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Burgeoning Biomass: Creating Efficient and Sustainable Forest Biomass Supply Chains in the Rockies

Woody biomass being loaded onto a truck. Photo credit: Rocky Mountain Research Station.

SUMMARY

Woody biomass could be used to generate energy in the western US if the utilization process is both economically feasible and ecologically sustainable. The purpose of the RMRS-led Biomass Research and Development Initiative (BRDI) is to develop technologies, approaches, and new science that will help to make this possible. This issue of the Bulletin is focused on research addressing challenges of the biomass supply chain, from the time that a forest treatment is initiated to the time that the biomass residue reaches an end user (a later issue will address the technology of biomass conversion after the material is delivered). A major roadblock to effective biomass utilization is the high handling costs and low market value of woody biomass. As part of this project, new technologies are being developed to enhance biomass resources assessment, improve supply chain logistics, and reduce handling costs through equipment modification and more efficiently managing operations in forest treatment areas. To assist managers in inexpensively and quickly assessing forest biomass supplies, new and innovative tools are now available.

The BRDI project also addresses the long-term effects of biomass utilization on soil and forest productivity by resampling research sites that were established and harvested 40 years ago. These understandings of long-term effects and improvements in the biomass supply chain have the potential to make biomass utilization a feasible renewable energy option to reduce our long-term carbon footprint, and address many significant land management challenges.

There is an abundant, renewable fuel source locked in Rocky Mountain forests. Most active forest management activities on public and private land, such as thinning and removing beetle-killed trees, produce a byproduct called woody biomass. Also known as "slash", this material includes stems, limbs, tops, needles, leaves, and other parts of trees and woody plants that are cut down to produce timber or meet other land management objectives. Though often burned for disposal, woody biomass can be collected, processed and transported to a facility where it can be converted into fuel, heat and electricity. Eagle Valley Clean Energy in Gypsum, Colorado, is one such facility, and is Colorado's first dedicated biomass power plant, producing 11.5 megawatts of electricity. Biomass power plants like the one in Gypsum can help states reach their renewable portfolio standard goals of acquiring a portion of their energy from renewable sources.

However, the reality is that biomass in the Rockies is largely unused due to its

high production cost and comparatively low market value. Before it can be used as fuel or raw material, woody biomass must be collected, chipped or ground, and delivered to the end user—and each step of the process adds to the mounting cost. Once delivered, the chips or ground fuel have low market value compared to logs—less than $50 per bone dry ton in most cases, which is often less than the cost of production. In this case, the least expensive option is to simply treat woody biomass as waste and either leave it in the forest to decompose or burn it in open piles for disposal. Open burning generates unchecked air pollution, including smoke and carbon dioxide, but is necessary to reduce fire hazard and open growing space for seedlings. Without an efficient supply chain to gather and move the material, and without the infrastructure to convert it to energy, the options for using woody biomass for energy in the Rockies are limited.

What if we could develop a cost-effective biomass supply chain and use this material for value-added energy and products instead of burning it or leaving it in the forest? In this alternative scenario, what is now a waste byproduct of forest management could be converted into a renewable fuel source, generating revenue, offsetting fossil fuel use, and reducing emissions from pile burning. To this end, research directed by the US Forest Service Rocky Mountain Research Station (RMRS) is focused on developing technologies, approaches, and new science that will allow for the economic, social, and environmentally sustainable harvest of forest biomass.

Funded by the Biomass Research and Development Initiative (BRDI) of the USDA National Institute for Food and Agriculture (NIFA), a team led by RMRS research forester Nate Anderson, with Debbie Dumroese, John Hogland, and Bill Elliot, and collaborators Han-Sup Han (Humboldt State University), Chris Keyes (University of Montana) and Woodam Chung (Oregon State University), have been evaluating major aspects of the biomass supply chain, with an eye toward optimizing operational efficiency and minimizing environmental impacts to help make biomass a viable renewable fuel source in the Rockies. In this first of a two-part Bulletin series, the focus is on research to efficiently harvest and move woody biomass from the forest to conversion facilities in a cost-effective and environmentally sustainable way. Part two will focus on biomass conversion technology and the social and economic aspects of conversion, and will be available in 2015.

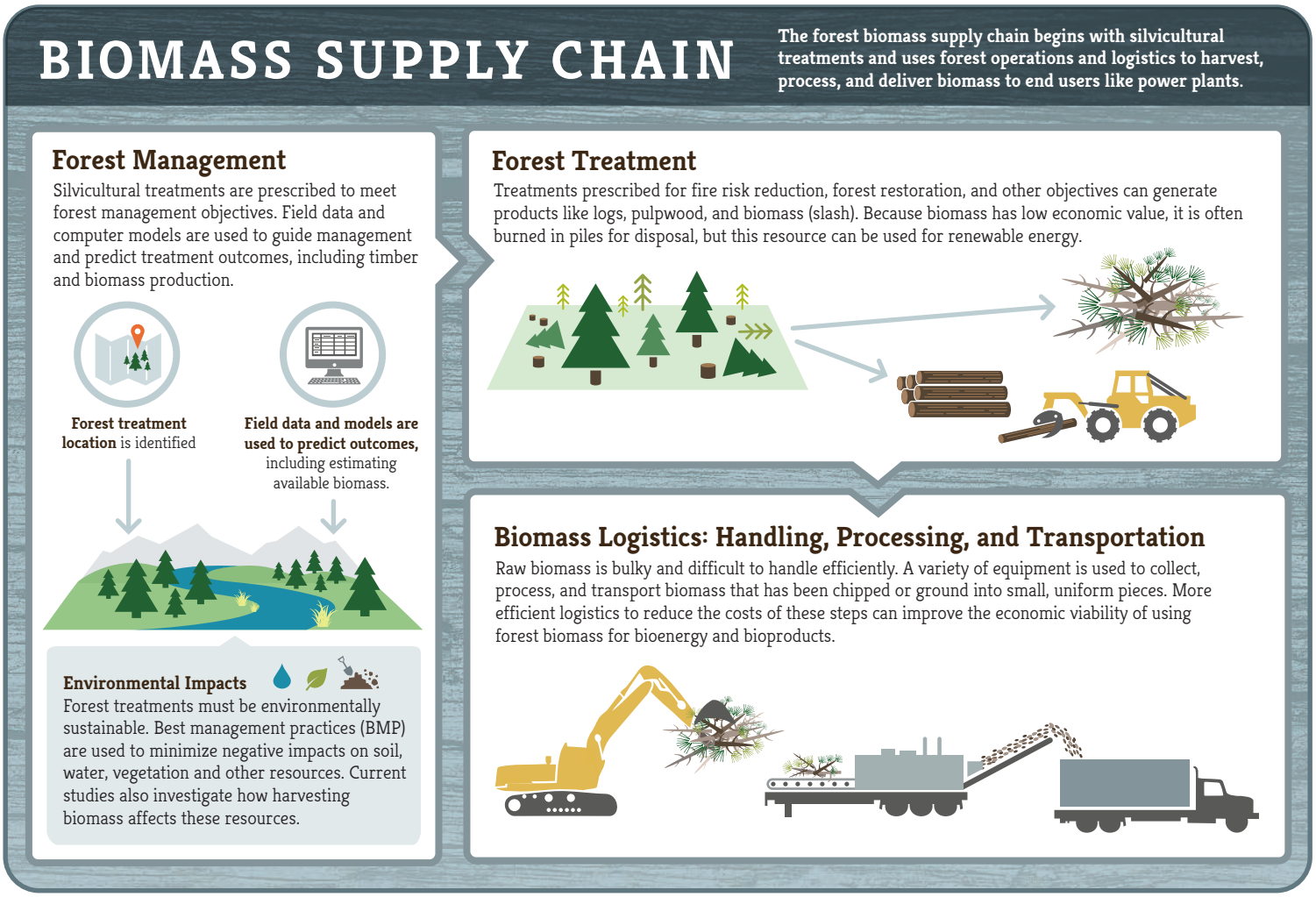
WHY WOODY BIOMASS ENERGY RESEARCH NOW?

Woody biomass energy has great promise in the western United States. It can contribute, directly or indirectly, to lowering our dependence on fossil fuels, increasing energy security, decreasinh forest insect and disease outbreaks, lowering our long-term carbon footprint, and helping to reduce severe wildfire hazards. Consequently, the use of woody biomass may address many significant land management challenges, including the prevalence of large severe wildfires and the disposal of forest residues. Despite these important drivers to develop woody biomass as an energy source, it is difficult for woody biomass energy to compete with coal and natural gas. With existing infrastructure heavily oriented toward exploiting abundant supplies of coal and natural gas, the cost of production of these energy sources is low compared to woody biomass.

To overcome this fact and capture emission reduction benefits from bioenergy, many European countries support power plants through the use of feed-in tariffs (FITs) on woody biomass, which set a guaranteed price for electricity generated from a range of renewable technologies for a guaranteed period. This creates financial incentives for biomass power that are strong enough to move wood chips and pellets across the ocean from the US to Europe. Though FITs are not commonly used in the US, many states have adopted renewable energy portfolio standards requiring a certain percentage of power production from renewable sources. These standards help build a market for renewable energy from sources such as wind, biomass, and solar. Biomass has an advantage over solar and wind power because it can produce power on a consistent basis regardless of the weather, using stockpiled biomass fuel. According to Nate Anderson, research forester and RMRS BRDI project director.

"These energy sources are complementary to the current energy use in the US, and biomass can serve effectively as a renewable base load for a diversified grid," Anderson states.

In the US, where policy instruments to support bioenergy are less common than in Europe, research and development is needed to improve the economic feasibility of using biomass for heat and power, and potentially for liquid fuels as new conversion technologies become commercialized. Anderson explains that biomass research is concentrated in the "gray zone", where biomass use is not yet economically feasible, but could



be possible with new technologies and innovations that match biomass facilities with efficient, environmentally-sustainable biomass supply chains. As a result, portions of this research focus on further developing a steady and economically viable woody biomass supply, or feedstock, with the intended effect of lowering its associated costs.

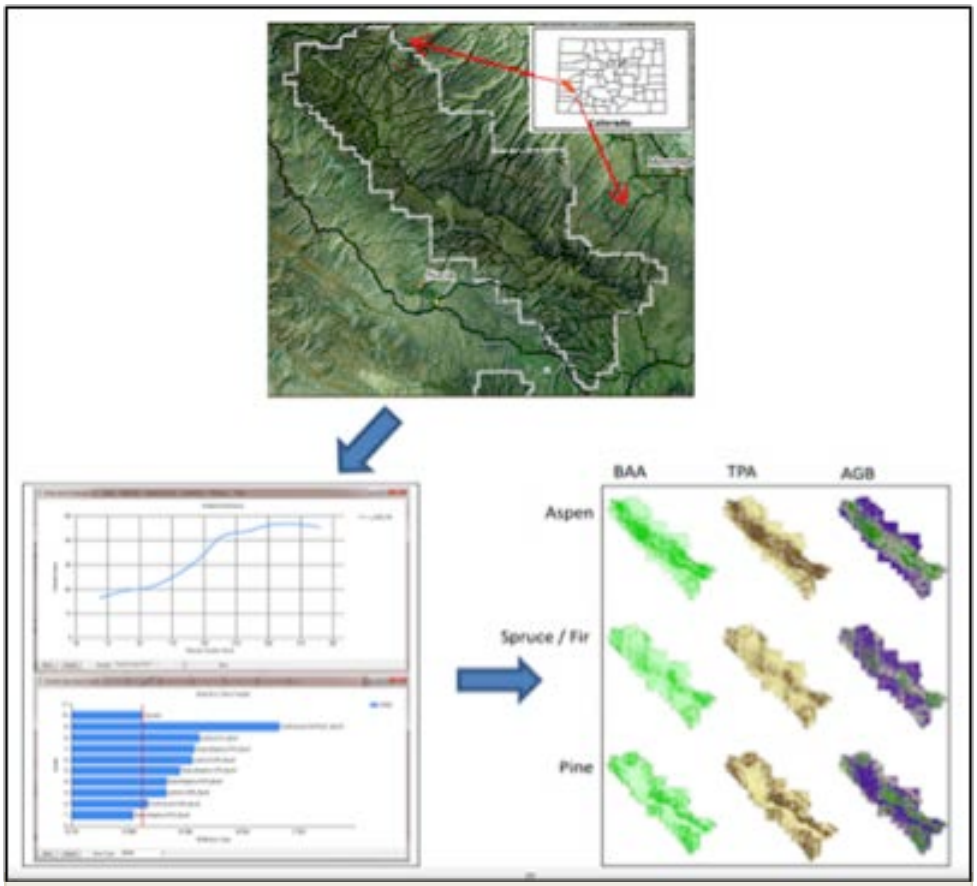
GAUGING THE FEEDSTOCK SUPPLY

When biomass is used as an industrial fuel or raw material, it is often referred to as "feedstock". An important part of developing a forest biomass feedstock supply is to estimate how much biomass is on the landscape and how much is likely available under particular management objectives and market conditions. From an economic standpoint, estimates of feedstock are necessary to address concerns of supply and demand and can be used to evaluate the sustainability of forest practices. Of particular interest to many is the amount of woody biomass needed to supply emerging biomass markets and the potential that the demand for woody biomass will lead to over-harvesting or other types of exploitation. Anderson explains that this is not likely to be the case under current social, economic, and political constraints: "The scale of industry that most people are thinking of deploying in the Rocky Mountains is well below the stocks of biomass on the landscape, and also well below the sustained yield that forests are capable of producing over the long term." In the USFS Northern Region, for example, the current levels of harvesting on national forests are around 10% of what they

"Matching the scale of the industry with the ability of the landscape to supply the material sustainably over the long term is what we will need to do," Anderson notes.

were at their peak in the late 1970s and 80s. "There is a lot of wiggle room to increase production and generate benefits, while simultaneously staying well below historic harvest levels and preventing environmentally damaging practices," he adds. In addition to reduced harvest levels, current management practices have far less impact on soil, water, remaining vegetation and wildlife than was the case in the last century.

As a part of the RMRS BRDI project, John Hogland, a biological scientist with RMRS, has developed new and innovative methods for managers to inexpensively and quickly estimate forest characteristics with a high level of accuracy and spatial detail. Important characteristics include basal area per acre, trees per acre, and bone dry tons of above ground biomass per acre split between tree stumps, boles, tops, and foliage. His approach uses statistical relationships derived from National Agricultural Imagery Program (NAIP) imagery and existing USFS Forest Inventory and Analysis (FIA) program data to produce spatially explicit, high resolution maps of these characteristics by species across relatively large landscapes (e.g., a National Forest). Hogland explains, "You can go into any given forest and, given readily available data, apply these methods to estimate characteristics of that forest. From these estimates, managers can then simulate multiple forest prescriptions and quantify the impacts of those prescriptions in a precise, spatial manner." To facilitate these new and innovative methods the RMRS Raster Utility has been developed to efficiently process and analyze large spatial datasets. Packaged as a suite of easy to use tools, managers can address a wide variety of natural resource related questions with the click of a button. Although these tools are useful for estimation and planning, Hogland cautions, "This is by no means a substitute for getting boots on the ground—field data collection and remote sensing work should happen in tandem."



An example of the tools and workflow used within ArcGIS to create raster surfaces depicting Aspen, Spruce/Fir, and Pine forest community characteristics (BAA, TPA, and AGB). In this example FIA plot locations are used to extract and relate textural values of NAIP derivatives to forest characteristics measured within each plot. From those relationships, raster surfaces are created depicting forest community BAA, TPA, and AGB at a spatial resolution of 1 m2 (Image credit: John Hogland).

IMPROVING THE EFFICIENCY OF THE SUPPLY CHAIN

Woody biomass left behind after forest treatments is typically burned or piled and left to decompose to prepare the site for regeneration and to reduce fire hazard. With current technology and markets, this approach is often more economically feasible than removing the material for other uses, like fueling a power plant. To make bioenergy from forest biomass more feasible, the efficiency of logistics, from harvesting to transportation, must be increased to the break-even point or better, covering the added costs of utilization with added revenues.

Han-Sup Han, professor of forest operations and engineering at Humboldt State University, explains that the main barrier to achieving this level of efficiency is the large, expensive equipment used to handle this low-value material. For example, a brand-new grinder to produce the woody biomass feedstock costs $650,000, while a loader, another

important piece of equipment to process the forest residues into woody biomass energy feedstock, runs upwards of $450,000. These costs are difficult for businesses to bear when working with low-value materials, and require efficient, high-production operations.

Compounding this challenge is the fact that biomass is not concentrated in one central location, but scattered over the treated area, usually a large and often rugged landscape. When an expensive machine must travel frequently to collect biomass, costly time and fuel are used unproductively, increasing the cost of forest operations and logistics. As Han put it, "It is very difficult to make any money doing this. There are few strategies in place to handle these materials cost-effectively.

One way to decrease handing costs is through improved equipment selection and design. As part of the BRDI project, Han and his research team have been studying the efficiency of innovative modifications to equipment and operations made by forest contractors. For example, a contractor added skidder tires, tires that are more capable of riding over rough terrain than a standard tire, to a large dump truck, and also increased the capacity of the truck by 50% by adding additional side walls allowing it to hold forest residues. "You can move more volume quickly on rough terrain with those modified dump trucks than with a standard truck," remarks Joel Bisson, who works on Han's team.

Efficiency dictates that the feedstock be moved quickly to a biomass facility, which can be difficult given most treatments are in remote locations accessed by forest roads. Long transportation distances at slow speeds on seasonally accessible forest roads translate to high transportation costs. The contractor working with Han and his team has started to employ an all-wheel-drive tractor to expedite moving the wood chips out of the forest. This tractor is used to pull trailers of wood chips down the rough forest roads from the remote grinding site to a high standard forest road accessible to a conventional highway tractor-trailer. From this point, they can be quickly hauled to an energy facility. This configuration minimizes expensive delays in moving material from the grinding site to the highway and extends the operation range of biomass harvesting operations.

A modified dump truck equipped with higher sides (to allow it to transport forest residue) and skidder tires (for improved forest accessibility). (Image credit: Joel Bisson)

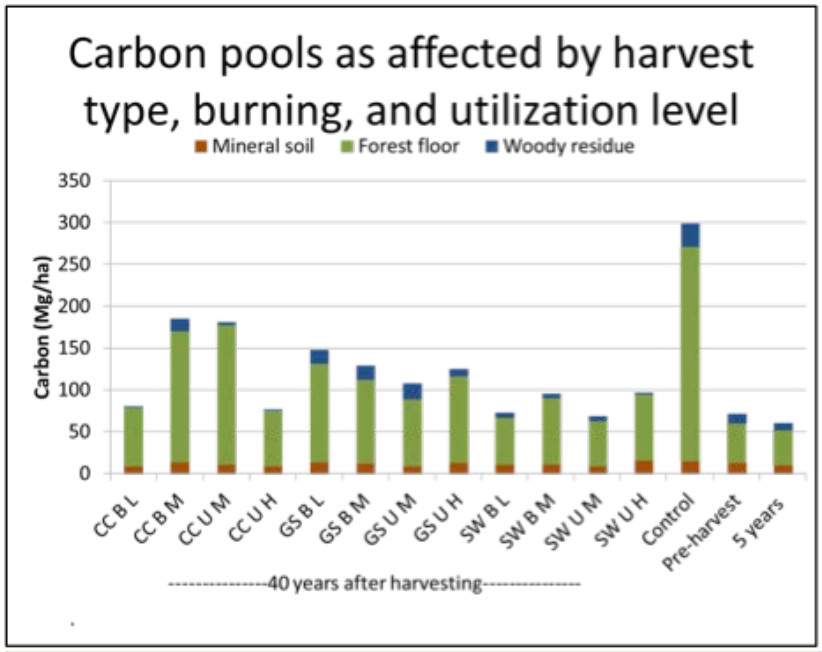
"A major effort of our study is to improve how we efficiently handle biomass in the field," notes Han.

A major objective of conducting this type of research is to provide information that will both improve the efficiency of operations with new configurations of existing equipment, and also encourage the design and development of new, more efficient equipment to meet emerging needs. For example, many new conversion technologies require drier, cleaner, smaller and more consistent biomass feedstocks than have been traditionally produced by forest management operations. This will require an evolution in logistics and technology to provide quality biomass feedstocks at the lowest cost possible.

ECOLOGICAL IMPACTS OF BIOMASS HARVESTING ON ROCKY MOUNTAIN FORESTS

Forest and soil productivity

Most biomass harvesting removes twigs and foliage, which can contain roughly 75% of the total tree nutrients. Consequently, the main ecological concern with biomass harvesting is the long-term reduction of forest growth and productivity due to the removal of these nutrients. Fortunately, we have a unique opportunity to assess how these harvests impact forest soils and ecology.



Forty years after biomass harvesting, most utilization treatments are at or above the pre-harvest levels for carbon (C) in the mineral soil and forest floor. Downed wood C has not returned to pre-harvest levels in the high utilization shelterwood and clearcut plots. In the group selection downed wood C is due to recruitment from dead trees near the plots. CC=clearcut; GS=group selection; SW=shelterwood. B=burning; U=Unburned. L=low utilization (to a 17.8 cm diameter top); M=medium utilization (to 7.6 cm diameter top) and H=high utilization (to a 2.5 cm diameter top).

Soil sample from the Coram Experimental Forest, which is located on the Flathead National Forest in northwest Montana. (Image credit: Debbie Page-Dumroese)

During the oil crisis of the 1970s, President Carter set forth policies that catalyzed the bioenergy industry, including woody biomass utilization. In 1974 an experiment was established at the RMRS Coram Experimental Forest in Northwest Montana to evaluate the ecological effects of intensive biomass harvesting, presenting a unique opportunity today to collect long-term data to provide information on ecological impacts of biomass harvests on forest productivity. These plots have been comprehensively resampled by RMRS research soil scientist Debbie Page-Dumroese and research professor of silviculture Chris Keyes as a part of the RMRS BRDI project. According to Page-Dumroese, "The 1974 plots were documented well enough that we could go back, find the original plots, and look at how different levels of biomass removal alter below- and above-ground forest productivity."

The experimental design at Coram Experimental Forest included four levels of biomass utilization up to removal of most of the biomass except for small tops followed by broadcast-burning treatments. Although the analysis for this study is ongoing, preliminary results suggest that past treatments may influence today's forest composition. Keyes reports, "For study plots corresponding with lower utilization treatments followed by fire, there are more early-seral species like western larch and Douglas-fir, and in the treatments where more biomass was removed but the area was not burned, similar to modern biomass harvesting techniques, we found more later seral species like subalpine fir and Engelmann spruce." The researchers have not yet observed any differences in forest productivity between the treatments, suggesting that a single rotation of biomass harvesting does not have a measurable negative impact on forest productivity.

Page-Dumroese has studied long-term soil productivity across many different sites, including those in Coram. She reports, "There's never really been a solid link between biomass harvesting and soil nutrient depletion on a site." One factor that may ameliorate the effect of more intensive biomass removal on both forest and soil productivity is that the proportion of nutrients within trees is very small compared to the pool of nutrients that exists in the soil. In other words, since far more nutrients are found in soils when compared to trees on these sites, removing most of the biomass has little bearing on nutrient levels in the soil. However, she points out, "We don't really understand how multiple rotations of biomass harvesting would affect productivity because we haven't looked at that long of a time-scale."

"There's never really been a solid link between biomass harvesting and soil nutrient depletion on a site," notes Page-Dumroese. Yet "[w]e don't really understand how multiple rotations of biomass harvesting would affect productivity because we haven't looked at that long of a time-scale."

Harvest intensity aside, Page-Dumroese and Keyes stress there are tradeoffs associated with the soil disturbance that can occur during forest operations, whether traditional silvicultural treatments or biomass harvests. Retaining an intact forest floor is vital to maintaining the nutrient cycling and moisture retention functions of productive forest soils. On the other hand, mineral soil exposure is critical to regenerating early-seral species, including western larch. In the northern Rockies, western larch is fire-resistant and less susceptible to insect and disease outbreaks than other species, making the region's mixed conifer forests more resilient to a range of disturbances. "In moist, cool temperate forest ecosystems such as those at Coram, designing biomass harvest systems that strike a balance between these two important objectives—protecting productive soils while restoring a rich diversity of species—will be key to their long-term sustainability" says Keyes.

Watersheds and soil erosion

Another important impact of biomass harvesting is the effects on surface water runoff and associated soil erosion after harvest. Compared to saw log harvests, harvesting forest biomass may result in increased disturbance to the forest floor and more bare soil exposure. When harvesting biomass, small diameter trees and crowns may be chipped and removed from the site rather than left as slash material to contribute to forest ground cover. In watersheds, ground cover plays three important roles: 1) by blocking raindrops from hitting the soil directly, ground cover helps prevent "surface sealing", thereby reducing runoff and enabling more rainfall infiltration; 2) ground cover decreases erosion due to raindrop impact on the soil; and 3) decreased runoff combined with increased surface cover will decrease concentrated flow erosion. In addition to impacting cover, biomass removal operations may cause soil compaction, leading to a decrease in soil infiltration rates and an increase in runoff and erosion.

The RMRS BRDI project initiated field studies to better understand the impacts of biomass harvest on ground cover. Following biomass harvest, soil movement by water erosion using silt fences and soil hydraulic conductivity were measured in field sites located in the Boise, Colville, and Kalispell National Forests in Idaho, Washington and Montana, respectively.

Silt fences installed on two skidder trails to measure soil erosion in the Payette National Forest, Idaho.

The study is ongoing, but some preliminary results indicate there was no difference in ground cover between treated and untreated sites over time. For example, on the Montana site, the ground cover dropped to 75 percent in the year following biomass harvest, but recovered to more than 95 percent, similar to the adjacent untreated area, the second year after biomass removal. There are unlikely to be any differences in soil hydraulic conductivity due biomass removal. Only the Idaho site showed any soil movement on access trails, which was aggravated by deer and elk-related soil disturbance. The greatest measured erosion rate was 40 kg/ha on the Idaho site the year following the harvest, which is considered relatively low.

To integrate new field data with management tools, the BRDI project is developing an online erosion prediction interface based on measured soil erodability values. This is intended to be used by forest managers to evaluate erosion risks.

THE WAY FORWARD WITH BIOMASS UTILIZATION IN THE ROCKIES

This issue of the Bulletin focused on both the biomass supply side of forest-based bioenergy and on some of its environmental impacts, which are all portions of the current RMRS BRDI project. A subsequent issue in early 2015 will detail three other important components of the project: woody biomass conversion technology, local economic impacts of bioenergy, and social perceptions of woody biomass energy in the Rocky Mountains, so please stay tuned!

MANAGEMENT IMPLICATIONS:

- New logistics and equipment technologies are being developed to improve woody biomass supply chains by reducing costs and increasing productivity.
- Removal of woody biomass after a single treatment is not likely to negatively impact forest productivity.
- Novel techniques for biomass assessment and planning have been developed to accurately estimate forest characteristics such as species basal area, trees per acre, and aboveground biomass per acre at fine spatial resolutions and across large landscapes.
- Best management practices (BMP) should always be used during forest treatments to minimize on and off site impacts.

FURTHER READING

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BILL ELLIOT is a research engineer in the Rocky Mountain Research Station. He has BS and PhD degrees in Agricultural Engineering from Iowa State University, and an MSc from the University of Aberdeen, Scotland. For more than 20 years, Bill's research has focused on forest soil erosion processes and prediction.

DEB PAGE-DUMROESE is a research soil scientist with the Rocky Mountain Research Station. Deb has a PhD in forest soils from the University of Idaho. Her research efforts relate to soil productivity during harvest operations.

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JOHN HOGLAND is a biological scientist working for the Rocky Mountain Research Station. His research interests revolve around quantitative methods within geographic information systems (GIS) and understanding the relationships between landscape patterns and forested ecosystems processes.

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