Global Atmospheric Change

Minnesota’s Forest Resources at a Crossroads

This brief summarizes the relationship and/or interaction between global atmospheric change and Minnesota’s forests. Global warming is emphasized because it is a subject with the greatest potential impact and with a large number of studies relevant to Minnesota in progress.

Global atmospheric change is defined in this paper to mean one or more of the following:

1. **Global warming**: A potential increase in air temperature at the earth’s surface, brought about by human-caused increases in atmospheric concentrations of greenhouse gases such as carbon dioxide (CO₂).

2. **Ozone depletion**: Thinning of the earth’s stratospheric ozone layer by chlorofluorocarbons (CFCs or freons) used in air conditioners, refrigerators, as solvents, and as propellants in aerosol cans.

3. **Air pollution**: Addition of gaseous chemicals such as sulfur dioxide, nitrous oxides, and hydrocarbons to the atmosphere. These chemicals can directly affect tree growth and also react in the atmosphere to form acid rain and excess ozone near the ground.

Global Warming

The greenhouse effect is the retention of heat from sunlight at the earth’s surface caused by atmospheric gases like water vapor, carbon dioxide (CO₂), nitrous oxides (NOₓ), and methane (CH₄). These gases have existed on the earth for several billion years. Global warming refers to increasing the greenhouse effect with the addition to the atmosphere of human-caused natural greenhouse gases (CO₂, NOₓ, CH₄) and artificial chemicals called chlorofluorocarbons (CFCs or freons).

Several facts about the greenhouse effect are well-supported in scientific literature: 1) there currently is, and has been for several billion years, a very significant greenhouse effect on the earth; 2) this greenhouse effect is caused by atmospheric gases including carbon dioxide (CO₂) and methane; 3) the concentration of CO₂ in the atmosphere has been highly correlated with temperature over the last 160,000 years; 4) the concentration of CO₂ and methane has been increasing in recent years; and 5) recent increases in CO₂ and methane have been caused largely by human activities.

Although the occurrence of global warming has not been established at this time, the facts previously listed make it seem likely that global warming due to pollution of the atmosphere will occur in the future. This likelihood will remain unless some other event occurs, such as a reduction in the sun’s output of energy, or a series of volcanic eruptions that throw dust into the atmosphere that will filter out sunlight.

The topics most controversial at this time are 1) how much warmer
will the air temperatures at the earth's surface get and 2) when will global warming be noticeable against the background of natural variability in temperatures. It is uncertain how much warming is likely to occur, the regional distribution of temperature change around the earth, and the effects of a possible lag time between the increase of greenhouse gases in the atmosphere and onset of warming. It's also uncertain how greenhouse gases will accumulate in the atmosphere. Accumulation will depend on how much the use of fossil fuel is increased or curtailed and how much deforestation, tree planting, and absorption of greenhouse gases by the oceans is taking place.

**Predicting Climate**

General circulation models (GCMs) are used to predict climate. They imitate the actions of the earth's atmosphere, including possible responses to changes in greenhouse gases. Five major GCMs have been developed by various research groups, each using different assumptions and equations. These models are capable of producing a reasonable prediction of temperatures as the seasons change over the year. However, this does not provide a good test of their ability to simulate changes over several decades. Even though there are now limitations to using GCMs, the development of more powerful computers and accessibility to large data sets from satellite monitoring of clouds will bring major improvements to climate prediction during the next several years.

**Vegetation Changes in Minnesota**

Interior continental areas such as Minnesota are likely to warm more than the global average, due to their relative remoteness from oceans that act to buffer temperature extremes. However, nothing is currently known about how the Great Lakes might modify warming in the Upper Midwest, nor of the geographic extent of any such modifying effects.

If warming occurs, there might be more evaporation, more cloud formation, and more precipitation during the summer. However, the higher level of evaporation could more than equal the increase in precipitation, leaving the soil drier unless there is a really large increase in summer rainfall as three of the five GCMs suggest. The response of vegetation to drier growing seasons will be a northeastward shift in vegetation types, including the prairie-forest border. Nonetheless, both natural forces and management activities may lessen the impact of these projected changes as the examples below indicate.

**Fire suppression.** The location of various vegetation types in presettlement Minnesota was determined not only by summer temperature and soil dryness, but also by fire frequency. Fires kept the prairie-forest border further to the northeast than would be predicted from climatic requirements of the tree species alone. With fire suppression, woodlots with maple-basswood forest now occur in southwestern Minnesota, an area warmer in summer than the hardwood region of southeastern Minnesota, and an area formerly occupied by prairie. Also, summer temperatures within the Twin Cities Metropolitan Area are warmer in summer than the surrounding rural areas. This urban “heat island” has developed over the past 100 years, yet remnant sugar maple, basswood, and bur oak trees in city parks continue to grow and reproduce. Thus, as long as fire suppression is effective, there is probably some leeway in warming before great shifts occur in the ranges of some tree species.

**Use of drought-resistant tree varieties.** Forest researchers could respond to warmer and drier summers by breeding new varieties of trees or bringing in varieties from regions currently experiencing a climate similar to that predicted for the future in Minnesota. For example, Black Hills spruce is a natural variety of white spruce found in relatively dry southwestern South Dakota. It is already planted in the urban heat island of the Twin Cities, where it grows much better than the Minnesota native white spruce. Black maple, a close relative of sugar maple found in central Iowa, is another possible choice for future Minnesota forests. Red oak from southern Minnesota would also make a good reforestation choice for northern Minnesota if summer climates warm significantly during the coming century.

**Winter precipitation.** A natural compensatory mechanism may be found in precipitation patterns. In various scenarios, four of the five GCMs predict more dormant season precipitation and soil moisture in Minnesota than is currently occurring. The ground may not be frozen as long as it currently is, due to warmer fall and spring temperatures and possibly a heavier snowfall that would insulate the ground during the cold
spells. This would allow precipitation to soak in and recharge subsoil moisture during the winter and could compensate for a series of drier summers. With more winter recharge of subsoil moisture, trees would be able to draw on the stored water during summer droughts when the surface of the soil is dry. This is what currently takes place in the Pacific Northwest, where there are very dry summers.

**Longer growing season.** Another natural compensation for vegetation shifts is likely to be the effect of increased growing seasons. Global warming would increase the number of warm spring and fall days, therefore increasing the growing season. Even if midsummers become too hot for growth, there may be more growth during the early and late parts of the growing season, when evaporation rates are relatively low and soil moisture is higher.

**Summary**

All global circulation models (GCMs)—although not all scientists—predict that significant warming of the earth’s climate is likely to occur over the next century. GCMs can simulate the changes in the earth’s temperature during the annual seasonal cycle. However, this does not guarantee accurate simulation over longer time periods. Therefore, long-term GCM predictions should be considered speculative at this time.

**Warming**: If warming occurs, productivity of individual sites might increase on deep, loamy soils in northern Minnesota as the growing season lengthens. However, sandy soils might experience a large decrease in productivity due to intensified summer drought. No realistic prediction can be made for overall future productivity of Minnesota’s forests under global change given the uncertainty of GCM predictions, the current poor understanding of future range shifts, lack of information on adaptability of trees to environmental stress, and failure of growth models to take into account the currently existing conditions in Minnesota.

**Air pollution and ozone depletion**: Most forests in Minnesota are apparently healthy.

Known forest health problems are in most instances related to natural stresses and/or past land-use practices. Atmospheric ozone depletion is definitely occurring, though, allowing more ultraviolet light to penetrate the lower portions of the earth’s atmosphere. This depletion will continue for several decades, even if use of all chlorofluorocarbons (CFCs) is discontinued at this time. The ultimate level of depletion that will occur and the effects of the resulting ultraviolet light on forest health is not known. However, this depletion could, along with global warming, produce multiple effects on Minnesota forests. Current research indicates that air pollution such as lower level ozone and acid rain is not likely to add much to multiple impacts on Minnesota forests, except very locally near point sources of air pollution.
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