4.5 ANNUAL CO_2 FLUXES ABOVE DESERET SHRUB AND GRASS PLANT COMMUNITIES IN ARIZONA

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1. INTRODUCTION

Globally, arid and semiarid soils contain large amounts of inorganic carbon and are the third largest pool behind oceanic and soil organic carbon (Schlesinger, 1997). Inorganic soil carbon accumulation takes place over hundreds to thousands of years and requires an arid environment and a source of Ca/Mg from a non carbonate source. Accumulations and loses are controlled by the carbonate-bicarbonate equilibria equations 1 and 2.

$$CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+ \quad \text{(Eq. 1)}$$

$$CaCO_3 + H^+ \rightleftharpoons Ca^{+2} + HCO_3^- \quad \text{(Eq. 2)}$$

The equations are constantly shifting to the right and left on daily, annual, and decadal cycles with the uptake and loss of inorganic carbon to the soil. A predominate shift to carbon sequestration, loss, or equilibrium for this large carbon pool is unknown under present climatic conditions. Intertwined with the inorganic carbon fluxes are the organic fluxes from plant uptake and decomposition. Separation of inorganic and organic carbon fluxes is problematic at best. In a tallgrass prairie, it has been estimated that several years of flux data are needed to begin an accurate quantification of grasslands as a sink/source for carbon (Suyker and Verma, 2001). The hypothesis is that semiarid rangeland soils already containing large amounts of carbonates are still sequestering on an annual basis under present climate conditions. The objective of the study was to quantify daily through annual CO_2 fluxes for two different soil and plant community types for four years to evaluate them as sink/source of carbon to the atmosphere under present climatic conditions.

2. METHODS

Brushland (i.e. Lucky Hills) and grassland (i.e. Kendall) sites were established on the Walnut Gulch Experimental Watershed in southeastern Arizona. The soil classification at the sites are complexes with the dominate soils Calciorthids. Average inorganic carbon content in the top 30cm. of the Lucky Hills soil is 3.2% and the Kendall 1.1%.

Twenty minute CO_2 fluxes were calculated from Bowen ratio/energy balance (BREB) measurements (Dugas, 1993). The convention of flux away from the surface as positive was used. Bowen ratio, net radiation, soil heat flux, and soil temperature were used to calculate sensible heat flux. Eddy diffusivity was calculated from sensible heat fluxes and temperature gradients and assumed to be equal for heat, water vapor, and CO_2. Carbon dioxide fluxes were calculated as the product of the eddy diffusivity and CO_2 gradient corrected for vapor density gradients at the two heights (Webb et al., 1980).

A compass rose was setup with the Bowen ratio systems at the center. Twelve radials were established every 30° with sample locations between 80 to 110m out. Soil and biomass samples were collected every spring and fall and analyzed for carbon content.

3. RESULTS AND DISCUSSION

Precipitation was a major influence on the CO_2 fluxes at both sites (Fig. 1 & 2). During numerous precipitation events there were loses of CO_2 associated with the rainfall down to the 20 min. time step of the data collection. These loses were concluded to be from the dissolving of $CaCO_3$ by low pH rainfall events (see Eqs. 1 & 2). There were also loses of CO_2 that occurred 6-24 hours after the a rainfall event and were reasoned to be from decomposition of organic carbon. Another accelerated loss of carbon happened at the start of the growing season (i.e. around day 200) as the soil became moist from the summer rains and before the large uptake of CO_2 occurred during the growing season. The growing season carbon sequestration flux rates were generally greater for the Kendall grassland site.

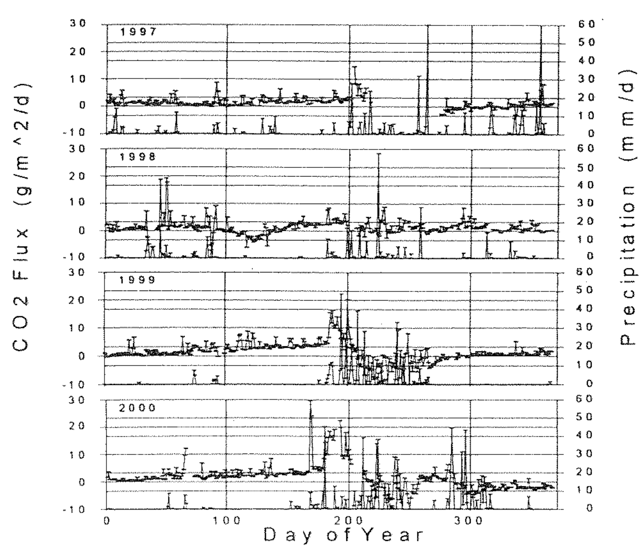

Figure 1. Lucky Hills site yearly carbon dioxide flux and precipitation (negative values, carbon sequestration).

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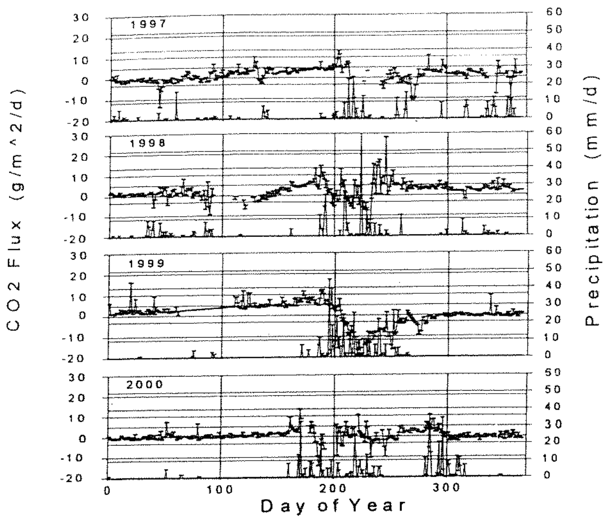

Figure 2. Kendall site yearly carbon dioxide flux and precipitation (negative values, carbon sequestration; values estimated 1999 day 62-115 and 266-271).

The precipitation timing throughout the year was influential in the CO_2 fluxes. In 1999 and 2000, winter and spring at both sites were unusually dry. As the soil dried out and became warmer, the CO_2 loss rate gradually increased until the summer rains started (Figs. 1 & 2). This equates to equation 1 shifting to the left and releasing CO_2. At this time, it was unlikely there was a lot of microbiological activity decomposing organic carbon, hence the carbon loss was probably inorganic. Separating the fluxes at Lucky Hills for 1999 into day and night time flux, the night time flux was small and constant, and was regarded as the amount of microbial respiration taking place (Fig. 3). The larger and increasing day time flux was again attributed to mostly loss of inorganic carbon. In 1998 with more winter precipitation at both locations, the plants responded by using the winter moisture to sequester carbon when the temperatures warmed up around day 100-120, then when the summer growing season came there tended to be less carbon uptake (Figs. 1 & 2).

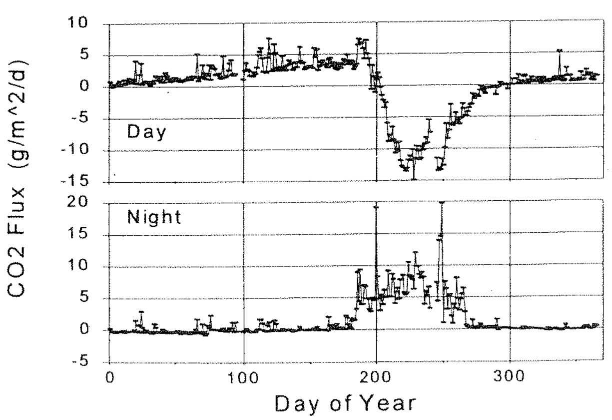

Figure 3. Lucky Hill site, 1999, day and night carbon dioxide fluxes (negative values carbon sequestration).

Annual CO_2 fluxes in and out of the Kendall site was greater than the Lucky Hills site (Table 1). Annual day time fluxes for Kendall showed that there was carbon sequestration, while Lucky Hills was losing carbon. Night time flux loses were small for most of the year except during the summer growing season (Fig.3). Day time flux loses were generally greater than night time fluxes, except during the growing season. Both sites were losing carbon on an annual basis with more carbon loss at Lucky Hill where the soil contained higher carbonates.

Table 1. Annual daily, day and night time CO_2 fluxes at Lucky Hills and Kendall sites for years 1997-2000.

Year	Daily	Day	Night
	----------------	g C / m^2	----------------
		Lucky Hills	
1997	134	76	56
1998	136	11	125
1999	152	5	147
2000	155	14	141
		Kendall	
1997	128	-32	161
1998	209	-139	348
1999	105	-78	186
2000	62	-96	157

The results of the soils analysis established a significant ($p<0.05$) seasonal difference in the inorganic carbon at the two sites. The combined site average Fall soil inorganic carbon was 2.24% and Spring 1.96% to a depth of 30 cm. On an annual basis, some of the carbon flux in and out of the sites was sequestered and lost from the inorganic carbon pool. The aboveground biomass carbon showed the same trends, but separation of fluxes from organic and inorganic pools is for future research.

4. CONCLUSIONS

These two sites with high carbonate soils for the years measured were losing carbon on an annual basis. More carbon was cycled through the grassland Kendall site than the brushland Lucky Hills. Some of the carbon cycling through the sites was being sequestered into and lost from the inorganic carbon pool.

5. REFERENCES

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