Up In The Air

How might global warming and the greenhouse effect impact rangelands?

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The earth has a history of almost continuous climatic change. The presence of carbon dioxide and other greenhouse gases are extremely important to the maintenance of the earth's temperature. However, increases in the quantities of these gases—especialy carbon dioxide due to human activities—is raising concern about climatic change and global warming.

The carbon dioxide(CO_2) levels in the atmosphere have an affect on the global heat balance. Carbon dioxide is virtually transparent to incoming solar radiation but absorbs outgoing terrestrial infra-red radiation. This outgoing radiation that is absorbed would otherwise escape to space and result in loss of heat from the lower atmosphere. This is called the greenhouse effect.

Carbon dioxide concentration in the global atmosphere is increasing due to the accelerating use of fossil fuels, the harvesting of timber, and conversion of forested lands to agricultural production. Burning cut vegetation also adds CO_2 to the atmosphere, and reduces one important CO_2 sink. Such continued patterns are expected to double the global CO_2 concentration by the end of 21st century (Bolin et al. 1986).

This increase means the earth's climate is likely changing. The greenhouse effect is part of the change.

What's The Impact On Vegetation?

Since plants respond directly to CO_2, it is important to determine how the rise in the concentration of global CO_2 will affect productivity of the individual plants and therefore the community in the ecosystem. Research indicates plant communities will be affected in several ways:

1) Water Use. Plant shoot responses to elevated CO_2. are well documented. Research has shown that high concentration of CO_2 often change plant water use efficiency, net photosynthesis, biomass production and yield (Rogers and Dahlman 1993).

Water use efficiency is increased with elevated CO_2. However, water use efficiency responses to high CO_2 become muted by feedback effects at the whole plant level and acclimation adjustments over time (Mooney et al. 1991).

2) Nutrient Use. Under elevated CO_2, C_4 plants (warm season) can be more nutrient efficient in terms of nutrient retrieval from the soil and nutrient utilization in the plant which may have resulted in more efficient fertilizer utilization (Prior et al. 1998). However, biomass allocation to roots increased with increasing CO_2 leading to significantly lower leaf mass and leaf area (Huttenschwiler and Krner 1997).

Several plant species have also shown increases in root dry weight (Rogers et al. 1992b), because carbon allocation to the roots may increase in elevated CO_2. The root systems of CO_2-enriched plants could more thoroughly explore a given soil volume. Therefore, positive effects of CO_2 on root system proliferation (Rogers et al. 1992a) may have influenced the plant nutritional condition and nutrient utilization efficiency.

3) Seed Set And Maturity. Other important effects caused by increasing CO2 could be increases in plant leaf temperature (Mooney et al. 1991), shifting in plant flowering phonology, and delay in seed setting and maturity. Shifting in flowering phenology may result in ineffectiveness of plant natural pollinators, whereas, delaying seed setting and maturity will prevent plant seed production under short arid growing season.

4) C/N Ratio. The chemical composition of the plant may be changed under elevated CO_2. Carbon: Nitrogen ratios will increase with increasing CO_2 (Huttenschwiler and Krner 1997).

Under high C/N ratio condition, NH^4 mineralization rates will be decreased and the nitrogen availability to the plant will decline (Berntson and Bazzaz 1997). This can cause plant shoot increases in the concentrations of condensed tannins (Gebauer 1997), increases in cell wall fraction (Barnes et al. 1997) and increases in the leaf epidermis thickness and a lower leaf water contents (Joutei et al. 2000).

Other studies indicate that changes in carbon/nitrogen ratio in plants induced changes in plant growth and ectomycorrhizal colonization of tree fine roots, therby changing the structure and function of the ecosystems (Berntson and Bazzaz 1997).

The Bigger Picture

As these small changes to plant communities occur, collectively it can have a large impact on habitats. Ultimately, rising CO_2 levels may shift ecological habitats across the landscape as temperature and moisture patterns change, and cause widespread extinction of forms of life unable to adjust to the change and its effect. Species will start migration to cooler sites. Past records indicate that plant species migrated individually since the last glaciation. Plants will not likely shift as a unit. Rather, new plant communities can be expected.

For example, one study suggests the increased levels of atmospheric CO_2 since the industrial revolution could have been the driving force for encroachment of the C_3 woody plants into the C_4 grasslands, and would cause a shift in the balance between grasses and woody plants (Archer 1994).

As CO_2 concentrations and temperatures rise the direct physiological effects on plants—such as changes in photosynthesis efficiencies, germination and growth requirements, water use efficiencies and requirement—may alter interspecific relationships in the ecosystems.

In addition, changes in precipitation, temperature and CO_2 levels can alter soil chemistry (Raven 1988). Rising atmospheric CO_2 concentrations may reduce leaf litter quality and decomposition rates in terrestrial ecosystems.

Moreover, plant species in the ecosystem disperse at a different rate. Thus, major climatic changes will result in resorting of the species constituting natural communities and creation of new plant animal associations, thereby causing new, sometimes, stressful interactions among species. However, species may not be able to colonize the new habitat, therefore they might be extinct (Raven 1988).

Increases in global CO_2 concentration can also cause large increases in plant biomass and in the length of arbuscular mycorrhizal. Changes in growth of mycorhizal fungi resulted in changes in the species competitive ability and therefore created a shift in community structure.

Indirect effects of atmospheric change on fire frequency and intensity, soil water and nitrogen availability may be as important to vegetation dynamics and production as the direct effects of increasing CO_2 on the individual plant photosynthesis and growth.

These indirect effects on soil moisture could have far-ranging consequences on plant species composition, soil bacterial and faunal activity as well as soil physical structure. Hydrology, trace gas emissions, atmospheric chemistry; nitrogen fixation, nitrogen mineralization, plant nitrogen uptake and increases in tannin contents of plants could also be affected.

Finally, changes in the frequency and magnitude of extreme events may be more important than gradual shifts in mean values. Drier climate may cause some area to loose their ability to sustain a forest and change to rangelands. In contrast, wetter climates might enable shrubs and other woody plants to grow in areas that are now grasslands, and also enable range grasses to grow in areas that are deserts.

Sophisticated research studies are needed to further understand how the interactions between the carbon, nitrogen and water cycles influence the response of net primary productivity of the ecosystems to elevated atmospheric CO_2.

Managing For The Future

Past research indicates climate change could harm grazing activities on the rangelands. Water availability is the most important factor determining the grazing value of rangelands for grazing. The decline in water availability would seriously decrease the economic viability and the grazing value of many rangelands in the world.

The increases in carbon dioxide concentration will impact the plant species composition, plant productivity and quality of the rangeland. The forage will be relatively high in fiber, low in protein, high in the concentrations of condensed tannins, and low in water contents.

This, along with increasing C:N ratios in plants, will lower the quality of the animal feed which could induce changes in grazing behavior of the animals and insects in the ecosystems (Hughes and Bazzaz 1997).

Under such condition, rangeland vegetation may need nitrogen fertilization and grazing animals may require higher amounts of feed supplement.

The range management challenge is how to recognize states that may augment effects of carbon dioxide enrichment and to develop management strategies to enhance or to offset the enrichment effects (Polley 1997). The transition-state model (Westoby et al. 1989) could be manipulated to manage rangeland under high atmospheric carbon dioxide conditions (Polley 1997).

Proper range management can not stop the increases in the global carbon dioxide, but the proper management could maintain and/or may improve the cover and the productivity of the rangeland vegetation. By managing our rangelands properly, the carbon sink may become larger and as a result, the rate of global increases in CO_2 could be minimized.

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