

Biomass Utilization, Forest Restoration, and Soil Productivity Associated with Bioenergy Harvesting and Biochar Application

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1. Background

The removal of forestry residues from public lands is crucial for reducing the risk of stand-replacing wildfires, restoring ecosystems to be more resilient from insect and disease outbreaks, and adapting to climate change. Residues include the tops, limbs, unmerchantable roundwood, and other woody debris that is the byproduct of silvicultural treatments prescribed to achieve these and other management objectives. Using this waste biomass for bioenergy and bioproducts production could improve the economics of silvicultural treatments and produce renewable energy. One bioproduct in particular, the biomass-derived high carbon charcoal known as “biochar”, has shown particular promise for offsetting fossil fuels, improving site conditions, and sequestering carbon. However, a variety of ecological, social, and economic impacts must be considered in order to evaluate alternative strategies for the utilization of biomass harvested from public lands.

It is important that soil quality, function, and site productivity potential are protected during biomass removals in order to maintain a sustained yield of the many resources that forests provide, including biomass for future harvests. Further, removing biomass decreases potential input for the formation of soil organic matter and may, therefore, have negative impacts on soil fertility. Biochar application to forests can be used to cycle nutrients contained in the feedstock back into forest sites, increase soil carbon, and improve soil water holding capacity. Appropriately scaled thermochemical conversion technologies can be used to produce biofuels that offset fossil fuels and biochar that can be used to sequester carbon when added to the soil. As part of an integrated system that processes residues into both bioenergy and biochar, excess forest fuel loads can be used as a potential energy source while reducing the risk of wildfires, and biochar can be

used to increase soil carbon and improve soil quality. However, the ecological impacts of these activities have not been adequately quantified in forest systems.

It is also critically important that utilization of waste biomass from forest treatments generate greater benefits and/or lower costs than current residue disposal strategies, including on-site burning. In this case, the assessment of benefits and costs includes both market values, such as increasing revenues from the sale of biomass to offset treatment costs, and non-market values, such as reducing the carbon footprint of forest management activities. Such assessment takes place at a variety of scales, from stand-level financial considerations to regional and national level objectives, including Forest Service commitments to climate change adaptation and mitigation. From an economic standpoint, biomass utilization has the potential to generate net benefits by reducing air pollution, offsetting fossil fuel emissions, sequestering carbon in the soil, and generating revenue from residues that often have high disposal costs. Because facilities that use forest biomass as raw material tend to be located close to forest resources, utilization also has the potential to support local economic activity, including new bioenergy and bioproducts industry.

2. Goals

2.1 Biomass utilization and soil productivity: Our goal is to assess the impact of woody biomass removal on sustained forest production. Woody biomass from western conifer forests is viewed as a potential source of feedstock for biofuel using thermochemical or biochemical conversion processes. There are numerous advantages to removing a portion of net forest growth, including protection from wildfires, pests and disease, as well as acclimating to climate change. Conversely, it is possible to remove too much biomass and degrade a site's future productivity potential. As the biofuel industry expands, demand for woody biomass will increase. Knowing the impacts of biomass extraction is critical to providing renewable forest resources without degrading site productivity. Attaining that balance is necessary to provide future generations with all of the goods and services that we have traditionally enjoyed from our National Forests. Understanding the ecological limits of biomass removal, as well as viable strategies to compensate for removals, must be a basis for any biofuel production approach that extracts biomass from native forest production systems. RMRS is considering the effects of various levels of biomass removal on soil physical, chemical, and biological properties and incorporates various ameliorative treatments, including slash retention, site fertilization, and biochar soil amendment.

While there is an abundance of literature that demonstrates the importance of standing and down coarse woody debris to provide habitat for vertebrate species, there is little information on small life forms associated with fine woody debris. In addition, few studies have quantified site-specific amounts of woody debris needed to maintain specific populations. Harvest of slash and other woody biomass for bioenergy decreases the amount of wood on forest landscapes and changes the above-and belowground physical, chemical, and biological properties. Understanding the balance between harvesting and retention levels, including remediation from adding biochar or fertilizer, and developing guidelines to maintain species diversity are the critical points of our research.

2.2 Biochar additions – Our goal is to evaluate the effects of additions of biochar to forest soils and determine the conditions under which biochar soil additions improve or are detrimental to soil quality, function, and site productivity. Biochar is a granular, carbon-rich substance derived from biogenic feedstocks, including forest biomass. Its particulate form resists decomposition and therefore persists in the environment. Biochar can be a byproduct of creating bioenergy from biomass (e.g., a byproduct of gasification) or it can be a primary product manufactured specifically for emerging markets. In either case, adding value to biochar output can improve the overall efficiency of bioenergy production. Biochar has potential to be used to filter liquids and gases, can serve as a base product for the production of nitrogen fertilizer, and can be used in the manufacture of a wide range of industrial chemicals and products. It can also be used to improve forest productivity by increasing water-holding capacity, reducing bulk density, and providing cation exchange sites. Biochar derived from forest feedstock (e.g., fire salvage or mixed conifer slash) commonly has a pH that ranges from 7.5-8.0, has a relatively high C:N ratio (150-200), and has been shown to contain macro- or micro-nutrients similar to those naturally occurring in live trees. Additionally, bulk or pelletized biochar could be used in native plant nurseries as a replacement for vermiculite and as a method of sequestering carbon during planting. These properties make it a good candidate for improving the properties of forest soils, but there are many knowledge gaps related to this use of biochar.

2.3 The economics of biomass utilization: Our goal is to quantify the conditions under which biomass utilization delivers the greatest net benefits to society, including both market and non-market benefits, with an emphasis on evaluating advanced conversion technologies used to process forest biomass. Though pyrolysis of woody biomass has

been used for thousands of years to make charcoal, many of the advanced thermochemical technologies currently being developed to convert biomass into heat, biochar, liquid fuels (e.g., pyrolysis oil), and gases used for fuel and chemical production have never been used commercially in the forest sector. Relatively little scientific information is available to characterize the products they produce, their emissions and other environmental impacts, and their financial and economic viability. There is a high degree of uncertainty associated with investment in this emerging sector of the economy. We are working to provide new knowledge to guide the sustainable use of biomass for bioenergy and bioproducts and to reduce the uncertainty for stakeholders involved in making decisions about biomass utilization and investments in new technologies.

An important aspect of the non-market benefits and costs is the effect of forest biomass utilization on reducing greenhouse gas and particulate matter emissions. Our goal in this research is to quantify the greenhouse gas and particulate matter emissions associated with collecting or harvesting, comminuting, hauling, and utilizing forest biomass as a feedstock in various types of bioenergy facilities. These results will be compared with the alternative of not utilizing forest biomass and instead using various fossil fuels to produce the equivalent amount useable energy. The amount that fossil fuel consumption can be reduced by sustainable utilization of forest biomass to produce energy products and the resulting effects on greenhouse gas and particulate matter emissions is important information for informing managers, stakeholders and public policy regarding the use of forest resources for energy production.

3. Strategies and Objectives

3.1 RMRS Strategy to address the ecological sustainability of biomass harvest and biochar application

Our approach to defining best management practices for harvesting and residual coarse and fine woody debris and the application of biochar will meet the following objectives:

Objective 1. Establish long-term soil monitoring plots that include various levels of downed woody biomass and amendment treatments designed to mitigate impacts of biomass removal.

Objective 2. Quantify energy, carbon and nutrients taken from overstocked forest sites during biomass removal and determine mitigation potential for amendment treatments.

Objective 3. Compare growth response of retained trees and soil physiochemical attributes, including 'natural' (i.e., wildfire generated) black carbon levels, among treatments.

Objective 4. Monitor above- and belowground woody biomass decomposition rates among treatments using standardized wood stakes.

Objective 5. Establish leaching rates of biochar through various forest soils and determine field-site potential for individual biochars.

These objectives will be met on all field sites by a standardized set of treatments that include leaving slash, removing slash, adding biochar at the same level that slash is removed, adding biochar at an elevated rate to push an ecosystem response, and fertilizer additions.

3.2 RMRS Strategy to address the economics of biomass utilization

Our approach to quantifying the economic tradeoffs of biomass utilization involves three general areas of research: supply chain research, spatial biomass supply modeling, and the economic evaluation of specific thermochemical conversion technologies.

Research in these areas is designed to meet the following objectives:

Objective 6. Understand the productivity, costs, and financial performance of alternative methods for harvesting and delivering biomass from the forest to end users using operations and supply chain research.

Objective 7. Use this new knowledge to develop novel biomass supply systems and improve existing biomass supply chains by making them more efficient, allowing forest managers to treat more acres at lower cost.

Objective 8. Develop landscape-level forest biomass supply models to predict biomass flows under alternative economic conditions and understand the scales of utilization that match specific treatment regimes (i.e., harvest levels).

Objective 9. Partner with industry and technology firms to evaluate alternative thermochemical biomass conversion technologies with regards to the products they produce, their financial performance in various forest sector settings, and their environmental impacts.

Objective 10. Use information from these studies to construct empirically-grounded financial and economic models for advanced biomass conversion technologies.

Objective 11. Quantify the environmental tradeoffs of alternative biomass utilization scenarios, including air pollution, greenhouse gas emissions, energy balance, and carbon footprint.

Objective 12. Provide useful information to stakeholders and decision makers regarding biomass utilization and biomass conversion technologies.

4. Recent and Current Research

RMRS scientists are leading a number of recently completed and ongoing projects under this strategy to accomplish these goals and objectives. These projects include a wide range of funding agencies, partners, and locations. Completed projects are marked with an asterisk (*).

- Maintaining soil productivity after thinning by applying biochar, fertilization, and woody biomass. Funded by National Fire Plan (NFP) and United States Department of Agriculture (USDA) Forest Service Research and Development (FS R&D).
- Improving wildlife forage plots by soil amendments of biochar. Funded by USDA-FS Region 6.
- Using biochar to filter water and sediment from roads. Funded by USDA-FS Region 6 and Federal Highway Board.
- Biochar amendment impact on belowground soil physical, chemical, and biological properties. Funded by American Recovery and Reinvestment Act (ARRA).
- Leaching properties of biochar in forest and agricultural soil.* Funded by ARRA.
- Using biochar to reduce compaction and invasive plants during forest road obliteration. Funded by USDS-FS Helena National Forest
- Sustainability of forest biomass removals. Funded by ARRA.

- Hydrophobicity of biochar on forest soils.* Funded by NFP and FS R&D.
- Amending degraded agricultural lands with biochar to improve growing conditions and yield. Funded by USDA-FS Region 6.
- Using biochar to replace vermiculite in tree seedling nurseries. Funded by FS R&D and USDA-FS State and Private Forestry (SPF).
- Pelletizing biochar to facilitate application on forest sites.* Funded by ARRA.
- Integration of Biofuels and Bioproducts Production into Forest Products Supply Chains Using Modular Biomass Gasification and Carbon Activation. Funded by USDA National Institute of Food and Agriculture (NIFA), Biomass Research and Development Initiative (BRDI).
- Uncompahgre Plateau Restoration: Assessing the Economic Feasibility and Net Greenhouse Gas Emissions of Producing Bioenergy from Forest and Range Treatment Residues. Funded by RMRS Competitive Research Initiative (CRI) and NFP.
- Analysis of Sort Yards to Increase Value Recovery and Utilization of Small-diameter Trees and Forest Biomass for Landscape-scale Forest Health Treatments.* Funded by FS R&D Biomass Grant.
- Sensitivity of the Economic Feasibility of Utilizing Forest Residue Biomass to Delivered Biomass Price and Diesel Fuel Price.* Funded by NFP R&D for utilizing treatment residues.
- Assessing Costs and Benefits of Alternative Methods for Handling and Transporting Forest Treatment Residues for Bioenergy. Funded by USDA-FS Agenda 2020.
- Sustainable Forest Bioenergy Production Using In-woods Fast Pyrolysis Conversion Including Bio-oil Production and Biochar Soil Amendment. Funded by FS R&D Biomass, Bioenergy, and Bioproducts Grant.
- Economic and Environmental Analysis of Mobile Fast Pyrolysis Deployed Under Field Conditions.* Funded by ARRA.
- Biochar from Biomass: A Process for Utilizing Forest Treatment and Mill Residues. Funded by RMRS CRI and NFP.
- Integrating modular pyrolysis processing into forest operations to improve the sustainability and efficiency of treatment residue utilization. Funded by FS R&D Biomass, Bioenergy and Bioproducts Grant.

- Development of a GIS Tool for Measuring Changes in the Forest Carbon Sequestered Over Time in Ravalli County as a result of Growth, Disturbance Preprocesses, and Forest Treatments.* Funded by USDA-FS Forest Inventory and Analysis Program (FIA), RMRS Human Dimensions Program (RMRS-HD), and the University of Montana (UM).
- Emissions and Energy Return of Utilizing Forest Fuel Treatment Residues for Thermal Energy Production for a Landscape in the Northern Rocky Mountains of the United States.* Funded by RMRS Bitterroot Ecosystem Management Research Project (BEMRP) and RMRS-HD.
- Regional Assessments of Carbon in Harvested Wood Products: Estimates for the U.S. Forest Service Northern Region, 1906 to 2010. Funded by USDA-FS Resource Information Management (RIM) Board and RMRS-HD.
- An evaluation of forest carbon accounting methods with emphasis on carbon stocks and flows from using residues for energy. Funded by NFP and FS R&D.
- Enhancing Western Managers' Knowledge and Use of Available Economic and Financial Biomass Information and Tools.* Funded by Joint Fire Science Program (JFSP).

5. Contact Information

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