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Decomposition of wheat straw influences organic carbon contents of the aerobically cultivated soils

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Abstract:

Carbon sequestration mechanism and potential in different pedogenetical types of paddy soils are not well understood. We incubated the three representative paddy soils and a marsh soil with maize straw for six-months at (24°C) and investigated the changes in soil organic carbon (SOC) and different fractions of soil organic matter (SOM). It was found that total soil organic carbon, Ca-bound soil organic carbon (Ca-SOC), Fe- and Al-bound soil organic carbon (Fe (Al)-SOC) and insoluble residual soil organic carbon (IR-SOC) increased after adding 8% wheat straw into the soils. The increased carbon existed as Fe (Al)-SOC during the first phase (30 days), followed by decreased in the bulk SOC, Ca-SOC and Fe (Al)-SOC while IR-SOC increased with the time. Thus, the Ca-SOC and Fe (Al)-SOC were gradually transformed into IR-SOC with time. Finally, the increased carbon was sequestrated as Fe (Al)-SOC and IR-SOC in these four soils. There was positive correlation between increased total SOC and increased Fe (Al)-SOC during the first phase (30 days). We also observed positive correlation between increased Fe (Al)-SOC and total SOC without corn straw (CK treatment) at the end of incubation

(120 days), but there was negative correlation between increased Ca-SOC and total SOC under CK treatment after 120 days of incubation. The increased contents of bulk SOC and fractions of SOM were significantly higher in HP than in other three soils. The results of covariance analysis showed that there was significant difference between increased SOC and soil types and the original SOC did not make any effect on it. As compared to other paddy soils, HP showed more potential for carbon sequestration. Our findings suggest that association of SOC with ferric oxyhydrates plays an important role in SOC sequestration in China's paddy soils and the potential of carbon sequestration in paddy soils is related to their different soil types.

Key words: soil organic carbon, carbon sequestration, Fe- and Al-bound soil organic carbon, different pedogenetical types of soil

Introduction

To increase soil carbon storage, managing soils is as a means to reduce carbon dioxide (CO_2) concentrations in the atmosphere. Appropriate action, however, is required to understand the mechanisms governing the long-term residence time of organic matter (OM) in soils (Abro *et al.*, 2014). Substantial research indicates that soil mineral assemblage is more important than clay content in controlling soil C dynamics, particularly in the presence of short-range-order materials and Al-humus complexes (Rasmussen *et al.*, 2006). Some studies have shown the importance of minerals for OM stabilization that are slower decomposition rates of OM associated with mineral surfaces (Jones & Edwards, 1998; Van Hees *et al.*, 2003; Kalbitz *et al.*, 2005). Wiseman and Püttmann (2005) observed that the relationship between specific surface area (SSA) and organic carbon (OC) concentrations was likely to be restricted to certain soils and might be a product of the sorptive capacity of Fe and Al oxides. Al and Fe oxides appear to be especially significant and might have a greater affinity for organic material than other surfaces such as clay minerals (Kaiser & Zech, 1999; Kaiser *et al.*, 2002). In addition, the metallic ions play an important role in the formation and stabilization of soil organo-mineral complexes, mainly as bonding bridges between the humic substances and the clay minerals. Ca-bound and Fe- and Al-bound humus have been considered the most basic types of soil bound humus all along (Xu & Yuan, 1993). The stability of Ca-bound soil organic carbon (SOC) and Fe- and Al-bound soil organic carbon, Fe (Al)-SOC, is different and the Fe (Al)-SOC is more stable than Ca-SOC in soil (Li *et al.*, 2003). Pandey et al. (2000) studied the stability constant (log K) for different metal-humic acid complexes and indicated that Fe-bound humus was more stable than Ca-bound humus. The organic carbon associated with Fe^{3+} irons, bound with humic substances has shown a high stability (Senesi *et al.*, 1977; Senesi & Calderonib, 1988). Moreover, the protective effect of both aluminium and iron against the biodegradation of all types of organic matter is high (Boudot *et al.*, 1989; Aran *et al.*, 2001; Li *et al.*, 2003) and the Fe_d and Al_d are positively correlated to soil organic carbon (He *et al.*, 1998; Curtin, 2002; Kiem & Kögel-Knabner, 2002). Fe polycations associated with humic colloids are slowly degraded, and more binding sites are occupied as a consequence of dispersion (Lippold *et al.*, 2007). These studies have shown that the stability of soil organic carbon relates to the Fe and Al oxides, and Fe- and Al-bound soil organic carbon play an important role in carbon sequestration. However, limited information is available about role of Fe and Al-bound organic carbon to understand the mechanism of carbon sequestration and potential for C stabilization in different pedogenetical types of paddy soils (Stott *et al.*, 1983; Six *et al.*, 2002; Lützow *et al.*, 2006; Pan *et al.*, 2008).

In this study, we investigated the changes of total organic carbon (TOC) and fractions of soil organic matter (Ca-bound SOC, Fe- and Al-bound SOC and insoluble residue SOC) by conducting 120-days laboratory incubation study of maize straw in three typical types of paddy soils and a marsh soil. The aim of our study was to understand the potential of carbon sequestration in different pedogenetical types of soil and the stability of different soil organic carbon complexes associated with humic substances and metal oxides during the decomposition of plant materials.

Specifically, we addressed the following questions:

(1) Is the increased SOC of different types of paddy soil and mash soil related to soil types during decomposition of plant materials?

(2) Which kind of SOM fractions is the principal contributor in increased SOC after adding plant materials into paddy soils and marsh soil?

(3) How do the fractions of SOM of different types of paddy soil and marsh soil transform during decomposition of plant materials?

Material and Methods

Soils and experimental design

The soil used in this incubation study was collected in August, 2009 from Sanyuan County, Guanzhong Plain area, Shaanxi Province, Northwest China. Annual winter wheat and summer maize rotation is a major cropping system in this area. The mean annual temperature and precipitation are approximately 13.6°C and 656 mm, respectively. The soils were classified as Earth-cumuli-Orthic- Anthrosols according to Chinese Soil Taxonomy (CRG-CST, 2001). The texture of soil was clay loam with field water capacity of 300 g kg-1, pH 7.6, organic carbon of 9.2 g kg-1 and total nitrogen of 0.86 g kg-1. Maize (*Zea Mays* L.) Soil samples were collected from surface horizon (0 to 15 cm) using soil auger. The soil was air dried and kept in plastic bags. Visible plant residues such as roots and leaves were removed by hand. The soil was ground and sieved through 2 mm sieve and then stored for 5 days at 4°C.

The maize straw (including leaves and stems) was collected from the same was harvested and taken to the laboratory, washed with distilled water and dried at 70°C. The maize straw was cut into small pieces (<1 cm), ground and mixed with the soil samples for incubation The dried wheat residue which contained 438 removed. The dried maize residue which contained 438 g C kg^{-1} and 6.81 g N kg^{-1} was crushed and sieved through 0.42 mm mesh, mixed and stored.

The 8% wheat straw was mixed into moist soils (dry maize straw to dry soil) in polyethylene (PE) containers and water holding capacity (WHC) was adjusted to 60%. All PE containers were weighed and covered with plastic film with few holes, and then transferred to incubation machine with a beaker of distilled water to maintain air humidity. All treatments were in triplicate and incubated in the laboratory for 30, 90 and 120 days at 25±1°C and throughout moisture content was kept at 60% of WHC by adding distilled water per 48 hours as necessary. Control treatments (CK, without maize straw) were also incubated in the same conditions during each phase. Soil replicates were extracted for Ca-bound soil organic carbon (Ca-SOC) and Fe- and Al-bound soil organic carbon (Fe (Al)-SOC) before and after incubation.

Ca-bound SOC, Fe- and Al-bound SOC and insoluble residue SOC

Ca-bound SOC and Fe- and Al-bound SOC were extracted from soils with selected solution as described by Xu and Yuan (1993).

(1) Ca-SOC was extracted by 0.5 M Na_2SO_4 and washed by 1% Na_2SO_4 solution.

(2) Fe (Al)-SOC was extracted by a 0.1 M NaOH and 0.1 M $Na_4P_2O_7$ solution.

0.5 M Na_2SO_4 had a well specificity to Ca, by only extracting Ca-bound humus without destroying Fe- and Al-bound organo-mineral complexes (Xu & Yuan, 1993) [26]. Soil samples (2 g) were placed in polyethylene / plastic centrifuge tubes with 0.5 M Na_2SO_4 solution (1:10) and shaken for one hour on a mechanical shaker, allowed to stand overnight. The mixture was centrifuged at approximately 1780 g for 15 minutes at 20ºC and the supernatant extracts (Ca-SOC) were put in a 250 mL plastic bottle. The soil residue was further extracted with the same extracting solutions for twice, thus the extracts were almost free of Ca and SOC and combined the solutions. Then the soil residue was washed with 1% Na_2SO_4 solution for triplicate. All the washings and extracts were put in the same bottle and centrifuged at approximately 7150 g for 20 minutes at 20ºC, and then these solutions were filtered into a volumetric flask. And the residue was washed with distilled water for three times.

After this, the soil residue was extracted by a 0.1 M NaOH and 0.1 M $Na_4P_2O_7$ solution and shaken for one hour, allowed to stand overnight. Then the mixture was centrifuged at approximately 1780 g for 15 minutes at 20ºC and the supernatant extracts (Fe (Al)-SOC) were transferred to a 250 mL plastic bottle. The s residual soil was further extracted with the same extracting solutions twice and all extracts were put in the same bottle, centrifuged at approximately 7150 g for 20 minutes at 20ºC, and then these extracted solutions were filtered into a volumetric flask. The insoluble residual soil organic carbon (IR-SOC) in the bottom of centrifuge tube was not soluble in water at any pH value.

Analysis of soils and fractions

Organic carbon was estimated by digestion with 0.4 M potassium dichromate and back-titrating with 0.2 M ferrous ammonium sulphate (Lu, 2000); Total N was measured by kjeldahl method (Lu, 2000). Water holding capacity (WHC) was determined as described by Cai and Mosier (1999). Soil pH was measured with a composite electrode using a 1:2.5 soil to water ratio. The content of Ca-SOC and Fe (Al)-SOC extraction was determined on a Total Organic Carbon Analyzer (Analyzer multi N/C 2100), and the amount of IR-SOC was calculated by TOC minus Ca-SOC and Fe (Al)-SOC.

Results and Discussion

Wheat straw decomposition and the increase in soil organic matter

The residual carbon of plant materials not only included undecomposed and semi-decomposed plant materials but also contained the carbon of humus formed recently. The residual ratio gradually decreased and the decomposition ratio increased with time (Fig. 3). Comparing PP and MS, the decomposition ratio of maize straw in HP and RP were lower and the residual ratios were higher after 120 days of incubation (Fig. 3). The total organic carbon of four soils was increased after adding 8% wheat straw, then it decreased with time. after 120 days of incubation, compared to control (0% maize straw), treatments with 6% maize straw showed an increase SOC contents of 11.18 g kg^{-1}, 10.73 g kg^{-1}, 7.41 g kg^{-1} and 4.81 g kg^{-1} in HP, RP, PP and MS, respectively (table 2). There was significant difference between increased SOC and soil types while the original SOC contents did not make an effect on it (table 3). As compared to mash soil, the increased SOC was higher in paddy soils, especially in HP.

The increase of Ca-SOC was observed in four soils with maize straw and as well as under CK treatment after 120 days of incubation. In four soils, the amount of Ca-SOC increased by 25.23% in PP which was the highest, and the lowest increase was 12.20% in RP (table 2). The increased Ca-SOC contents positively reduced with increase in the TOC contents under CK treatment after 120 days of incubation ($R^2 = 0.94$, $p = 0.03$, fig. 1).

The Fe (Al)-SOC of four soils was increased after adding 6% maize straw followed by decreased with time too. It was also higher than under CK treatment after 120 days of incubation and there was increase of 3.37 g kg^{-1}, 4.00 g kg^{-1}, 1.19 g kg^{-1} and 2.29 g kg^{-1} in HP, RP, PP and MS, respectively (table 2), which could account for 16%−37% of the total increase. However, there was 66%−77% in the first phase (30 days). These results showed that there was more Fe (Al)-SOC in RP than in PP and the increased Fe (Al)-SOC decreased with time. The increased Fe (Al)-SOC was positively correlated with the increased total SOC after 30 days of incubation ($R^2 = 0.90$, $p = 0.05$, fig. 2). The increased Fe (Al)-SOC was positively correlated with the total SOC in without maize straw treatment after 60 and 120 days of incubation ($R^2 = 0.90$, $p = 0.05$; $R^2 = 0.96$, $p = 0.02$, fig. 2).

The IR-SOC was insoluble residual organic carbon after extracting Ca-SOC and Fe (Al)-SOC, and it was as stable as Fe (Al)-SOC in the fractions of SOM and both constituted the most part of SOC. In four soils, an increased IR-SOC contents of 7.63 g kg^{-1}, 6.62 g kg^{-1}, 5.94 g kg^{-1} and 2.33 g kg^{-1} in HP, RP, PP and MS, respectively (table 2) was observed after adding 6% maize straw over CK treatment after 180 days of incubation which could account for 48%−80% of the total increase. But there was 16%−23% after 30 days of incubation. When compared to mash soil, the increased IR-SOC of paddy soils was higher, especially in HP. There was significant difference between the amount of increased IR-SOC and soil types. Moreover, original amount of SOC didn't make an effect on it (table 4).

Decomposition and transformation of the fractions of soil organic matter

The relative content was the results of comparing the fractions of SOM to TOC. The relative content of Ca-SOC reduced 0.26−1.76% after 30 days of incubation in four soils, and it also decreased 0.63%−1.75% in the end of incubation (120 days, table 5). In contrast, the relative content of Fe (Al)-SOC increased 2.50%−7.43% during the first phase (30 days) in paddy soils, and then, it reduced 2.92%−17.46% after 120 days of incubation. When compared with the relative contents of IR-

SOC of paddy soils, it reduced 1.45%−5.82% during the first phase, then it increased 3.55−19.20% after 120 days of incubation.

Discussion

Decomposition of wheat straw and increase in SOC between different soil types

Comparing different types of soil, we found that the decomposition ratio of maize straw in neutral soils (PP and MS) was bigger than acid soils (HP and RP). And the results of this study were consistent with Stott (1983) [27], suggesting that greater amounts of CO_2, especially during the early incubation stages, were evolved from neutral and alkaline soils than from acid soils, and more residual C was stabilized into humic substances in acid soils than in neutral soils.

The difference in potential of carbon sequestration in different pedogenetical types of paddy soil had been described by Pan (2008). Our results also showed that the difference in potential of carbon sequestration was related to soil types. Maize straw contained great quantities of organic carbon and it increased the SOC of fours soils after 120 days of incubation. These results are in line with previous results (Martin *et al.*, 1980; Yin & Cai, 2007). The increase of SOC contents in four types of soil were also correlated with the results of decomposition and residual ratios showing the higher potential of carbon sequestration of HP and RP than PP and MS. Marsh soil was long-term in the condition of saturation, when the water was drained, the decomposition ratio of plant residues and SOM increased under human utilization (Song *et al.*, 2003; Lin *et al.*, 2008), and the improving of temperature and humidity of soil increased the soil breath and decomposition of SOM (Song *et al.*, 2004; Chi *et al.*, 2006). Our results also associated to previous studies.

Increased OC of fractions of SOM in different pedogenetical types of soils

Various studies (Schwesig *et al.*, 2003; Kleber *et al.*, 2005; Mikutta *et al.*, 2006) have reported that the SOC was related to Fe and Al oxides in some soils. Different pedogenetical types of soil contain varied metal oxides. Some studies showed that Fe- and Al-bound SOC was more stable than Ca-bound SOC (Xu *et al.*, 1999; Li *et al.*, 2003). The negative correlation between TOC under CK treatment and increased Ca-SOC indicated that the Ca-SOC was not the main form for the high carbon sequestration potential in paddy soils. On the other hand, the positive correlation between increased Fe (Al)-SOC and increased TOC in the first phase (30 days) demonstrated that the Fe (Al)-SOC was the principal fraction of SOM responsible for carbon sequestration in paddy soils. Moreover, the positive correlation between TOC under CK treatment and increased Fe (Al)-SOC after 90 and 120 days of incubation showed that the carbon sequestration was related to the Fe- and Al-bound complexes in paddy soils, which was in consent with the previous results (Pan *et al.*, 2003). Other findings suggested that native soil humic substances contributed to the accumulation of new organic matter in soils (Spaccini *et al.*, 2000). When compared to the amount of Fe (Al)-SOC in different pedogenetical types of soils, the results showed that the paddy soil derived from red soil (PP) had more capacity of Fe (Al)-SOC sequestration than the paddy soil derived from Jurassic purple shale and sandstone (PP) due to the fact that the silicate decomposed and the Fe and Al oxides seriously accumulated in the formation of red soil. Thus there was more SOC complex formation with Fe and Al oxides in HP than in PP. Li et al. (2003) compared the Ca-SOC and Fe (Al)-SOC of different types of soil and found that the Fe (Al)-SOC of soil derived from red soil was higher.

The IR-SOC was as stable as Fe (Al)-SOC in soils and was difficult to be extracted by a 0.1 M NaOH and 0.1 M

$Na_4P_2O_7$ solution after extracting Fe (Al)-SOC. There was scarce knowledge available about IR-SOC extraction after Ca-SOC and Fe (Al)-SOC in the soil samples incubated with maize straw. Our results on showed that the paddy soils have more capacity in sequestrating IR-SOC than marsh soil, especially HP.

Changes of fractions of SOM in different types of soil with wheat straw

There are many studies on the importance of minerals and metal oxides for OM stabilization (Kaiser & Guggenberger, 2000; Van Hees *et al.*, 2001; Krull *et al.*, 2003) but limited research is done on the transformation between Ca-SOC, Fe (Al)-SOC and IR-SOC. In this study, it was investigated that the Fe (Al)-SOC and IR-SOC contents were relatively the main fractions of SOM in different types of soils. And the new carbon principally existed as Fe (Al)-SOC during the primary phase (30 days) of decomposition of maize straw, and then, parts of Ca-SOC and Fe (Al)-SOC were decomposed and transformed into IR-SOC with time. Finally, the new carbon mainly stabilized as Fe (Al)-SOC and IR-SOC. Although we investigated the changes in various fractions of SOM in different pedogenetical types of soils, but still we did not clearly understand the trace of new carbon in soils. Thus, we need to unravel this secret by isotope tracing technique. In addition, the relationship between stability of SOC and structural characteristics of SOM also need further research.

Conclusion

Our results showed that the decomposition ratios of maize straw of paddy soils and marsh soil increased and the residual ratios decreased with time. The amounts of total SOC, Ca-SOC, Fe (Al)-SOC and IR-SOC increased after adding 8% wheat straw into soils, afterward the total SOC, Ca-SOC and Fe (Al)-

SOC decreased and the IR-SOC increased during the decomposition of wheat straw after 120 days of incubation. The Ca-SOC and Fe (Al)-SOC of paddy soils and marsh soil were gradually transformed into IR-SOC with time. Finally, the new carbon was mainly sequestrated as Fe (Al)-SOC and IR-SOC in soils. The data further supported that association of SOC with ferric oxyhydrates played an important role in SOC sequestration in China's paddy soils. Well developed paddy soil (HP), as compared to other soils, had more potential of carbon sequestration.

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Table 1 Basic property of the representative types of soils

Soil types	SOC ($g\ kg^{-1}$)	Total N ($g\ kg^{-1}$)	C/N	pH (H_2O)	Water holding capacity ($g\ kg^{-1}$)
HP	1902	165	1156	528	666
RP	2179	189	1154	461	708
PP	1761	170	1037	726	594
MS	1788	174	1029	733	573

HP: Well developed paddy soil; RP: Paddy soils derived from red earth; PP: Purple sandstone soil; MS: Fresh marsh soils

Table 2 Amounts of different fractions of soil organic matter Standard error in parentheses; n=3

		Without wheat straw				With 8% wheat straw			
Incubation time days	Soil types	SOC ($g\ kg^{-1}$)	Ca-SOC ($g\ kg^{-1}$)	Fe (Al)-SOC ($g\ kg^{-1}$)	IR-SOC ($g\ kg^{-1}$)	SOC ($g\ kg^{-1}$)	Ca-SOC ($g\ kg^{-1}$)	Fe (Al)-SOC ($g\ kg^{-1}$)	IR-SOC ($g\ kg^{-1}$)
0	HP	1902	083	1060	759				
	RP	2179	103	1244	833				
	PP	1761	108	925	727				
	MS	1788	091	1108	589				
30	HP	1922 (021)	095 (006)	1104 (029)	723 (027)	3052 (019)	102 (012)	1980 (078)	70 (096)
	RP	2174 (045)	104 (005)	1448 (081)	622 (092)	3038 (038)	114 (009)	2100 (018)	824 (042)
	PP	1718 (015)	160 (005)	1034 (008)	525 (015)	2752 (025)	192 (005)	1800 (044)	760 (050)
	MS	1768 (021)	166 (006)	1326 (031)	276 (056)	2679 (049)	201 (011)	1933 (006)	545 (057)
60	HP	1762 (078)	088 (006)	1060 (010)	615 (069)	2936 (045)	103 (001)	1522 (032)	1311 (034)
	RP	1911 (020)	105 (007)	1248 (054)	557 (044)	2933 (029)	111 (003)	1815 (050)	1008 (061)
	PP	1537 (024)	106 (001)	900 (023)	530 (024)	2205 (011)	124 (004)	1061 (032)	1020 (030)
	MS	1622 (014)	097 (003)	1116 (015)	409 (032)	2369 (032)	157 (008)	1248 (067)	965 (079)
120	HP	1626 (039)	066 (007)	1032 (032)	528 (060)	2744 (083)	084 (006)	1369 (028)	1291 (085)
	RP	1747 (071)	082(003)	1073 (037)	592 (094)	2820 (068)	092 (006)	1473 (049)	1254 (113)
	PP	1267 (052)	107 (005)	802 (014)	359 (046)	2008 (018)	134 (001)	921 (034)	953 (046)
	MS	1531 (027)	098 (005)	920 (017)	514 (018)	2012 (017)	116 (004)	1149 (026)	747 (039)

HP: Well developed paddy soil; RP: Paddy soils derived from red earth; PP: Purple sandstone soil; MS: Fresh marsh soils

Table 3 Results of covariance analysis of increased SOC

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	81055(a)	4	20264	61264	000
Intercept	1228	1	1228	3711	095
CK	105	1	105	318	590

Soil type	57902	3	19301	58352	000
Error	2315	7	331		
Total	956842	12			
Corrected Total	83370	11			

Dependent Variable: Increased SOC; a: R Squared = 972 (Adjusted R Squared = 956)

Table 4 Results of covariance analysis of increased IS-SOC

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	48598(a)	4	12150	20319	001
Intercept	1569	1	1569	2624	149
CK	541	1	541	906	373
Soiltype	46711	3	15570	26040	000
Error	4186	7	598		
Total	433147	12			
Corrected Total	52784	11			

Dependent Variable: IR-SOC; a: R Squared = 921 (Adjusted R Squared = 875)

Table 5 Relative amounts of different fractions of soil organic matter Standard error in parentheses; n=3

		Without maize straw			With 6% maize straw		
Incubation time days	Soil types	Ca-SOC (%)	Fe (Al)-SOC (%)	IR-SOC (%)	Ca-SOC (%)	Fe (Al)-SOC (%)	IR-SOC (%)
0	HP	437	5572	3992			
	RP	471	5707	3822			
	PP	616	5254	4131			
	MS	509	6198	3293			
30	HP	494 (033)	5745 (140)	3761 (123)	333 (039)	6488 (267)	3179 (306)
	RP	480 (029)	6663 (402)	2857 (387)	374 (032)	6913 (095)	2712 (107)
	PP	928 (037)	6017 (057)	3055 (063)	699 (015)	6541 (161)	2760 (175)
	MS	938 (047)	7504 (255)	1558 (297)	751 (050)	7215 (132)	2034 (173)
60	HP	497 (020)	6021 (244)	3482 (243)	352 (007)	5184 (084)	4464 (081)
	RP	551 (039)	6533 (263)	2917 (229)	377 (013)	6189 (188)	3434 (189)
	PP	692 (016)	5858 (132)	3450 (133)	562 (016)	4812 (130)	4626 (146)
	MS	597 (021)	6883 (153)	2520 (174)	663 (043)	5267 (291)	4071 (314)
120	HP	407 (040)	6353 (315)	3240 (300)	306 (014)	4993 (196)	4701 (182)
	RP	471 (009)	6151 (399)	3378 (402)	328 (018)	5229 (301)	4443 (299)
	PP	841 (011)	6333 (261)	2826 (262)	666 (003)	4587 (195)	4071 (314)
	MS	638 (032)	6006 (055)	3356 (087)	575 (015)	5714 (175)	3711 (162)

HP: Well developed paddy soil; RP: Paddy soils derived from red earth; PP: Purple sandstone soil; MS: Fresh marsh soils

Figure Legends.

Fig 1 Relationship between the increased Ca-SOC and bulk SOC under CK treatment incubated for 120 days
Fig 2 Relationship between increased Fe (Al)-SOC and increased bulk SOC incubated for 30 days (a), bulk SOC under CK treatment incubated respectively for 90 (b) and 120 (c) days
Fig 3 Residual and decomposition ratios of maize straw incubated for 30, 90 and 120 days in four soils

Fig 1

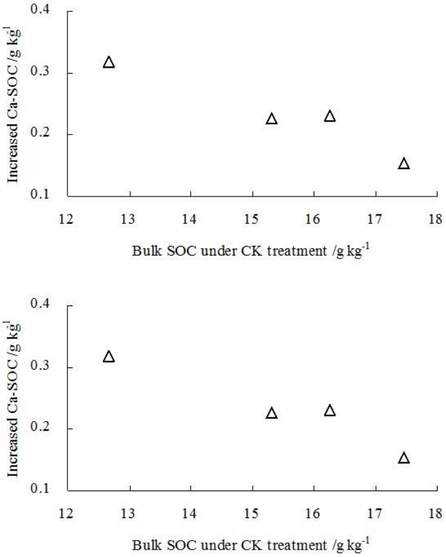
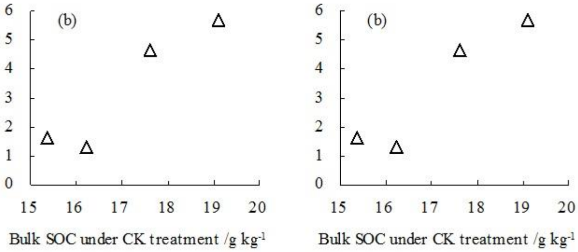


Fig 2



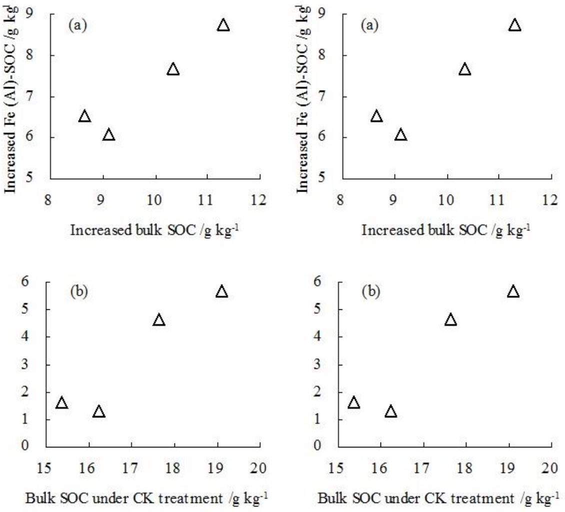
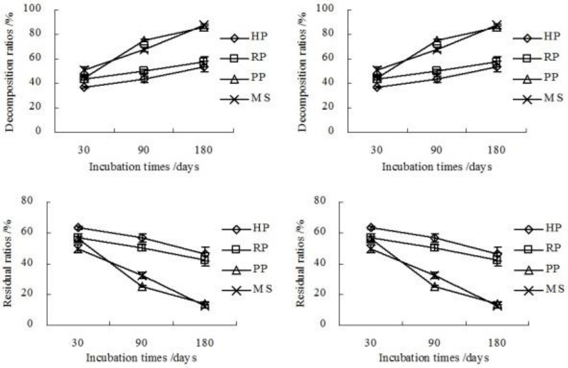


Fig 3



HP: Well developed paddy soil; RP: Paddy soils derived from red earth; PP: Purple sandstone soil; MS: Fresh marsh soils