Effect of Management on Storage and Turnover of C and N in Upper Midwest Cropping Systems

Deborah Allan, Karina Fabrizzi, Silvano Abreu and Keith Piotrowski
Dept. of Soil, Water, and Climate, University of Minnesota, St. Paul, MN

Background

Effective management of agricultural systems can improve soil quality and minimize or potentially mitigate adverse environmental impacts of agriculture-associated carbon (C) and nitrogen (N) losses. To advance our understanding of the impacts of crop management on C and N cycling and promote sustainable agricultural production, we must examine the pathways by which these elements enter soil organic matter pools and leave the system through gaseous and dissolved phase losses.

The objective of this study was to determine the effect of long-term management differences (tillage intensity and crop rotation) on soil C and N storage and dynamics using ^{13}C and ^{15}N labeled shoot, root and nutrient inputs.

Approach

The study was conducted at the Univ. of Minnesota's Southwest Research and Outreach Center in Lamberton, MN on a 40 acre long-term cropping systems trial which has been in place since 1989. The soils located at the site include calcic and aquic Hapludolls and typic Endoaquolls (Ves, Normania, Webster association).

Table 1. Management systems

Treatment	Rotation	Crop sequence	Fertilization	Tillage
Organic without cover crops (ORG-CC)	4 year rotation	corn, soybean, oat/alfalfa, alfalfa	+ manure	moldboard plow most frequent tillage
Organic with cover crops (ORG+CC)	4 year rotation	corn, soybean, oat/alfalfa, alfalfa	+ manure, + cover crop	moldboard plow most frequent tillage
Low Purchased Input (LPI-2yr)	2 year rotation	corn/soybean	+ reduced N,P, K, banded	low or no tillage
Low Purchased Input (LPI-4yr)	4 year rotation	corn, soybean, oat/alfalfa, alfalfa	+ reduced N,P, K, banded	low or no tillage
High Purchased Input (HPI-2yr)	2 year rotation	corn/soybean	+N, P, K, broadcast	conventional tillage
High Purchased Input (HPI-4yr)	4 year rotation	corn, soybean, oat/alfalfa, alfalfa	+N, P, K, broadcast	conventional tillage

Four microplots of one m^2 were established in each experimental plot:

•**Foliar Labeled (roots):** Corn was labeled with ^{13}C (using $^{13}CO_2$) and foliar ^{15}N (using ^{15}N urea) during the 2004 and 2005 growing seasons. Shoot residue was reciprocally transferred to the foliar labeled (shoots) plots after harvest.

•**Foliar Labeled (shoots):** Labeled shoot residue was transferred after harvest from foliar labeled plots.

•**Fertilizer/Manure Labeled:** Fertilizer with labeled manure in the ORG plots (33% enriched with ^{15}N) in the fall, or spring- applied labeled fertilizer (urea, 10% enriched with ^{15}N) in the HPI (broadcast) or LPI (banded) plots.

•**Control:** Unlabeled, but with microplot borders and operations imposed.

Soil Analysis

- $\delta^{15}N$, $\delta^{13}C$, total C and N, and microbial biomass C and N, aggregate stability at 0-10 cm.
- Total and labeled C and N in the occluded and free light fraction for the 0-10 cm depth.
- **Free Light-Fraction (FLF)** was obtained by sieving soils to 8 mm, air-drying, and then gently swirling 40 g samples in 1.4 g m^{-3} NaI. After 36 h, floating material (FLF) was collected by aspiration and scooping. FLF was rinsed to remove NaI residue, then dried, ball-milled, and analyzed for %C, %N, $\delta^{13}C$, and $\delta^{15}N$ by mass spectrometer.
- **Occluded Light-Fraction (OLF)** was released from soil aggregates by sonic disruption of the same samples that had already been stripped of FLF. After sonication, samples were allowed to settle for 36 h in 120 ml of 1.8 g cm^{-3} NaI. OLF was then collected and analyzed in the same manner as FLF.

Results

Table 2. Effect of management and rotation on C and N in soil organic matter and free (FLF) and occluded (OLF) light fraction at 0-10 cm.

	Soil		FLF		OLF	
	SOC	**TN**	**C**	**N**	**C**	**N**
	Mg C or N ha^{-1}		……………g C or N m^{-2}................			
ORG-CC	34.9 a	3.40 ab	121.0 ab	6.1 abc	147.3 ab	11.0 a
ORG+CC	36.8 a	3.54 a	123.7 ab	7.3 a	164.5 a	11.6 a
LPI-2yr	36.1 a	3.47 ab	137.8 a	7.1 ab	132.3 b	8.0 b
LPI-4yr	35.1 a	3.27 ab	97.5 bc	5.3 bc	92.8 c	5.7 c
HPI-2yr	29.9 b	2.89 c	85.5 c	4.5 c	74.9 c	4.5 c
HPI-4yr	33.3 ab	3.13 bc	103.1 bc	5.2 bc	81.7 c	4.7 c
Rotation Effect						
2-yr	33.0 a	3.18 a	111.6 a	5.8 a	103.6 a	6.4 a
4-yr	34.2 a	3.20 a	110.3 a	5.2 a	87.3 a	5.2 b

Soil organic C and total N were lowest in the HPI-2yr treatments at 0-10 cm (Table 2) and at 10-30 and 0-30 cm (data not shown). At 10-30 and 0-30 cm, SOC and TN were greater under the 4-yr rotation than the 2-yr rotation. The ORG and LPI-2yr management systems had the greatest amounts of C and N in both free and occluded organic matter fractions.

Macroaggregate stability (Fig. 1) and microbial biomass (data not shown) were significantly greater in the ORG and LPI than HPI management systems.

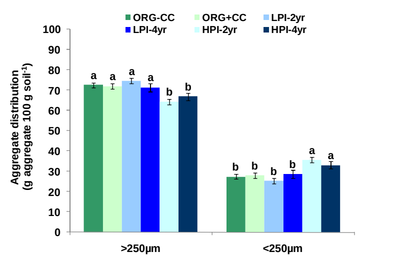

Fig. 1. Aggregate distribution affected by management

Table 3. Biochemistry of corn roots and shoots

	Soluble sugars	Starch	Hemicellulose	Cellulose	Al-Lignin	AS-Lignin
	………Mg component g $sample^{-1}$………					
Shoot	43.0 a	4.8 a	195.3 b	332.0 a	150.8 b	9.9 b
Root	3.1 b	2.9 b	280.2 a	318.4 a	187.4 a	13.1 a

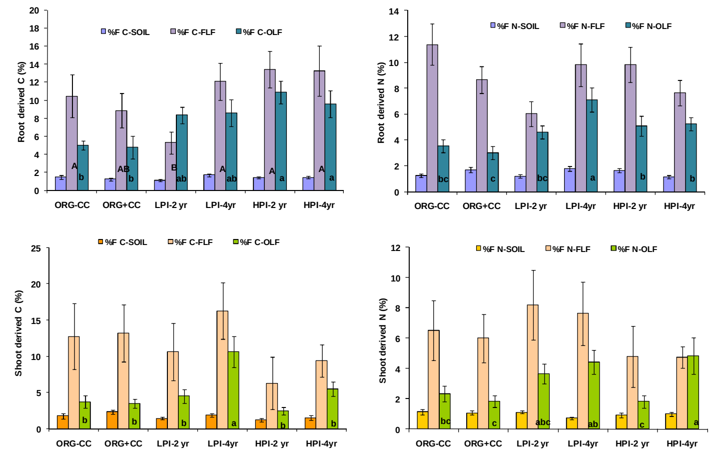

Fig. 2. Root and Shoot derived C and N. Letters indicates significant differences among management for soil, FLF and OLF

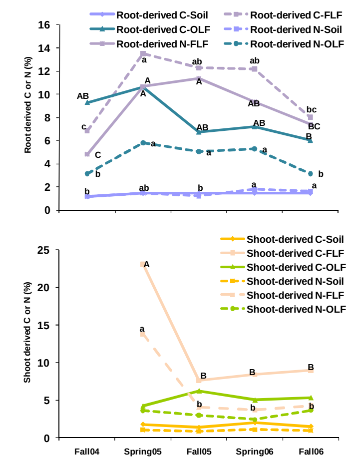

Fig. 3. Root and shoot derived C and N through time.

The fraction of root- and shoot-derived C and N in the soil was similar among management treatments. However, ORG systems had a lower proportion of root-derived C and N in the occluded fraction than HPI because occluded C and N pools in ORG were significantly larger than in HPI (Table 2). On average across management, fractions of shoot-derived C and N were more highly correlated over time than root-derived C and N, indicating that turnover was more closely coupled in the shoot residue (Fig. 3). For soil, r^2 averaged 0.82 for shoots compared to 0.49 for roots.

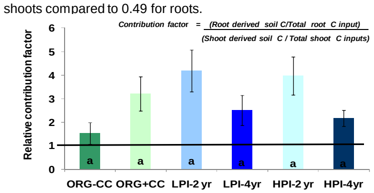

Fig. 4. Relative contribution factor of roots vs. shoot to SOC

Roots contributed approximately 3 times as much as shoots to soil C but there were no significant management differences (Fig. 4). Roots had lower sugar and starch content but greater amounts of hemicellulose and lignin than shoots (Table 3). After 2 years, an average of 39% of the ^{13}C added in roots remained, compared with 17% of that added to the soil via labeled shoots; however, similar proportions of ^{15}N in roots and shoots remained in the soil (59%) (data not shown). As expected, the mass of labeled C disappeared more quickly than that of labeled N.

Table 4. Root- and shoot-derived C remaining in soil pools, averaged over time

	Root-derived Soil C	Root-derived FLF C	Root-derived OLF C	Shoot-derived Soil C	Shoot-derived FLF C	Shoot-derived OLF C
	………µg C g^{-1} soil………					
2-yr	287 a	92 a	64 a	294 a	96 a	25 a
4-yr	373 a	81 a	48 a	438 a	101 a	42 a

Conclusions

• Both macroaggregation and aggregate-occluded C and N were greater in ORG and LPI than in HPI, but there were no differences between the 2-yr and 4-yr rotations.

• Of the soil, FLF, and OLF pools, the proportion of root- or shoot-derived C and N differed by management only for OLF. However, total amounts of root-derived C in OLF did not differ.

• Although amounts of root- and shoot-derived C in soil, FLF and OLF did not differ significantly by management or rotation, disappearance from the soil tended to be greater in the 2-yr compared to the 4-yr rotation (Table 4).

•Turnover of C and N was more closely coupled for shoot residue than for roots.

Acknowledgements

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