The Potential of U.S. Forest Soils to Sequester Carbon and Mitigate the Greenhouse Effect. J.M. KIMBLE, LINDA S. HEATH, RICHARD A. BIRDSEY, and R. LAL (ed.) CRC Press, Boca Raton, FL. 2002. Hardback, 429 p. $159.95. ISBN 1-56670-583-5.

This book on forest soils is the third in a series, with the first two books focusing on the potential of U.S. cropland and grazing lands to sequester C. The information provided serves mostly policymakers, soil managers, and scientists interested in soil C sequestration as a means to mitigate global climate change. Thus, the focus is on improving forest management practices to increase soil C in forested ecosystems, which cover about 33% of the total land area in the USA, including alpine and permafrost-affected ecosystems, tropical and subtropical systems, natural and managed temperate forests, wetlands, and urban forest systems. Whereas most of the reported literature is on the C pool of forests in the forest floor and aboveground biomass, this overview considers the hidden belowground C. Surprisingly, soil C is the largest C store in most forests. All authors have a demonstrated expertise in soils, global climate change, or forestry, with a collective focus on C budgets and cycling.

Briefly, terrestrial ecosystems can be a major sink or source for C depending on soil environmental conditions. The soil acts as a sink for C, by removing CO_2 from the atmosphere by photosynthesis, leading to subsequent storage of organic C through plant and microbial biomass and by soil C. While it is estimated that the total global terrestrial biomass is almost as large as the atmospheric C pool, the soil C stock is about equal to the sum of these two major C stocks, with its magnitude depending on the considered soil depth. On the other hand, the soil system is a major source of CO_2 through soil and root respiration processes, as well as by biomass removal such as by forest clearing and forest fires. Net primary production (NPP), defined as the difference between photosynthesis and respiration, as opposed to gross primary productivity, generally decreases from the equator towards the high-latitude boreal forests. However, the amount of stored C in forest soils generally shows the opposite trend, with boreal forest soils possibly accounting for the largest inventory of global soil C.

The decrease in U.S. forested land from about 46% in the 1600s to about 33% currently has been the result of conversion of forests to agriculture land. This conversion of forestland to cropland (deforestation) led to dramatic changes in soil C content and major emissions of CO_2 in the past. Hence, it is natural to suggest replanting of cropland to forests (i.e., by reforestation) or changing land use from non-forest to forest (afforestation), thereby bringing C back into the soil. As the C stock in forested systems is generally larger than in croplands or grazing lands, with large above- and belowground C stocks, forests have the potential to increase soil C at the long term because of its long residence time. The text provides much needed information to make informed decisions, as well detailing the benefits of forest management practices on the C sequestration potential of forest ecosystems.

The book is organized into five main sections, for a total of 25 chapters, by about 40 different contributors. The chapters in Section 1 describe the extent and amount of the various forested ecosystems and make an inventory of the C stored as well how the various soil C components are measured. Section 2 deals with soil processes and C dynamics, the role of the forest floor in nutrient cycling, and the effects of various natural disturbances, such as forest fires and droughts on soil C pools, and points out the importance of including these in global climate change predictions. As pointed out by one of the authors in this section, "The key to understanding C storage in forest soils is to develop a better mechanistic understanding of how environmental signals influence substrate inputs, quality, and utilization by soil organism." It is here where vadose zone science can largely contribute, to better understand the control of forest management practices on soil C cycling and sequestration. The third section deals with management impacts on U.S. forest soils, including forest harvesting, forest reestablishment, prescribed forest fires, and soil management. Section 4 reviews specific unique forest ecosystems such as boreal, arid, wetland, tropical, and urban forests and includes a chapter on agroforestry. Surprisingly, about 27% of the total terrestrial C is contained in the permafrost-dominated northern ecosystems, making them especially vulnerable to global climate change, as temperature changes of 4 to 8°C will likely switch these ecosystems from a net sink to net source of atmospheric CO_2, potentially exacerbating climate change in the immediate future. Although making up only a small proportion of the earth's terrestrial surface, wetland soils contain the largest C pool, and are the main source of global methane emissions. The chapter reviewing wetland forest system concludes that the role of hydrology is critical in understanding C dynamics, yet hydrologic processes are hardly considered in most C cycling models. The final section five comprises three chapters that combined synthesize all provided information and pay specific attention to the economics of C sequestration.

As pointed out, relatively little attention has been paid to the potential of forest soils to sequester C, including the Kyoto protocol, with its focus mostly on aboveground biomass. The editors estimate a potential net C sequestration rate of U.S. forest soils ranging from 50 to 185 Mt C yr^{-1}, achieved through forest management activities that include fertilization and modest afforestation. This is a significant number, considering that such an average rate will sequester 1 Pg C during 10 yr (1 Pg = 1 billion metric tons) in soils only, not counting the associated C increases in tree biomass and forest-floor pools. Yet, the current uncertainty of these numbers is huge, reaffirming the need for research in this area. In their last chapter the editors identify research opportunities, highlighting the need for baseline information on soil C pool and fluxes, so that impacts of management practices and climate change can be predicted and evaluated.

Understanding the C dynamics is especially relevant since rate processes are small relative to the large C pools. I like to argue that most of the C cycling is controlled by soil environmental factors that are both dynamic and highly spatially variable, depending on soil and forest type, and soil physical, chemical, and biological properties. Clearly, the most relevant factors are soil moisture and temperature, affecting both biomass production and respiration processes. Yet, almost none of the soil carbon literature related to global climate change considers the soil physical processes that determine variables such as soil moisture and temperature. Also, this text is no exception. Hence, for all of us interested in soil C cycling, vadose zone expertise and research are needed to complement C cycling studies. This will provide much-needed information to better quantify soil C dynamics and soil C sequestration potential by changing land management practices and climatic

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conditions, as well as to better define and reduce their uncertainty.

In summary, this collective work makes clear that forests have a great potential for soil C storage. Considerations must include a mechanistic understanding of the major soil physical processes that control C cycling. Specifically, of major relevance are the spatial and temporal variations of soil temperature and soil moisture because these variables interact with tree health and soil biota and control respiration processes. The text is a great resource to learn more about soil C sequestration. For those that are especially interested in forested ecosystems, the review is complementary to other existing literature.

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