Chapter 30.

Overview of Global Climate Change and Carbon Sequestration

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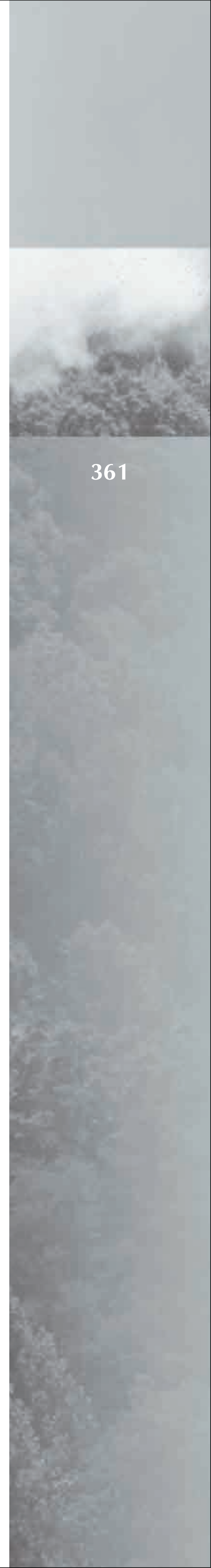

The potential influence of global climate change on southern forests is uncertain. Outputs of climate change models differ considerably in their projections for precipitation and other variables that affect forests. Forest responses, particularly effects on competition among species, are difficult to assess. Even the responses of relatively simple ecosystems, such as managed pine plantations, will be affected by complex interactions. Large-scale perturbations, such as rising atmospheric carbon dioxide (CO_2) and changes in precipitation regimes, will interact with site-specific factors such as soil nutrition.

Because making global change predictions is difficult, it may be tempting to ignore the issue entirely and base management and societal planning solely on historical climate and forest responses. However, scientific uncertainty and difficulties in making predictions of system responses are not relegated to this issue alone. Chapters in this book and in the Southern Forest Resource Assessment (Wear and Greis 2002) discuss uncertainties connected with biodiversity, forest productivity, societal demands for forest values, forecasts of future forest type and extent, urbanization, and the relative profit margins of forest vs. agricultural lands. Economic forecasts are particularly uncertain, as responses depend not only on regional supply and demand but also on national and international economic forces that are in great flux. In all these cases, research provides tools to assess past, current, and future system flux so that planning can be based on the best information available. Such planning ranges from the small scale, as when a private landowner considers options for a particular parcel of land, to larger scales, as when States consider regulation of forest-dependent water resources. In almost all cases, science does not provide a definitive answer to a question; rather, it provides probabilities for potential directions and magnitudes of change. In other words, science permits us to assess the spectrum of risks that may be faced.

Clearly, the smaller the scale of inference, the greater will be certainty of predictions, and vice versa. For example, we can have strong confidence how a particular fertilization treatment may impact a stand of trees of a given age, species, and site index, but much less confidence on what effect such a treatment would have on a larger, less refined land base. It is likely the largest uncertainties are associated with issues that may well have the biggest impact on people and ecosystems. Consider some of the major perturbations that have drastically altered the forest landscape of the South over the past century. Chestnut blight {*Cryphonectria parasitica* (Murrill) Barr [formerly *Endothia parasitica* (Murrill) Anderson & Anderson]} rapidly altered the Appalachian forest structure and did so with little warning. Large-scale deforestation [often of longleaf pine (*Pinus palustris* Mill.) or hardwood stands] was followed by intensive agriculture, and in many cases this was followed by natural reforestation to stands largely made up of loblolly pine (*P. taeda* L.). This "introduction" of loblolly pine led to a major forest industry that both owned and with increasing intensity managed forest land and has provided a market for timber and fiber for private landowners. Thus, just over a century ago the forest landscape was one largely dominated by longleaf pine and hardwoods (including chestnut), and loblolly pine was a minor component. Now we have a landscape in which longleaf pine ecosystems occupy 5 percent of their previous acreage (Outcalt and Sheffield 1996) and are the focus of an active restoration effort, a greatly increased proportion of hardwood stands are early to midsuccession, and there are large expanses of pine-hardwood forests and managed pine plantations where loblolly is the most prevalent pine. These examples illustrate two important points. First, southern forest ecosystems can be incredibly resilient to great perturbation. Second, the state of our forests has been and continues to be in rapid flux.

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Global change is predicated due to human-induced increases in greenhouse gases (chiefly CO_2) in the atmosphere. Current increases in atmospheric CO_2 are well documented and are due to the combustion of fossil fuel and other human activities. Atmospheric CO_2 concentrations are currently over 365 parts per million, 35 percent higher than preindustrial values. They are increasing at a rate of about 0.5 percent per year and are predicted to equal or exceed 550 parts per million by the middle of this century (Wigley and others 1996). Thus, the first basic cog in the global change physical machinery is clearly engaged, but the ramifications for potential consequences are in the realm of scientifically derived probabilities. Science, as shown in this book, endeavors to provide systematic methods for evaluating current and anticipated ecosystem function and composition given projected conditions, and to provide information that can guide ecological, economic, and social decisions that are made by landowners, corporations, and governments.

Predictions and discussions of potential global change have existed in both the scientific and political arenas. In the chapter, "Implications of Global Climate Change for Southern Forests: Can We Separate Fact from Fiction?" by Hermann Gucinski, Ron Neilson, and Steve McNulty provide a discussion on discriminating fact from fiction in this polarized debate. They discuss the evidence that global change is currently impacting climate and consider predictions of future climate scenarios. Their major conclusion is that the climate is likely to change given historical climate variation and the possibility that an accelerating greenhouse effect is in progress.

Interestingly, the major greenhouse gas, CO_2, is fundamental to photosynthesis and provides the carbon (C) that constitutes 50 percent of the dry matter of woody tissue. Increasing CO_2 concentration increases photosynthesis, at least in the short run. Most plants, including trees, initially grow faster when CO_2 concentration is increased. Until recently, studies on the growth response of trees were mostly performed using seedlings and saplings, and with only a handful of species, loblolly pine being the most extensively researched (Groninger and others 1999). Recent work indicates that longer-term growth responses of loblolly pine to elevated CO_2 are largely dependent on soil nutrient availability (Oren and others 2001), which also greatly influences belowground C cycling (Butnor and others 2003). Besides research on direct responses to elevated CO_2, forest tree biology knowledge gained through research is being incorporated into models to predict forest responses to changes in environment and/or management.

Because they are major constituents of the landscape, forests can also sequester large quantities of atmospheric C, thus offsetting emissions from fossil fuel burning and thus the rate of increase of CO_2. Again, C sequestration potential has been most evaluated in loblolly pine. Forest C sequestration can be characterized as *in situ* and *ex situ* (Johnsen and others 2001). The former represents C on a forest site in its biomass and soil. Deforestation, reforestation, growth rate, and rotation length can impact *in situ* C sequestration. *Ex situ* C sequestration represents C that remains sequestered in forest products. Various product types (paper, lumber, etc.) have various lifespans before their C returns to the atmosphere via combustion or decomposition.

Forest C sequestration can provide a short- to medium-term offset for atmospheric CO_2 emissions, while potential additional C sinks are filled. Additionally, utilization of woody biomass for bioenergy production can provide long-term offsets, as these partly supplant fossil fuel combustion.

As result of concern about the potential impacts of global change, international policies have been established to reduce total C emissions to a predetermined baseline (Kyoto Protocol) (Oberthür and Ott 1999). Carbon emissions are the algebraic sum of total emissions and C sequestered, again relative to the baseline. Forests are recognized as one of the important avenues for biologically sequestering C. Thus, the concept of C credits has been born. Although the United States has not signed the Kyoto Treaty, industry is still interested in working with C emissions and sequestration as a commodity. In the early to mid-1990s some companies, particularly energy companies, established programs to promote forest C sequestration on private land. They did this so that they could apply these offsets against their own plant emissions. Nongovernment organizations such as The Nature Conservancy have established large forest C sequestration programs throughout the world with a major emphasis on managing for and quantifying C sequestration. Very recently, a large-scale C commodity exchange has been established for the first time in the United States.

Large-scale policy (regional, national, global) requires large-scale analyses. In the chapter, "Forest Carbon Trends in the Southern United States," by Robert A. Mickler, James E. Smith, and Linda S. Heath provides an analysis of aboveground C stocks by forest types in the Southern United States, and the change in composition and extent of these stocks since 1957. This work is based on Forest Inventory and Analysis data and a process model. Mickler and others estimated that approximately 29 percent of the aboveground forest C in the United States occurs in the South. Their analyses indicate that aboveground forest C has increased at the rate of 42 megatons per year from 1957 through 1997. Their analyses also indicate that acreage in private pineland decreased by 18 percent from 1957 to 1997. However, C stocks on this landownership type are estimated to have decreased by only 2 percent. These estimates only hint at the tremendous increase in productivity that has accompanied the continued development of pine plantation forestry over recent decades. Pine forestry has continued to develop and use management tools such as site preparation, fertilization, weed control, and the use of genetically improved material, and the result has been a steady increase in productivity on managed pinelands.

Thus, managed pinelands represent a major opportunity for increasing C sequestration in the South. However, it is clear that any system of C credits will require simple but reliable methods for quantifying C sequestration. As the major industrial forest species in the world, loblolly pine has been the subject of a large body of research, research that has steadily advanced to make possible increased productivity in forest stands. The same body of research, and the fact that pine plantations are relatively simple ecosystems, make loblolly pine plantations a prime target for the implementation of C credits. In the chapter, "Carbon Sequestration in Loblolly Pine Plantations: Methods, Limitations, and Research Needs for Estimating Storage Pools" by Kurt Johnsen, Bob Teskey, Lisa Samuelson, John Butnor, David Sampson, Felipe Sanchez, Chris Maier, and Steve McKeand detail the methodologies and tools required to quantify C on a stand basis, and they identify areas in which important work is still required to improve and reduce the cost of quantifying forest C.

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