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# Dynamics of Carbon Sequestered in Concentric Layers of Soil Macroaggregates

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**ABSTRACT**: Methods used to study carbon sequestration by soil aggregates have often excluded the concentric spatial variability and other dynamic processes that contribute to resource accessibility and solute transport within aggregates. We investigated the spatial gradients of carbon (C) and nitrogen (N) from the exterior to interior layers within macroaggregates, 6.3~9.5 mm, sampled from conventional tillage (CT) and no tillage (NT) sites of a Hoytville silt clay loam. Spatial gradients in C accumulation within macroaggregates were related to the differences in C dynamics by determining the sizes and the turnover rates of fast C and slow C pools in the concentric layers of aggregates. Aggregate exteriors contained more labile C and were characterized by greater C mineralization rates than their interiors in both management systems. In contrast, C in the interior layers of aggregates was more resistant in both systems. These results indicated the spatial differentiation of C dynamics within macroaggregates, i.e., exterior layers as a reactive site and interior layers as a protective site. Greater total C distribution in the exterior layers of NT aggregates indicated more influx of C from the macropores in interaggregate space than C mineralization (net gain of C), whereas lower C distribution within the exterior layers of CT aggregates indicated net loss of C by greater C mineralization than C influx. We found total C increased approximately 1.6-fold by the conversion of CT soils to NT management systems for a period of 36 years. Differences in total accumulation and the spatial distribution of C within aggregates affected by management were attributed to the differences in aggregate stability and pore networks controlling the spatial heterogeneities of resource availability and microbial activity within aggregates.

***Key words***: Carbon sequestration, Concentric layers of aggregates, Fast C pool, Mean residence time, Slow C pool, Soil aggregates

## INTRODUCTION

International concerns about the global warming potential and the adverse affects of soil tillage have augmented interest in the study of numerous biogeochemical and physical mechanisms that better sequester carbon (C). Substantial researches have focused on soil organic matter (SOM) and soil aggregate dynamics to elucidate the changes of soil C sequestration by management, yet the mechanism of soil C sequestration is not fully understood.

In recent studies, the role of newly added C and particulate organic matter in aggregation (Puget *et al.* 1995, 2000, Jastrow and Miller 1998, Gale *et al.* 2000) and the turnover times of C pools within different aggregate size fractions (Six *et al.* 2000b, Plante and McGill 2002) have been emphasized. However, research has focused on the separation of aggregates stabilized by SOM and disregarded process-based dynamic mechanisms relying on the connectivity, tortuosity, and heterogeneity of pore space in natural soil profile (Young *et al.* 2001). The stability of soil aggregates, inter- and intra-aggregate porosity, and the distribution of pores are the factors controlling the movement and storage of soil solutions, aeration, chemical processes, erosion, roots and associated microbial activities. These dynamic processes characterize the structural and functional complexity of soil and control SOM turnover (Christensen 2001).

The methods and energy used to separate soil aggregates from natural soil blocks have profound effects on the distribution of C among aggregate size fractions and detection of aggregates as a functional unit (Gale *et al.* 2000, Young *et al.* 2001, Ashman *et al.* 2003). Rapid wetting dried soil by wet sieving, which induces slaking of soil minerals from aggregates has been most widely used to separate aggregate size fractions. These rapid wetting methods separate highly stabilized aggregates containing more C and emphasize the stabilizing effects of C, i.e., a result of SOM stabilization within soil aggregates. It destroys the spatial distributions of components within or surrounding soil aggregates and thus does not reflect the dynamic processes of aggregate stabilization and C sequestration. Young *et al.* (2001) described how soil aggregates serve as structural surrogates of soils as they contain naturally developed internal pores and are surrounded by macropores. The spatial heterogeneity

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and connectivity of these pores strictly control many dynamic functional processes associated with solution flow.

Previous studies have reported the spatial heterogeneities of pores, water and air, and microbial community within aggregates developed by the actions of roots growth and their associated exudates, preferential macropore flows, and drying/wetting cycles surrounding soil aggregates. Sextone *et al.* (1985) reported anaerobic centers and concentric gradients in $O_2$ profiles within macroaggregates and Philippot *et al.* (1997) demonstrated the spatial distribution of denitrifying bacteria within artificial soil aggregates consistent with the development of anoxic zone in the center of aggregates. The distribution and activity of microorganisms within soil aggregates are controlled by pore arrangement and substrate availability (Chenu *et al.* 2001). Park and Smucker (2005a, b) reported greater porosities and lower strengths in external regions of macroaggregates from silty clay loam soils. The exterior regions of aggregates are considered to be more reactive zones because their greater porosity facilitates more microbial metabolism of the many accumulating labile substrates while the centers of aggregates may maintain stable conditions for longer periods of time and protect organic C from microbial attack.

Tillage management in agricultural soils destroys soil aggregates and exposes aggregate-protected C to microbial degradation (Beare *et al.* 1994, Balesdent *et al.* 2000). Increased aggregate stability and soil C content by replacement of conventional tillage (CT) to no tillage (NT) management systems have been reported (Mahboubi *et al.* 1993, Franzluebbers and Arshad 1996, Bossuyt *et al.* 2002, Mikha and Rice 2004). Among other conclusions, they have reported that lower turnover rates of macroaggregates under NT management have resulted in the increase of microaggregate formation within macroaggregates, which is crucial for the storage and stabilization of long term soil C (Jastrow and Miller 1998, Six *et al.* 1998, 2000a, Gale *et al.* 2000). However, these studies have excluded the investigations of spatial structural traits within and among aggregates which enable us to better understand the heterogeneity and the dynamics of functional hot spots.

In this study, we focused on 1) the spatial distribution of C within aggregates according to the concept of structural heterogeneity reflecting dynamic processes and 2) the dynamics of C harbored in concentric layers by determination of the sizes and turnover rates of fast (labile) C pool and slow (more resistant) C pool using two C pool model.

## MATERIALS AND METHODS

### Soil Samples and Peeling Aggregates

Soil aggregates were sampled from CT and NT continuous corn (*Zea mays* L.) production systems at the Hoytville research station of the Ohio Agricultural Research and Development Center in October 1998. The Hoytville soil series is a poorly drained, silty clay loam containing about 37% clay and 17% sand (Park and Smucker 2005b).

Soil blocks (15 cm × 15 cm) were taken from 0- to 5-cm depth in three field replicates using a sharp flat spade and transported to the laboratory in rigid and sealed plastic containers. Soil samples were manually broken along the natural failure surfaces and air-dried with constant gentle manual breakage as the soils dried. Care was taken to exclude the side portions of the original soil cube which may have been compressed during the sampling process. Air-dried soils were manually sieved, for less than one minute, to obtain the distribution of soil aggregates <1, 1~2, 2~4, 4~6.3, 6.3~9.5 and >9.5 mm. Aggregate fraction, 6.3~9.5 mm across, was used for this study. Aggregates were peeled using the soil aggregate erosion (SAE) chamber system (Park and Smucker 2005a) to separate soil aggregates into three concentric layers of equal mass, designated as exterior, transitional, and interior layers (Fig. 1). The separation of aggregates into three concentric layers of equal mass has been used in many studies (Santos *et al.* 1997, Chenu *et al.* 2001, Park and Smucker 2005a, Yasemin and Smucker 2005). SAE chamber system was designed to peel the surface of single aggregate by abrasion on the knurled wall inside chamber rotating an orbital shaker. One-third exterior and one-third transitional layers were saved after peeling and remaining interior portions were crushed for total C and N analyses and incubation experiment.

### Total Soil C and Nitrogen (N)

Total C and N were determined for sand-free exterior and interior layer samples. Sand-free samples were prepared by sieving with 53 $\mu$m sieve after gentle grinding peeled soil samples. Total C and N were determined by the dry combustion method using a Carlo-Erba, model NA1500 series 2 Nitrogen-Carbon-Sulfur Analyzer.

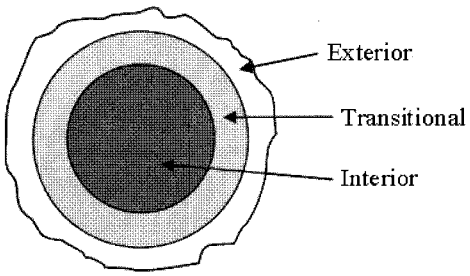


Fig. 1. Concentric layers of soil aggregate with equal mass. Exterior and transitional layers were peeled using SAE chambers and remaining interior layers were crushed.

### Soil Sample Incubation and Respiration Measurement

Duplicate 10 g subsamples of peeled layers for each field sample were gently packed in 25 ml scintillation vials. Soils in vials were re-wetted with degassed/deionized water to bring the soil to approximately 55%(v/v) water-filled pore space. Available pore space was estimated by measuring the volume of soil sample in vial and assuming a particle density of 2.65 Mg $m^{-3}$. Duplicate 10 g subsamples of whole intact (non-peeled) aggregates for each field sample were also prepared in 25 ml vials. Appropriate water content for intact aggregates were determined by preliminary incubation study (data not shown) considering only intra-aggregate pore space because great inter-aggregate pore space among 6.3~9.5 mm aggregates does not contribute to water holding capacity of samples. We determined that 80% water-filled intra-aggregate pore space was the optimum water content for incubation of intact aggregate samples to maximize respiration rate. Available intra-aggregate pore spaces were calculated using bulk density and particle density values for Hoytville soil aggregates from Park and Smucker (2005a).

Three hours after rewetting, vials were placed in 240 ml glass canning jars containing 1 ml degassed water to maintain humidity within the chambers. Incubation jars were sealed using lids fit with rubber septa to allow syringe sampling of head-space gas. Air inside jars was flushed for 10 min with $CO_2$-free air and incubation jars were placed at 25℃ incubation room. Concentrations of head-space $CO_2$-C were periodically determined using a LICOR infra-red gas analyzer, model LI-6252. $CO_2$ samples were taken every 12 to 24 hours for the first week of incubation and the interval was increased as respiration rates decreased. Incubation jars were flushed periodically to lower $CO_2$ level inside jars. Efflux of $CO_2$-C was calculated considering the concentration of $CO_2$ and incubation time. Peeled soil samples were incubated for 188 days and whole intact aggregate samples were incubated for 40 days.

### Sizes and Turnover Rates of C Pools

Long-term C mineralization rates for peeled soil samples were fitted to two-pool nonlinear model to estimate the turnover rates and the sizes of fast C pool and slow C pool (Robertson *et al.* 1999). The fast soil C pool is comprised of labile C compounds with residence times of a few days to a few years, whereas the slow C pool contains more recalcitrant C compounds with residence times ranging from several to 100 years. In our study, C mineralization rates ($\mu$g C $g^{-1}$ soil $d^{-1}$) from laboratory incubation experiment were fitted to following model using SAS PROC NLIN (SAS Institute 2001).

$$C\ Mineralization\ rate(t) = k_1 C_1 e^{-k_1 t} + k_2 C_2 e^{-k_2 t} \quad (1)$$

where $C_1$ = fast C pool ($\mu$g C $g^{-1}$ soil), $C_2$ = slow C pool ($\mu$g C $g^{-1}$ soil) that was calculated by subtracting $C_1$ from total C, $k_1$ = rate constant for $C_1$ ($d^{-1}$), $k_2$ = rate constants for $C_2$ ($d^{-1}$), and $t$ = time ($d$). Mean residence times (MRT) of C in fast pool ($C_1$) and slow pool ($C_2$) were calculated as the inverses of $k_1$ and $k_2$ indicating turnover rates.

### Statistical Analyses

The effects of management and aggregate layer were tested at significance level of $P < 0.05$ using PROC MIXED in SAS/STAT (SAS Institute 2001).

## RESULTS AND DISCUSSION

### Spatial Distributions of C and N within Soil Macroaggregates

There were significant differences in total C and N contents between two management systems and also in their distributions between exterior and interior layers within aggregates (Table 1). Soil aggregates from NT contained approximately 60% more C and 45% more N than those from CT. The differences in total C and N contents between two managements were greater in exterior layers than interior layers.

Table 1. Total C, total N, C/N ratio, and porosity for concentric layers of soil aggregates, 6.3~9.5 mm across, from NT and CT sites of Hoytville silt clay loam

| | C | | | N | | | C/N | | | Porosity† | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exterior | Interior | Ext / Int | Exterior | Interior | Ext / Int | Exterior | Interior | Ext / Int | Exterior | Interior | Ext / Int |
| | ------ mg $g^{-1}$ soil ----- | | | ----- mg $g^{-1}$ soil ----- | | | | | | -------- cm $cm^{-3}$ ------ | | |
| NT | 33.9$^{A‡}$ | 32.3$^{A}$ | 1.05$^{*}$ | 3.20$^{A}$ | 2.76$^{A}$ | 1.16$^{*}$ | 10.6$^{A}$ | 11.6$^{A}$ | 0.91$^{*}$ | 0.49$^{A}$ | 0.34$^{A}$ | 1.44$^{*}$ |
| CT | 20.4$^{B}$ | 21.4$^{B}$ | 0.95$^{*}$ | 2.17$^{B}$ | 1.99$^{B}$ | 1.09$^{*}$ | 9.4$^{B}$ | 10.8$^{B}$ | 0.87$^{*}$ | 0.42$^{B}$ | 0.29$^{B}$ | 1.45$^{*}$ |

† Data adopted from Park and Smucker (2005a)

‡ Means with different letters indicate significant differences between treatments within each aggregate layer at $P<0.05$.

* for the ratio of exterior to interior indicates significant difference between exterior and interior layers within each management at $P<0.05$.

Although there was great variability among three field replicates for each layer and each management, the ratios of exterior to interior for C and N showed significant difference between exteriors and interiors for both managements, e.g., greater C was always observed in exterior layers for all NT aggregates and in interior layers for all CT aggregates (Table 1). These C gradients indicate that there must be spatial differences in C mineralization rates and/or supply rates of new C absorbed by aggregate structures from these two different tillage systems. Plante and McGill (2002) proposed a conceptual model explaining the effects of macroaggregate turnover rate on the mineralization and sequestration of newly added C. They suggested intermediate aggregate turnover is needed to have aggregate formation and occlusion of newly incoming fresh residue and to maximize C sequestration. Park and Smucker (2005b) reported greater aggregate strength in NT than CT of Hoytville and we found significantly higher water stability of aggregates from NT in Hoytville compared to CT (data not shown). Increased aggregate stability and recovery of total C by conversion of CT to NT for 36 years in Hoytville imply that the turnover rates of NT aggregates are below the threshold rate where incoming organic matter is re-exposed more quickly than it is occluded. However, the spatial distribution of C within aggregates in our study, especially, reversed spatial gradients within NT and CT aggregates, can not be explained by comparison between the occlusion rate of newly incoming aggregates and macroaggregate turnover rate. If the physical protection of occluded C within stabilized macroaggregates is a major mechanism of C sequestration, organic C should be more labile and more distributed in the interior layers of aggregates than in exterior layers because C in exterior layers of aggregates is more accessible to microorganisms and thus more mineralized (Chenu *et al.* 2001). We found more C in the interior layer of CT aggregates (Table 1) but interior layer C was less labile and more highly processed or longer mean residence time (MRT) than exterior layer C (Table 2). In particular, more labile C and total C in the exterior layers of NT (Table 2) suggests there is a greater influx of new C from the exterior regions of aggregates to their interiors. More labile C but lower total C in the exterior layers of CT aggregates, compared to their interiors indicates greater removal of C by mineralization than the influx of new C (net loss of C).

We conclude that the spatial gradients of C, N, and C/N ratio within aggregates appear to be closely associated with the pore arrangements within aggregates which influence the flux of C and N substrates and the spatial distributions of microbial activity. Park and Smucker (2005a) reported greater saturated hydraulic conductivities for NT aggregates containing higher total porosity than CT aggregates and suggests greater soil solution flow rates through NT aggregates than CT aggregates. They also reported significant decreases in the total porosities from the exterior to the interior layers of macroaggregates from both CT and NT managements. We observed significantly greater N contents and lower C/N ratios in exterior layers than in interior layers for both CT and NT soils (Table 1). These results suggest more microbial biomass was harbored in the exterior layers of aggregates having greater porosity and accessibility to substrate.

## C Mineralization Rates of Crushed Aggregates and Intact Aggregates

Physical protection of soil organic C within macroaggregates was investigated by comparing the cumulative $CO_2$-C effluxes from crushed aggregates and intact aggregates (Fig. 2). The cumulative $CO_2$-C effluxes from crushed aggregates were obtained by taking the average $CO_2$-C effluxes from three concentric layers (exterior, transitional, and interior). We found C mineralization rates (the slopes of cumulative $CO_2$-C efflux curves in Fig. 2) of intact aggregates was lower than that of crushed aggregates in CT. Although there appeared to be a lower efflux rate from the intact aggregates, the difference in $CO_2$ efflux between intact and crushed NT aggregates was not significant.

Table 2. The sizes of fast C and slow C pools and C mineralization kinetics derived from 188-day laboratory incubations of concentric layers of soil aggregates, 6.3 to 9.5 mm across, Hoytville silt clay loam

| Management | Aggregate layer | Fast C | | | Slow C | | |
|---|---|---|---|---|---|---|---|
| | | $k_1$ ($d^{-1}$) | $C_1$ (mg $g^{-1}$ soil) | MRT (d) | $k_2$ ($d^{-1}$) | $C_2$ (mg $g^{-1}$ soil) | MRT (yr) |
| NT | Exterior | $0.1348^{a\dagger}$ | $0.87^{a*}$ | $8.6^{a}$ | $0.000193^{a*}$ | $33.0^{a*}$ | $15.0^{a*}$ |
| | Interior | $0.1071^{a}$ | $0.54^{a*}$ | $9.6^{a}$ | $0.000156^{a*}$ | $31.8^{a*}$ | $18.1^{a*}$ |
| CT | Exterior | $0.1085^{a*}$ | $0.43^{b*}$ | $9.3^{a}$ | $0.000148^{a*}$ | $19.9^{b*}$ | $19.1^{a*}$ |
| | Interior | $0.1468^{a*}$ | $0.25^{b*}$ | $7.1^{a}$ | $0.000117^{a*}$ | $21.1^{b*}$ | $23.6^{a*}$ |

† Means with different letters indicate significant differences between treatments within each aggregate layer at $P<0.05$.

* Indicates significant difference between exterior and interior layers within each management at $P<0.05$.

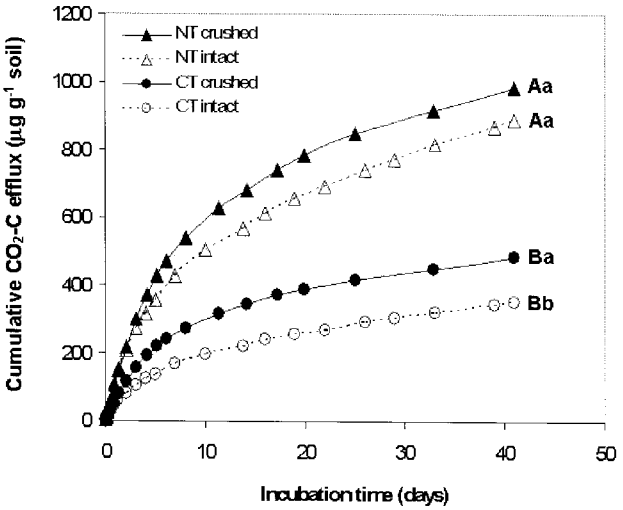


Fig. 2. Cumulative $CO_2$-C effluxes during 40-day laboratory incubations of crushed aggregates and intact aggregates from NT and CT, Hoytville silt clay loam. Different uppercase letters indicate significant differences between tillage systems within each treatment of crushed or intact aggregates. Different lowercase letters indicate significant differences between crushed and intact aggregates within each management of CT or NT system at $P<0.05$.

According to the aggregate hierarchy model, the organic matter associated macroaggregates is more labile and less processed (Elliott 1986). Beare *et al.* (1994) evaluated macroaggregate-protected C pools by comparing C mineralization rates of crushed aggregates and intact aggregates and reported macroaggregate-protected C was more labile than unprotected C (mineralized C from intact aggregates). Our results indicate that labile C was physically protected by macroaggregation in CT but not in NT which showed no difference in C mineralization between crushed and intact aggregates (Fig. 2). However, it might be more related to the location of labile C within aggregates and the accessibility of microorganisms to substrates in incubated soils rather than the role of macroaggregate in physical protection of C in natural field. Crushing macroaggregates causes the reduction of porosity and more homogeneous distribution of labile C in incubated soils, whereas the incubation of intact macroaggregates preserves the distribution of C within aggregates and interaggregate pore space that provides microorganisms with more accessibility to substrates in the exterior layers of aggregates during incubation. Carbon was more distributed in the exterior layers of NT aggregates, but was greater within the interior layers of CT aggregates (Table 1). These results indicate the effects of crushing aggregates on C mineralization during laboratory incubation can be different based upon previous history of the soils which control intraaggregate porosities. Respiration is more affected by crushing of CT aggregates due to the exposure of more C retained by the interior layers. In contrast, the intra- and interaggregate porosities of NT aggregates are decreased more significantly by crushing because the internal total porosity of NT aggregates is approximately 6% higher than that of CT aggregates (Table 1). The reduction of porosity by crushing of NT aggregates diminishes the effects of crushing on mineralization.

Average total C of NT aggregates was approximately 1.6-fold greater than that of CT aggregates (Table 1), while cumulative $CO_2$-C effluxes from NT aggregates during 40-day laboratory incubation were 2 to 2.5-fold greater than CT aggregates (Fig. 2). It indicates NT aggregates contain more labile C comparing to CT aggregates. These results correspond well with the sizes of fast C pools estimated from long-term incubation of peeled layers of aggregates (Table 2).

## Sizes and MRTs of C Pools in Exterior and Interior Layers

We observed lower C mineralization rates in the interior layers of both NT and CT aggregates comparing to their exterior layers (Fig. 3). Variability in C mineralization rates among field replicates in CT aggregates was lower (Fig. 3A and 3B). During 188-day laboratory incubation, approximately 25% and 39% less $CO_2$ were evolved from the interior layers of NT and CT aggregates, respectively, compared to their exterior layers (Fig. 4). The higher variability among C mineralization rates of the various NT field replicates (Fig. 3A) hid significant differences between exterior and interior layers within each field replicate. Therefore, the exterior to interior ratio of C mineralization rate for each field replicate was calculated (Fig. 3C). We found significantly greater C mineralization rates in exterior layers for the first half of the laboratory incubation and their ratios approached 1, i.e., no differences between exterior and interior layers, as incubation continued. However, the C in the exterior regions of CT aggregates was mineralized approximately 20% faster than the interior C of CT aggregates for the duration of the incubation indicating greater quantities of more slowly metabolizable C was contained by CT interiors.

The sizes and MRTs of fast C and slow C pools for each layer of each management were compared in Table 2. The fast C pools were about 2.1% and 1.6% in of the total C within NT and CT aggregates and were significantly different between two layers within each tillage treatment. Fast C pools were 1.6-fold and 1.7-fold greater in exterior layers of NT and CT aggregates than their interior regions (Table 2). Although the proportions of fast C to slower pools are rather small, the differences in C mineralization during laboratory incubation between two layers were primarily attributed to the differences in this fast C pool between two layers (Fig. 4B). In contrast, cumulative $CO_2$ effluxes derived from slow C pool were 4% and 19% greater in the exterior layers of NT and CT aggre-

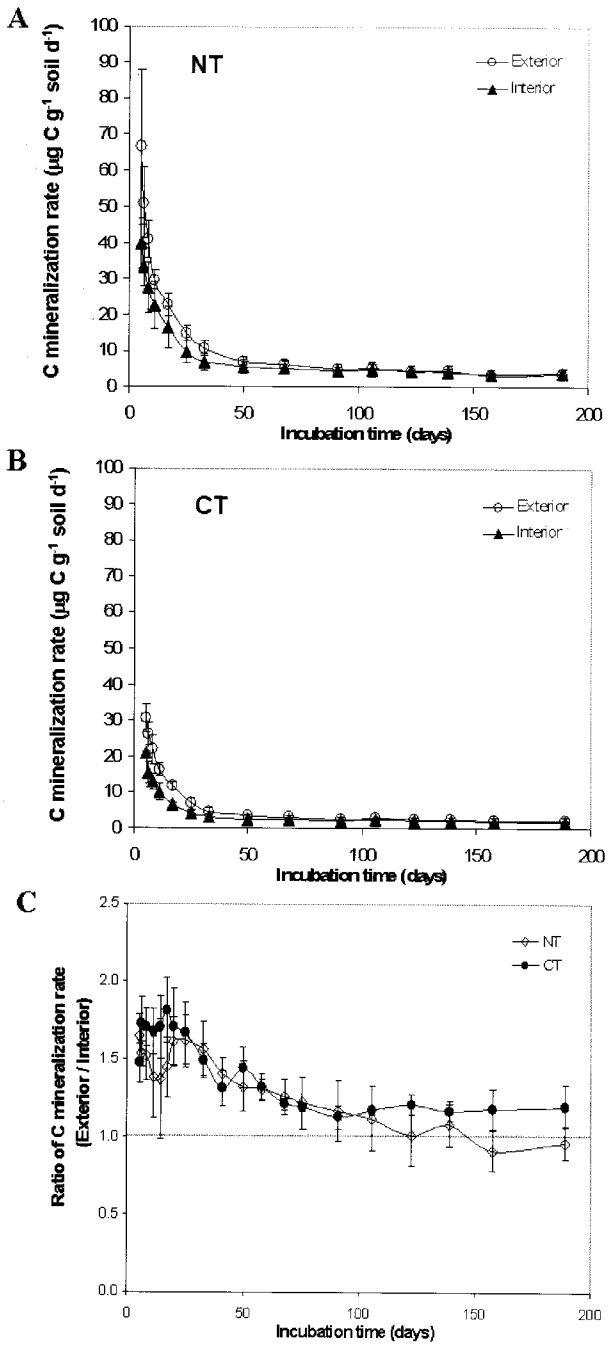


Fig. 3. C mineralization rates of peeled exterior and interior layers of soil aggregates, 6.3~9.5 mm across, sampled from NT (A) and CT (B) during 188-day laboratory incubation and their ratios of exterior layers to interior layers of aggregates from Hoytville silt clay loam (C). Ratio greater than 1 indicates C mineralization rate of exterior layers is higher than that of interior layers. Error bars are the standard deviation of three field replicates.

gates, respectively (Fig. 4B).

The size of fast pool was also significantly different between managements within each layer. The NT aggregates contained nearly

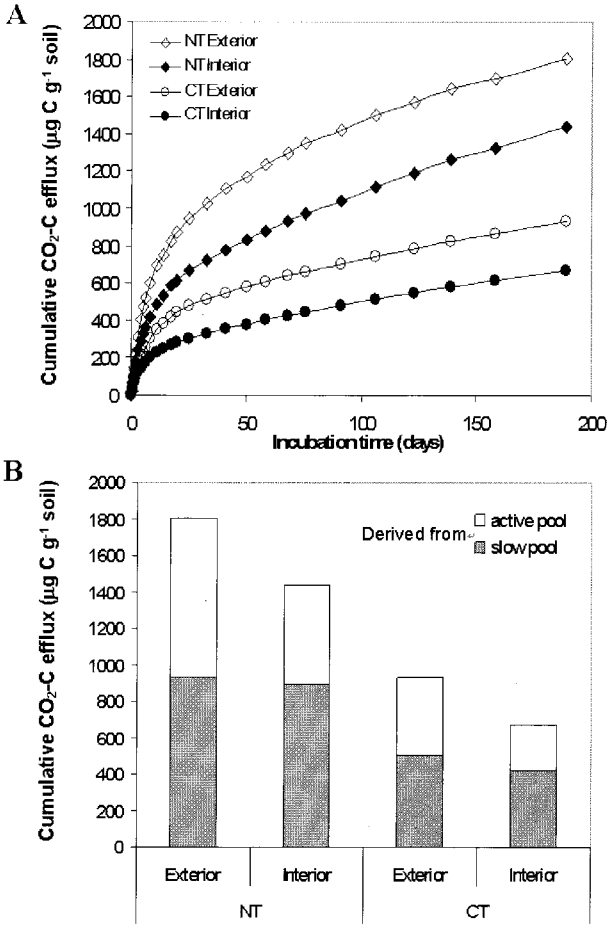


Fig. 4. Cumulative $CO_2$-C effluxes from exterior and interior layers of NT and CT aggregates (A) and the contributions of fast pool and slow pool C to cumulative $CO_2$-C effluxes at the end of 188-day laboratory incubations (B).

2-fold greater fast C than CT aggregates, in both layers (Table 2). The MRT of fast pool ranged from 7.1 to 9.6 days with no difference between soil managements or between their exterior and interior regions. However, the MRTs of slow C pools were significantly longer in interior regions when compared to exterior regions for all three field replicates of each management. Contrasting distributions of slow C pools within aggregates between NT and CT systems were similar to those of total C.

The comparison of the sizes and the MRTs of C pools between concentric aggregate layers emphasizes the dynamic processes occurring at soil aggregate surfaces *in situ* and proposes a mechanism of C sequestration that is based upon the spatial gradient of C and pore size distribution and its connectivity within aggregates. We consider the exterior layers of soil aggregates as a reactive site absorbing soil solutions from adjacent macropores distributed around aggregates that supply microorganisms with substrates and habitats. Concentrations of dissolved organic carbon (DOC) are greatest among

aggregates within the rhizosphere, or near surface plant residues and buried particulate organic matter (POM) distributed throughout the soil matrix. Seasonal fluctuations of precipitation and temperature produce surges of DOC moving through soils following macropore flow across gradients among and within aggregates. Macropore flow of DOC solutions frequently bathe or saturate surfaces of soil aggregates and some labile C compounds can be aborbed by exterior regions of soil aggregates positioning them for rapid microbial respiration. The DOC compounds diffuse more into aggregate interiors having lower porosity (Park and Smucker 2005a), possibly more micropores providing absorption sites where organo-mineral complexes form between DOC and mineral surfaces, adding to the stability of the aggregate. Kaiser and Guggenberger (2003) emphasized the role of micropores in preferential sorbing of DOC and suggest increasing DOC input into subsoil horizons to increase the recalcitrant C pool in soil.

## CONCLUSION

The C sequestration within aggregates is determined by the rate of C influx into aggregates, whether by the occlusion of POM or the absorption of DOC, and the rate of C mineralization. These processes are under spatial gradients from the surfaces of aggregates into their central regions due to the spatial gradients of pore arrangement and resource availability within aggregates. We addressed the spatial gradients of structural properties (porosity and stability) within aggregates sampled from same soils in previous studies (Park and Smucker 2005a, b). In this study, we focused on the difference in C dynamics between concentric layers of macroaggregates from NT and CT management systems. We found tillage management influenced both the total C accumulation and the distribution of C within aggregates. Total C sequestered by this macroaggregate size class increased approximately 1.6-fold during the 36 year conversion from CT to NT management system. More C was distributed in the exterior layers of aggregates in NT, whereas the interior layers of aggregates contained more C in CT aggregates. We also found more labile and more recently deposited C in the exterior layers of aggregates from both tillage systems, especially more in the exteriors of NT aggregates. These results emphasized the dynamic processes in the exterior layers of aggregates as absorbent and reactive sites and proposed a mechanism of soil C sequestration by the influx of DOC into aggregates from the macropores surrounding aggregates to the complex pore geometries of their interiors.

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