# Soil inorganic carbon pool changed in long-term fertilization experiments in north China plain

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**Abstract**
While soil organic carbon (SOC) concerned soil component in most research on the global carbon cycle, soil inorganic carbon (SIC) was given less attention. New evidence shows there was significant change in SIC in around 30 years, especially in the systems with intensive human being activities. The present work focused on the change of total amount, active form proportion, and soil profile distribution of SIC in different fertilization systems of 4 long-term experiments in the North China Plain (NCP). The change in percentage of secondary carbonate of SIC was estimated with $\delta^{13}C$ values of SOC and soil carbonate. Results showed that the fertilization system had a great impact on the size of SIC pool, profile distribution, and the proportion of active and secondary carbonate of SIC. The result indicated that the SIC pool would change in 20-30 year farming system and $CO_2$ from SOC decomposition was involved in the transformation process of soil carbonate in the NCP. Both pool balance and transformation processes of SIC should be considered as a component of C cycling in the soil-plant system in semi- and/or arid zone areas like the NCP.

**Key Words**
Inorganic carbon, balance, active form, secondary carbonate, north China plain.

**Introduction**
Soil organic carbon (SOC) is a hot topic in global carbon cycling researc while soil inorganic carbon (SIC) is a relatively cool one. But in arid and semi-arid region, SIC is the most important C form in soils (Eswaran *et al.* 2000). Recently, several researchers had shown that long term (about 30 years) effects of land use and agronomic activities on SIC balance and transformation could be demonstrated by conventional methods (Silva and Alexandre 2004; Reeder *et al.* 2004; Mikhailova and Post 2006). In North China Plain (NCP), agricultural practices changed a lot during the last 30 years. Manure application to arable soil, which was a traditional way to sustain soil fertility in China, stopped totally around 1980s in NCP, while more and more chemical N and P fertilizers were used instead. Irrigation area had increased more than 2 times since 1980s and irrigation pattern changed a lot after 2000. In suburban areas, horticulture was becoming the predominant form of land use, with an extra huge amount of fertilizers (up to 1000 N kg/ha) and irrigation applied. Greenhouse production systems became more popular, which changed soil fertility in a significant way. All these activities had great possibility to impact on SIC. The present work focused on the change in pool size, active form, profile distribution, and secondary carbonate ratio of SIC for different fertilization systems from 4 long-term fertilization experiments in NCP. The aim of the work was to evaluate soil total C pool to give a more correct assessment of the effects of human being activities on the soil carbon pool, which would give a clear answer to the question of whether soil is a C sink or source to atmospheric $CO_2$.

**Methods**
*Study sites location*
Four long-term fertilization experiments with 47 treatments in total within NCP were chosen to do the research. The experimental periods of the 4 experiments were 22 to 27 years. They were all winter wheat and summer maize cropping system, the most common system in NCP. The average temperature was around 13℃ and rainfall around 550 mm. All soils were long-term cultivated arable soil for a long time, except for Quzhou, which was converted from salty soil 30 years ago. The altitude of the 4 sites was 4 to 43 m above sea level, and groundwater table was about 1 to 3 m. Flood irrigation was about 300 mm every year. Mean yield of winter wheat and summer maize was about 6.0 and 5.7 t/ha, respectively.

**Table 1. Basic information of the 4 long-term experiments selected in NCP.**

| Site | Changping | Tianjin | Hengshui | Quzhou |
|---|---|---|---|---|
| Experimental span (a) | 25 | 23 | 27 | 22 |
| Location | N: 40º02′<br>E: 116º10′ | N: 39º10′<br>E: 117º06′ | N: 37º42′<br>E: 115º42′ | N: 36º52′<br>E: 115º01′ |
| Relief | Plain | Sea shore plain | Low plain | Plain before mountain |
| Climate | monsoon | monsoon | monsoon | monsoon |
| Soil type | alluvial soil | alluvial soil | alluvial soil | Once salt-affected soil |
| Soil texture | loam | loam | sandy loam | sandy loam |
| $ET_0$ by FAO (mm) | 2002 | 1684 | 1935 | 1841 |
| Mean sunshine hours | 2684 | 2468 | 2617 | 2593 |
| accumulated T (>0℃) | 4606 | 4722 | 4904 | 4982 |
| frostless season (d) | 195 | 198 | 190 | 201 |

*Sampling and measurements*

Samples were taken in 2006 and 2007. Three to 6 samples were taken with soil drill from each plot deep to 180 cm at 20 cm interval. After air drying, samples were passed through 0.5mm sieve.

Soil organic carbon (SOC) was measured with a traditional method. Total carbonate content was measured by $CO_2$ volume after HCl addition to samples in air-tight system. Active carbonate was measured by the method of Loeppert and Suarez (1994). $\delta^{13}C$ of SOC and soil carbonate was measured by MAT-253.

*Data statistics*

The treatment effects were assessed with the Analysis of Variance (ANOVA) using SPSS. Treatments were compared using two statistical tests (LSD and Tukey HSD tests).

## Results

*SOC and STC pool*

The change tendency of SOC and STC (SOC+SIC) among the 47 treatments of 4 long-term experiment sites was not the same, especially for the treatments with addition of organic matter or straw (Fig 1). This discord indicated that SIC pool size was changeds in the opposite direction of SOC. The result gave us evidence to consider STC, but not SOC alone, as soil C pool concerning soil carbon balance in arable soil-cropping system in semi- and/or arid zone.

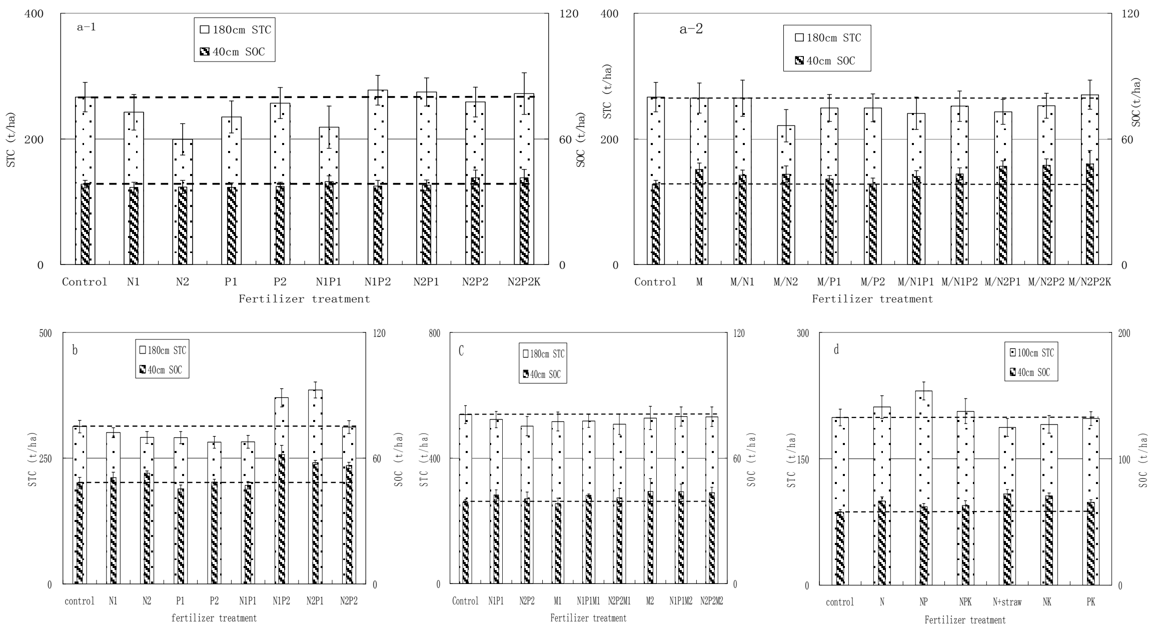


**Figure 1. SOC and STC pool of different fertilization treatments in 4 long-term experiments in NCP.**
**a-1 and a-2 was treatments of fertilizer only and manure+ fertilizer in Changping, respectively. b, c, and d was treatments in Quzhou, Hengshui, and Tianjin, respectively.**

*Soil profile distribution of SIC*

Not only the SIC pool size changed, the distribution of SIC along soil profile was also changed. In general, more carbonate moved down to deeper layers (120-160cm in most cases, or 40-80cm in Tianjin), comparing to CK treatment at each site (Fig 2). With organic manure or straw addition, SIC in top soil was significantly reduced, indicating a negative influence of SOC happened to SIC. The deeper movement of SIC may became more difficult to convert to be $CO_2$, but be easily to move into groundwater.

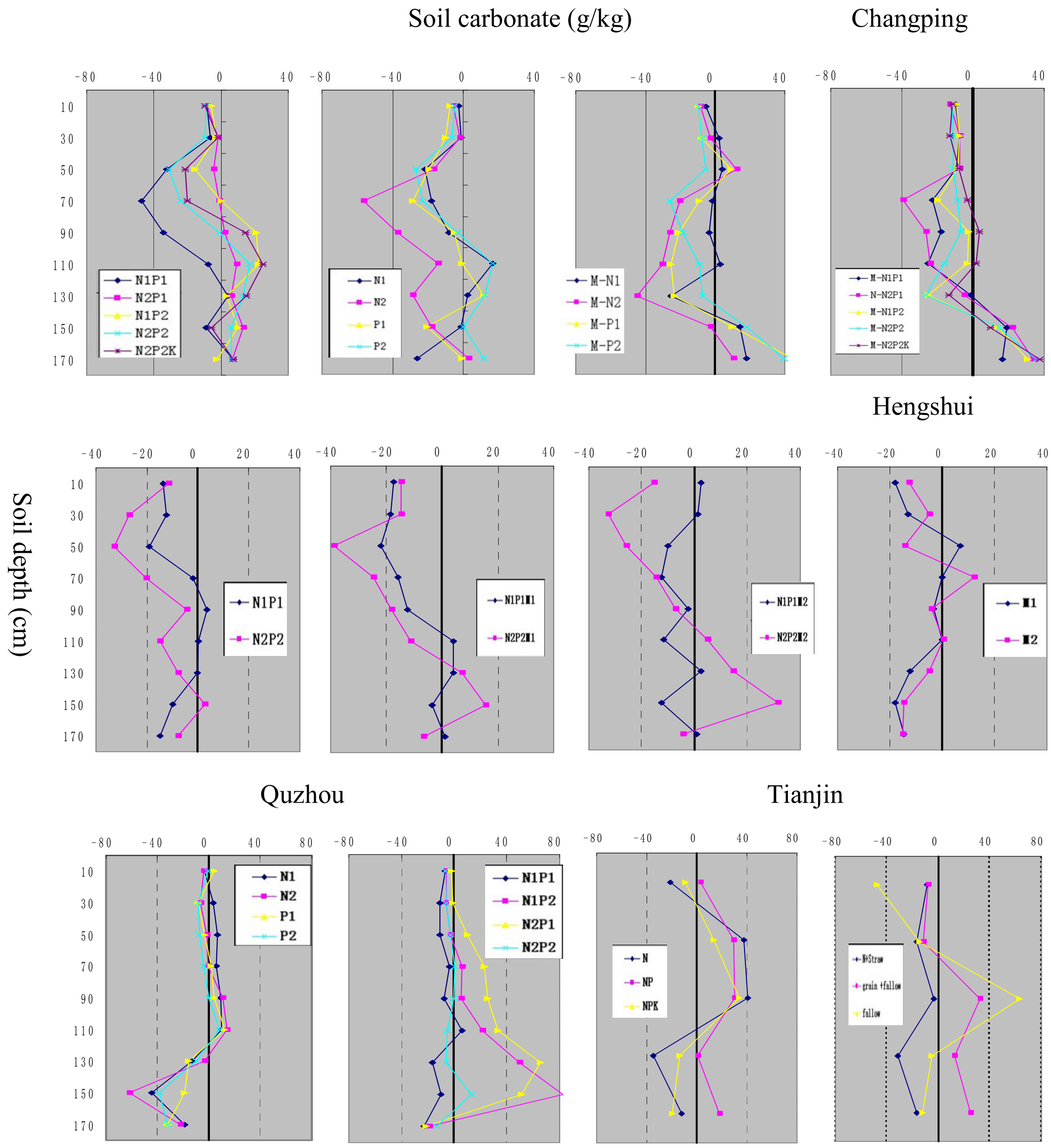


**Figure 2. Soil profile distribution of SIC of different treatments in 4 long-term experiment sites in NCP.**

*Proportion of Active and secondary carbonate*

The proportion of active carbonate (AC) changed among treatments in 4 experiment sites (Table2), especially in plots of Changping. This change indicated that carbonate stability was influenced by fertilization and would have great impact on SIC pool size in the future. In view of long term, the stability of SIC in soils of semi-arid and arid zone was important issue concerning global C balance, especially in arable soils where intensive disturbance was put by human being. Secondary carbonate (SC) formed in soil profile with $CO_2$ mostly provided from SOC decomposition. More SC mean more $CO_2$ from SOC decomposition was converted to carbonate without emitting out to atmosphere. In 0-20cm, fertilizer and manure generally reduced the SC proportion, especially in Changping and Quzhou. However, in 60-100cm, SC proportion generally increased in fertilizer and manure plots. This result indicated that the amount of $CO_2$ from SOC decomposition precipitated into carbonate in soil would depend on the mode of fertilization and organic matter addition. Detailed research was needed to quantify these processes.

**Table 2. Proportion of active and secondary carbonate in selected treatments of 4 sites (%)**

| Site | Treatment | Soil layer (cm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0-20 | | 60-80 | | 140-160* | |
| | | AC | SC | AC | SC | AC | SC |
| Fertilizer plot | CK | 47 | 100 | 45 | 89 | 36 | 78 |
| Changping | N2 | 55 | | 87 | | 56 | |
| | N2P2 | 65 | 88 | 32 | 95 | 42 | 70 |
| Fertilizer/manure plot | CK-M | 53 | 100 | 34 | 100 | 40 | 75 |
| Changping | N2-M | 62 | | 34 | | 39 | |
| | N2P2-M | 69 | 95 | 63 | 100 | 50 | 73 |
| Quzhou | CK | 31 | 77 | 20 | 56 | 35 | 45 |
| | N2 | 29 | 70 | 31 | 84 | 55 | 76 |
| | N2P2 | 33 | 64 | 33 | 70 | 44 | 64 |
| Tianjin | CK | 60 | 78 | 82 | 74 | 66 | 69 |
| | N | 54 | 79 | 100 | 73 | 71 | 68 |
| | NPK | 48 | 77 | 73 | 68 | 95 | 62 |
| | N-S | 49 | 62 | 100 | 79 | 86 | 57 |
| Hengshui | CK | 41 | 80 | 68 | 94 | 69 | 89 |
| | N1P1 | 41 | | 66 | | 72 | |
| | N2P2 | 41 | 79 | 73 | 95 | 70 | 88 |
| | N2P2-M | 38 | 92 | 69 | 92 | 65 | 89 |

* For SC, AC and SC in Tianjin, the depth was 80-100cm.

## Conclusion

It was important to include SIC pool balance in the accurate evaluation of the impact of fertilization on the balance of soil carbon pool in arid and semi-arid region. The negative relationship between SIC and SOC, though not significant in some cases among the 4 experiment sites, showed that SOC could accelerate the losing of surface SIC. In this context, the present results had great significance in proper evaluation of the effect of fertilization on soil carbon balance. Moreover, the process and scale of soil $CO_2$ from SOC decomposition converting into carbonate in soil was also an important potential reduce $CO_2$ emission in arable soils.

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