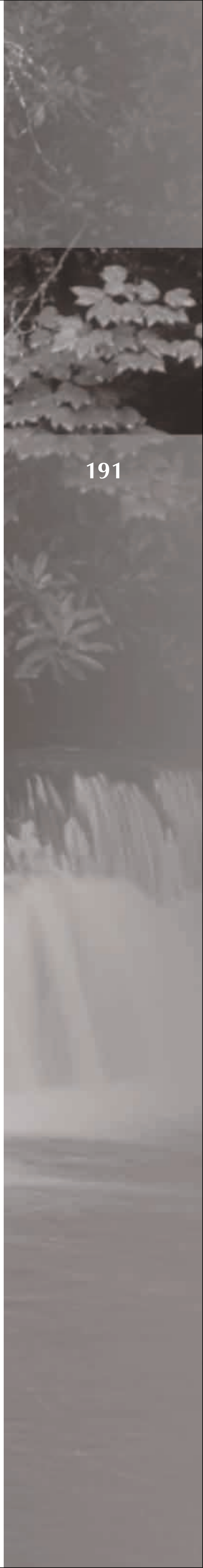

Chapter 18.

Water and Soils

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In the second chapter, Ge Sun and others discuss the effects of management of southern forests on water quantity and quality. Their thorough review of water quality and quantity research in the South provides valuable insights. This research has shown that the greatest changes in streamwater yield or ground-water table occur immediately following forest land disturbances. The overall water-quantity impact of silvicultural operations is much less on wetlands than in areas having greater relief and shallow soils. Silvicultural practices in the South cause relatively minor water-quality problems. Roads managed without regard to best management practices (BMP) are the major source of sedimentation from forestry operations. Studies of the cumulative effects of land use changes on water quality are lacking. The capability of existing computer modeling tools to describe the forest hydrologic processes and provide practical guidance in designing forest BMPs is limited.

The research discussed by Sun and others is very closely related to the study of forest soils, and I think it appropriate to say a little about work in soil science in the South.

ADVANCES AND CHALLENGES IN FOREST SOIL SCIENCE

It wasn't until the early 1900s that linkages between soils and silviculture were recognized, and the forest soils discipline was established (Wilde 1946). By the late 1930s, the forest was recognized as a system consisting of aboveground and belowground components. In the words of Wilde, "An understanding of the forest lies just as much below as above the ground line." Organic matter was known to be a critical component of the soil, affecting fertility, moisture retention properties, and the rooting environment. Studies of the factors affecting soil organic matter turnover and the role of organisms were well known. The early forest soil scientists established that soil quality could be affected by silvicultural practices, especially harvesting and fire. It was well understood that careless harvesting caused reductions in soil organic matter, increased bulk density to the detriment of rooting, and promoted erosion. Fire was known to effect soil fertility, especially when hot fires followed a harvesting operation. Woodland grazing was very common, and it was recognized that this grazing reduced soil organic matter, altered the nutrient cycle balance within the forest, and increased erosion.

Soil management was a well-established concept by the early 1930s. In the silvicultural context, soil management included the application of practices to conserve soil organic matter, maintain nutrient cycles and organic matter, and enhance fertility. The biggest factor driving the development of soil management practices was the challenge of restoring millions of acres of degraded agricultural lands to forest. Much of this land occurred in the Southeastern United States, and was the basis for many of the national forests that were established during that period. The need to reforest large acreages across a diverse landscape led to the recognition of species suitability, which was an early precursor to the considerable body of soil-site research that was to emerge in the 1960s to 1970s.

The tremendous advances in forest productivity that have been realized in the Southeastern United States are a testament to the effectiveness of the soil management practices that are based on a large body of forest soils research. The relationships of species to site conditions were recognized early on, and eventually led to the development of formal classification systems and the design of forest soil or site surveys. Those systems also facilitated the application of soil management prescriptions across the region. These approaches were embraced by the forest products industry in the Southeast, which used soil and site inventories as a basis for harvest scheduling, site preparation prescriptions, fertilization, and weed control prescriptions.

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Major advances in forest soil science occurred in the areas of fertilization, water management, and site preparation (Bernier and Winget 1975, Stone 1984, Youngberg 1978, Youngberg and Davey 1970). Given that the soils of the Southeastern United States are old, highly weathered, and generally abused, development of fertilization prescriptions was fundamental to the reforestation efforts and for improving site productivity. As a result, prescriptions for nitrogen and phosphorus fertilization are now routine across the region. Similarly, the site preparation techniques developed to ameliorate certain soil conditions and reduce vegetative competition also represent an important advance in soil management. Bedding is perhaps the best example of these techniques. The use of elevated planting beds improves aeration and moisture conditions and tends to concentrate nutrients in the rooting zone. Water management prescriptions evolved when it was recognized that water regimes could be manipulated to reduce potential soil damage during forest operations, improve regeneration, and sustain productivity and water quality.

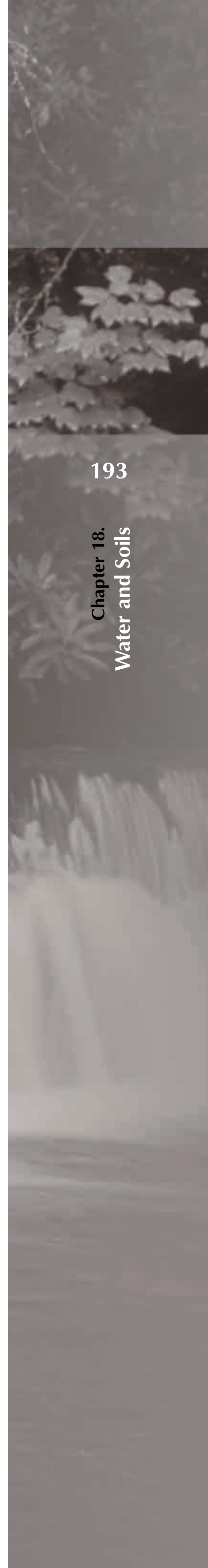
Research in the Southeastern United States produced major advances made in the fields of soil biology and soil chemistry. A prominent example is Marx's research on mycorrhizae (Marx and Bryan 1975), which has widely influenced nursery practices, stand regeneration, and fertility management. The various "acid rain" research programs also made considerable contributions to the understanding of soil biology and chemical processes. That work provided the basis for detailed investigations on nutrient cycling, soil acidification, and organic matter dynamics. Understanding the different sensitivities among forest types, e.g., high-elevation spruce-fir vs. Piedmont mixed hardwoods, has provided the basis for improved environmental management.

The impacts of silvicultural practices on the soil have been explored extensively. Considerations about the effects of harvesting, site preparation, or water management on soil quality were based on concerns about sustaining the productive capacity of the site. Research usually showed that such operations significantly affected soil characteristics, e.g., soil bulk density and organic matter decomposition rate, during the immediate posttreatment period. However, such short-term effects are rarely linked to changes in site productivity and impact studies are rarely sustained beyond 2 to 3 years. Tools for interpreting short-term effects over the long term, i.e, rotation, have not been developed.

The concept of riparian buffer zones acknowledges the fundamental linkages between soil and hydrologic processes. Effective design and implementation of buffer zones depends on understanding the ameliorative goal (i.e., sediment removal, reduction in nitrate concentration), and biogeochemical and hydrologic processes. This would not be possible without the advances in soil and hydrologic sciences. The application of this information and concept has been extensive, affecting the design of BMPs and the evolution of ecological engineering as a discipline. The ability to manage natural systems or engineer biological systems, e.g., constructed wetlands, to achieve particular outcomes is fundamental to sustaining healthy forests.

Now and in the next few decades, the maintenance of productivity will be the most important challenge. As the acreage of commercially available forest land declines, there will be a need to produce even greater biomass on the remaining land. Therefore, it will be necessary to develop more intensive fertilization and water management prescriptions. Similarly, advances in the production and use of genetically improved stock may necessitate a parallel effort to optimize fertility and moisture regimes. Questions about impacts of land management on the soil remain. For example, fire effects are still under study. Considerable work remains to be done before we understand sufficiently the role of roots in soil biogeochemical processes and the associated interactions with plant productivity.

How will a changing environment affect the region's forest soils? Climate change may involve altered thermal and moisture regimes; How will this affect the sustainability of the resource? The southern forests are being fragmented by suburban development (Wear and Greis 2002). What are the implications for soil and water resources? Clearly, most of the forest soils in the Southeastern United States have been disturbed, and have changed over the past 200 years. If we knew more about the history of that process, it would be easier to anticipate the future. Unfortunately, there is virtually no basis for assessing the long-term changes in forest soils in the Southeastern States. An exception is the work on the Calhoun Experimental Forest



over the past 40 years, which highlights the importance of being able to assess long-term change (Richter and Markewitz 2001). It is clear from that work, and the numerous short-term impact studies, that long-term soils studies are needed to provide the basis for sustainable management. The U.S. Department of Agriculture Forest Service's experimental forest network could be used to address soil and water science questions over time and across most of the major forest types in North America.

Perhaps the most difficult challenge will be the development of spatially explicit, process-based forest soil simulation models that will allow the consideration of management alternatives at the landscape scale. As forest resource management moves into the realm of precision agriculture, better information is going to be needed to optimize both economic and noncommodity values. At present, most process-based forest soil simulation models are based on data for uplands and cannot be applied directly to the complex mosaic of upland, wetland, and aquatic resources at the landscape scale. Models provide a means for synthesizing data, providing interpretations, and identifying important knowledge gaps. Improving the quality and applicability of forest soil and hydrology models will enhance our ability to provide interpretations at the spatial and temporal scales that are appropriate to major issues and questions. The models will also provide the basis for quantifying the uncertainties associated with our interpretations.

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