The Rangeland Carbon Dioxide Flux Project

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The Agricultural Research Service (ARS) conducts a broad array of research on rangelands, as described in a previous issue of *Rangelands* (Child and Frasier 1992). Many of the projects involve interdisciplinary teams of scientists at one location, or cooperation among several locations. This article describes a unique cooperative research project that currently involves eleven ARS rangeland research locations. The goals of the project are to: 1) determine the role our nation's rangelands play in the global carbon cycle, and 2) test the utility of carbon dioxide (CO_2) flux technology for assessing the productivity of the various rangeland ecosystems. There are also a number of associated benefits of the study. We hope the results will provide a quantitative basis for comparing the diverse rangeland ecosystem types of the United States. We also hope to define how global increases in atmospheric CO_2 affect plant production.

Background

There has been controversy over the subject of human-induced climate change and what we might expect in the future. However, one part of the climate change debate is relatively clear: atmospheric levels of CO_2 have increased during the past 200 years. Global atmospheric CO_2 has increased from about 280 parts per million (ppm) at the beginning of the Industrial Revolution to about 360 ppm at present. The rate of increase is currently about 1.5 ppm per year (Amthor 1995). This increase has important implications for rangelands worldwide. Plants use the energy in sunlight to take CO_2 out of the air and grow new shoots and roots. Therefore, the level of CO_2 in the atmosphere can also have fairly dramatic impacts on plant growth, water use, and competition among plant species.

Sage (1995) suggested that immediately after the last Ice Age (20,000 years ago), atmospheric CO_2 was too low (about 200 ppm) for successful establishment of agriculture because plant productivity was too low. He proposed that the rise in CO_2 from below 200 to about 270 ppm, which occurred between 12,000 and 15,000 years ago, was a prerequisite for agriculture. Increases in productivity of the Earth's vegetation as a result of the rise in atmospheric CO_2 were documented by experiments in which plants were grown over the range of CO_2 concentrations from less than 200 to 350 ppm (Polley et al. 1993).

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

There is an extensive base of laboratory research on the effects of increased CO_2 on plant growth. Additionally, CO_2 uptake by plants has been measured in the field over crops and in forests. But we cannot adequately predict how rising CO_2 will influence rangelands. In fact, it is not clear what role the rangelands of the world play in the global cycle, even at present CO_2 levels. Scientists have been unable to balance the global carbon cycle, as a substantial amount of CO_2 released to the atmosphere by human activities remains unaccounted for. It has been suggested that rangeland vegetation generally, and grasslands in particular, may be sequestering (storing) more atmospheric CO_2 than is commonly assumed, thus reducing the rate of increase in atmospheric CO_2 levels. Rangelands (including grasslands) constitute about 50 percent of the Earth's land surface. In general, the more arid ecosystems have received relatively little research attention because of their low productivity, and thus their contributions to the global carbon cycle is largely unknown. Until we document the magnitude of the Earth's various sources and sinks, we will be unable to predict future atmospheric CO_2 levels, and consequently, we will have difficulty predicting the extent and timing of possible climate changes.

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To better understand the role of rangelands in the global carbon cycle, scientists from eleven ARS locations have established a coordinated network for the purpose of measuring CO_2 fluxes (Fig. 1). Flux refers to the net movement of CO_2 back and forth between the surface (soil and plants) and the atmosphere. Program planning was initiated in 1993 and some locations have collected two full seasons of CO_2 flux data. The last locations were equipped in early 1996. The measurements of CO_2 exchange between rangeland and the atmosphere were made on good condition rangeland sites in the central and western U.S. The sites include widely divergent environments, from humid tallgrass prairie to desert grassland and sagebrush-steppe cold desert.

We are employing both closed chamber and Bowen ratio techniques in this study. The Bowen ratio method is in use at all the locations shown in Figure 1. A Bowen ratio unit (Fig. 2) looks very much like a weather station,

Fig. 1. *Research locations currently participating in the rangeland carbon dioxide flux project. Open circles indicate locations using both Chamber and Bowen ratio methods.*

for determining CO_2 and water vapor levels in the air. Measurement of the CO_2 and water vapor gradient above the plant canopy in conjunction with energy balance measurements allows us to calculate the amount of CO_2 and water that enters or leaves the site (Held et al. 1990). Measurements integrate activity over a large area (at least 10 acres), and are recorded continuously (24 hours) by a data logger.

The chamber method (Fig. 3) is also being used by several northern locations (Burns, Dubois, Cheyenne, Ft. Collins, Miles City). In this case we are using large chambers (about 1 cubic yard) which are placed on rangeland to measure CO_2 change on a specific plot. This method is better suited than the Bowen Ratio to comparing repeated small-plot treatments.

There are four specific questions we hope to answer with this project:

- What role do U.S. rangelands play in the carbon cycle? Are they a sink for atmospheric CO_2?
- Is CO_2 flux correlated to climatic or ecosystem characteristics, and are the relationships strong enough to allow extrapolation?
- What influence do land management activities (such as grazing and burning) have on rangeland CO_2 flux?
- Do direct measurements of CO_2 flux provide an accurate assessment of primary productivity?

The study will also provide important baseline information that may be used in the future to assess the impacts of rising atmospheric CO_2 on rangelands. Modeling is an important component in forecasting plant response to global change. However, there are serious questions about the ability of

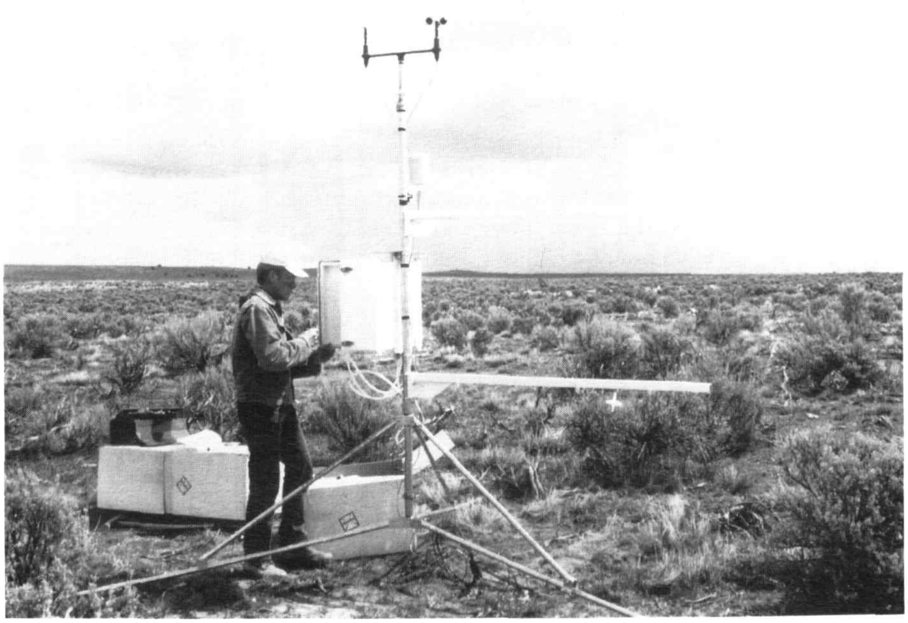

Fig. 2. *Installation of a Bowen ratio station used to measure carbon dioxide exchange between the surface (plants and soil) and the atmosphere.*

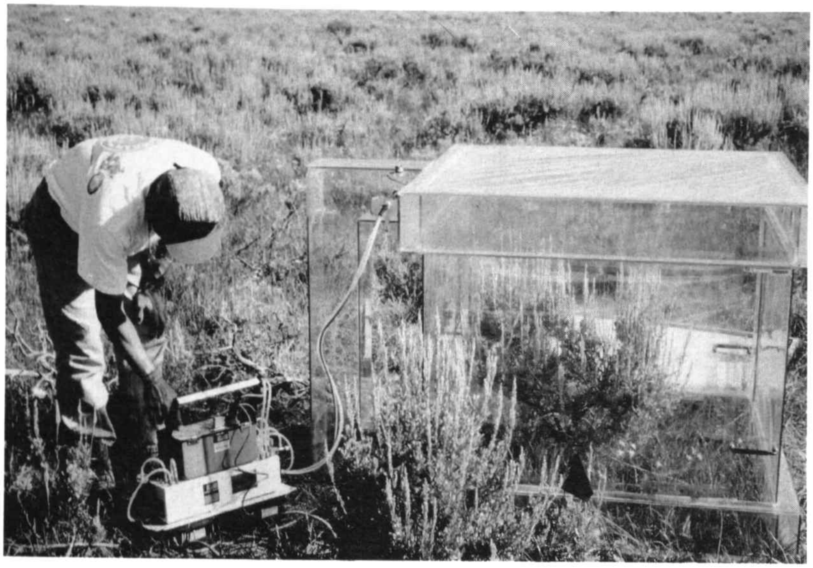

Fig. 3. *A chamber used to measure carbon dioxide exchange on small plots in native rangeland.*

ecosystem-level models to predict future responses to elevated CO_2 (Rastetter 1996). Given the limited resources for research, it is unlikely we will be able to conduct extensive long-term elevated CO_2 studies at multiple sites. One alternative is to collect detailed information now and then again several years in the future. If the current rate of CO_2 increase continues, one decade translates into a 15 ppm increase in atmospheric CO_2. The CO_2 flux measurements coupled with other long-term data sets from participating ARS rangeland locations will be a valuable resource for assessing global change impacts.

Many of the ARS locations also have long-term data sets that describe the changes in vegetation that have occurred in the past half-century. The current study, in conjunction with historic long-term trend information provides us the best opportunity to understand the implications of future environmental changes. Most assessments of range and/or pasture lands are based on productivity and species composition. If we are to use these measures to evaluate the conditions of our rangelands and pastures, it will be critical to determine which changes are a result of management and which are a result of climate and/or CO_2 change.

The National Research Council (NRC) has suggested that part of the definition of ecosystem health should include some measure of energy flow through the system (NRC 1994). Carbon dioxide is the currency, if you will, by which energy exchange is transacted. Our ability to measure net carbon dioxide flux on rangeland provides a direct, quantitative measurement of this aspect of rangeland health. The relationship between energy flows and site productivity should be of interest whether we are raising livestock or wildlife, or simply ensuring that we have properly functioning rangelands capable of sustaining a variety of uses.

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