

Carbon Dynamics in Tallgrass Prairie and Wheat Ecosystems

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Abstract: Soil carbon (C) dynamics is an important aspect of the global C cycle. Soils can be a sink or source for atmospheric CO₂ depending upon management. Tallgrass prairie and wheat (*Triticum aestivum* L.) are 2 dominant ecosystems in the Great Plains. This study determined the distribution of C in these 2 ecosystems. Soil C pools, plant root biomass, and aboveground plant biomass were determined at a wheat (winter wheat) and a tallgrass prairie site in northern Oklahoma from 1998 through 2001. The objectives of this study were to determine C storage and changes in soil organic matter in tallgrass prairie and wheat ecosystems under similar environmental conditions and soil characteristics. Soil C was assessed by measuring soil C pools (active, slow and recalcitrant). Mineralizable C and N (C_o and N_o) were determined by long-term laboratory incubation, 314 days at 35 °C. Soil C and N content was 2 times greater in the prairie than under wheat. The greater level of C_o and N_o occurred in prairie. Wheat had proportionally greater mineralizable C and N than did prairie, but microbial biomass was the opposite, being greater in prairie. Wheat had more dynamic C pools with a faster turnover rate than did prairie. The more dynamic C pools with a faster turnover rate in wheat was the result of the greater disturbance effects of intensive tillage practices on soil structure.

Key Words: Soil carbon, carbon pools, mineralizable carbon, microbial biomass carbon, recalcitrant carbon.

Yüksek Otlak ve Buğday Ekosistemlerinde Karbon Dinamiği

Özet: Toprak karbon (C) dinamiğinin, global C döngüsünde önemli bir yeri vardır. Topraklar yönetim sistemlerine bağlı olarak C için bir depo veya atmosferik CO₂ için bir kaynak olabilir. A.B.D.'de "Great Plain'de" otlak ve buğday (*Triticum aestivum* L.) alanları en yaygın iki ekosistemi oluşturmaktadır. Bu çalışmada her iki ekosistemdeki C dağılımları araştırılmıştır. Toprak C kaynakları, bitki kök kuru ağırlığı ve toprak üzeri bitki kuru ağırlıkları kuzey Oklahoma'nın kışlık buğday ve otlak alanlarında 1998 yılından 2001 yılına kadar incelenmiştir. Bu çalışmanın amacı, aynı iklim ve toprak koşullarında otlak ve buğday ekosistemlerinde karbon depolanması ve toprak organik maddesindeki değişimleri tanımlamaktır. Toprak organik C'nu, topraktaki C kaynakları (aktif, yavaş ve kalıcı) ölçülerek belirlenmiştir. Mineralize C ve N miktarı ise (C_o ve N_o) 35 °C'de uzun süreli bir (314 gün) inkübyasyonla saptanmıştır. Otlak toprakları, buğday vejetasyonu altındaki topraklara oranla iki kat daha fazla C ve N içeriğine ve daha fazla C_o ve N_o miktarına sahip olmuştur. Buğdayda otlaka göre oransal olarak daha fazla mineralize C ve N saptanırken, mikrobiyal toplam kuru ağırlıkta tam tersi bir durum ortaya çıkmıştır. Buğday otlaka kıyasla hızlı C döngü ile birlikte daha dinamik C kaynaklarına sahip olmuştur. Bu hızlı C döngüsü ve daha dinamik C kaynakları yoğun toprak işlemenin toprak sürtükürüne yapmış olduğu tahribatın bir sonucudur.

Anahtar Sözcükler: Toprak karbonu; karbon kaynakları; mineralize karbon; mikrobiyal C; kalıcı karbon.

Introduction

Global mean temperature has risen by around 0.5 °C during the last century (Jones et al., 1998). This change is consistent with increased radiative forcing of climate by increasing greenhouse gas concentrations (Mann et al., 1998). The atmospheric CO₂ concentration has risen from around 295 ppm to more than 360 ppm during the past century (Keeling and Whorf, 1998). The increase in

atmospheric CO₂ concentration increases the importance of C sequestration in soil. Soil organic matter is an important component of soil (Paustian et al., 1997; Lal et al., 1998). Soil management systems may accelerate or retard soil organic matter decomposition and CO₂ release from soil.

Cultivation of native lands causes a sharp decrease in soil organic matter during the first years of cultivation,

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but the loss stabilizes once the ecosystem reaches a new steady-state (Buyanovsky et al., 1987; Sotomayor and Rice, 1999; Lal, 2002). The loss of soil C from agricultural practices, principally as a result of tillage (Buyanovsky et al., 1987; Grant, 1997; Paustian et al., 1997), is due to accelerated C oxidation by increasing soil aeration and increasing the surface area of soil organic matter accessible to microbial mineralization. The decrease in soil C of tilled soils is dependent upon the type and intensity of tillage (Haas et al., 1957; Greeland and Nye, 1959; Paustian et al., 2000).

Cultivation of soils can also alter the distribution and form of C in the surface and subsurface (Ajwa et al., 1998). Cultivation translocates soil organic carbon to the subsurface and changes soil properties and soil quality (McCarty et al., 1998). Cultivation causes reductions in total organic C and microbial biomass (Groffman et al., 1993). Several researchers have reported higher microbial biomass carbon under no-tillage than under conventional tillage (Franzluebbers and Arshad, 1996; 1997; Meyer et al., 1997). The higher microbial biomass under no-tillage is a result of greater quantities of labile C compared with conventional tillage systems.

Soil organic C and N have been proposed as useful indicators of soil quality (Arshad and Coen, 1992). Soil organic matter changes slowly; however, some fractions of soil organic matter may be more sensitive to soil management systems. The organic fraction of soil is made up of microbial biomass, potentially mineralizable C and N (C_o and N_o), and recalcitrant C and N. Potentially mineralizable C and N can be a good indicator of the change of soil organic matter due to different soil management systems (Campbell et al., 1989). Potentially mineralizable N is an index of the capacity of soil to supply plant available N (Robertson et al., 1988). The dynamics of N_o are closely linked to C_o , which provides a better understanding of soil organic matter turnover (Bonde and Lindberg, 1988; Robertson et al., 1988; Nadelhoffer, 1990).

Fire and grazing are common disturbance factors in native tallgrass prairie resulting in removal of aboveground biomass. In burned prairie, roots are the major source of organic C input. Fire generally increases aboveground productivity in tallgrass prairie. This increase has been attributed to the release of readily available N and P, and increased N mineralization following burning, enhanced N_2 fixation, and altered microclimatic conditions (Knapp and Seastedt, 1986;

Eisele et al., 1989). Ojima et al. (1994) reported short-term responses to burning as higher microbial C and N and higher in situ net N mineralization rates relative to unburned prairie. However, the long-term effects of fire caused significant reductions of microbial C and N and net N mineralization rates due to decreased soil organic N (Ojima et al., 1990; Blair, 1997; Burke et al., 1997).

The objectives of this study were to determine C storage and changes in soil organic matter in tallgrass prairie and wheat ecosystems under similar environmental conditions and soil characteristics. Soil C was assessed by measuring plant and soil C pools (active, slow and recalcitrant) in both ecosystems.

Materials and Methods

Site description

The prairie and wheat sites were located on the southern end of the Flint Hills in Oklahoma, which are characterized by relatively flat topography at an elevation of ~375 m. The 30-year annual average precipitation is 838 mm with 21 °C average annual temperature.

The 65 ha tallgrass prairie site was located in Osage County, Oklahoma (36° 56' N, 90° 41' W), and was annually burned and ungrazed. The flora of the tallgrass prairie was dominated by warm-season (C_4) grasses, including little bluestem (*Schizachyrium scoparium* [Michx.] Nash), blue grama (*Bouteloua gracilis* [H.B.K.] Lag. ex Steud.), big bluestem (*Andropogon gerardii*), and indiangrass (*Sorghastrum nutans*) (Suyker and Verma, 2001). Historically, the site was predominantly used for low intensity cattle grazing starting sometime between 1905 and 1935. The soil was classified as Wolco-Dwight complex (fine, mixed, thermic Pachic Argiustolls and fine, smectitic, mesic Typic Natrustolls) with a silty loam to silty clay loam texture (unpublished soil survey, Dept. Plant and Soil Science, Oklahoma State University, Stillwater, OK). The prairie site was divided into 4 sampling locations and 2 subsamples were taken from each sampling location. A total of 8 samples were taken and analyzed independently.

The 65 ha wheat site was located in Kay County, Ponca City, Oklahoma (36° 46' N, 97° 08' W). The history of this site was uncertain; however, recent management of the site included the planting of winter wheat (*Triticum aestivum* L.) from 1996 to 2001. In 2000 the site was planted with Asego 2174 at 84 kg

ha⁻¹. The average yield was 2.4 Mg ha⁻¹ from 1997 to 2000. Tillage was conducted at least 3 times in a year and in some years there were up to 6 tillage events. Tillage was chisel plow and disking for seed-bed preparation. The soil was classified as Pond Creek-Kirkland complex (fine-silty, mixed, superactive thermic Pachic Argiustolls, and fine-silty, mixed, superactive thermic Udic Paleustolls) with a silty clay loam texture (unpublished soil survey, Dept. Plant and Soil Science, Oklahoma State University, Stillwater, OK). Anhydrous ammonia was applied as the N source prior to planting at a rate of 56 kg N ha⁻¹. A post emergence herbicide, GLEAM™, was aerially applied at 1.5 ml ha⁻¹. The wheat site was also divided into 4 sampling locations with 2 subsamples per sampling location, similar to the tallgrass prairie site.

Soil Sampling

Soil samples were taken from 0-5, 5-15, and 15-30 cm depths with a 2 cm Oakfield soil probe (Apparatus Camp., Oakfield, WI). Samples were collected in polyurethane whirl-pak bags (NASCO Inc., Modesto, CA), placed inside a cooler, transported back to the laboratory and stored at 5 °C until analysis. Soil samples were passed through a 4 mm mesh to remove large particles of plant materials and homogenize the soil. Soil dry weight was determined gravimetrically by drying at 105 °C for 24 h.

Bulk density was determined by inserting a stainless steel core (5 cm id, 5 cm increments) into the soil to a depth of 30 cm. The cores then were placed in individual whirl-pak bags and brought back to the laboratory for drying (105 °C, 24 h).

Soil C and N were determined using air-dried subsamples from the May or June samples of that year. Plant material was removed from the sub-samples and the soil ground to a fine powder with a mortar and pestle. Samples were then analyzed by direct combustion using a Carlo Erba Elemental Analyzer, Model 1500 CNS Analyzer (Carlo Erba Strumentazione, Milan, Italy). Since the pH was <7 it was assumed that carbonates were insignificant and the measured C was organic C.

Aboveground Biomass

Aboveground biomass was measured from 1998 to 2000 every other week by clipping plant materials. Plant

materials were dried at 65 °C, and weighed. Sub-samples were ground and analyzed for total C and N by direct combustion as described earlier.

Root Sampling

Root biomass was measured monthly from March through August 2000. To determine root biomass, metal cylinders (5 cm dia, 25 cm length) were inserted into the soil to a depth of 20 cm. Two subsamples were obtained from each of the 4 replicates adjacent to the area. The roots were initially washed over a 0.71-mm sieve. The roots were then soaked for 1 h in 0.1 M sodium hexametaphosphate to separate clay particles and debris, washed with distilled water, dried at 65 °C, and weighed. Sub-samples were ground and analyzed for total C and N by direct combustion as described earlier.

In order to determine annual root production in the tallgrass prairie, root ingrowth bags were placed at each sampling location as duplicates in April, 2000. The growth bags were placed to a depth of 20 cm by placing root-free soil at a bulk density similar to the surrounding soil. The growth bags were removed at the end of growth season in November, 2000. Samples were prepared for total C analysis as explained in the previous paragraph.

Fractionation of Soil Carbon and Nitrogen

Biological fractionation of soil C and N was determined by long-term laboratory incubations as described by Garcia (1992). Soil samples were packed into cores of polyvinylchloride (PVC) (5.08 cm inner diameter, 10 cm height) as duplicates from each sample and a total of 16 cores were prepared for each site. For determining mineralized N during incubation, cores were leached with 400 ml of 0.01 M CaCl₂ solution, which was analyzed for NH₄⁺-N and NO₃⁻-N. After leaching, soil water potential was adjusted to 0.033 MPa and an N-free solution (50 ml) added to replenish nutrients lost by leaching (Cabrera and Kissel, 1988a). Cores were leached at 7, 14, 28, 42, 56, and 84 days, and every 4 weeks thereafter. During the leaching of N the cores were placed on plastic Buchner funnels (7 cm diameter), which were attached to a side-arm 500 ml Erlenmeyer flask, connected to a vacuum pump. Between leachings, the cores were placed in 940-ml mason jars and incubated at 35 °C. The CO₂-C evolved from the soil was determined

every 2 days for 2 weeks and on a weekly basis thereafter. This was done by taking a 0.5 mL gas sample of the headspace through a rubber septum fitted in the lid of the jars. The concentration of CO₂-C was measured on a Shimadzu Gas Chromatograph-8A (Shimadzu Inc., Kyoto, Japan). The gas chromatograph was equipped with a thermal conductivity detector (TCD) and 2 m Porapak column. After the headspace gas was sampled, the jars were opened to equilibrate with the atmosphere.

Soil C mineralization was described by fitting each core to a one-pool model:

$$C_m = C_o [1 - e^{(-kt)}]$$

where C_m = mineralizable C (mg CO₂-C g⁻¹)

C_o = potentially mineralizable C (mg CO₂-C g⁻¹)

k_c = rate constant of mineralization in day⁻¹

t = time in days

Nitrogen mineralization data were also fitted to a one-pool model (Stanford and Smith, 1972). The model is

$$N_m = N_o [1 - e^{(-kt)}]$$

where N_m = mineralizable N (mg N g⁻¹)

N_o = potentially mineralizable N (mg N g⁻¹)

k_n = rate constant of mineralization in day⁻¹

t = time in days

Microbial biomass C and N were determined using the chloroform fumigation incubation method (Jenkinson and Powlson, 1976; Voroney and Paul, 1984).

Recalcitrant C was determined by subtracting potentially mineralizable C and microbial biomass C from total organic C. Recalcitrant N was also determined in a similar way.

Data Analysis

A direct comparison between fields could not be made because the field sites were different in location and soil series. In order to determine measurement within each field, measurements were averaged at each sampling location. Analysis of variance and separation of means by least significant differences were performed using SAS procedures (SAS Institute Inc., 1996).

Results

Soil Properties

The wheat site had a lower pH (5.5) at the surface (0-15 cm) depth compared to the prairie site (5.7) (Table 1), but pH was slightly higher at 15-30 cm (6.5 vs. 6.2). Both soils were silty clay loam, and fairly uniform through

Table 1. Soil chemical and physical properties by soil depth for the tallgrass prairie and the wheat sites.

Soil properties	Depth (cm)	Prairie	Wheat
pH	0 – 15	5.7	5.5
	15 – 30	6.2	6.5
Electrical conductivity (meq cm ⁻¹)	0 – 15	540	1050
	15 – 30	613	985
Clay (g kg ⁻¹)	0 – 15	248	278
	15 – 30	422	360
Bulk density (g cm ⁻³)	0 – 5	1.3	1.2
	5 – 15	1.3	1.2
	15 – 30	1.3	1.3
Carbon (g kg ⁻¹)	0 – 5	29	11
	5 – 15	20	10
	15 – 30	15	9
Nitrogen (g kg ⁻¹)	0 – 5	2.7	1.1
	5 – 15	2	1
	15 – 30	1.7	0.9
C:N	0 – 5	10.9	10.3
	5 – 15	9.8	10
	15 – 30	8.6	10.1

soil depth. The bulk density was also fairly uniform in prairie across 0-30 cm ($1.3\text{-}1.31\text{ g cm}^{-3}$), while the wheat site had a lower bulk density at the surface (1.15 g cm^{-3}) and a distinct clay-pan layer at ~ 15 cm with a bulk density of 1.49 g cm^{-3} . This sharp change in bulk density was due to tillage. A dense clay layer was also present in the prairie but at a depth of $\sim 45\text{-}60$ cm.

Aboveground and root biomass

Aboveground biomass followed the precipitation in the prairie (Figures 1 and 2). In 1999, aboveground biomass in the prairie was higher than in the other years

(Figure 1) due to high precipitation during the early spring. The total precipitation was greater in 1999 than in 1998 and 2000. Aboveground biomass in wheat sharply increased from April through May (Figures 3 and 4). Annual aboveground production in prairie ranged from 193 to 335 g C m^{-2} and for wheat from 600 to 693 g C m^{-2} . The high variation in aboveground biomass was the result of variable growing conditions. The 3-year average of aboveground biomass was greater in wheat (646 g C m^{-2}) than in prairie (243 g C m^{-2}) (Table 2). However, a large portion of aboveground biomass was removed with the harvest in wheat.

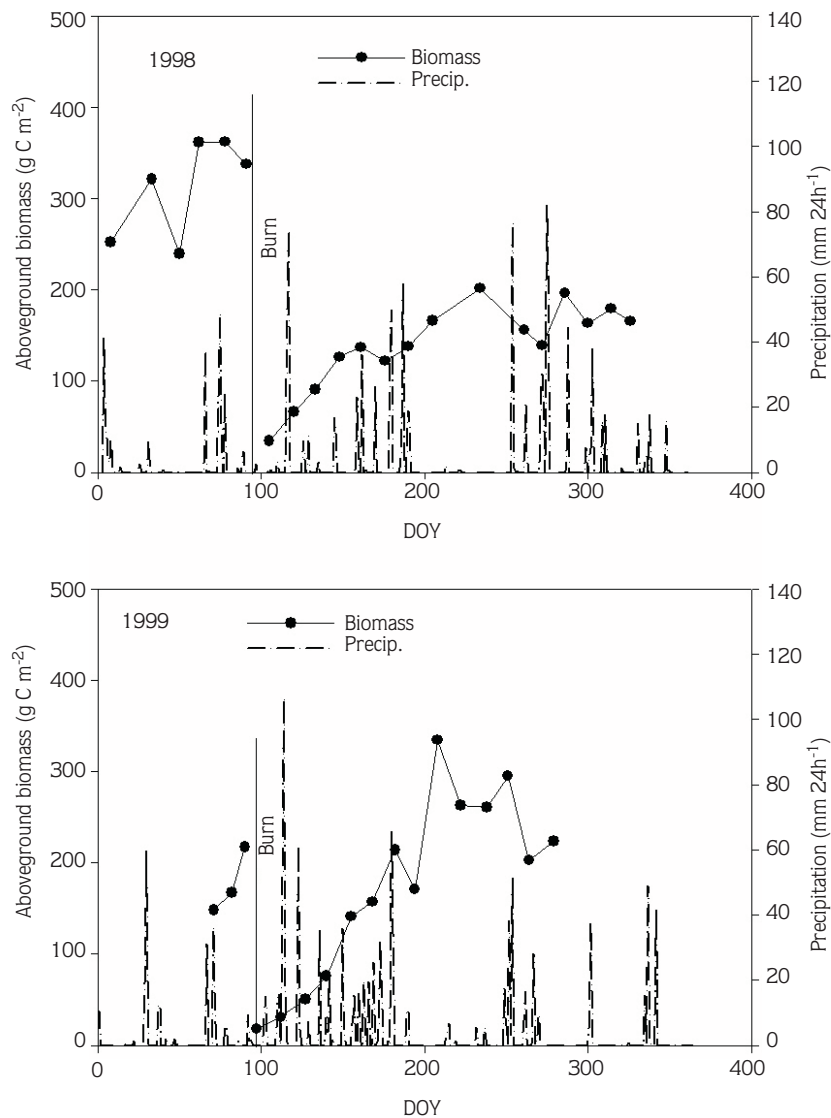


Figure 1. Aboveground biomass and daily precipitations in the Oklahoma prairie site in 1998 and 1999.

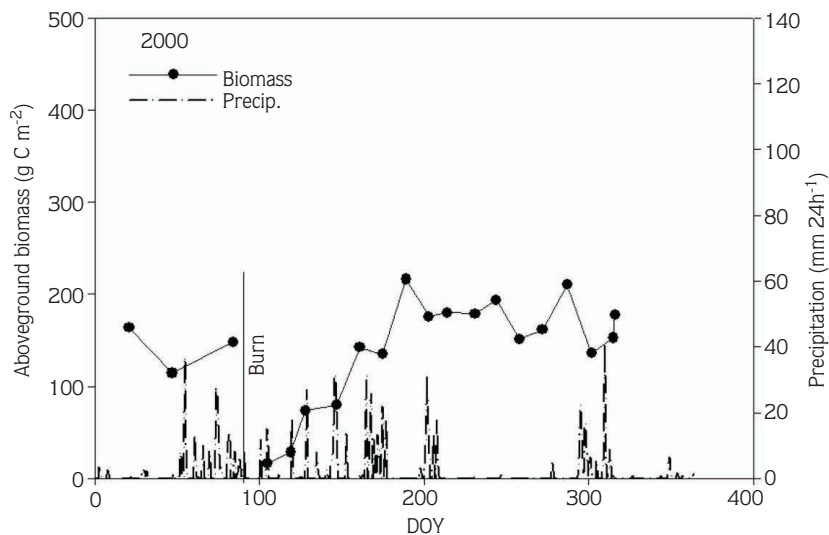


Figure 2. Aboveground biomass and daily precipitation in the prairie site in 2000.

As expected prairie had a greater mass of root C compared with wheat (Figure 5). The 3-year average for root C in the tallgrass prairie and the wheat sites accounted for 204 and 10 g C m⁻², respectively (Table 2). This lower root C in both locations compared to a tallgrass prairie in Kansas could be the result of the shallow soil at the tallgrass prairie site and the small

sampling core, which may not provide a representative sample. While annual root turnover occurs in wheat, a higher portion of root C in prairie is perennial. In 2000, annual root productivity in prairie was measured by in-growth bags as 38 g C m⁻², which indicated that the greatest portion of root biomass in prairie was in standing stock.

Table 2. Production and distribution of C (g m⁻²) in wheat and tallgrass prairie ecosystems, averaged over 3 years (standard error in parentheses).

	Winter wheat	Tallgrass prairie
Carbon pool		
Plant C		
	g C m ⁻²	
Aboveground	646 (26)	243 (46)
Root*	10 (2)	204 (78)
Total	656	447
Soil Organic Matter†		
Microbial	29 (3)	127 (5)
Potentially mineralizable	468 (21)	924 (56)
Recalcitrant	1215 (51)	3256 (78)
Total	1712	4307

* To a depth of 20 cm

† To a depth of 15 cm

Soil organic carbon and nitrogen pools

Soil organic C was greater in prairie at all depths compared with wheat (Table 1). The same trend was also observed for organic N. Soil C and N for prairie were generally 2 times greater than for wheat at the soil surface.

Potentially mineralizable C (C_o) was also greater in prairie at all depths, and depth was not significant at either site (Table 3). The estimated values of C_o, and mineralization rate constant (k_c) are shown in Table 3. The average potentially mineralizable C was almost 2 times greater in prairie for all depths, while k_c was similar for both sites. Prairie had almost 2 times higher C than the wheat site. Mineralizable C accounted for 22% of total C in prairie and 27% in wheat (Figure 6). However, microbial biomass was greater in prairie, both proportionally and quantitatively (Figure 6 and Table 2). This indicates that tillage reduced microbial biomass, while substantially increasing the pool of mineralizable C.

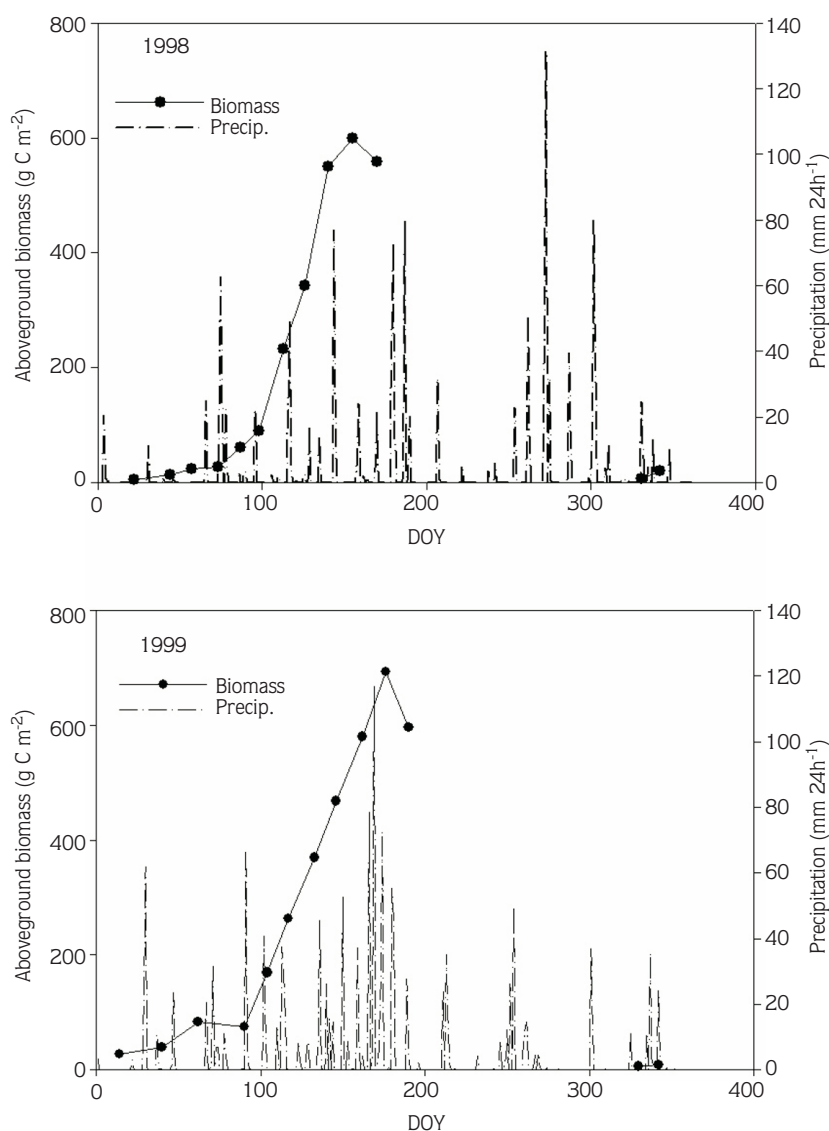


Figure 3. Aboveground biomass and daily precipitations in the Oklahoma wheat site in 1998 and 1999.

The recalcitrant pool was 76% of total C in prairie, compared to 71% for wheat. This indicates that prairie had more C in the stable pool compared to wheat.

Potentially mineralizable N was higher in prairie compared to wheat (Table 3). Potentially mineralizable N was similar through the soil, though the depth was not significant in either ecosystem. Mineralizable N accounted for 9% of total N in prairie and 10% in wheat (Figure 7). However, microbial biomass N, relative to the total, was more than 2 times greater in prairie (10%) than in wheat (4%). The recalcitrant N pool was 81% of total N in

prairie while it was 86% in wheat. The rate constant k_n was lower in prairie than in wheat, and the lower k_n indicates that the N mineralization rate is slower. Thus, wheat with a lower organic matter pool could have a faster turnover of N compared to prairie.

The C:N ratio in tallgrass prairie was 21 at the surface and increased to 26 at the 5-15 cm depth. The C:N ratio was nearly constant with depth for the wheat (27) site (Table 3). The lower ratio at the surface of prairie indicates higher quality of soil organic matter compared to lower depths of prairie and the wheat site. Soil organic

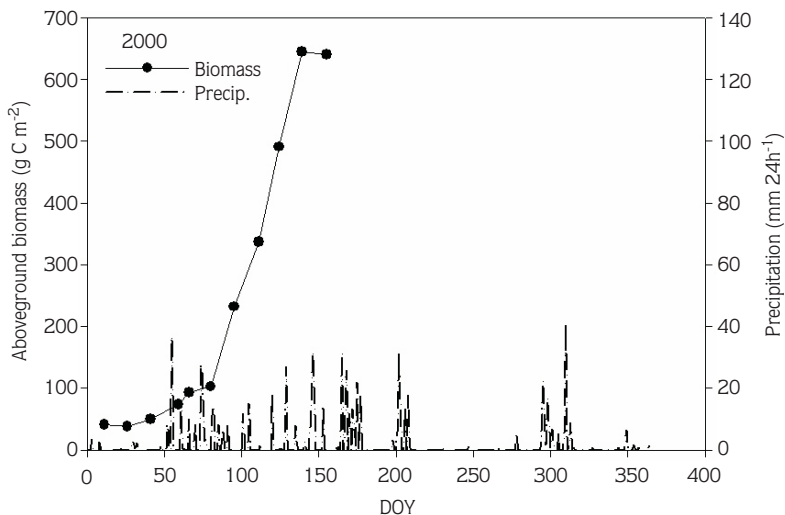


Figure 4. Aboveground biomass and daily precipitation in the wheat site in 2000.

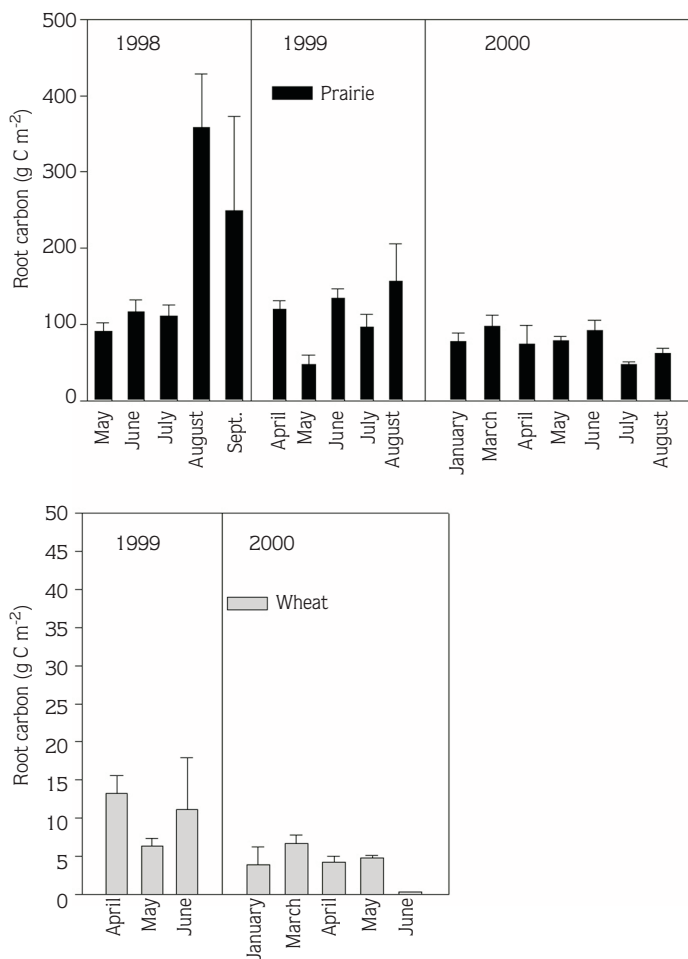


Figure 5. Total root C in prairie and wheat ecosystems to a depth of 20 cm from 1998 to 2000.

Table 3. Pool sizes, rate constants, and C:N ratios derived from a one-pool model used to describe C and N mineralization for the prairie and wheat sites.

Site	Depth	C ₀	k _c	N ₀	k _n	C ₀ /N ₀
	cm	g C kg ⁻¹	day ⁻¹	g N kg ⁻¹	day ⁻¹	
Prairie	0-5	5.04 a (1.01)	0.007 (0.0002)	0.24 a (0.04)	0.005 a (0.0004)	21.0
	5-15	4.8 a (0.8)	0.008 (0.0003)	0.18 a (0.07)	0.005 a (0.0008)	26.6
Wheat	0-5	2.7 b (0.5)	0.008 (0.0008)	0.10 b (0.01)	0.006 b (0.0002)	27.0
	5-15	2.7 b (0.5)	0.008 (0.0004)	0.10 b (0.02)	0.007 b (0.0007)	27.0
LSD (0.05)						
Depth		ns	ns	ns	ns	

C₀: potentially mineralizable carbonN₀: potentially mineralizable nitrogenk_c: decay constant for carbonk_n: decay constant for carbon

ns: not significant.

matter at the surface of prairie has a higher potential to be mineralized by soil microorganisms due to a lower C to N ratio. This is a very important source of N for unfertilized native ecosystems.

Discussion

The greater C inputs to the belowground and nondisturbance in prairie created a greater amount of soil C in prairie, while in wheat a lower amount of root biomass, greater removal of aboveground biomass by harvest, and tillage disturbance, caused lower soil C. The annual surface CO₂ flux and C budgets were near equilibrium in both ecosystems (Doyle, 2002). Management systems can affect soil organic matter (Knapp, 1984; Buyanovsky et al., 1987; Hulbert, 1988; Ojima et al., 1990; 1994; Collins et al., 1992, 2000; Burke et al., 1997; Paustian et al., 1997; Havlin and Kissel, 1997; Schimel et al., 2001). In this study, more than 20 years of intensive cultivation and monoculture

(wheat) reduced the soil C level up to 60% compared to a native tallgrass prairie. Cultivation of native soils generally results in a 50–60% reduction in organic matter content, usually in the first ~50 years, followed by stabilization and a new soil C equilibrium (Buyanovsky et al., 1987; Paul et al., 1997; Sotomayor and Rice, 1999; Collins et al., 1999).

The C₀ and N₀ in prairie can be affected by burning. Garcia (1992) indicated that after 5 years of annual burning, prairie tended to have higher C₀ and N₀ compared with unburned prairie, but the difference was not statistically significant. On the other hand, Dell (1998) reported that burning had little effect on the size of potentially mineralizable C after 8 years of burning, but potentially mineralizable N decreased over time with burning in the absence of fertilization indicating a decrease in potential N availability. In this study, the C₀ accounted for 22% of total C in prairie, which was less than the 33% reported by Garcia (1992) in a different

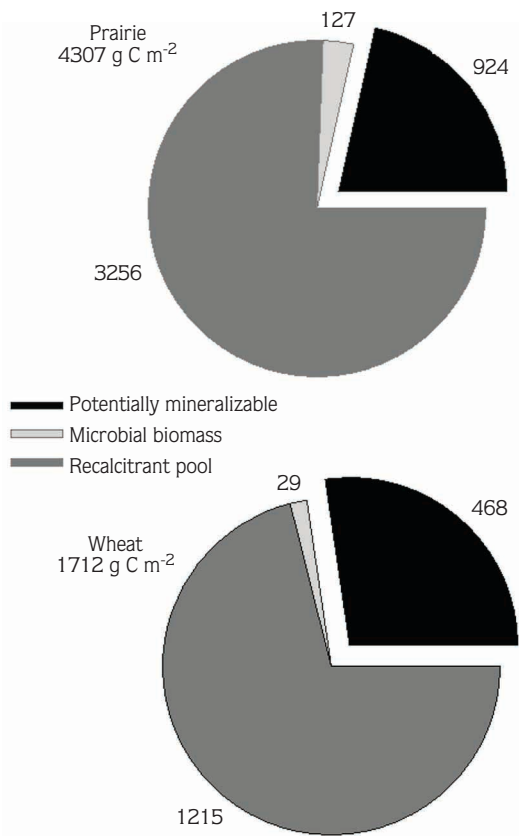


Figure 6. Distribution of soil C for the tallgrass prairie and wheat 0-15 cm.

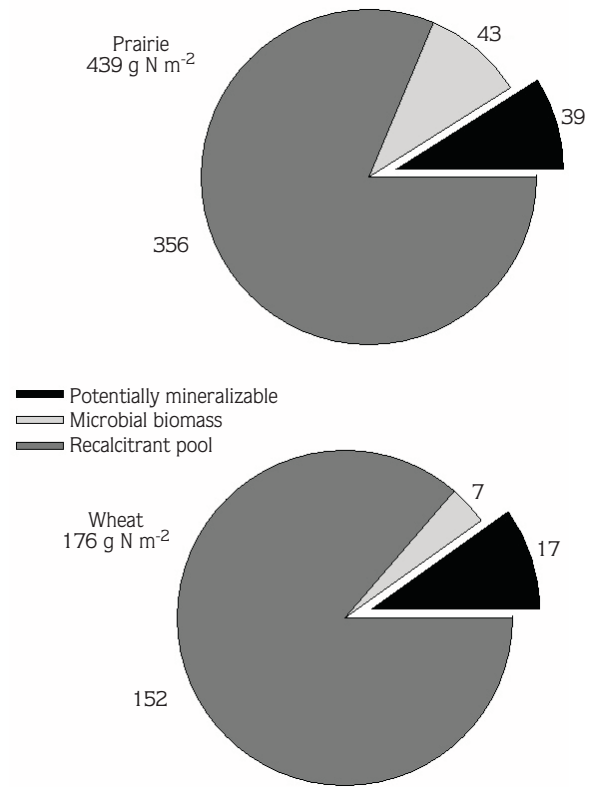


Figure 7. Distribution of soil organic N for the tallgrass prairie and wheat 0-15 cm.

prairie soil. However, Ajwa et al. (1998) found that C_o of the surface layer accounted for 12% of total C in tallgrass prairie and 21% in agricultural soil, which were similar to our findings for wheat. Our results indicate that cultivation practices increased the proportion of C in the C_o pool (27%), and decreased the recalcitrant (71%) and microbial biomass pools (2%). These more apparent changes in the mineralizable and microbial pools indicate greater sensitivity to changes in soil management systems. The greater microbial biomass pool, the part of the active pool of soil organic matter, plays an important role in nutrient cycling and C turnover in prairie (Franzluebbers et al., 1999). These findings also suggest that a greater portion of soil C in tallgrass prairie was stored in the more stable pool (recalcitrant) compared to wheat.

Potentially mineralizable organic N was slightly lower in prairie (9%) in than wheat (10%), which is similar to values reported by Ajwa et al. (1998). Garcia (1992)

found that the N_o pool of the surface layer accounted for 15% of total organic N pool in a different prairie soil. However, Weier and MacRae (1993) reported greater ratios of N_o to total N for pasture (3-9%) than for cultivated soil (0.8-5%). Our results were slightly greater than these values, but lower than the results reported by Garcia (1992). This difference could be due to different techniques used to estimate the mineralization potential of soils and soil type. However, several studies have found that the N_o /total N ratio ranged from 5 to 18% in various surface soils (Campbell and Souster, 1982; Bonde and Lindberg, 1988; Cabrera and Kissel, 1988b).

The $C_o:N_o$ ratio was lower in the prairie compared to wheat. This lower ratio in the prairie could be the result of a greater microbial biomass that has a low C:N ratio, and therefore may have contributed to the lower ratio of the soil. This lower ratio at the surface of the prairie suggested greater N availability compared to wheat. The total C to N ratio was similar at the surface in both

ecosystems (~10). Because changes in the ratios associated with active and mineralizable pools are more rapid and extensive than those associated with total C and N (McCarty and Meisinger, 1997; McCarty et al., 1998), it can be concluded that changes in microbial biomass and mineralizable pools of C and N are more sensitive to soil management systems than are gross changes in soil organic matter composition as indicated by the total C:N ratio. The higher N limitations with burning are most likely caused by increased N demand resulting from greater C input and N loss during burning. A similar $C_o:N_o$ ratio in prairie was found by Schimel et al. (1985), and Garcia (1992). Soils with a lower C:N ratio have a greater potential to decompose organic material and release plant nutrients (N, P, K etc.) to the soil environment.

The 3-year average aboveground biomass in prairie was slightly lower than that in tallgrass prairie in eastern Kansas, reported as 269 g C cm⁻² (Rice et al., 1998). The average root C in the prairie was measured as 204 g C m⁻², which is almost two-thirds of the root biomass at the Kansas site (337 g C m⁻²). The root C of the prairie was 2 times greater than the aboveground biomass C, while root C was reported as 2 to 4 times the aboveground biomass throughout a range of prairie soil (Hayes and Seastedt, 1987; Rice et al. 1998). The differences in aboveground and root C in these 2 different locations could be the result of differences in environmental factors (precipitation and temperature) and soil profile characteristics (profile depth, bulk density and nutrient availability). The annual precipitation at the Oklahoma site was similar to that at the Konza Prairie Biological Station, while the Oklahoma site had a greater annual average temperature than the Konza Prairie Biological Station. In addition to these climatic factors, the shallow soil profile and clay texture limit water infiltration and nutrient availability in the Oklahoma site.

In the wheat ecosystem, some researchers indicated a 1:1 ratio for the above- to belowground biomass C (Buyanovsky et al., 1987; Curtain et al., 2000), which is greater than that in this study. The greater ratio could be a result of the underestimation of root biomass. Buyanovsky et al. (1987) reported that net primary productivity in winter wheat was about 10% higher than in native grassland, but the amount of C allocation to soil organic matter is less than the grassland. The tillage

disturbance of the wheat site would increase the decomposition rate of the residue. Tillage breaks up soil aggregates, and mixes in litter and roots with the soil. Soil surface temperature in the wheat was higher during the early portion of the growing season and after harvest (Doyle, 2002), which could increase microbial activity and thus decomposition of soil organic matter. The greater soil water content after harvest could also create a more favorable environment for microbial activity from June through November, but water limitation during the growing season could decrease microbial activity and decomposition. Therefore, the wheat site had lower soil C pools with more active and shorter turnover times than did the prairie site. The higher C_o and N_o of the prairie could be related to the higher belowground productivity and greater physical protection of organic matter compared to the tilled wheat system. The rate constants of C mineralization were similar between the sites. However, the rate constants of N mineralization were higher in wheat than in prairie. The similar k_c and k_n were comparable to those of the tallgrass prairie in Kansas (Garcia, 1992). The higher rate constant in the wheat could be associated with N fertilization, the nature of the organic matter, and disturbance of the soil. Potentially mineralizable C, N and rate constants were not significantly affected by depth.

In conclusion, the proportional distributions of soil organic C pools were similar in both ecosystems, but wheat had proportionally greater mineralizable C and a lower stable C pool than prairie. The similar decay constants indicated that prairie, with the larger soil organic C pools, was less active and had a greater turnover time, whereas wheat had small soil organic C pools with a more active and shorter turnover time.

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