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Potential Effects of Elevated Atmospheric Carbon Dioxide (CO_2) on Coastal Wetlands

Elevated Atmospheric CO_2 Concentration

Carbon dioxide (CO_2) concentration in the atmosphere has steadily increased from 280 parts per million (ppm) in preindustrial times to 381 ppm today and is predicted by some models to double within the next century. Some of the important pathways whereby changes in atmospheric CO_2 may impact coastal wetlands include changes in temperature, rainfall, and hurricane intensity (fig. 1). Increases in CO_2 can contribute to global warming, which may (1) accelerate sea-level rise through melting of polar ice fields and steric expansion of oceans, (2) alter rainfall patterns and salinity regimes, and (3) change the intensity and frequency of tropical storms and hurricanes. Sea-level rise combined with changes in storm activity may affect erosion and sedimentation rates and patterns in coastal wetlands and maintenance of soil elevations. Feedback loops between plant growth and hydroedaphic conditions also contribute to maintenance of marsh elevations through accumulation of organic matter. Although increasing CO_2 concentration may contribute to global warming and climate changes, it may also have a direct impact on plant growth and development by stimulating photosynthesis or improving water use efficiency. Scientists with the U.S. Geological Survey are examining responses of wetland plants to elevated CO_2 concentration and other factors. This research will lead to a better understanding of future changes in marsh species composition, successional rates and patterns, ecological functioning, and vulnerability to sea-level rise and other global change factors.

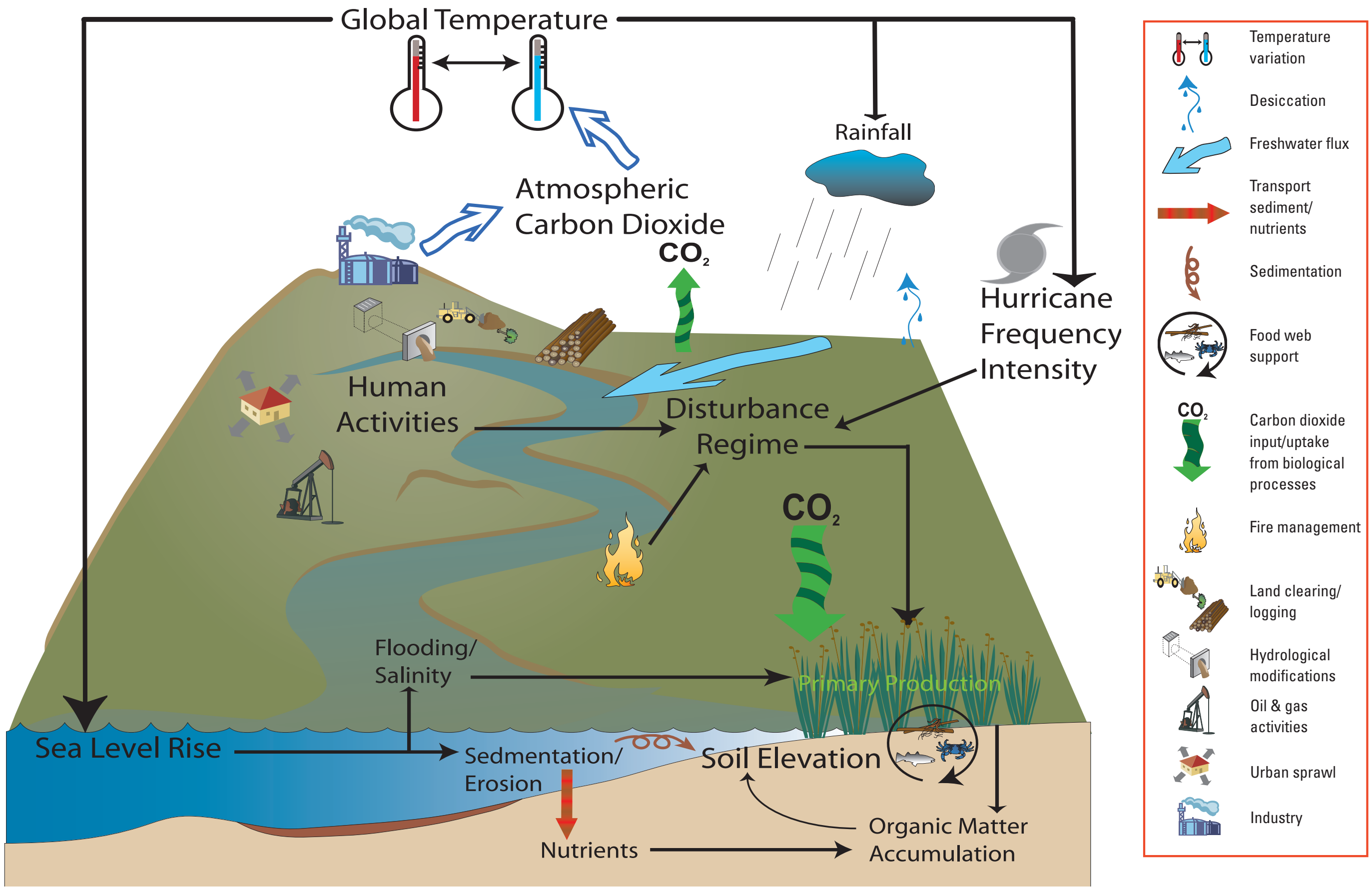

Figure 1. Conceptual Model of Global Change Factors and Wetlands Diagram showing how changes in atmospheric CO_2 and other global and local factors may impact coastal wetlands. Symbols courtesy of the Integration and Application Network (ian.umces.edu/symbols), University of Maryland Center for Environmental Science.

The Wetland Elevated CO_2 Experimental Facility (WECEF)

An experimental facility was built at the USGS National Wetlands Research Center in Lafayette, La., where questions about wetland plant responses to global change and interactions with local conditions could be addressed under controlled conditions. A system composed of four greenhouses and a control room (to house electronics and gas cylinders) was constructed to manipulate atmospheric CO_2 concentrations and other environmental conditions (fig. 2). The design and construction of the CO_2 control and environmental monitoring system was carried out in collaboration with Dr. Bent Lorenzen, Aarhus University, Denmark. The system, which includes individual CO_2 controllers, infrared gas analyzers, and environmental sensors for each greenhouse, is completely automated and computerized to allow continuous monitoring of conditions during experiments.

Figure 2. Wetland Elevated CO_2 Experimental Facility at the USGS National Wetlands Research Center, Lafayette, La.

A Mesocosm Approach

The objective of experiments conducted in the WECEF is not to precisely duplicate natural conditions but rather to examine relative responses of plant communities to hypothesized levels of selected factors while other conditions are held constant. Factors difficult to manipulate in the field, such as flooding or salinity regime, can be more readily controlled in the greenhouse. To provide a link between greenhouse and field, however, use of mesocosms containing intact marsh allows experimentation with natural soil substrates and vegetation. Mesocosms containing monoliths of soil and vegetation are collected from coastal Louisiana and transported to the WECEF, where they are subjected to various combinations of CO_2 treatment and soil factors such as nutrient availability and salinity (fig. 3). Concurrent field experiments provide information about natural plant communities to set realistic treatment levels in greenhouse experiments and to examine the fate of plant materials produced under experimental conditions.

Figure 3. Greenhouse experiments (A) are conducted with mesocosms containing intact marsh collected from the field (B). Field observations and experiments (C) complement greenhouse studies.

Effects of Elevated CO_2 and Soil Nitrogen on a Mangrove-Salt Marsh Community

Effects of elevated CO_2 and climate changes will likely be first apparent in geographic areas where major vegetation types meet. One experiment focused on the ecotone between salt marsh, dominated by the temperate species smooth cordgrass (*Spartina alterniflora)*, and by black mangrove *(Avicennia germinans*), a tropical/subtropical species (fig. 4). The results indicate that salt marsh will not be displaced easily by black mangrove under an elevated CO_2 atmosphere, especially where other environmental conditions promote vigorous growth of smooth cordgrass, which suppresses expansion of black mangrove. Conversely, where smooth cordgrass is stressed or eliminated, black mangrove may rapidly invade salt marsh. Climate change could also lengthen the growing season and decrease the frequency and severity of freezes in coastal Louisiana, promoting growth of black mangrove. Species shifts may have consequences for critical ecosystem processes such as support of trophic food webs and contributions of organic matter to soils.

Application of Research Findings

The information acquired in the WECEF will be useful in the design of management and restoration programs by wetland managers. If future elevated CO_2 concentrations in the atmosphere differentially affect growth, production, and biomass allocation (aboveground versus belowground) of marsh plant species, specific information about such differences will be essential to management programs involving plantings of native vegetation and control of factors affecting ecosystem properties. Furthermore, an understanding of interactions between atmospheric CO_2 concentrations and edaphic factors such as nutrients, salinity, and flooding will be critical in making management and policy decisions involving areas with different hydroedaphic regimes.

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Figure 4. After 1 year, growth of black mangrove was greatly suppressed when grown in mixture with salt marsh plants, especially when soil nitrogen (N) was high (A) compared to mangroves grown in monoculture (B). Although CO_2 enrichment increased growth of mangroves grown alone, it did not reverse the suppression by salt marsh plants when grown in mixture.