Ecosystem Carbon & Nitrogen Cycling Across a Precipitation Gradient of the Central Great Plains

R.L. McCulley[1], I.C. Burke[1], W.K. Lauenroth[1], & A.K. Knapp[2]

[1] Shortgrass Steppe LTER, Colorado State University [2]Konza LTER, Kansas State University

Abstract:

Regional analyses have shown that ecosystem pools of carbon (C) and nitrogen (N) increase as precipitation increases from the semi-arid shortgrass steppe to the tallgrass prairie of the Central Great Plains. Models based on our functional understanding of biogeochemical processes predict that ecosystem C and N fluxes also increase across this community gradient; however, few field flux data exist to evaluate these predictions. We measured decomposition rates, soil respiration, and *in situ* net nitrogen mineralization at five sites across a precipitation gradient in the Great Plains region. Soil respiration (SResp) and the decomposition constant, *k*, for common substrate litter bags were significantly higher in the sub-humid mixed and tallgrass prairie (growing season average mid-day SResp = 7.20 μmol CO_2 m^{-2} sec^{-1}, $k = 0.66$ yr^{-1}) than the semi-arid shortgrass steppe (SResp = 4.55 μmol CO_2 m^{-2} sec^{-1}, $k = 0.32$ yr^{-1}). In contrast, *in situ* net nitrogen mineralization was not significantly different across sites. The C flux data concur with predictions from current biogeochemical models; however, the *in situ* net nitrogen mineralization results do not. We hypothesize that this discrepancy results from the difficulties associated with measuring *in situ* net nitrogen mineralization in soils with vastly different immobilization potentials.

Introduction:

In the Central Great Plains region, mean annual precipitation varies from 300 mm/yr in the western shortgrass steppe to 1000 mm/yr in the eastern tallgrass prairie. Ecosystem structure, species composition, net primary productivity (NPP), and soil biogeochemistry change across this community gradient. In general, NPP, litter C:N ratios, and soil C and N pools increase with increasing precipitation. Based on these observed trends in C and N pools across the community gradient, current biogeochemical models predict a similar increase in C and N fluxes across the gradient. However, few C and N flux data exist to evaluate these predictions.

Thus, our **objective** was:

- to quantify seasonal C and N fluxes, as measured by soil respiration, decomposition rates, and *in situ* net N mineralization rates, across a community gradient in the Central Great Plains region.

Methods:

Site Selection

Five sites representing short-, mixed, and tallgrass prairies were established across a precipitation/community gradient from eastern Colorado to eastern Kansas in June 1999 (Figure 1). Four cattle exclosures, representing 4 replicates, were built on topographically level uplands at each of the sites. Table 1 lists the climatic, soils, and vegetation characteristics of these sites.

Soil Respiration, Temperature and Moisture

Soil respiration and temperature measurements were made with a soil respirometer (PP Systems, EGM-1, U.K.) and a soil temperature probe one day (once between 10 a.m. and 5 p.m.) each month. Gravimetric soil moisture samples (0-20 cm in depth) were also taken monthly on the same day soil respiration measurements were made.

Decomposition Rates

Litter bags containing 3 g of dry plant material (3 types of material: aboveground material of *Bouteloua gracilis* (BOGR), BOGR roots, and aboveground dominant vegetation at each of the sites) inside a 12 cm x 12 cm fiberglass-nylon mesh bag were constructed and placed either above- or belowground in late June 1999.

***In situ* Net Nitrogen Mineralization**

0-20 cm soil cores with resin bags were field incubated for 30 days each month. N concentrations in the initial soil samples, the 30 day soil, and the resin bags were determined using an Alpkem Auto-Analyzer.

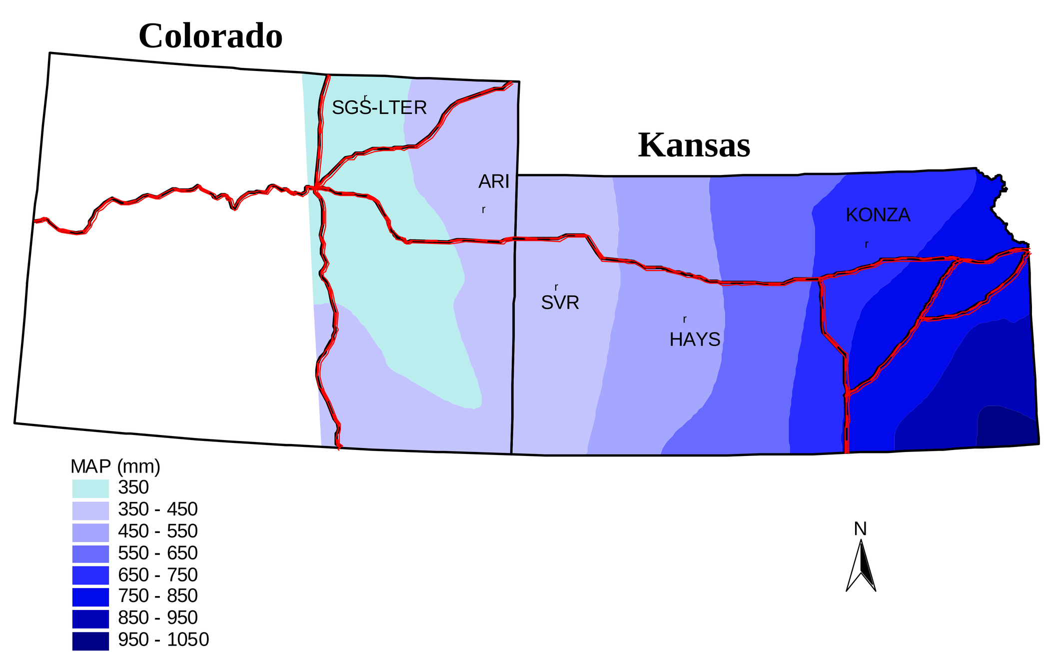


Figure 1: Site location along the precipitation gradient. Refer to Table 1 for specific site characteristics.

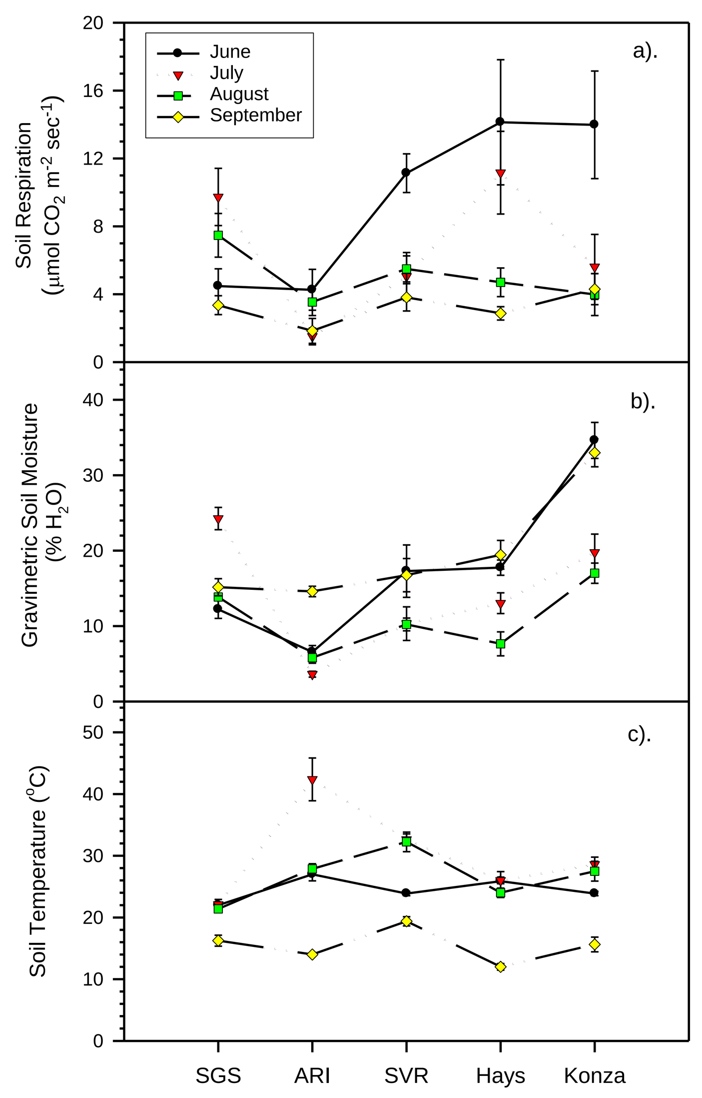
Table 1: Site Characteristics (MAP = mean annual precipitation, MAT = mean annual temperature, ANPP = aboveground net primary production, TNC = The Nature Conservancy)

	SGS Shortgrass Steppe - LTER	ARI Arikaree River - TNC	SVR Smokey River - TNC	Hays Ft. Hays State University	Konza Konza Prairie - LTER
MAP (mm)	345	450	506	578	835
MAT (°C)	8.5	10.3		11.9	13
Vegetation Type	shortgrass steppe	shortgrass steppe	mixed grass	mixed grass	tallgrass
ANPP [a] (g/m^2)	160				400
Root biomass [b,d] (g/m^2)	1119			1121	859-1086
% Sand [a,c]	38	72	44	37	22
% Clay [a,c]	31	17	21	25	30
% C [a,c]	1.30	1.65	1.68	2.53	4.56
% N [a,c]	0.131	0.165	0.173	0.25	0.39

[a] - values from LTER datasets at the two sites respectively
[b] - values from Reeder et al. (*in press*)
[c] - values determined from field samples in summer 1999
[d] – Konza value from Rice et al. (1998)

Carbon Flux Measurements

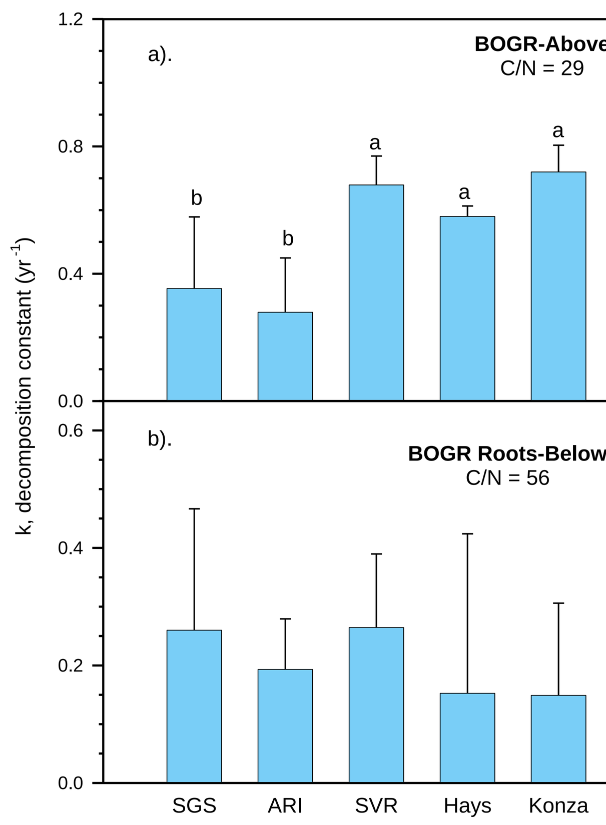
Figure 2: Seasonal trends in soil respiration (a), gravimetric soil moisture (b) and soil temperature (c) across the precipitation/community gradient.



- Soil respiration increases across the gradient with the greatest differences between sites occurring early in the growing season.

- Soil moisture increases across the gradient and better reflects measured trends in soil respiration than soil temperature.

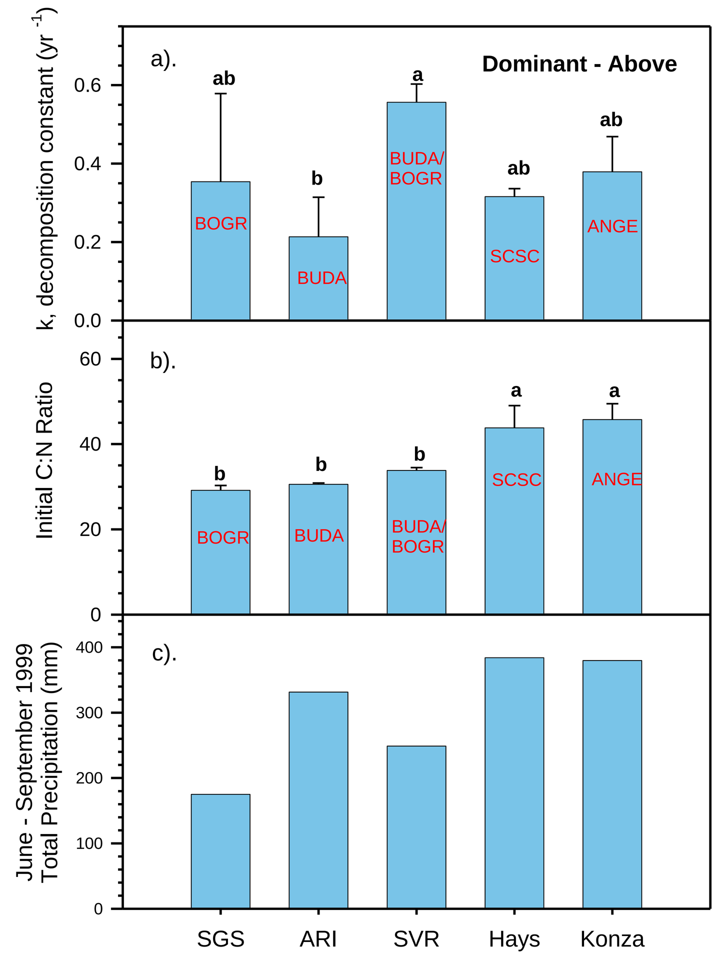
Figure 3: (a) Decomposition rates of *Bouteloua gracilis* (BOGR) aboveground material litter bags placed on aboveground bare soil at all sites across the gradient. (b) Decomposition rates of root litter bags placed belowground (at an angle, 5-10 cm depth) at all sites across the gradient. C/N values indicate the C:N ratio of the initial litter. Different letters represent significant differences in decomposition constants between sites (p< 0.01).



- Decomposition rates of BOGR aboveground litter bags increased with increasing precipitation across the gradient.

- Decomposition rates of BOGR root litter bags did not differ across the gradient

Figure 4: (a) Decomposition rates of aboveground vegetation of the dominant species litter bags at each of the sites. Litter bags were placed aboveground on bare soil and where made up of the following species for each site: SGS - *Bouteloua gracilis* (BOGR), ARI – *Buchloe dactyloides* (BUDA), SVR – a mixture of BOGR and BUDA, Hays – *Schizachyrium scoparium* (SCSC), Konza – *Andropogon gerardii* (ANGE). (b) Initial C/N ratios of the aboveground dominant vegetation used in the litter bags. (c) Total precipitation received at each of the sites (mm) for the months measured (June – September 1999). Different letters represent significant differences in decomposition constants between sites ((a) p< 0.05, (b) p< 0.001).

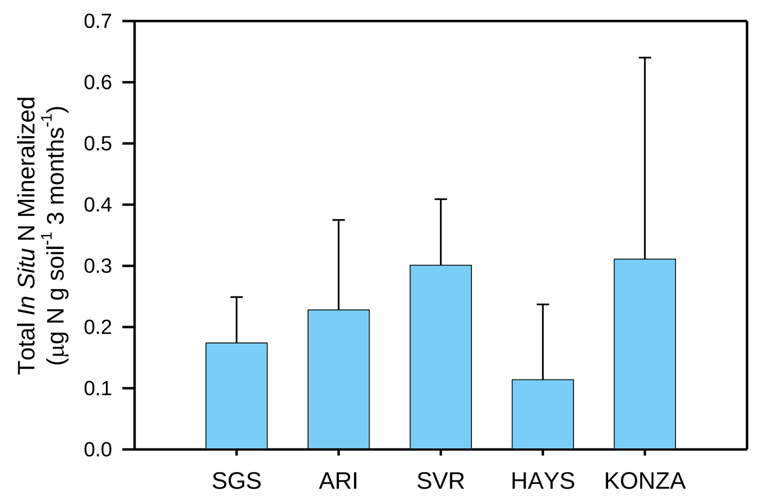


- Decomposition rates of dominant litter with similar initial C/N ratios did not closely track trends in growing season precipitation.

- ARI precipitation data does not concur with gravimetric moisture data.

Nitrogen Flux Measurements

Figure 5: Total *in situ* net N mineralized over the 3 month study period at each of the sites.



- No significant differences between sites were observed for total *in situ* net N mineralization.

Table 2: Proportion of Variance and Statistics on Measured Variables.

	Soil Respiration		Soil Moisture		Soil Temperature		Nitrogen Mineralization	
	Var.	*P-value*	*Var.*	*P-Value*	*Var.*	*P-Value*	*Var.*	*P-Value*
month	0.297	0.0001	0.177	0.0001	0.614	0.0001	0.029	0.2857
site	0.314	0.0001	0.552	0.0001	0.165	0.0001	0.062	0.1385
month*site	0.268	0.0001	0.231	0.0001	0.196	0.0001	0.290	0.0082

Conclusions:

1). As predicted by biogeochemical models, C flux, as measured by soil respiration and decomposition rates, increases concomittantly with increasing precipitation and productivity across the gradient.

2). However, *in situ* net N mineralization rates did not increase across the gradient. We hypothesize this result is partially related to the difficulty of measuring net N mineralization in soils of differing immobilization potential.