ABSTRACT: It is generally assumed that healthy, natural ecosystems have the potential to sequester carbon under favorable environmental conditions. There is also evidence that CO₂ acts as a plant fertilizer. It is of interest to know if these assumptions are valid and how natural systems might respond under future scenarios of CO₂ increase and possible climate changes. Few measurements of the effects of CO₂ and global climate change have been made on "natural" ecosystems under realistic field conditions. Most measurements have been conducted in the synthetic environments of totally controlled greenhouses and growth chambers. Several lines of evidence indicate that controlled environment studies using plants growing in pots induce experimental artifacts that reduce confidence in the use of results for prediction of future global responses. Open top chambers are being used in several autecological field studies in an attempt to obtain more realistic field environments. A few field microcosm studies have been completed and a system for the free air release of CO₂ has been applied in cotton fields. Unfortunately, the requirement of large amounts of CO₂ and financial restrictions have precluded the initiation of larger scale field studies in natural vegetation. This paper lists and summarizes the best field studies available but draws heavily on studies from artificial environments and conditions in an attempt to summarize knowledge of global environmental change on forests and other non-agricultural ecosystems. Finally the paper concludes that there is a need for the development and application of equipment for field measurements in several representative natural ecosystems and makes specific recommendation of the creation of a tropical research center.

1. Introduction

There is irrefutable evidence that atmospheric carbon dioxide is limiting to plant productivity at the current mean global concentration of 355 ppm (Strain and Cure 1985, Cure and Acock 1986, Strain 1992, Poorter 1992). There is considerable uncertainty, however, about the response of natural, "unmanaged" ecosystems to CO₂ increase and climate change (Sionit and Kramer 1985, Kramer and Sionit 1987, Jarvis 1989, Bazzaz 1990, Arp and Drake 1991, Oechel and Billings 1992). Although several attempts have
been made to model CO2 and climate change effects on forests (Botkin 1977, Shugart et al. 1986, Solomon 1986, Pastor and Post 1988), shortcomings of the application of empirical stand models for prediction into uncertain futures have been described in detail and a recommendation made for mechanistic modeling using modular, generic models (Reynolds and Acey 1985). These problems and other issues specific to forests were considered at a workshop in 1984 (Shands and Hoffman 1986). Most of the uncertainty considering natural ecosystem responses derives from the fact that few realistic field experiments have been attempted. Most evidence available has been obtained from the synthetic environments of controlled chambers using plants grown and studied in an autecological fashion (Rogers et al. 1983a, Williams et al. 1986, Norby et al. 1986a, 1987, Fetcher et al. 1988, Conroy et al. 1990, Ziska et al. 1991). Recent studies, however, indicate that the restrictive conditions of potted plants growing in controlled environment chambers or greenhouses induce artifacts in plant response that prevent the extrapolation of results to real time field conditions (Thomas and Strain 1991, Arp 1991).

This paper will review the information available from the few field studies that have been published and will draw on selected autecological studies that provide evidence that can be extrapolated to open field conditions. The review will reveal that the primary producers of unmanaged ecosystems have the potential to absorb and store carbon from the atmospheric reservoir of CO2. Resource limitations (e.g. soil fertility, drought, air and soil temperature), however place important restrictions on the magnitude of carbon sequestration to be realized in net primary productivity (NPP). In addition, the energy and carbon requirements of animals and microorganisms reduce the realized net ecosystem productivity (NEP) to values significantly below potential NPP. Known responses of primary producers to CO2 increase and climate change will be itemized. A conclusion will be drawn that extensive field experimentation will be required to obtain reliable information on carbon sequestering and on the natural carbon cycle of "unmanaged" ecosystems. Available and perceived technologies appropriate for application to the problem are summarized from the more extensive recommendations made in Strain (1991b).

2. Summary of Studies Completed in Model Ecosystems (Microcosms)

2.1. ALASKAN TUNDRA

A microcosm approach was applied by W.D. Billings and his colleagues in a series of studies beginning in 1980. They removed cores from the permafrosted tundra of Point Barrow in March when the ground was still ice covered. The cores were air freighted to the Phytotron at Duke University were they were placed in controlled environments and then thawed in simulated spring environments. Environmental conditions were established representing 1980 and a future year in which CO2 was doubled and mean July air temperature warmed from 4 to 8 ºC. In the warmer condition, water table was lowered simulating deeper and more rapid draw down with climate warming. Both warming and increased depth to permafrost and the water table decreased carbon storage in the cores (Billings et al. 1982, 1983). In their last experiment of the series they controlled temperature and water table but also increased soil N. Productivity increased with N enrichment but there was no CO2 enhancement of primary productivity (Billings et al. 1984). They concluded that warming and drying would increase system respiration and carbon loss whereas N additions would stimulate net primary productivity. There were no direct CO2 effects observed in their studies.