Surface-Atmosphere Carbon Fluxes On a Southern High Plains Shortgrass Prairie

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Introduction

The Southern Shortgrass Prairie Ecoregion occupies 27 million ha in mostly west Texas and eastern New Mexico. Half the land cover of this ecoregion is composed of grasslands dominated by blue grama (Bouteloua gracilis (H.B.K.))and buffalo grass (Buchloe dactyloides ((Nutt.) Engelm.). The region is characterized by low and erratic precipitation, extreme temperatures and relatively low net primary productivity compared with other grasslands. Upland soils on which shortgrass prairie occurs are generally considered sinks for atmospheric carbon dioxide (CO_2) and methane (CH_4). Given its areal extent, shortgrass prairie could have potential to sequester atmospheric carbon. We established a site on an extensive shortgrass prairie pasture in the western Texas Panhandle to measure CO_2 and CH_4 fluxes using the eddy covariance method during the historic Texas drought of 2011-2012. Our objective was to determine whether the pasture was a net sink or source for atmospheric carbon.

Methods and Materials

Study Site

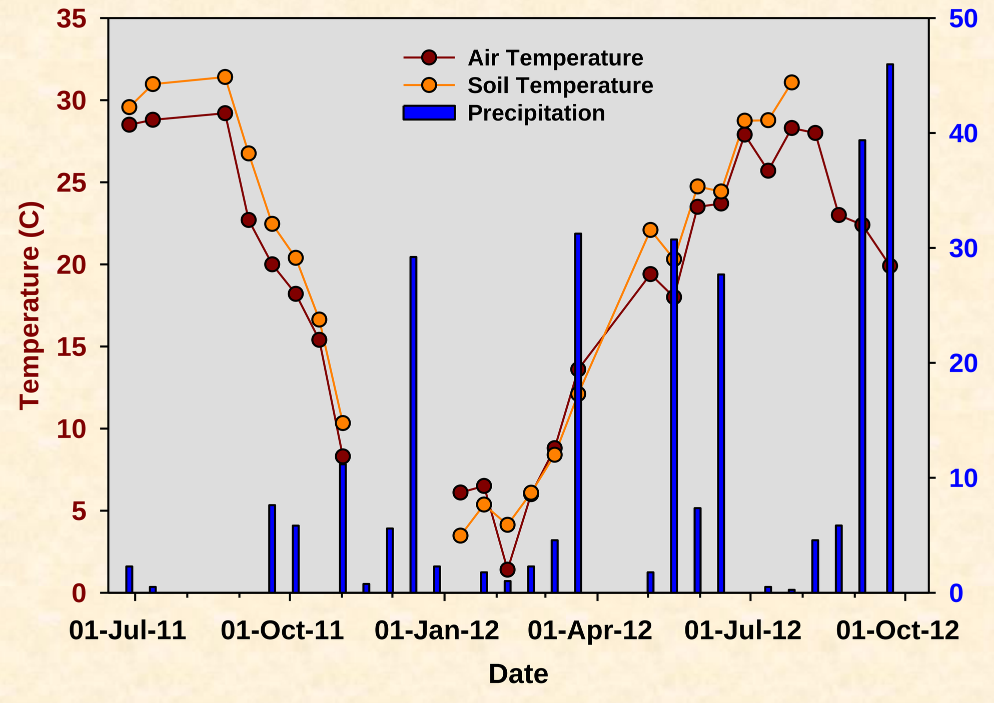
- Potter County, Texas, 35.226490 N, 102.13878 W, 1190 m elevation
- Shortgrass prairie dominated by blue grama and buffalo grass
- Pullman silty clay loam (fine, mixed, thermic Torrertic Paleustoll)
- 400 ha flat area within ~1500 ha pasture
- Fetch from 700 m to 2700 m
- Occasionally grazed at stocking density of ~ 12 ha/head

Eddy Covariance System

- GHG-2, Licor Inc., Lincoln, NE
- CH_4: LI-7700 open path laser
- CO_2/H_2O: LI-7200 closed path infrared gas analyzer
- Sonic anemometer: model 81000, RM Young, Traverse City, MI
- All instruments at 2.5 m height, sampled at 10 Hz
- Processed using EddyPro software (Version 2.1.1)
- Output at 30-min time steps, integrated into 2-week periods
- Flux convention: Positive is emission to atmosphere (surface is source)

Results and Discussion

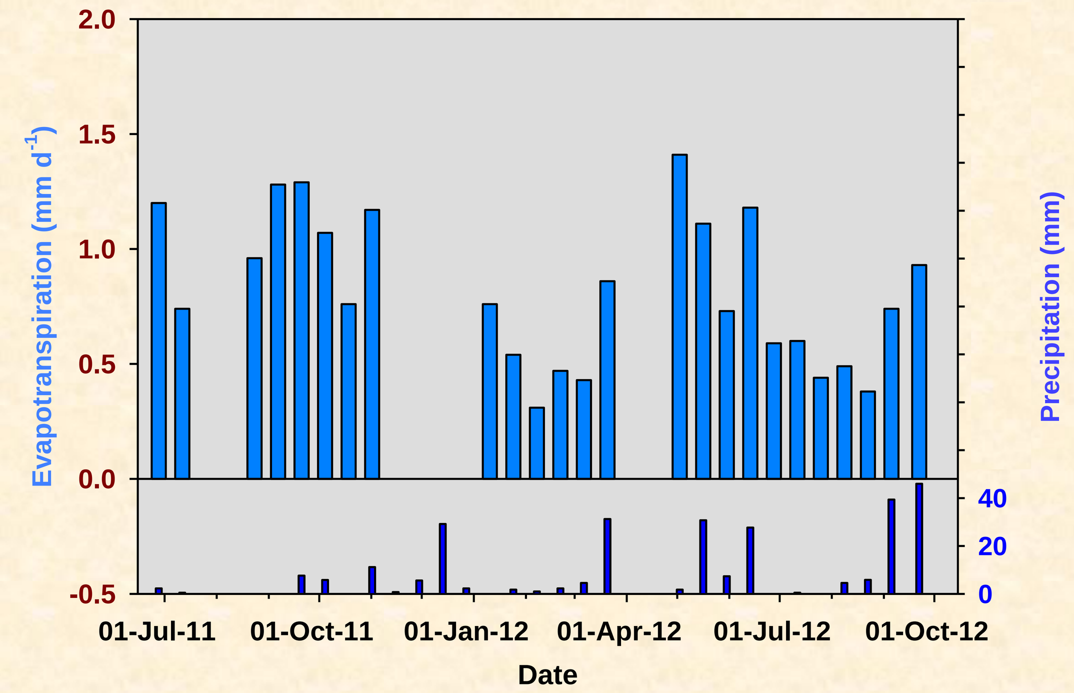
Figure 1. Temperature and Precipitation



The study was conducted during the historic Texas drought of 2011-2012, and was characterized by record-breaking temperatures and extreme dryness. During the period from Jun-2011 through Aug-2012, 185 mm of precipitation fell; the long-term total precipitation for this period is 730 mm.

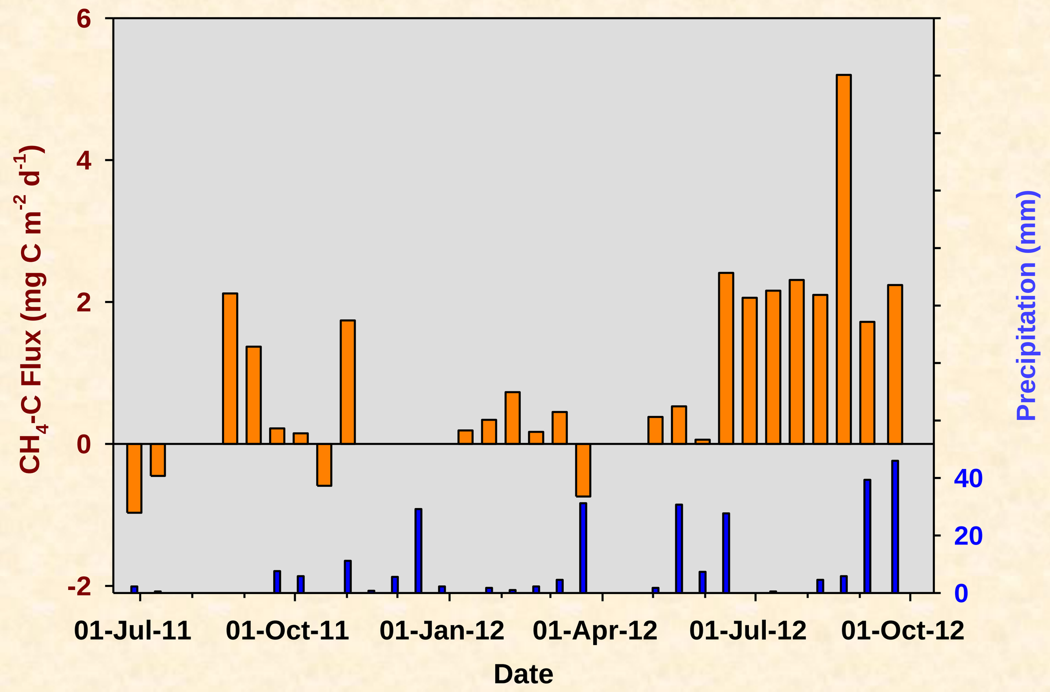
The drought was well underway by spring 2011 and most vegetation remained dormant throughout the growing season of 2011. Above- or near-normal precipitation from Dec-2011 through Apr-2012 encouraged growth of cool-season annual grasses during the spring. Drought intensified through the summer of 2012 and vegetation was mostly dormant until 85 mm of rain fell during Sep-2012.

Figure 2. Evapotranspiration



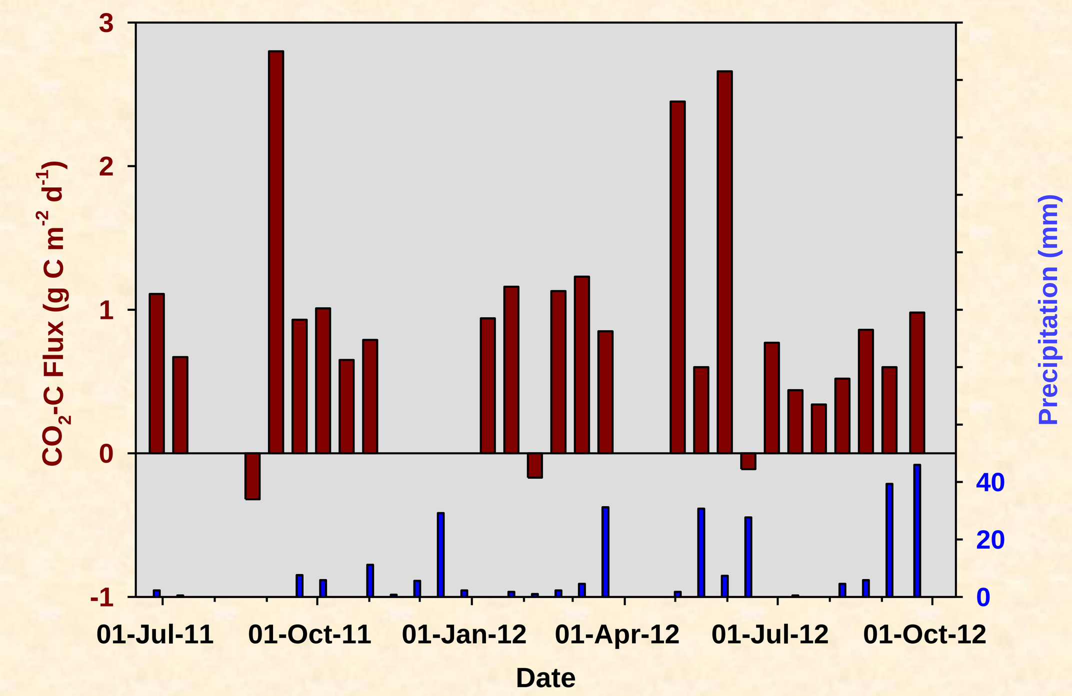
Because vegetation was dormant during most of the study, evapotranspiration (ET)was mostly of evaporation from soil. Biweekly ET ranged from 0.31 mm d^{-1} during February to 1.41 mm d^{-1} during May following April showers, and annually averaged 0.82 mm d^{-1}. Evapotranspiration was sensitive to precipitation, decreasing during extended drought, and increasing following precipitation. During the 58 weeks of the study, ET totaled 286 mm, while precipitation totaled 270 mm.

Figure 4. Methane Flux



Methane flux was three orders of magnitude less than CO_2 flux and generally was less variable than that of CO_2. The pasture was a net source of CH_4; only four out of 25 biweekly periods showed uptake of CH_4 from the atmosphere. Methane emission tended to be less during winter (0.36 mg C m^{-2} d^{-1}) and was greater (2.53 mg C m^{-2} d^{-1}) following the spring rains of 2012.

Figure 3. Carbon Dioxide Flux



Carbon dioxide flux was highly variable, ranging from -0.32 g C m^{-2} d^{-1} (uptake of CO_2) to peak releases of 2.45 to 2.80 g C m^{-2} d^{-1}, and averaged 0.95 g C m^{-2} d^{-1}. Peak emissions were correlated with precipitation. The peak in Sep-2011 was exceptional, occurring during an extended period of very high temperatures and very low precipitation. A highly localized rain shower that fell on part of the pasture but was not recorded may have triggered this high CO_2 emission. We attributed CO_2 emission to soil respiration because photosynthesis was negligible. The annual average of 0.95 g C m^{-2} d^{-1} we observed is in the lower range of reported values. Soil respiration rates were 0.6 g C m^{-2} d^{-1} in desert shrub ecosystems (Raich and Schlesinger, 1992; Zhang et al., 2010) , ranged from 0.63 to 2.27 g C m^{-2} d^{-1} in temperate grasslands (Raich and Schlesinger, 1992), while 113 globally distributed grasslands averaged 2.3 g C m^{-2} d^{-1} (Chen et al., 2010).

Table 1. Net Ecosystem Carbon Exchange

Annual Net Ecosystem Exchange of Carbon	
Carbon dioxide (kg C ha^{-1} yr^{-1})	3470
Methane (kg C ha^{-1} yr^{-1})	3.1

The shortgrass prairie pasture was a source of carbon during drought. Sims and Bradford (2001), at a more mesic site in Oklahoma, reported net annual CO_2 emission of 458 kg C ha^{-1} yr^{-1} during a drought year. The net annual emission of methane that we observed contrasts with net methane exchange observed in other studies that showed grasslands as a sink for methane. Chen et al. (2011) reported that methane uptake across 12 semiarid steppe sites in Asia ranged from -2.3 to -4.5 kg C ha^{-1} yr^{-1}. Mosier and Schimel (1991) observed methane uptake rates from Colorado shortgrass prairie that ranged from -1.28 to -3.07 kg C ha^{-1} yr^{-1}.

Conclusions

- Shortgrass prairie during the exceptional Texas drought of 2011-12 was a net source of CO_2 and CH_4.
- Emission of CO_2 was attributed to soil respiration because photosynthesis was negligible due to the drought.
- Annual total carbon equivalent emitted was 3700 kg C ha^{-1} yr^{-1} when CH_4 was assigned a 20-yr global warming potential of 72.
- The ability of the Southern Shortgrass Prairie Ecoregion to function as a carbon sink depends critically on precipitation. Model predictions of persistent drought in the southwest U.S. because of global warming could transform the ecoregion into a carbon source.

References

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