MEASURING CARBON DIOXIDE FLUX ON SAGEBRUSH RANGE: PRELIMINARY RESULTS

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SUMMARY

Rangeland plants use carbon dioxide (CO_2) in the process of photosynthesis to create high-energy organic compounds that are then used for their own growth, or are stored in plant tiss These stored compounds such as sugar, starch, and cellulose are used as food by herbivores. Measurement of the net uptake of carbon dioxide by plants can provide a new way to measur ecosystem productivity on daily time scales. It also allows us to determine whether rangelan has the potential to capture and store some of the CO_2 that is being released by man's use of fossil fuels. We used a technique called the Bowen-ratio energy balance method to measure daily CO_2 uptake by plants on an ungrazed Wyoming big sagebrush community. Annual patterns of carbon dioxide uptake were very similar, with maximum rates occurring during M and June when soil moisture was high and soils had warmed. We found significant variation from year to year, with maximum rates in 1997 almost twice those observed in 1995 and 199

INTRODUCTION

Carbon dioxide (CO_2) makes up a small proportion of the mixture of gasses we call 'a In fact, it only represents about 0.036 percent of the atmosphere. For convenience, we speak the CO_2 concentration in terms of "parts per million" (ppm), which for CO_2 is about 360 ppm Even though CO_2 is a small component of air, it is in the news a lot because it is one of the elements of global climate change, and it is essential in the production of food for humans.

Concentration of CO_2 in the atmosphere has increased about 28 percent during the pa 200 yr. It was about 280 ppm at the beginning of the Industrial Revolution, but has increasec more than 360 ppm at present. The rate of increase is currently about 1.5 ppm per year. This increase has important implications for rangelands worldwide because plants grow by taking out of the air using the process of photosynthesis. Carbon dioxide is required for plant grow so increased CO_2 means, in a sense, that the air is being "fertilized" with CO_2. During photo-synthesis plants fix CO_2 and make sugars. The photosynthetic capture and storage of solar energy in plant material is called primary production. The sugars that plants make during photosynthesis are later used to create other organic substances such as starch, cellulose, and protein. All animals on earth depend on this process of primary production for the food they

Plants not only take in CO_2 for growth, but they also release CO_2 through respiration: they use some of the sugars they make for their own growth and development. Soil also constantly releases CO_2 because of root and microbial respiration. The sum of these two activities (photosynthesis and respiration) determines whether ecosystems release CO_2 to the atmosphere (serve as sources for increasing atmospheric CO_2) or store it in soil and plant mas (serve as "sinks", helping to reduce atmospheric CO_2).

Carbon dioxide is one of the important gasses implicated in the process of global warming: it is able to slow the rate of heat loss from the earth. Consequently, as this gas increases in the atmosphere, it is becoming an important factor in global warming. The ability of plants to capture CO_2 and store it in roots and shoots may help to offset this increase.

This project is a cooperative effort among several USDA research facilities. The objective of this work is to measure the annual cycle of CO_2 movement to and from rangeland plants and soil. By so doing we can find out if sagebrush rangeland is serving as a sink or a source for carbon dioxide. We will also be able to quantitatively measure the effect of management strategies such as prescribed burning on the annual CO_2 cycle, as well as quantify the rate and magnitude of primary production on sagebrush steppe rangeland.

METHODS

The study began in 1995 at the Northern Great Basin Experimental Range (119° 43'W, 43° 29'N; 4,500 ft. elev.), approximately 40 miles west of Burns, Oregon, in a Wyoming big sagebrush (*Artemisia tridentata* Nutt. subsp. *Wyomingensis*) community. Understory species include Thurber's needlegrass (*Stipa thurberiana* Piper), bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Löve), Sandberg's bluegrass (*Poa sandbergii* Vasey.), bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) Smith), prairie lupine (*Lupinus lepidus* Dougl.), hawksbeard (*Crepis occidentalis* Nutt.), and longleaf phlox (*Phlox longifolia* Nutt.) Soils are coarse-to-fine sandy loam Holte-Milican complex.

Carbon dioxide flux was measured by employing a technique which measured the concentration of CO_2 and water vapor at two heights, one just above the plants and another about 3 ft above the plants. Other measurements included solar radiation, air temperature, soil temperature, heat movement in the surface four inches of the soil, wind speed and direction, and precipitation. All this information was stored at 20-minute intervals, 24 hours a day. Later we used a method referred to as the Bowen-ratio energy balance method to determine the direction and amount of CO_2 movement between the atmosphere and the plants and soil. Finally, each 20-minute period was summed to obtain an estimate of total daily CO_2 flux.

Carbon dioxide movement between plants and atmosphere is measured in either molar or metric units because equivalent English units are not meaningful. In this study, the rate of exchange for CO_2 was measured in units of mg CO_2 m^{-2} $second^{-1}$.

RESULTS

This is a preliminary report of our findings at this time. Weekly carbon dioxide flux between the earth's surface and the atmosphere varied year to year and seasonally (Figure 1). Equipment limitations prevent measurement during winter; however flux rates during that time are fairly low and can be estimated based on measured air and soil temperature and solar radiation. Daytime fluxes were measured with good success; however night time measurements often were unreliable because of limitations to the technique. When necessary, we interpolated for bad data points by using good measurements on either side of the erroneous data. Mathematical models of nightly flux were developed for 1995 and 1996 data. The models used nightly minimum temperature and soil water content to estimate nighttime respiration. These models were then applied to the 1997 nightly flux data for use in this paper.

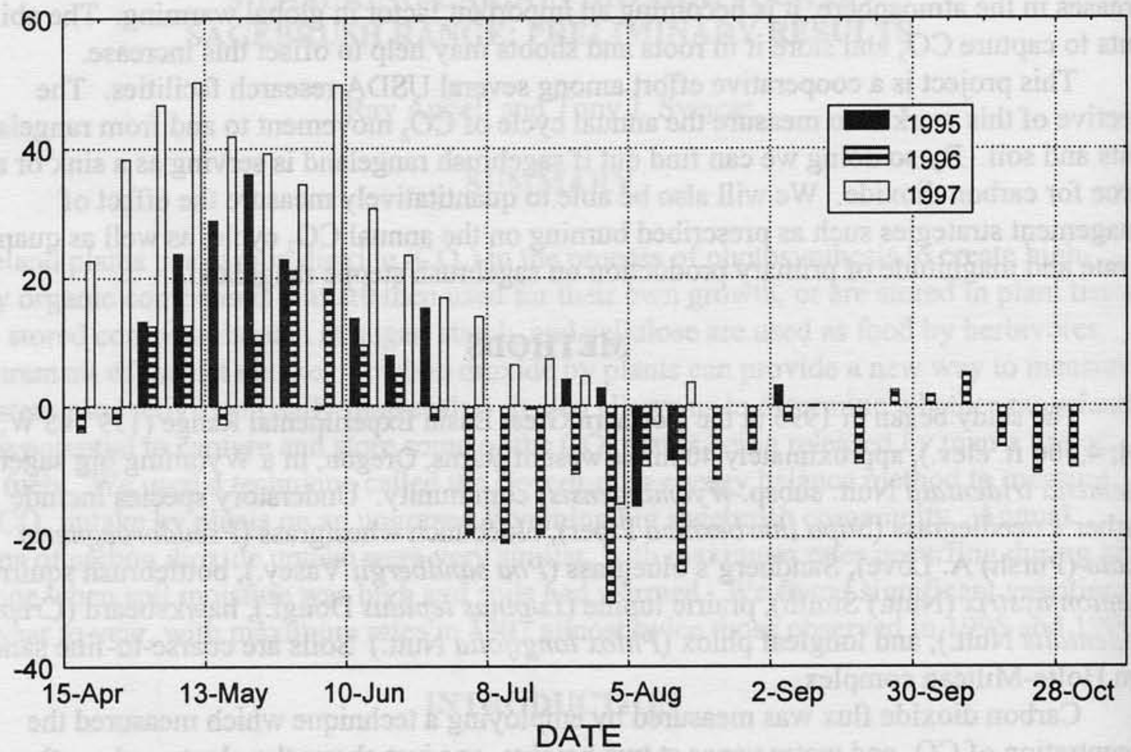

Figure 1. Net weekly carbon dioxide flux (g m^{-2} wk^{-1}) measured over a Wyoming big sagebrush community at the Northern Great Basin Experimental Range. Positive values represent movement of CO_2 from atmosphere to plants via photosynthesis. Negative values occur when net CO_2 movement is from the surface into the atmosphere.

The annual pattern of CO_2 uptake by plants was quite consistent, with peak uptake by plants occurring during May and June. Soil moisture was high, and air and soil temperatures were optimal. Interestingly, CO_2 uptake appeared to have been significantly higher in 1997: plant primary production increased earlier and remained high through late June. Part of this may be explained as a response to improved soil-moisture conditions in 1997. Soil moisture averaged 15 percent from mid-May to late-June, 1997, compared to about 10 percent during the same time period in 1995 and 1996. We are continuing to investigate other factors which influence plant growth, such as soil and air temperatures, as well as daily solar radiation.

Freezing temperatures occurred in 1996 between the nights of June 17 and June 19. Net CO_2 uptake during the following 2 weeks was lower than in 1995 or 1997, dropping to near zero. We speculate that the freezing temperatures had a major impact on the plants in this community because they were not acclimated to such low temperatures. Preliminary results indicate that this low-temperature period had enough impact on the plant community to cause it to become a source rather than a sink for CO_2.

In late June, and through the end of the measurement period each year, net carbon assimilation by plants decreased. Two factors which caused this effect were decreasing soil water and the decreasing green leaf area of plants as they matured and died back. In mid-summer each year, between mid-July and late-August, there were several occurrences of negative fluxes.

These were usually associated with rainfall events. Bowen-ratio methods don't work well during periods of rain, so during such times, we had to interpolate or use the modeling approach to estimate fluxes. These extended periods of high respiration may reflect an increase in soil respiration after rainfall events. Plant growth at this time was limited because plants had gone dormant, so it is likely that most of the response to the rainfall came from soil microbial activity and perhaps from increased root respiration.

CONCLUSIONS

Carbon dioxide flux on sagebrush range can be measured successfully with modern equipment which uses the Bowen-ratio technique. These measures of flux can be used to estimate net growth rate of an entire plant community on a daily time step. We found that daytime flux estimates were quite reliable, but that night time estimates of respiration were more difficult to obtain. Difficulties at night included frost and erratic buildups of CO_2 at ground level. Based on the 3 years reported here, annual fluctuations in net CO_2 uptake can vary by nearly 100 percent, even in non-drought years. Much of the production recorded by this technique is underground, and is quite difficult to measure by other means. The ability to determine these responses to climate will provide powerful tools for land managers who need to separate plant production responses to environment from plant responses to management practices. Based on the success of this preliminary research effort, we are going to use this technique to measure plant growth and net primary production on burned and unburned sagebrush rangeland.