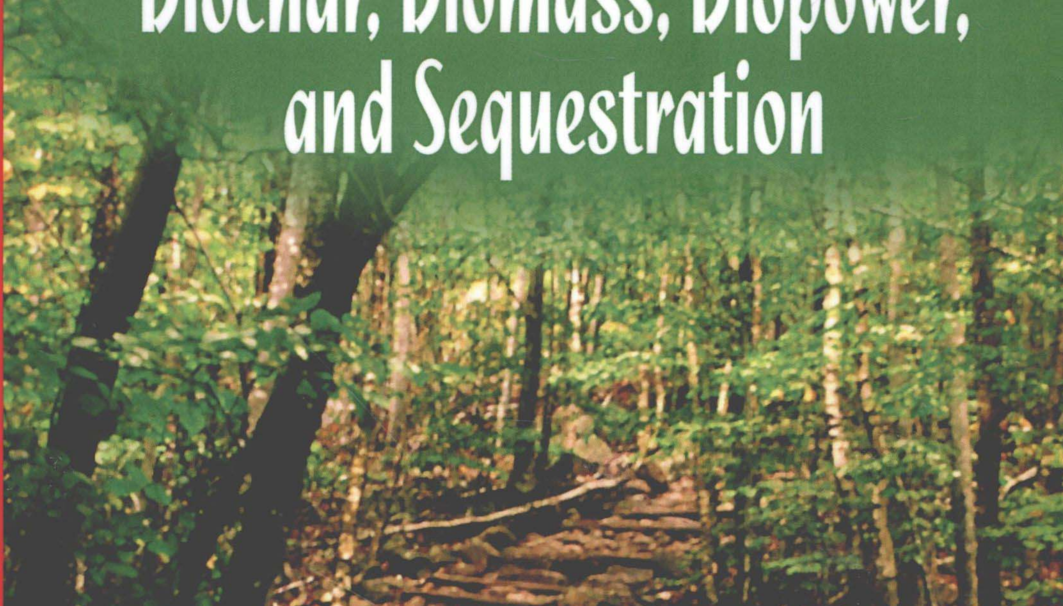
Carbon Considerations

Biochar, Biomass, Biopower, and Sequestration



ENVIRONMENTAL SCIENCE, ENGINEERING AND TECHNOLOGY

Wesley A. Green • Lori G. Wayman
Editors

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WESLEY A. GREEN
AND
LORI G. WAYMAN
EDITORS

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PREFACE

Widespread concern about global climate change has led to interest in reducing emissions of carbon dioxide (CO_2) and, under certain circumstances, in counting additional carbon absorbed in soils and vegetation as part of the emissions reductions. Congress may consider options to increase the carbon stored (sequestered) in forests as it debates this and related issues. Forest are a significant part of the global carbon cycle. Plants use sunlight to convert CO_2, water, and nutrients into sugars and carbohydrates, which accumulate in leaves, twigs, stems, and roots. Plants also respire, releasing CO_2. Plants eventually die, releasing their stored carbon to the atmosphere quickly or to the soil where it decomposes slowly and increases soil carbon levels. Little information exists on the processes and diverse rates of soil carbon change. This book examines basic questions concerning carbon sequestration with a focus on biochar for soil fertility and natural carbon sequestration in forests; and biomass feedstocks for biopower.

Chapter 1 - Widespread concern about global climate change has led to interest in reducing emissions of carbon dioxide (CO_2) and, under certain circumstances, in counting additional carbon absorbed in soils and vegetation as part of the emissions reductions. Congress may consider options to increase the carbon stored (sequestered) in forests as it debates this and related issues.

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How to account for changes in forest carbon has been contentious. Land use changes—especially afforestation and deforestation—can have major impacts on carbon storage. Foresters often cut some vegetation to enhance growth of desired trees. Enhanced growth stores more carbon, but the cut vegetation releases CO_2; the net effect depends on many factors, such as prior and subsequent growth rates and the quantity and disposal of cut vegetation. Rising atmospheric CO_2 may stimulate tree growth, but limited availability of other nutrients may constrain that growth.

In this context, timber harvesting is an especially controversial forestry practice. Some argue that the carbon released by cutting exceeds the carbon stored in wood products and in tree growth by new forests. Others counter that old-growth forests store little or no additional carbon, and that new forest growth and efficient wood use can increase net carbon storage. The impacts vary widely, and depend on many factors, including soil impacts, treatment of residual forest biomass, proportion of carbon removed from the site, and duration and disposal of the products. To date, the quantitative relationships between these factors and net carbon storage have not been established.

Some observers are concerned that "leakage" will undermine any U.S. efforts to sequester carbon by protecting domestic forests. By leakage, they mean that wood supply might shift to other sites, including other countries, exacerbating global climate change and causing other environmental problems, or that wood products might be replaced by other products that use more energy to manufacture (thus releasing more CO_2). Others counter that the "leakage" arguments ignore the enormous disparity in ecological systems and product preferences, and discount possible technological solutions.

Several federal government programs affect forestry practices and thus carbon sequestration. Activities in federal forests affect carbon storage and release; timber harvesting is the most controversial such activity. Federal programs also provide technical and financial help for managing and protecting private forests, and tax provisions affect private forest management. Various federal programs can also affect the extent of forested area, by supporting development (which may cause deforestation) or encouraging tree planting in open areas, such as pastures.

Global climate change is a widespread and growing concern that has led to extensive international discussions and negotiations. Responses to this concern have focused on reducing emissions of greenhouse gases, especially carbon dioxide, and on measuring carbon absorbed by and stored in forests, soils, and oceans. One option for slowing the rise of greenhouse gas concentrations in the atmosphere, and thus possible climate change, is to increase the amount of carbon removed by and stored in forests. As Congress debates climate change and options for addressing the issue, ideas for increasing carbon sequestration in forests are likely to be discussed.

This report examines basic questions concerning carbon sequestration in forests. The first section provides a brief background on congressional interest in forest carbon sequestration. The second describes the basic carbon cycle in forests, with an overview of how carbon cycling and storage vary among different types of forests. The third section then addresses how forest carbon is considered in the global climate change debate. This third section begins with an overview of accounting for forest carbon, then discusses the carbon consequences of forest management practices, the effects of changes in land use, and "leakage." The section then concludes with a summary of existing federal programs that could affect forest carbon sequestration.

Chapter 2 - Biochar is charcoal (similar to chars generated by forest fires) that is made for incorporation into soils to increase soil fertility while providing natural carbon sequestration. The incorporation of biochar into soils can preserve and enrich soils and also slow the rate at which climate change is affecting our planet. Studies on biochar, such as those cited in this Fact Sheet, are applicable to both fire science and soil science.

When plant materials—such as wood, bark, corn stalks, switchgrass, and the like, which scientists generically term biomass—are heated in a low- or no-oxygen atmosphere (this process is termed pyrolysis), the resulting product is called biochar. For example, pyrolysis of wood yields a familiar biochar: charcoal, once the staple fuel for backyard cookouts.

Carbon in the form of carbon dioxide (CO_2), which is released into the atmosphere when carbon-based fuels are burned and when biomass decays, is a major contributor to global climate change. For this reason, carbon sequestration (the process of capturing CO_2 before it escapes into the atmosphere) has the potential to slow global warming. Increasingly, scientists are looking at biochars as additives that can simultaneously enrich soil and sequester carbon that would otherwise be released into the atmosphere if biomass were simply left aboveground to decay.

Chapter 3 - Biochar is a charcoal produced under high temperatures using crop residues, animal manure, or any type of organic waste material. Depending on the feedstock, biochar may look similar to potting soil or to a charred substance. The combined production and use of biochar is considered a carbon-negative process, meaning that it removes carbon from the atmosphere.

Biochar has multiple potential environmental benefits, foremost the potential to sequester carbon in the soil for hundreds to thousands of years at an estimate. Studies suggest that crop yields can increase as a result of applying biochar as a soil amendment. Some contend that biochar has value as an immediate climate change mitigation strategy. Scientific experiments suggest that greenhouse gas emissions are reduced significantly with biochar application to crop fields.

Obstacles that may stall rapid adoption of biochar production systems include technology costs, system operation and maintenance, feedstock availability, and biochar handling. Biochar research and development is in its infancy. Nevertheless, interest in biochar as a multifaceted solution to agricultural and natural resource issues is growing at a rapid pace both nationally and internationally.

Past Congresses have proposed numerous climate change bills, many of which do not directly address mitigation and adaptation technologies at developmental stages, such as biochar. However, biochar may equip agricultural and forestry producers with numerous revenue-generating products: carbon offsets, soil amendments, and energy.

This report briefly describes biochar, some of its potential advantages and disadvantages, legislative support, and research and development activities underway in the United States.

Chapter 4 - Bioenergy production from forest biomass offers a unique solution to reduce wildfire hazard fuel while producing a useful source of renewable energy. However, biomass removals raise concerns about reducing soil carbon and altering forest site productivity. Biochar additions have been suggested as a way to mitigate soil carbon loss and cycle nutrients back into forestry sites; yet, little is known about the effects of intentional biochar amendments to temperate forest soil in conjunction with biomass removals for bioenergy production. In this review, the authors evaluate the potential for mobile bioenergy systems and the environmental implications of biochar application in forests. Using forest biomass that accumulates annually during forest harvest operations, bioenergy can be produced on-site and the biochar that is generated can be redistributed to return nutrients and help improve water holding capacity of the site. Little is known about the short- and long-term impacts of biochar application in forest ecosystems. Some sites may benefit from biochar application, while others show no or negative responses. Field studies on soil and vegetation responses combined with laboratory studies will elucidate the best sites for biochar application and sustainable bioenergy production.

Chapter 5 - Biopower—a form of renewable energy—is the generation of electric power from biomass feedstocks. Biopower, which comprised about 1% of electricity generation in 2008, may reduce greenhouse gas emissions, provide energy security, and promote economic development. A large range of feedstocks can be used, from woody and herbaceous biomass to agricultural residues. Each feedstock has technical and economic advantages and challenges compared to fossil fuels.

Unlike wind or solar energy, a biopower plant is considered to be a baseload power source because some biomass feedstocks can be used for continuous power production. However, ensuring a sustainable supply of biomass feedstocks is a major challenge. Although there are multiple biopower technologies, few of them except combustion have been deployed at commercial scale nationwide.

Federal policymakers are supporting biopower through feedstock supply analysis and biopower technology assessments. However, there is limited comprehensive data about the type and amount of biomass feedstock available to meet U.S. biopower needs at a national level. If the use of dedicated biomass feedstocks to generate biopower were to develop into a sizeable industry, concerns would likely include the effect of the industry on land use (i.e., how much land would it take to grow the crops needed to fuel or co-fuel power plants) and the effect on the broader economy, including farm income and food prices. To date, these have not been issues: most existing biomass feedstocks have been waste products generated by the forest products industry or by farms, or municipal solid waste for which combustion served as both a disposal method and a source of energy.

Growing crops for use as a power source would be different from using waste. Under generally accepted assumptions regarding crop yields and energy content, approximately 31 million acres— roughly the amount of land in farms in Iowa—would be needed to supply enough biomass feedstock to satisfy 6% of total 2008 U.S. electricity retail sales. When added to the amount of land needed to meet the requirements of the Renewable Fuel Standard (RFS), a federally mandated transportation fuel requirement, the potential impacts could be significant: the RFS already consumes 35% of the nation's corn crop, and its requirements will triple between 2010 and 2022 (although much of this fuel will come from feedstocks other than corn).

Beyond land use and economic impacts, others are concerned that the use of biomass feedstocks to generate biopower, particularly through combustion, could add to greenhouse gas (GHG) emission levels and exacerbate climate change concerns. They fear that certain areas may be unsustainably harvested to meet biomass feedstock demand, or that less biomass may be left for other purposes (e.g., wood and paper products). The concerns exist partly because biomass used for biopower does not face the same constraints as biomass used for liquid transportation fuels under the RFS. In addition, the idea that biomass combustion is carbon-neutral is under scrutiny. The Environmental Protection Agency has not exempted biomass combustion emissions from the Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule, although it announced plans to defer for three years GHG permitting requirements for carbon dioxide emissions from biomass-fired and other biogenic sources (those produced by living organisms). In the PSD and Title V Permitting Guidance for Greenhouse Gases issued in 2010, EPA noted that biomass could be considered a best available control technology (BACT)—a pollution control standard mandated by the Clean Air Act.

Chapter 6 - Congress has expressed interest in biopower—electricity generated from biomass. Biopower, a baseload power source, has the potential to strengthen rural economies, enhance energy security, and improve the environment, proponents say. Biopower could be produced from a large range of biomass feedstocks nationwide (e.g., urban, agricultural, and forestry wastes and residues). One challenge to biopower production is a readily available feedstock supply. At present, biopower requires tax incentives to be competitive with conventional fossil fuels. If Congress considers a renewable electricity standard or other measures (e.g., farm bill energy programs) that include biopower, there may be concerns about the carbon neutrality of biopower. Congressional support for biopower has aimed to promote energy diversity and improve energy security, and has generally assumed that biopower is carbon neutral. An energy production activity is typically classified as carbon neutral if it produces no net increase in greenhouse gas (GHG) emissions on a life-cycle basis. The premise that biopower is carbon neutral has come under scrutiny as its potential to help meet U.S. energy demands and reduce U.S. greenhouse gas emissions is more closely examined.

Whether biopower is carbon neutral depends on many factors, including the definition of carbon neutrality, the feedstock type, the technology used, and the time frame examined. Carbon flux (emission and sequestration) varies at each phase of the biopower pathway, given site- and operation-specific factors. A life-cycle assessment (LCA) is a common technique to calculate the environmental footprint, including the carbon flux, of a particular biopower pathway. However, past legislation has not required a standardized LCA.

Interest in the carbon classification of biopower is in part due to sustainability and air quality concerns. Where the feedstock supply for biopower originates, if it is managed in a sustainable manner, and whether the associated air quality impacts from biopower generation are tolerable are questions that are part of the biopower carbon-neutrality debate. Congress may decide whether the current carbon-neutral designation for biopower is accurate, or whether additional carbon accounting for biopower is warranted and what impact this accounting might have on renewable energy, agricultural, and environmental legislative goals.

Rulings by the U.S. Environmental Protection Agency have raised questions about the carbon neutrality of biopower. For instance, the 2010 Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule did not exempt emissions from biomass combustion. Some view EPA's decision as equating biomass emissions with fossil fuel emissions. EPA decided in 2011 to defer for three years GHG permitting requirements for carbon dioxide emissions from bioenergy and other biogenic stationary sources in order to conduct a detailed examination of the science associated with these emissions. EPA's Scientific Advisory Board conducted an independent review of the agency's biogenic accounting framework and released its findings in September 2012. The board acknowledged the "daunting task" of assessing the greenhouse gas implications of bioenergy, and the "narrow regulatory boundaries" within EPA's purview that limit the consideration of greenhouse gas flux at various points along the bioenergy pathway.

State perspectives on the tailoring rule are divided. Some states contend that treating biomass combustion the same as fossil fuel combustion will result in excessive permitting requirements and fees that jeopardize renewable energy development. Other states argue that not treating it the same will aggravate climate change over time.

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Chapter 1

CARBON SEQUESTRATION IN FORESTS*

Ross W. Gorte

SUMMARY

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* This is an edited, reformatted and augmented version of a Congressional Research Service publication, RL31432, dated August 6, 2009.

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