Climate Change and Forest Ecosystems

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DEFINING "CLIMATE CHANGE"

I was requested to provide comments on the implications of modern climate change on forested ecosystems in the northeastern US. I provide this perspective as a soil scientist working on environmental stressors in forested ecosystems, and focusing on the biogeochemical responses of these ecosystems over varying spatial and temporal scales.

How will climate change influence northeastern US forests? First, we need to determine what changes in climate will be expected. This is likely the subject of numerous other comments during these meetings. Second, we need to define climate change. Indeed, I view "climate" as a term defining the sum total of both the *chemical* and *physical* climate. While it may facilitate our discussions of modern stressors on forests, or the development of national programs of research, to separate the components of our chemical and physical environment, forested ecosystems reflect an integrated response to the sum of these components.

Therefore, "climate" change can be defined as changes over time that include responses to:

- Acid rain
- Tropospheric ozone
- Nitrogen deposition
- Metal deposition
- Atmospheric carbon dioxide
- UV-B radiation
- Temperature
- Moisture

WHAT DO WE KNOW?

We know that forest environments have been exposed to modern inputs of acidifying substances (primarily sulfur and nitrogen) from the combustion of fossil fuels. We know that soil solutions throughout the Northeast have a unique signal of sulfate concentrations reflecting these pollutant exposures, and while the potential for acidification remains, the rates of sulfur deposition appear to be on the decline. There remains concern for long-term acidification of vulnerable surface waters, and there exists a scientific debate over evidence for base cation depletion in forest soils throughout the region as to its cause and consequence.

Nitrogen is part of the acid deposition mix, but is usually retained by forested landscapes because of the typical deficiency of nitrogen for tree nutrient requirements. However, modern evidence exist for some ecosystems becoming "saturated" in the region with nitrogen, the phenomenon of "Nitrogen Saturation" widely prevalent in Europe and of some concern in the northeastern US. Nitrogen not only contributes to acidification and potential Nitrogen Saturation concerns, but is also a precursor to the formation of tropospheric ozone. Nitrogen deposition does not appear to be declining in the region.

Others are better qualified to describe the current status of tropospheric ozone exposure to both forests and humans. However, I believe it has been demonstrated that relatively high levels of this ozone can develop even in areas remote from major pollution sources. Additionally, research has shown that significant losses occur in agriculture annually due to tropospheric ozone and studies indicate that even forests may be negatively influenced by current ozone exposures. In most instances when ambient levels of ozone are removed from the atmosphere, all plants grow better.

Trace metals such as lead are also released by fossil fuel combustion and other processes, are transported long distances in the atmosphere, and can be deposited on forested landscapes. Indeed, numerous studies in the northeastern US in the early 1980's documented the accumulation of these metals in the forest floor throughout the region. The evidence also suggests that drastic reductions in the emission and deposition of these metals has resulted in a positive response in forest soil burdens, and that some evidence indicates a more rapid recovery is possible than previously suspected. One exception to this relatively positive outlook for trace metal trends has been mercury, where relatively high concentrations have been found in fish and the environment in remote

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forested regions without a clear cause of these exposures.

There is little question that the concentration of atmospheric carbon dioxide is increasing. It is well established that most plants will grow faster, if all other factors are adequate, under increased atmospheric concentrations of carbon dioxide. It is generally accepted, I believe, that increasing concentrations of atmospheric carbon dioxide can essentially "fertilize" forests, much like atmospherically derived nitrogen, and promote increased growth. Numerous other physiological and ecological changes would likely also occur, but these are poorly understood. Most plants increase their water use efficiency under increased carbon dioxide, thus leading to better use of water resources even if they are getting more scarce under a warming climate. One of the many interesting but complex interactions among these factors.

Very little is known about the direct and indirect consequences of UV-B radiation on forest ecosystems, except that increasing exposure will logically lead to a magnification of potential negative consequences and potentially greater interactive stress with other factors described here.

Both temperature and moisture are environmental factors that clearly influence forest condition, and both are predicted to change with changing climate. A warming climate can be expected to warm both the atmosphere bathing forest canopies and the soil supporting root systems. Both biological and chemical reactions speed up with warming, and we expect these effects to result in shifts in forest condition. Whether soil moisture becomes more or less available is a critical unknown in predicting the response of individual ecosystems. Likewise shifting species composition and litter quality can play a key role in governing the response of forests to climate change. We know that increasing soil temperature will increase the rate of nutrient cycling and organic matter decomposition. This could lead to another source of increased available nitrogen further promoting plant growth. We know that increases in the most limiting growth factor cause forest productivity to increase, but result in subsequent stress due to secondary limiting factors such as other nutrients. One example could be increased forest growth due to warming, carbon dioxide, and nitrogen resulting in forest health concerns due to increased demand for calcium (a base cation) possibly being depleted due to chronic acidification.

We know that climate plays a critical role in the distribution of forest species across the landscape, and a warming climate is expected to promote the northward migration of boundaries between major forest types or species distributions. This change then becomes good or bad depending on the human value assigned to the end result.

WHAT WE DO NOT KNOW?

Certainly in science we recognize that what we do not know far exceeds what we know, and so it is with the broadly defined issue of climate change. At present, to my knowledge, we do not know precisely how the climate of the northeastern US will change in the next century, nor do we know how forests will respond to these undefined changes. We know some mechanisms of response, a few briefly mentioned above. Broader issues of "unknowns" might be summarized as the implications of:

- Interactions among stressors (e.g., nitrogen deposition, warming)
- Episodic processes (e.g., fire, pest/pathogen outbreaks, wind)
- Pattern of changes in temperature *and* moisture
- Mechanisms of *recovery* to one or more stressors
- The human response through management

MANAGEMENT CONSIDERATIONS?

Significant energy has been spent, and will be spent, in determining the implications of various potential changes in forest ecosystems on forest ecosystem management. This brief discussion has tended to focus on traditional forest productivity issues, but issues of surface water supply and quality, biodiversity, and recreation can be equally or even more important under certain scenarios. It can be instructive to include in this discussion some possible consequences of climate change that ultimately contribute to the scenarios of change over time. These could include:

1. Cutting practices as related to the size, method and pattern of harvesting.
2. Stand regeneration considerations given a potential shifting competitive advantage among species.
3. Simple growth rates as they effect the production of raw materials for the forest products industry.

4. Managing in consideration of changing risks for certain insect and disease concerns.
5. Pesticide use in response to shifting risks of insects and disease, and in response to the encroachment of species ranges.
6. Altered product quality (i.e., wood quality) due to changing growth rates.
7. Increased risk of wildfire and perhaps costs of fire suppression, and possible increased use of prescribed fire in management scenarios.
8. Need for forest fertilization due to alterations in forest ecosystems, that may result in added costs (e.g., commercial fertilizer) and opportunities (e.g., ash/sludge utilization).

CLOSING COMMENTS

There appears to be significant evidence to suggest that forest ecosystems as we know them today will change in response to long-term alterations in the chemical and physical climate. These changes may be the result of both positive and negative impacts on tree growth and other forest values. Interactions among primary factors, and with secondary factors, will play a turnkey role in the ultimate response of forest ecosystems from the tree to the landscape scale. Particularly noteworthy seems to be the growth promoting effects of (a) increased atmospheric carbon dioxide, (b) increased bioavailability of nitrogen due to several factors, and (c) increased warming of the soil and atmosphere. While these suggest better growth conditions, they may also promote forest susceptibility to other factors, thus resulting in changes that occur slowly or as events. Assigning “good” or “bad” labels to these changes is typically then a product of human judgement.