 t Cha^{-1}, while only a minor portion of uncultivated soils (an area of 4.07 Mha) showed high averaged topsoil SOC in range of 100 to 200 t Cha^{-1} . The mean topsoil SOC density (Table 1) of uncultivated soils was 50 $\pm$ 47 t Cha^{-1} and that of cultivated ones was 35 $\pm$ 32 t Cha^{-1}, showing a general reduction of topsoil

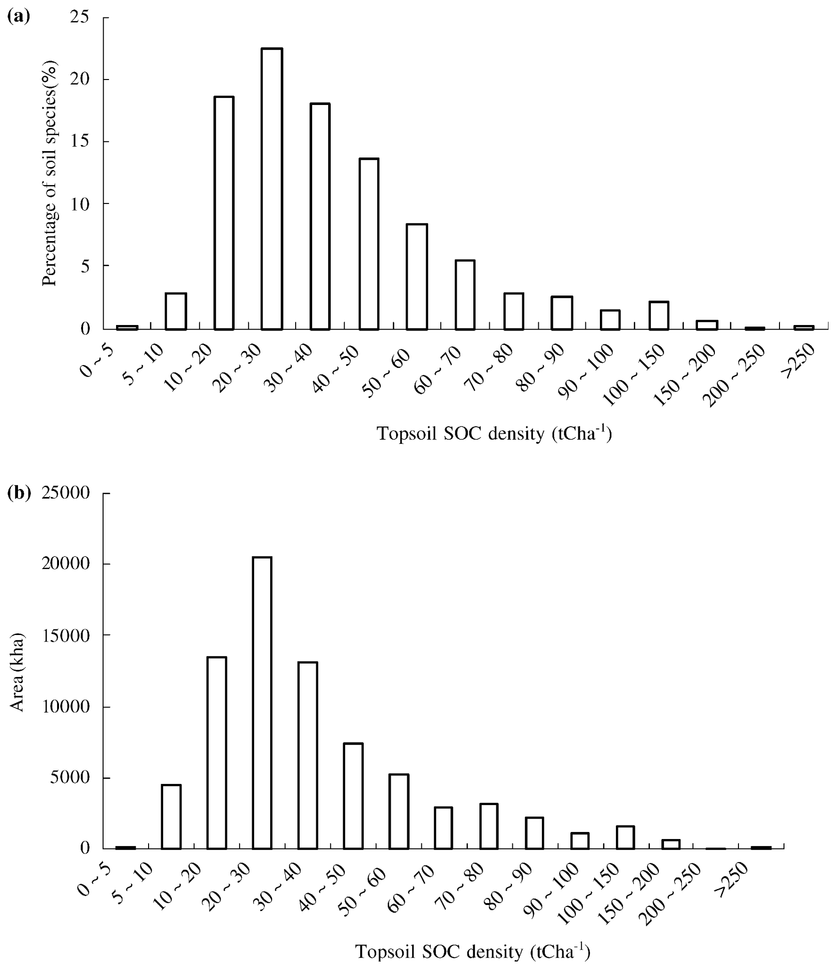

Figure 4. Frequency distribution of topsoil SOSOC density in the term of percentage of total number of soil species (a) and of occupying area (kha) (b) among cultivated soils.

SOC density at 15 t Cha^{-1} on mean due to cultivation of natural soils. Similarly, Arrouys and Balesdent (2002) reported that mean SOC of French soils under different land uses ranged from 30 to 90 t Cha^{-1} while of those under annual crops and perennial crops it was lower than 45 t Cha^{-1} and those under permanent grassland and forests exhibited higher SOC density up to 70 t Cha^{-1}. Their study showed a marked reduction in topsoil SOC pool after shifting from grassland and forests lands to farmlands. In Brazil where the SOC ranged from 15 to 418 t Cha^{-1}, most of the soil areas had an SOC varying between 30 and 60 t Cha^{-1} (Bernoux 2002). Comparatively, China's soils generally had lower topsoil SOC density.

Table 1. Distribution of topsoil C storage among the groups of uncultivated and cultivated soils in China (data source: SSSSC 1997).

FAO/UNESCO	Area (kha)		Sample number		SOC density (t Cha^{-1})		C pool (Tg)[a]	
Taxonomic group	Uncultivated	Cultivated	Uncultivated	Cultivated	Uncultivated	Cultivated	Uncultivated	Cultivated
Acrisols	2856.13	1074.00	424	606	28.91 ± 12.07	33.36 ± 16.49	86.08	33.35
Alisols	20131.8	3115.53	2656	1340	61.87 ± 33.14	37.50 ± 20.68	1259.24	126.15
Arenosols	112396.89	1066.40	1398	4934	20.22 ± 31.30	25.11 ± 33.50	968.86	17.04
Calcisols	61065.07	3288.40	2353	4686	14.90 ± 15.90	26.94 ± 12.63	451.88	93.29
Cambisols	185721.75	16539.90	32,287	40,898	45.70 ± 42.57	24.57 ± 11.82	14846.60	378.27
Chernozems	9234.60	3976.00	19,660	19,951	76.49 ± 54.60	71.59 ± 48.71	908.50	255.18
Fluvisols	6404.67	25989.53	14,070	49,187	18.65 ± 10.17	24.72 ± 14.84	138.92	553.84
Gleysols	12099.00	507.73	564	288	166.43 ± 252.21	121.92 ± 104.52	1844.13	84.07
Histosols	1442.27	38.93	84	66	246.95 ± 160.30	244.28 ± 198.40	186.20	16.54
Kastanozems	35195.67	7109.40	5589	6335	40.58 ± 23.21	36.28 ± 18.86	1488.07	258.00
Lixisols	930.60	905.60	868	12,751	24.31 ± 10.89	20.35 ± 7.09	26.20	18.14
Luvisols	28618.4	4014.33	9967	9571	74.77 ± 50.76	52.71 ± 26.08	1709.29	169.04
Phaeozems	2523.67	4822.87	15,423	3748	80.68 ± 30.75	72.85 ± 33.44	222.28	368.80
Podzols	0.067	–	1	–	133.62 ± 0.00	–	0.01	0.00
Regosols	20758.53	10411.93	16,028	16,574	26.99 ± 19.79	20.04 ± 9.83	538.06	164.09
Solonchaks	41243.14	717.93	2422	1572	18.27 ± 14.00	21.75 ± 14.61	483.37	16.20
Acrisols/Alisols	70486.13	4202.67	13,136	4530	30.95 ± 16.75	33.44 ± 17.87	2467.72	142.89
Fluvisols/Cambisols	–	29780.33	–	150,543	–	46.91 ± 25.73	0.00	1309.74
Gleysols/Phaeozem	18327.60	6742.40	9115	5656	65.25 ± 35.69	56.82 ± 29.75	1472.07	507.03
Leptisols/Cambisols	4103.67	78.67	144	16	151.68 ± 67.02	83.84 ± 44.26	569.38	4.47
Luvisols/Cambisols	54556.66	5785.27	8256	8128	73.72 ± 45.98	51.80 ± 35.72	6754.95	300.62
Regosols/Leptisols	51534.27	3869.86	8825	7312	42.79 ± 33.63	39.05 ± 24.66	2026.33	178.75
Vertisols/Cambisols	84.40	3676.67	1852	10,080	34.97 ± 11.72	28.90 ± 5.79	2.67	96.33
Total/Mean	739714.99	137714.35	165,122	358,772	49.84 ± 46.69(51.98)[b]	35.08 ± 31.57(36.97)	38450.82	5091.83

[a]Estimated using the area weighted mean SOC density.

[b]The number in parenthesis is the area weighted mean of all the soil groups.

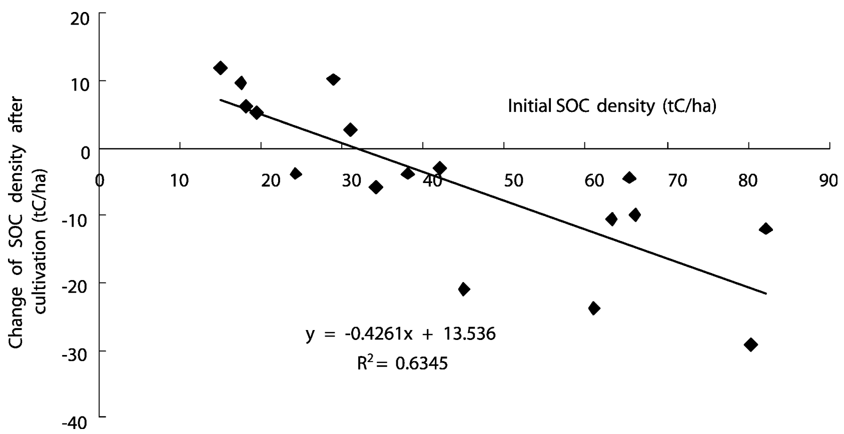

Figure 5. Change of mean topsoil SOC density of mineral soil groups after cultivation.

Distribution of SOC amount in pedogenic soil groups

The area number, means of SOC amounts and the calculated C pool of pedogenic soil groups in accordance to the system by FAO & UNESCO (1988) soils were given in Table 1. For uncultivated soils, the highest mean SOC density was found in Histosols being 247 ± 160 t Cha^{-1}, and the lowest one in Calcisols being 15 ± 16 t Cha^{-1}, of which most were in Northwest China where dry condition reduces crop growth depressing SOC accumulation. For cultivated soils, however, the highest mean SOC density was also found in Histosols being 244 ± 198 t Cha^{-1}, the lowest one was in Regosols being 20 ± 10 t Cha^{-1}. Cambisols had the biggest topsoil C pool for uncultivated soils at 15 Pg with a medium SOC density of 46 ± 43 t Cha^{-1} and the largest area of 186 Mha. The transitional group of Fluvisols/Cambisols was shown as a soil type of the biggest topsoil C pool (1.31 Pg) among the cultivated soils and had relatively high SOC amount of 47 ± 26 t Cha^{-1}. In fact, most of these soils were classified as paddy soils in Chinese Pedogenic Classification in (SSSSC 1998). Pan et al. (2003a) had reported an enhanced C storage in paddy soils of China of 0.3 Pg due to long term paddy management. The effect of cultivation on topsoil SOC differed from group to group, with those high in SOC contents susceptible to change promptly Figure 5). Cultivation did enhanced SOC accumulation in some soil groups originally poor in SOM due to application of organic manure and/or high biomass input under irrigation (Pan et al. 2003b), especially in soil groups of dry farmlands of West China (Wang et al. 1996; 2001). This is also true for some soil groups from South China. Batjes (1996) reported worldwide mean topsoil (0–30 cm) SOC density values of 31, 13, and 51 t Cha^{-1} of Acrisols, Arenosols, and Luvisols, respectively. Apparently, the topsoil SOC of cultivated soils of Acrisols, Arenosols and Luvisols in South China was comparable to or slightly higher than the world means. Enhancement of SOC in cultivated Alisols and Arenosols in subtropical China were frequently reported (Department of Agriculture, Hunan Province 1989; Liu et al. 1999).

Distribution of SOC by geographical regions

The distribution of topsoil SOC in terms of soil–geographical regions is shown in Table 2. The highest mean topsoil SOC both for uncultivated and cultivated soils was found in northeastern China, where high SOC amounts were frequently reported (Wang et al. 2002; Li et al. 2004). The mean SOC amounts of cultivated soils was 57 ± 54 t Cha^{-1} compared to 70 ± 104 t Cha^{-1} of uncultivated soils in this region. The lowest mean topsoil SOC of uncultivated soils (38 ± 33 t Cha^{-1}) was found in East China, the lowest of the cultivated soils (30 ± 30 t Cha^{-1}) was observed in North China. Considerable reduction of topsoil SOC in range of 20–40 t Cha^{-1} was found in Southwest China, Northeast China and North China, which are generally considered zones vulnerable to degradation (Zheng et al. 1997; Zhou 1999). The biggest reduction of SOC density in cultivated soils of Southwest China could be attributed to the severe desertification of the Karst lands due to improper cultivation of the sloping and stony lime stone terrains (Anonymous 2003). Nevertheless, there had been small reductions of SOC due to cultivation in South China. The natural upland and Savanna soils in this region had SOC density values below 110 t Cha^{-1} for 1 m soil. While the paddy soils, as the main soils under cultivation in this region, had a mean SOC density close to that of the soils under needle-leaf forest and higher than that of dry upland farmlands (Zhao et al. 1997; Li and Zhao 2001). While in many cases, increase of SOC content in cultivated soils was found as most of the red soils are poor in SOC in the region.

Wang et al. (2002) and Li et al. (2004) reported a wide range of SOC of 24–925 t Cha^{-1} with an area-weighted mean of over 200 t Cha^{-1} for the upper 1 m in Northeast China under various vegetation types. The dramatic reduction of the topsoil SOC density due to cultivation and the wide range of SOC in this region may reflect a high sensitivity of soil carbon in the temperate zone to management (Wang et al. 2002). Many studies have discussed the sensitivity of the ecosystems in high latitude regions to global climatic change (Bousquest et al. 1999), and the soils in such regions are especially susceptible to future land use change and projected climate change (Esser 1987; Tian et al. 2000). In fact, Xie (1999) had pointed out the high sensitivity of the terrestrial ecosystem of Northeast China to global warming. The SOC also decreased due to cultivation in northwestern China despite the very low mean SOC density (42 ± 49 t Cha^{-1} and 33 ± 23 t Cha^{-1}, respectively for uncultivated and cultivated soils). In this region, depletion of SOC in natural soils could be attributed to unfavorable plant growth (Wang et al. 2001) and enhanced decomposition and mineralization of biomass caused by aeration under

Table 2. Distribution of density and storage of topsoil SOC in geographical regions of China.

Geographical region	Surveyed area (Mha)		Topsoil thickness (cm)		SOC density (t Cha^{-1})		C storage (Tg)		Cultivation-induced loss	
	Uncultivated soils	Cultivated soils	Uncultivated soils	Cultivated soils	Uncultivated soils	Cultivated soils	Uncultivated soils	Cultivated soils	SOC density[b] (t Cha^{-1})	Pool (Tg)
East China	45.93	37.82	17.77 ± 7.00	23.46 ± 5.51	37.75 ± 32.83 (39.26)[a]	35.62 ± 16.81 (34.21)	1803.21	1293.82	5.05	191.0
Northeast China	55.52	21.17	25.56 ± 9.13	26.12 ± 7.40	70.49 ± 104.46 (100.53)	57.17 ± 53.67 (64.00)	5581.43	1354.88	36.53	773.3
South China	22.85	7.73	19.68 ± 6.52	22.77 ± 5.14	43.68 ± 32.64 (41.44)	38.02 ± 18.50 (39.47)	946.90	305.10	1.97	15.23
North China	17.53	18.06	24.98 ± 8.78	25.63 ± 7.38	39.96 ± 39.91 (47.64)	30.35 ± 29.93 (23.56)	835.13	425.49	24.08	434.9
Northwest China	221.97	25.21	23.32 ± 9.30	26.74 ± 4.73	41.74 ± 49.44 (36.73)	32.67 ± 22.76 (24.29)	8152.96	612.35	12.08	304.5
Southwest China	68.98	19.50	21.14 ± 8.33	24.49 ± 6.07	74.89 ± 81.74 (75.05)	48.29 ± 24.58 (42.08)	5176.95	820.56	32.97	642.9
Total/Mean	432.78	129.49	22.73 ± 8.88	24.81 ± 6.36	51.02 ± 66.11 (51.80)	38.41 ± 31.15 (37.16)	22416.67 (35249.41)[c]	4811.85 (5117.30)[c]	18.24	2.36

[a]The number in parenthesis is the area weighted mean.
[b]Area weighted mean of different types of cultivated soils in each region.
[c]The total area of uncultivated soils uncultivated soils was 739.71 and 137.71 Mha, respectively.

deficiency of water along with preferential removal of topsoil rich in SOC by erosion (Tisdall 1996). Relatively low topsoil SOC levels and reductions due to cultivation could be found in South China and East China where traditional agriculture was characterized by well managed practices for enhancing soil fertility for a long time (Li 1992; He 1994). A remarkable increase of topsoil SOC density has been observed in cropland soils in these regions shifting from triple cropping to double cropping since the 1980's (Pan et al. 2003b; Zhang et al. 2004).

C stock of topsoil and cultivation-induced change in China

An estimate of topsoil SOC and pool reduction of soils after cultivation was conducted by using the different statistical mean values obtained in this work (Table 3). The mean reduction of the SOC varied from 13 to 15 t Cha^{-1} and the calculated pool reduction thus may lie between 1.7 to 2.0 Pg. This was apparently smaller than the sum of the pool reduction for all the geographical regions. Error may exist because sampling intensity in some regions (such as the Tibet plateau and Northwest China) was not sufficient as compared to the eastern China (cf: Figure 1). There is still uncertainty in estimating the overall pool of topsoil SOC of uncultivated soils as a large portion of them were not surveyed. Overall topsoil SOC pool of uncultivated soils of China could be estimated amounting to 36.86 Pg by using the mean SOC density of 50 t Cha^{-1} for the surveyed uncultivated soils (Table 1). When taking into account that the unsurveyed soils were mainly in the Tibet Plateau (Figure 1) due to inaccessibility to soil sampling in the early 1980's, the rest uncultivated soils may have a total topsoil C pool of 12.82 Pg using a mean topsoil SOC density of 42 t Cha^{-1} for China alpine soils. Therefore, a reasonable overall pool of the uncultivated soils of China may be 40.4–42.0 Pg. Nevertheless, long-term cultivation of China had induced a reduction of topsoil SOC around 14 t Cha^{-1} and an overall pool loss of 2 Pg after cultivation of natural soils. These C losses were especially remarkable in Northeast and North China.

Wu et al. (2003) made an estimation of total SOC stock of China's soils being 78.3 Pg in upper 1 m by using similar methodology and recently Li reported an estimate at 82.6 Pg by using a biogeochemical model. Accordingly,

Table 3. Estimate of loss of topsoil SOC density and pool of soils after cultivation.

Soils	Mean SOC density (t Cha^{-1})			C pool (Pg)	
	Soil profile statistics	Soil region statistics	Weighed by soil area	Surveyed area	Total area
Uncultivated	49.84 ± 46.69	51.02 ± 66.40	51.98	22.50	35.25
Cultivated soils	35.08 ± 31.57	38.41 ± 31.15	36.97	4.81	5.12
Cultivation-induced loss	14.76	12.61	15.01	1.63–1.94	1.74–2.07

the topsoil SOC pool size here accounted for 48–54% of the total of their estimates. The total topsoil SOC pool of China amounted to 5.1–5.3% to the world total in contrast to the soil area proportion of 6.4% of the world. In contrast, the soil area of French was 0.30% of the world and the total topsoil SOC storage was 0.47% of world's total (Arrouys and Balesdent 2002), and Brazil's area was 5.54% of the world, with the 5.32% of total topsoil SOC storage (Bernoux et al. 2002). Thus, China could be considered as a country of low topsoil C. The total cultivation-induced loss 2 Pg of topsoil SOC constituted 29% of the total cultivated C loss of China soils in 1 m depth of soil (Wu et al. 2003) and as much as 40% of the present stock of the cultivated soils of China.

While China is still facing the challenge of soil degradation, C sequestration is important for China under Kyoto Protocol. The present low topsoil SOC density may offer potential for C sequestration in agriculture when adopting C sequestration strategy and practical measures (Lal 2002b). The C loss could be expected to recoverable by conservation tillage, along with efficient management of inputs of irrigation, fertilizer, and pesticides in agricultural systems. Several authors have shown considerable rate of topsoil SOC increase in China agricultural soils (SESATC 2003), particularly in paddy soils (Pan et al. 2003a, b; Zhang et al. 2004). However, approaches for attaining rapid topsoil SOC sequestration deserve research needs for China soil studies on soil C policies and national C sequestration strategy.

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