4.6 ANNUAL CO_2 FLUXES ABOVE A SAGEBRUSH-STEPPE ECOSYSTEM IN EASTERN IDAHO

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1. INTRODUCTION

Rangelands comprise about 50% of the world's land surface area and could play an important role in the global carbon cycle. Because of their expansiveness, high potential productivity with increasing levels of CO_2, high root/shoot biomass compared to other ecosystems, and ability to accumulate relatively high stocks of soil organic matter in a predominantly stable form, rangeland ecosystems have the potential for sequestering significant amounts of carbon. Despite their potential for carbon sequestration, few long-term studies have been undertaken to document the magnitudes and dynamics of CO_2 fluxes on rangelands, and how climate and management affect fluxes in these ecosystems.

In an effort to quantify CO_2 fluxes on major rangeland ecosystems of the western U.S., the USDA's Agricultural Research Service (USDA-ARS) established a network of 11 study sites in 1995 (Svejcar et al., 1997). Because sagebrush-steppe rangelands cover more than 36 million ha in western North America, a CO_2 flux study site was established in a sagebrush-steppe ecosystem in eastern Idaho. The objective of our study was to measure the magnitudes and dynamics of CO_2 fluxes in this important ecosystem.

2. METHODS

Measurements were made during the growing season from 1996 through 2000 in a sagebrush-steppe ecosystem located at the U.S. Sheep Experiment Station near Dubois, ID, U.S.A. (44°16'N, 112°08'W, 1,700 m elevation). The study area has a diverse shrub-steppe community dominated by three-tipped sagebrush (*Artemisia tripartita* Ryb.). The climate of the area is semiarid with moderately cold winters and warm summers, with a characteristic late-summer drought period. Mean annual precipitation for the area is 325 mm with snow cover reaching up to 70 cm in depth.

We used a Bowen ratio energy balance (BREB) system (Model 023/CO_2 Bowen Ratio, Campbell Scientific Inc., Logan, UT) to continuously monitor CO_2 fluxes. The theory and operation of the BREB system were described by Dugas (1993). Concentration gradients of CO_2 and water vapor were measured with an infrared gas analyzer at 0.8 and 1 m above the soil surface. Air temperatures at the two heights, net radiation, soil heat flux, soil water content, PAR, wind speed and direction, and precipitation also were measured simultaneously.

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Bowen ratios were calculated from average temperature and water vapor gradients measured at the two heights. Sensible heat flux was calculated from the Bowen ratio, net radiation, and soil heat flux. Turbulent diffusivity, assumed equal for heat, water vapor, and CO_2, was calculated using the sensible heat flux and temperature gradient. Values of CO_2 fluxes, corrected for vapor density differences at the two heights (Webb et al., 1980), were calculated as a product of the turbulent diffusivity and the CO_2 gradient. Flux toward the surface (plant uptake of CO_2) was considered negative. Fluxes of CO_2 obtained with BREB techniques are similar to those obtained by other methods (Twine et al., 2000; Angell et al., 2001).

Using the meteorological sign convention, we defined net ecosystem CO_2 flux (F) as:

$$F = -(P - R) \qquad (1)$$

where P is the amount of CO_2 fixed by plants through photosynthesis minus the ecosystem respiratory loss during the daytime and R is the amount of CO_2 respired by the ecosystem during the night. For comparisons among years, we also defined the growing season as that period of time when P was consistently positive.

To estimate annual CO_2 fluxes for each of the years of our study, we determined the length of the cold season by subtracting the number of days in the growing season from the total days in the year. We then multiplied this number by 1.37 CO_2 m^{-2} d^{-1}, which is the mean daily ecosystem respiration for the cold season (R_{cold}) for the Dubois site (unpublished data).

3. RESULTS AND DISCUSSION

Values of P, R, and F for individual growing seasons (P_{gs}, R_{gs}, and F_{gs}) and mean values for 1996-2000 are presented in Table 1. The 1996 growing season had the least negative F_{gs} (-407 g CO_2 m^{-2}), whereas 1999 had the most negative F_{gs} (-1,211 g CO_2 m^{-2}). The dynamics of P_{gs}, R_{gs}, and F_{gs} for the 1999 growing season are depicted in Figure 1. In 1999, consistent positive values of P occurred during mid-April to mid-Oct. with the length of the growing season being 183 days. The length of the growing season varied for other years from 132 to 192 days (Table 1).

Values of P for the 1999 growing season reached a maximum rate of about 25 g CO_2 m^{-2} d^{-1} during late-June (Fig. 1). The P_{gs} for 1999 was 1,490 g CO_2 m^{-2}. Values of R reached maximum rates of about 7 g CO_2 m^{-2} d^{-1} during mid-June, although increased levels of R were also observed after rainfall events during late-July and late-Aug. The R_{gs} for 1999 was 279 g CO_2 m^{-2}.

Values of F for 1999 reached a maximum rate of -22 g CO_2 m^{-2} d^{-1} in late-June, and F_{gs} was -1,211 g CO_2 m^{-2}.

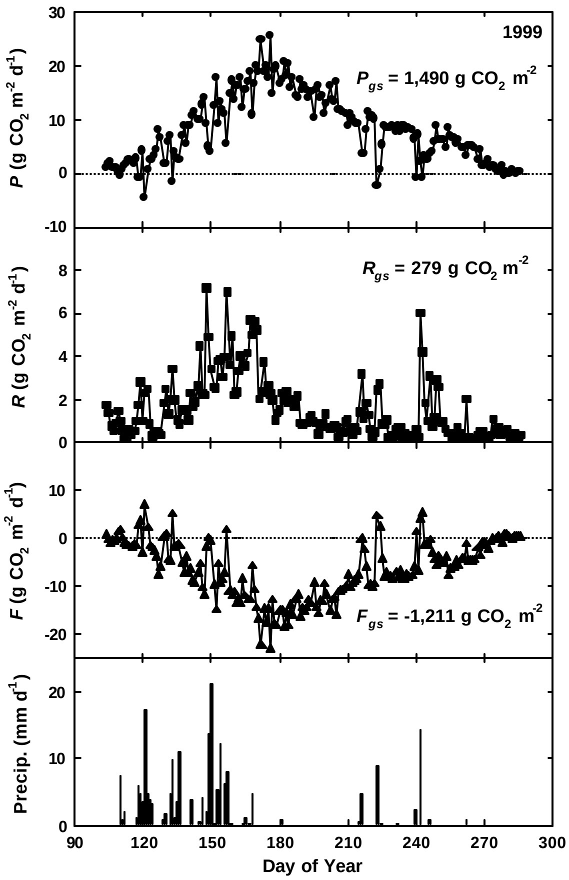

Fig. 1. Daily integrated values of P, R, and F and daily total precipitation for the 1999 growing season. Total values of P, R, and F for the 1999 growing season are indicated in the figure panel for each parameter.

Mean daily values of F were -6.6 g CO_2 m^{-2} d^{-1} in 1999 compared to values of -2.8 to -4.2 g CO_2 m^{-2} d^{-1} for the other years. Values of F_{gs} were also considerably higher for 1999 (-1,211 g CO_2 m^{-2}) compared to the other years of our study (mean of -530 g CO_2 m^{-2}) (Table 1). The reasons for the greater F_{gs} in 1999 are probably due to the amount and timing of precipitation, and possibly more favorable growing season temperatures. In 1999, precipitation during Nov. through June was 253 mm, and individual precipitation events during spring and early summer were of considerable magnitude. In addition, mean monthly air temperature during June was 14.2 ^{o}C in 1999, somewhat lower than most years. The combination of greater effective precipitation and cooler growth temperatures in June, the time period when F is typically near maximum, may have resulted in enhanced water-use efficiency in 1999 compared to other years.

To obtain estimates of annual total net CO_2 flux (F_{year}) for the various years of our study, respiratory losses during the cold season (R_{cold}) were estimated for each year from BREB measurements made during the cold period at Dubois (unpublished data). Using an average of 1.37 CO_2 m^{-2} d^{-1}, we calculated R_{cold} , which varied from 237 to 321 g CO_2 m^{-2} with a mean of 277 g CO_2 m^{-2} for the five years of our study (Table 1). We subtracted these values of R_{cold} from F_{gs} for each of our study years to estimate F_{year}. Resulting values of F_{year} ranged from -103 to -962 g CO_2 m^{-2} for the Dubois site with an overall mean of -389 g CO_2 m^{-2}. These estimates suggested that our sagebrush-steppe site at Dubois was a sink for carbon during the study period.

Table 1. Values of P, R, and F (g CO_2 m^{-2}) for the growing season, cold season, and entire year.

Year	Growing Season				Cold Season		**Annual**
	Days	Total			Days	Total	**Total**
		P_{gs}	R_{gs}	F_{gs}		R_{cold}	F_{year}
1996	144	638	231	-407	222	304	**-103**
1997	166	829	368	-461	199	273	**-188**
1998	192	1,341	527	-814	173	237	**-577**
1999	183	1,490	279	-1,211	182	249	**-962**
2000	132	719	280	-438	234	321	**-117**
Mean	**163**	**1,003**	**337**	**-666**	**202**	**277**	**-389**

4. CONCLUSIONS

Because climatic conditions vary considerably in semiarid environments, it is not surprising that the magnitudes and dynamics of CO_2 fluxes also varied markedly among years at our sagebrush-steppe study site. Despite this large variability in annual fluxes, our results suggested that our sagebrush-steppe study site was a sink for carbon during all five years of our study. Our results further suggest that sagebrush-steppe ecosystems could sequester an average of about 38 Mt carbon per year, which is about 2-3% of the missing sink for global carbon.

5. REFERENCES

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