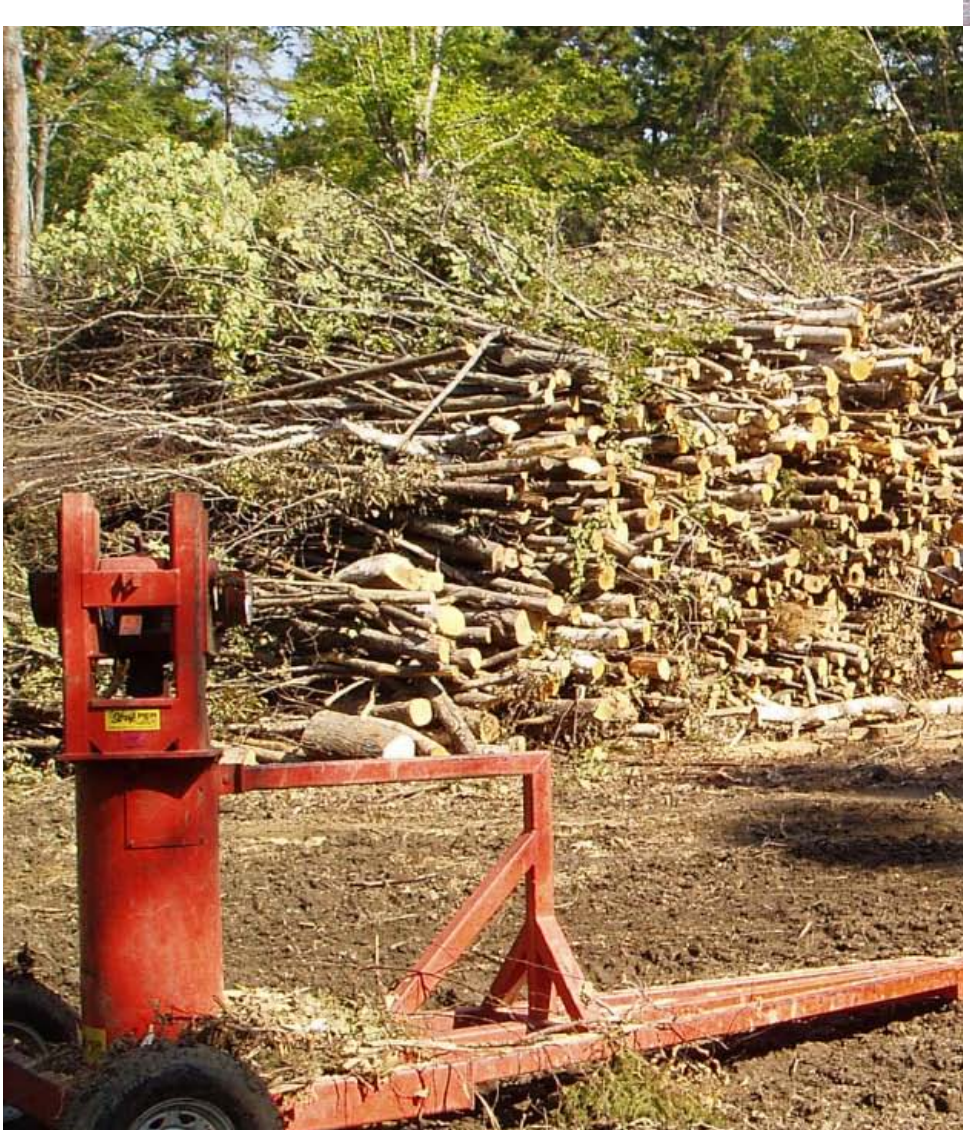
An Assesment of Biomass Harvesting Guidelines

by Alexander M. Evans and Robert T. Perschel



forest GUILD

January 2009

Cover photo credits: chipwood pile by Jeff Smith, feller-buncher by Zander Evans.

Funding for this report was provided by the Merck Family Fund and French Foundation.

The Forest Guild practices and promotes ecologically, economically, and socially responsible forestry—"excellent forestry"—as a means of sustaining the integrity of forest ecosystems and the human communities dependent upon them.

Forest Guild PO Box 519 Santa Fe, NM 87504 505-983-8992 www.forestguild.org

Table of Contents

1. Executive Summary

States from Maine to Missouri are developing guidelines for harvesting woody biomass from forests. Many in the forestry community are unfamiliar with the issues driving biomass guideline development and the changing landscape of state recommendations. This report compares the existing guidelines and provides recommendations for the development of future guidelines.

Woody biomass is usually considered logging slash, small-diameter trees, tops, limbs, or trees that cannot be sold as higher-value products. Forest managers harvest biomass to generate income as well as for ecological restoration, fire-risk reduction, forest-stand improvement, and habitat improvement. Interest in extracting woody biomass for energy has increased because of rising fossil fuel costs, concerns about carbon emissions from fossil fuels, and risks from catastrophic wildfires. Previously developed forest practice guidelines did not anticipate the increased removal of biomass and offer no specific guidance on the amount of removal that is safe.

Recently developed biomass harvesting guidelines cover topics such as dead wood, wildlife and biodiversity, water quality and riparian zones, soil productivity, silviculture, and disturbance. Appendix I is a table of the subtopics covered by each set of guidelines. While there are differences in the subtopics each set of state guidelines addresses, they generally appear to provide sufficient protections for a range of forest values. Future guidelines should consider each of the subtopics listed in Appendix I and use the best available science to determine the appropriate recommendations for the ecoregion(s) they cover. Additionally, guidelines should be built with as much public input and collaboration as possible. Collaboration builds trust in and support for the harvesting guidelines. Finally, clear and appropriate definitions of woody biomass and other terms are needed to provide a foundation for effective guidelines and recommendations.

In general, wood that would have been left on-site under traditional harvest conditions is removed in a biomass harvest, which can mean a reduction of dead wood. This reduction of dead wood is one of the key differences between biomass removal and traditional harvest; it should be a focus of future guidelines. Guidelines should make clear and specific recommendations to retain standing dead trees (snags), existing coarse woody material (CWM), harvest generated CWM, fine woody material (FWM), and the forest floor and litter layer. The creation of new guidelines for forestry presents the opportunity to encourage practices that go beyond minimum requirements and enhance the full suite of ecological values.

Key Recommendations:

- Consider each of the subtopics listed in Appendix I when developing new guidelines.
- Use the best available science to determine the appropriate biomass harvesting recommendations for the ecoregion(s) covered by the guidelines.
- Include as much public input and collaboration as possible in guideline development.
- Define terms such “woody biomass” clearly and appropriately.
- Make clear and specific recommendations to retain standing dead trees, existing CWM, harvest generated CWM, FWM, and the forest floor and litter layer.

2. Introduction

Interest in removing low-grade wood from forests has increased because of rising fossil fuel costs, concerns about carbon emissions from fossil fuels, and the risk of catastrophic wildfires. For example, there were at least 65 major new wood-to-energy projects in 2008, with many more in the planning stages (RISI Inc. 2008). Most existing forest practice rules and recommendations did not anticipate this increased extraction of woody biomass and offer no specific guidance on how much removal is healthy for ecosystems. This report reviews a new set of guidelines developed to address increased use of woody biomass from forests. The following sections explore definitions of woody biomass and the motivations for establishing guidelines for the harvest of woody biomass. The report assesses existing guidelines and provides recommendations for future forestry guidelines focused on woody biomass removal.

2a. Woody Biomass

While definitions of biomass are usually similar, there can be surprising differences. For instance, the definition of biomass in New Brunswick, Canada's guidelines excludes pulpwood fiber from whole-tree chipping. Technically, the term woody biomass includes all the trees and woody plants in forests, woodlands, or rangelands. This biomass includes limbs, tops, needles, leaves, and other woody parts (Norton et al. 2003). In practice, woody biomass usually refers to material that has historically had a low value and cannot be sold as timber or pulp. Biomass harvesting might even remove dead trees, down logs, brush and stumps (MFRC 2007). Markets determine which trees are considered sawtimber material and which are relegated to the low-value biomass category. As markets change over time and from region to region, different kinds of material are considered biomass, but in general it is a very low-value product. In some cases, woody biomass is defined by how the material is used. For example, in Pennsylvania any material burned for energy is defined as biomass (PA DCNR 2008). Maine uses three working definitions to distinguish biomass, energy wood, and energy fiber (MFS et al. 2008).

In this report, the term **woody biomass** refers to *vegetation removed from the forest, usually logging slash, small-diameter trees, tops, limbs, or trees that cannot be sold as higher-value products such as sawtimber.* This report does not discuss biomass from agricultural lands and short-rotation woody biomass plantations.

Photo: Zander Evans

Biomass can be removed in a number of ways. Some harvests remove only woody biomass, some combine the harvest of sawtimber or other products with biomass removal, and some remove biomass after other products have been removed. This report focuses on what remains in the forest after harvest and not on the type of harvest. The goal is to ensure the forest can support wildlife, provide clean water, sequester carbon, protect forest soil productivity, and continue to produce income after a biomass harvest. In some regions, current wood utilization is such that no woody material is available for new markets such as energy. For these high-utilization areas, following biomass guidelines may result in more woody biomass being left in the forest.

2b. Coarse Woody Material

Coarse woody material (CWM; also called coarse woody debris or down woody material) is any piece of dead wood including logs, limbs, and large root masses on the ground or in streams. Woody debris is sometimes divided into CWM that is more than 6 inches in diameter at the large end and fine woody material (FWM) that is less than 6 inches in diameter at the large end (MFRC 2007). The U.S. Forest Service defines CWM as down dead wood with a small-end diameter of at least 3 inches and a length of at least 3 feet and FWM as having a diameter of less than 3 inches (Woodall and Monleon 2008).

Photo: Zander Evans

2c. Why "Biomass" Guidelines?

> Good biomass harvesting practices can enhance and improve forest land; poor practices can damage and devalue it. (PA DCNR 2008, p. 30)

In the United States, forestry on private and state forests is regulated primarily at the state level. At least 276 state agencies across the country have some oversight of forestry activities, including agencies focused on forestry and other state agencies, such as wildlife or environment protection (Ellefson et al. 2006). With so much existing regulation, why are additional biomass harvesting guidelines necessary? Reasons for biomass harvesting guidelines are likely to mirror the reasons forestry is regulated in general, which include (Ellefson and Cheng 1994):

- general public anxiety over environmental protection,
- the obligation to correct misapplied forestry practices,
- the need for greater accountability,
- growth of local ordinances,
- landscape-level concerns, and
- following the lead of others.

More specifically, biomass harvesting guidelines are designed to fill the gaps where existing Best Management Practices (BMPs) may not be sufficient to protect forest resources under new biomass harvesting regimes. In other words, BMPs were developed to address forest management issues at a particular point in time; as new issues emerge, new guidelines may be necessary. Existing guidelines did not anticipate the increased rate or new methods of biomass

removal and offer no specific guidance on the amount of extraction that is acceptable for meeting a range of forest management objectives. For example, Pennsylvania's old BMPs encouraged operators "to use as much of the harvested wood as possible to minimize debris," while the new guidelines recommend leaving "15 to 30 percent of harvestable biomass as coarse woody debris." Concerns about long-term site productivity, biodiversity, and wildlife populations drove the Minnesota state legislature to call for biomass harvesting guidelines, and the resulting guidelines are intended to be implemented in close conjunction with the existing Minnesota forestry guidelines, which cover a range of additional management considerations. More generally, biomass guidelines focus CWM levels, wildlife and biodiversity, water quality and riparian zones, soil productivity, silviculture, and, in some cases, other issues. For example, Maine's guidelines focus "on the amount of biomass that should be left on site after harvest and the effect on soil productivity, water quality, and biodiversity." The following sections describe both the development and content of five different guidelines that influence biomass harvests.

3. An Examination of Current Guidelines

This report reviews the biomass harvesting guidelines or standards that cover biomass removals currently available from Maine, Minnesota, Missouri, Pennsylvania, Wisconsin, parts of Canada, and the Forest Stewardship Council (FSC). Other state forest practice laws cover woody biomass removals insomuch as they are a type of forest management, but are not specific to biomass removals. The guidelines from Maine, Missouri, and Wisconsin, and FSC are still under review at the time of this writing and subject to change. Readers are encouraged to use the links in Appendix II to check the latest drafts of the guidelines.

Entities interested in addressing concerns about biomass removal have taken at least three different approaches. One is to verify that existing forest practice regulations cover the issues raised by biomass harvests, obviating the need for new guidelines. In instances where existing rules or recommendations are found to be insufficient, some entities—including Minnesota, Missouri, Pennsylvania, Wisconsin, and Maine—have taken a second type of approach and chosen to craft separate biomass guidelines that augment existing forest practice guidance. In the third case, entities, such as the FSC, have chosen to address concerns particular to biomass harvests in a revision of existing rules or recommendations. The examples in this report detail the status of rules and recommendations for removing biomass from our forests.

The existing guidelines cover topics such as dead wood, wildlife and biodiversity, water quality and riparian zones, soil productivity, silviculture, and disturbance. Appendix I lists the commonly used subtopics for each and identifies which are covered in a given set of guidelines. In some cases, a subtopic is noted as covered because it appears in another set of forestry practice rules or recommendations instead of that state's biomass guidelines. The list of subtopics was developed from section headings of the existing guidelines.

3a. Biomass Retention Guidelines for Timber Harvesting in Maine

Maine's draft guidelines were released for review and comment in September 2008. The guidelines are the product of a collaborative effort between the Maine Forest Service, the University of Maine, and the Trust to Conserve Northeast Forestlands. The Natural Resources Conservation Service, the Maine Forest Service, and the University of Maine's Forest Bioproducts Research Initiative all contributed funding to support the development of these

guidelines. The small technical committee was made up of experts from the Maine Forest Service, academia, and the conservation community.

The Maine guidelines carefully define biomass as all organic material, but go on to identify "energy wood," woody material used in a bioenergy facility, and "energy fiber," a subcategory of energy wood that excludes wood suitable for sawtimber. Maine's guidelines, like many, have sections on soil productivity, water quality, and biodiversity, and also provides specific recommendations for biomass retention. The retention guidelines include new guidance specific to biomass removals as well as references to existing rules and regulations where appropriate. Though Maine's guidelines cover the topics of soil productivity, water quality, and biodiversity well, they provide no guidance on regeneration, aesthetics, or re-entry. The guidelines suggest using forest disturbances as a guide for silvicultural treatments (i.e., leaving biological legacies as natural disturbances do), but does not deal specifically with the interaction between insects, diseases, or fire and with biomass removals. Concerns about invasive species and conversion of forestland are also absent from the guidelines.

3b. Minnesota: Biomass Harvesting Guidelines for Forestlands


Photo: Eli Sagor

The Minnesota state legislature directed the Minnesota Forest Resources Council (MFRC) and the Minnesota Department of Natural Resources (DNR) to develop guidelines for sustainably managed woody biomass. The goal of the guidelines was to help natural resource managers, loggers, equipment operators, contractors, and landowners make decisions about biomass harvesting. With the support of DNR's Ecological Services, Fisheries and Wildlife, and Forestry divisions, the MFRC directed the guideline development process. A 12-member interdisciplinary technical committee developed separate guidelines for brushland as well as for forestland. The technical committee reflected a range of expertise deemed pertinent to the development of these guidelines, including soil science, wildlife biology, hydrology, forest management, and silviculture. Meeting summaries were provided online and the committee's work was peer-reviewed and open to public comment. Minnesota's biomass harvesting guidelines were crafted to be part of MFRC's 2005 forest management guidebook, *Sustaining Minnesota Forest Resources*, and the existing guidelines were integrated into the new biomass recommendations.

Minnesota's biomass harvesting guidelines are rooted in precepts of ecological forestry. For example, the guidelines recommend emulating natural disturbances with silviculture and maintaining biological legacies after harvest. The guidelines make the case that, in Minnesota, biomass harvesting increases the disparity between managed stands and their natural analogs because it reduces the biological legacies left after harvest, such as slash and fallen logs. The guidelines cover almost all of the topics and subtopics related to biomass harvesting we

considered in our analysis (see Appendix I). The only topics not obviously included or referenced were aesthetics, forest diseases, and land conversion.

A recent field test suggests that the harvesting practices utilized for biomass harvest in Minnesota can remove woody biomass without significant negative impacts on snags and CWM. The experimental biomass harvest had a small effect on the number of snags and on the amount of CWM. Reductions in CWM were small (2 tons per acre or less) and one site showed an increase in CWM (Arnosti et al. 2008). In addition, across the seven test sites where snags were measured, only three sites had a lower number of snags after harvest (Arnosti et al. 2008).

3c. Missouri: Best Management Practices for Harvesting Woody Biomass

Photo: Zander Evans

The catalyst for the development of biomass harvesting guidelines in Missouri was state legislation introduced in February 2007 concerning cellulosic ethanol. In response to the lack of BMPs for biomass harvests, the Top of the Ozarks RC&D, in partnership with Big Springs RC&D, Bootheel RC&D, the Eastern Ozarks Forestry Council, and the Missouri Department of Conservation, applied for and received a grant from the Northeastern Area State and Private Forestry branch of the U.S. Forest Service to develop BMPs for biomass harvesting. The BMPs development process continued to emphasize participation through a stakeholder meeting for a cross-section of interested parties to discuss issues and possible criteria to be addressed in the BMPs for harvesting woody biomass. A technical committee brought expertise on soil science, wildlife biology, hydrology, forest management, and silviculture to the process. Meeting announcements and notes were provided online to allow for transparency in the development of BMPs.

The Missouri guidelines cover the major biomass harvesting topics (see Appendix I). Subtopics not covered in the Missouri guidelines include regeneration, removal of litter and forest floor, and fuel reduction. A section on pesticides was included in an early version of the biomass guidelines, but was later dropped because of its lack of relevance to biomass.

3d. Pennsylvania: Guidance on Harvesting Woody Biomass for Energy

Pennsylvania's guidelines are a direct result of increased interest in woody biomass for energy. The passage of Pennsylvania's Alternative Energy Portfolio Standards Act (Act 213 of 2004) helped drive that interest by requiring "all load-serving energy companies in the state to provide 18 percent of their electricity using alternative sources by the year 2020." In response to the interest in using Pennsylvania's forest to help meet alternative energy goals, the Department of Conservation and Natural Resources (DCNR) created the biomass harvesting guidelines, intending to balance the need for alternative energy sources with the need to protect forest

resources for all citizens and future generations. Pennsylvania's guidelines include short-term rotational biofuel crops that might not traditionally fall under forest management guidelines.

The Pennsylvania guidelines direct harvests on state forests and provide advice for private landowners. The BMPs presented for private lands are drawn from *Best Management Practices for Pennsylvania's Forests*, which was published by the Forest Issues Working Group in 1997; however, the new biomass guidelines did not draw on wider stakeholder participation, in part because of the time pressure to produce guidelines before forest-based energy projects were initiated. Pennsylvania's guidelines are also unusual in that they are bundled with comments on biomass policy and a supply assessment. For example, the guidelines suggest that facilities requiring 2,000 tons per year are better suited to Pennsylvania than larger facilities. The guidelines also make a case for woody biomass as a carbon-neutral fuel source.

Since Pennsylvania's state forestlands are certified as meeting the standards of the Forest Stewardship Council (FSC), their biomass harvesting guidelines directly reference FSC standards. Pennsylvania's DCNR uses the FSC's Appalachia Regional Standard, but the state biomass harvesting guidelines provide greater specificity on woody biomass removals. For example, the FSC standard requires that "measures to protect streams from degradation of water quality and/or their associated aquatic habitat are used in all operations." The Pennsylvania biomass guidelines extend this idea by saying "biomass harvesting of any materials along stream and river banks or along bodies of water is unacceptable." The Pennsylvania biomass guidelines cover the range of potential biomass harvesting subtopics. Non-point source pollution and pesticides are not dealt with in the biomass harvesting guidelines, but these are covered in general forestry guidelines for Pennsylvania.

3e. Wisconsin's Forestland Woody Biomass Harvesting Guidelines

Wisconsin's biomass guideline development has been motivated by new price incentives to produce wood-based renewable energy and concerns about the environmental impacts of increased woody biomass removal. The Wisconsin Council on Forestry created an advisory committee with members from tribal, state, non-profit, and private forestry organizations. The draft guidelines will also be reviewed by subject experts.

Photo: Zander Evans

The current draft (August 2008) covers much of the same ground as the other state guidelines described in this report. These guidelines specifically do not address resource availability, economics, short-rotation woody biomass plantations, landscape planning and management, or monitoring of impacts. On other topics, the guidelines take advantage of the existing guidance provided by Wisconsin's *Silviculture and Forest Aesthetics Handbook* and *Forestry Best Management Practices for Water Quality.* Issues such as regeneration, water

quality, and aesthetics are dealt with in the existing manuals rather than the new biomass guidelines.

3f. Forest Stewardship Council: U.S. National Forest Management Standard

The FSC standards for the U.S. are currently under revision, and one of the elements under consideration is biomass harvesting. The 60-day public consultation period on the revised standard began November 17, 2008, and revised standards are anticipated to be released in the first quarter of 2009. As proposed, the FSC U.S. National Standard covers much of the same ground that other biomass guidelines do, although at a more general level since they are nationwide. The main sections that affect biomass harvest are the habitat (Indicators 6.3.c; 6.3.d), dead wood (6.3.i), and retention sections (6.3.j). For example, Indicator 6.3.i of the guidelines requires that "management in all stands maintains, enhances, or restores habitat components, and associated stand structures, including…live trees with decay or declining health, snags, and well-distributed coarse down and dead woody material." This proposed requirement would place some limits on biomass removal. Since FSC guidelines are not focused solely on biomass harvests, they go beyond other biomass guidelines in areas such as habitat connectivity. By the same token, because FSC guidelines cover many different types of harvest in many different forest types with diverse forest management objectives, the standards do not contain many guidelines that are specific to biomass harvest.

The FSC standards are considered to be outcome focused. For example, one element that shows up in some biomass guidelines is re-entry. Missouri's guidelines advise, "Do not re-enter a harvested area [for the purposes of biomass harvesting] once the new forest has begun to grow," which is a sentiment echoed in the Minnesota and Pennsylvania guidelines. The FSC standards, however, do not specifically advise against re-entering a stand for the purpose of biomass harvesting. Rather than prescribing how to achieve desired outcomes, they allow a variety of practices to be used, so long as the management objectives and the FSC standards are not compromised.

3g. Biomass Harvesting Guidelines and Policy in Canada

Photo: Zander Evans

As with state biomass guidelines in the U.S., woody biomass policy and guidelines in Canada are designed and implemented at the provincial level, not by the central government. Another similarity between the U.S. and Canada is the shift from a greater proportion of private holdings in the east to greater government (i.e., Crown) land ownership in the west. While provincial biomass guidelines would apply to public land and not private land, private landowners in eastern Canada are asking provincial governments for guidance on how best to manage their private land for bioenergy.

An overview of biomass policy and guidelines from east to west in Canada reveals variation similar to that in the United States (Ralevic et al. 2008). Nova Scotia has formed a multi-stakeholder biomass committee of government, industry, and environmental groups that is discussing guidelines. There is currently a two-year moratorium on harvesting logging residue there to allow for input from this committee and then the creation of a government policy. In New Brunswick, the Department of Natural Resources has prepared draft guidelines on forest biomass harvesting. New Brunswick's guidelines take advantage of a decision support tool for sustainable biomass allocation that evolved from a model used to predict impacts of atmospheric deposition. The guidelines exclude harvests on high-risk (low-nutrient) areas, and harvest and silviculture planning remain separate processes guided by the Crown land management framework. The policy calls for biomass harvesting sustainability to be assessed over an 80 year time period, which is "equivalent to the life span of an average forest stand" (New Brunswick DNR 2008). The New Brunswick guidelines define biomass such that the guidelines do not apply to pulpwood fiber from whole-tree chipping.

Like New Brunswick, Quebec is in the process of developing biomass guidelines based on soil properties. Ontario's draft policy establishes objectives such as "to improve the utilization of forest resources by encouraging the use of forest biofibre for the production of energy and other value-added bioproducts." However, the management and sustainable use of forest biomass is still guided by existing legislation (e.g., the Crown Forest Sustainability Act and its associated regulated manuals and procedures). In British Columbia, biomass removals during current forest practices (e.g., full-tree with processing at roadside) are already covered under the Forest and Range Practices Act. However, a strategic plan for increased biomass removals is being developed, and scientists have begun to collate data that will be used to formulate guidelines for increased slash harvesting.

A 2008 conference entitled "The Scientific Foundation for Sustainable Forest Biomass Harvesting Guidelines and Policies," hosted by Canada's Sustainable Forest Management Network, helped set the stage for future policy development by providing an overview of existing research on biodiversity (Mallory 2008), site productivity considerations for biomass harvests (Titus et al. 2008a), and existing knowledge gaps (Titus et al. 2008b).

4. Common Elements of Biomass Harvesting Guidelines

Though the existing biomass guidelines cover different ecosystems, they share a number of important elements. The following sections assess the similarities and differences between the guidelines' recommendations on dead wood, wildlife and biodiversity, water quality and riparian zones, soil productivity, and silviculture. In addition, we compare the process used to develop each set of guidelines.

4a. Dead Wood

One of the central concerns in biomass removals is the reduction of the quantity of dead wood on-site. Most biomass harvests focus on material such as tree tops, branches, or small trees that would be left on-site in timber harvests due to their low value. Dead wood (including CWM, FWM, and snags) plays an important role in the ecosystem, from wildlife habitat and nutrient cycling to carbon storage. CWM provides habitat for mammals, amphibians, reptiles, and beetles (Hunter 1990, Carey and Johnson 1995, Butts and McComb 2000, Gunnarsson et al. 2004, Patrick et al. 2006). Birds use snags to build nests, search for insects, and as hunting perches. Logs that fall in the water form a critical component of aquatic habitat by ponding water, aerating streams, and storing sediments (Gurnell et al. 1995). Dead logs serve as a seedbed for tree and plant species (McGee 2001). Slash can be beneficial to seedling regeneration after harvest (Grisez, McInnis and Roberts 1994). Fungi, mosses, and liverworts depend on dead wood for nutrients and moisture, and in turn many trees rely on mutualistic relationships with ectomycorrhizal fungi (Hagan and Grove 1999, Åström et al. 2005). Dead wood slowly releases nutrients back to the soil and the forest (Johnson and Curtis 2001, Mahendrappa et al. 2006). Nitrogen fixation in CWM is an important source of this limiting nutrient in both terrestrial and aquatic ecosystems (Harmon et al. 1986). Woody material on the ground decreases water runoff and erosion. About 6 percent of carbon stored in the forests is in dead wood, while about 11 percent is stored in forest floor litter (Environmental Protection Agency 2007). Whole-tree or bundling operations may also remove leaves or needles traditionally left in the woods. Such removals add to concerns about nutrient loss due to biomass harvesting.

A review of scientific data suggests that when both sensitive sites (in including low-nutrient) and clearcutting with whole- tree removal are avoided, then nutrient capital can be protected (see also Hacker 2005). However, there is no scientific consensus on this point, because of the range of treatments and experimental sites (Grigal 2000). It is important to emphasize that the impact on soil nutrients is site dependent. Low-nutrient sites are much more likely to be damaged by intensive biomass removal than site with great nutrient capital or more rapid nutrient inputs. A report on impacts of biomass harvesting from Massachusetts suggests that with partial removals (i.e., a combination of crown thinning and low thinning that removes all small trees for biomass and generates from 9 to 25 dry tons per acre) stocks of calcium, the nutrient of greatest concern, could be replenished in 71 years (Kelty et al. 2008). The Massachusetts study was based on previous research with similar results from Connecticut (Tritton et al. 1987, Hornbeck et al. 1990). Leaching, particularly of calcium due to acidic precipitation, can reduce the nutrients available to forests even without harvests (Pierce et al. 1993). A similar study of an aspen/mixed-hardwood forest showed that even with a clearcut system calcium stocks would be replenished in 54 years (Boyle et al. 1973). Minnesota's biomass guidelines present data that show soil nutrient capital to be replenished in less than 50 years even under a whole-tree harvesting scenario (Grigal 2004, MFRC 2007). Maine's guidelines point out that the risk of nutrient loss increases

as more biomass is removed from the forest, but in one test harvest nutrient concentrations rose back to pre-treatment levels within three years (Briggs et al. 2000, MFS et al. 2008). Whole-tree harvesting has not greatly reduced amounts of soil carbon or nitrogen in some studies (Hendrickson 1988, Huntington and Ryan 1990, Olsson et al. 1996, Nord-Larsen 2002). Lack of significant reduction in carbon and nitrogen may be due to soil mixing by harvesting equipment (Huntington and Ryan 1990). However, intensive cutting, such as clearcutting with whole-tree removal, can result in significant nutrient losses—in one case, 13 percent of calcium site capital (Tritton et al. 1987, Hendrickson 1988, Hornbeck et al. 1990, Martin et al. 2000).

Low-impact logging techniques that reduce soil disturbance can help protect nutrient capital (Hallett and Hornbeck 2000). Harvesting during the winter after leaf fall can reduce nutrient loss from 10 to 20 percent (Boyle et al. 1973, Hallett and Hornbeck 2000). Following a procedure might be difficult to implement in the U.S., Nordic countries have demonstrated that leaving cut trees on the ground in the harvest area until their needles have dropped (one growing season) can also reduce nutrient loss (Nord-Larsen 2002, Richardson et al. 2002). Where forest biomass is used for energy production, the return and distribution of wood ash from biomass combustion on harvest sites has been suggested as a way to counteract long-term nutrient depletion (Richardson et al. 2002).

General restrictions on the removal of CWM related to traditional conceptions of merchantability may not be sufficient in the context of biomass harvesting. Maine's guidelines recommend leaving all existing CWM and creating at least 3 logs per acre greater than 15 inches in diameter and one 21 inches in diameter if fewer exist. Maine's guidelines also recommend 20 percent of FWM be left distributed on-site. To ensure sufficient CWM debris is left on-site, Minnesota guidelines recommend leaving all preexisting CWM and to "retain and scatter tops and limbs from 20 percent of trees harvested." Wisconsin's guidelines recommend retaining all pre-harvest CWM and a minimum of 5 tons per acre of FWM (either pre- or post-harvest FWM) after even-aged regeneration treatments and at least 1 ton per acre after thinning or uneven-aged regeneration treatments. Wisconsin's guidelines also point out that "some forests lack woody debris because of past management," and that extra CWM and FWM should be left in those areas. Pennsylvania's guidelines suggest leaving 15 to 30 percent of "harvestable biomass" as CWM, while Missouri's suggest 33 percent of harvest residue (with variations for special locations such as stream sides). Maine, Minnesota, Pennsylvania, and Wisconsin suggest leaving all snags possible and Missouri recommends 6 snags per acre in upland forests and 12 in riparian corridors.

4b. Wildlife and Biodiversity

Many of the potential wildlife and biodiversity impacts stem from leaving too little dead wood on-site. The biomass guidelines reviewed here agree on the importance of avoiding sensitive sites for wildlife. These include areas of high biodiversity or high conservation value such as wetlands, caves, and breeding areas. Obviously, areas inhabited by threatened or endangered animals and plants receive special consideration. However, as the Minnesota guidelines point out, biomass harvesting may still be appropriate if management plans include specific strategies for maintaining habitat for rare species and/or to restore degraded ecosystems. Pennsylvania's guidelines suggest that biomass removal may be an opportunity to "develop missing special habitats, such as herbaceous openings for grouse and other species, through planting, cutting, or

other manipulations." Additional suggestions from state guidelines include inventorying habitat features on the property, promoting individual trees and species that provide mast, and retaining slash piles that show evidence of use by wildlife. Missouri's guidelines make the case against forest conversion on wildlife grounds: "Do not convert natural forests into tree plantations or pasture; natural forests provide more wildlife food and habitat."

4c. Water Quality and Riparian Zones

Photo: Zander Evans

In general, water quality and riparian concerns do not change with the addition of biomass removals to a harvest plan. Streams and wetlands tend to be protected by existing regulation. For example, Maine's guidelines cite the existing laws governing water quality protection as well as the publication *Protecting Maine's Water Quality*. Where restriction on harvesting in wetlands and riparian zones is based on basal area regulations, more specific guidance may be needed for biomass harvests, which can have large impact with small changes in basal areas. An example from Minnesota's guidelines of riparian recommendations is to "avoid harvest of additional biomass from within riparian management zones over and above the tops and limbs of trees normally removed in a roundwood harvest under existing timber harvesting guidelines." Though the *Missouri Watershed Protection Practice* already includes requirements for stream and river management zones, the Missouri biomass guidelines reiterate how to protect streams and rivers during a harvest.

4d. Soil Productivity

As with water quality, some aspects of soil productivity are usually included in standard forestry BMPs. For instance, Minnesota's biomass guidelines point readers to the state's timber harvesting guidelines which contain sections titled "Design Outcomes to Maintain Soil Productivity" and "Minimizing Rutting." However, Minnesota's biomass guidelines do add warnings about harvesting biomass on bog soils and shallow soils (less than 8 inches) over bedrock. Wisconsin's guidelines list 17 specific soil types which are nutrient poor and unlikely to be able to support sustainable biomass removal. Maine's guidelines use the Briggs classification of soil drainage classes to identify site classes that are more sensitive to biomass removals (Briggs 1994). Missouri's guidelines contain a specific section on sustaining soil productivity, especially on steep slopes and shallow soils. Another concern that arises with biomass harvest is removal of the litter layer or forest floor. Maine, Minnesota, Pennsylvania, and Wisconsin's guidelines state that forest floor, litter layer, and root systems should be left.

4e. Silviculture

Many silvicultural prescriptions call for the removal of small, unhealthy, or poorly formed trees to open up more growing space for crop trees or regeneration, but these types of removals often

cost money rather than generate income. By providing income from the removal of this material, biomass markets can help support good silviculture. At the same time, biomass removals raise some silvicultural concerns. The Minnesota guidelines point out that an increase in the amount of live vegetation removed may cause swamping, i.e., a decrease in transpiration and an increase in soil moisture. Swamping can kill seedlings and negatively impact regeneration. Removal of tree tops and branches may also remove seeds or cones, which may reduce the amount of natural regeneration. Biomass removals can help deal with forest insect problems, but removing the biomass material from the site must be timed to avoid contributing to pest problems such as bark beetles.

Some states have used biomass guidelines to make silvicultural recommendations that may improve stands but are not directly related to biomass harvesting. The Missouri biomass guidelines provide silvicultural suggestions for the number of crop trees per acre for stands in different stages of development. Pennsylvania's guidelines suggest that forest stewards "provide for regeneration each time harvests are made under the uneven-aged system," focus on the residual stand more than the trees being removed, and avoid high grading. Wisconsin's guidelines suggest retaining "reserve trees and patches at 5–15 percent crown cover or stand area" in even-aged regeneration cuts and three or more large-cavity trees, large mast trees, and trees that can become large trees in the future. Maine's guidelines have detailed recommendations on retention of cavity and mast trees as well as retention patches from 5 to 15 percent of the area in regeneration harvests.

Another operational recommendation that Minnesota, Missouri, and Pennsylvania all make is not to re-enter a stand to remove biomass. Re-entering a site where timber was recently harvested to remove biomass can increase site impacts such as soil compaction and harm post-harvest regeneration. For this reason, the Missouri guidelines advise that "woody biomass should be harvested at the same time as sawlog timber to avoid re-entry." The current version of Wisconsin's guidelines does not explicitly mention re-entry.

4f. Biomass Guideline Development

The process of developing guidelines can be as important as the specific recommendations. Most guidelines try to draw from the most recent forest science. Developing new biomass guidelines allows states to incorporate new research and ideas. Minnesota used funding from University of Minnesota Initiative for Renewable Energy and the Environment to conduct a review of the scientific literature on biomass harvests. Other guidelines borrow from existing guidelines. For example, Pennsylvania's guidelines borrow extensively from Minnesota's guidelines and summarize the FSC's standards for the region.

The amount of stakeholder participation varies across the guidelines. While Pennsylvania's guidelines were created from within the DCNR, Minnesota, Missouri and Wisconsin included public participation and a technical committee from the wider forestry community. Public participation can be unwieldy, but often generates greater public support for forestry projects (Evans and McKinley 2007).

Some of the biomass guidelines, such as those from New Brunswick, Canada, focus on the identification of geographies where biomass harvesting is most appropriate. Wisconsin takes a

complementary approach, identifying soil types where biomass removal is inappropriate. By mapping soil types, guidelines can highlight those areas where concerns about nutrient depletion are lowest. Suitability mapping also permits the consideration of the landscape-scale impacts of biomass harvesting. Pennsylvania's guidelines are notable because they consider the supply of biomass from forests as well as the appropriate scale of utilization. As mentioned previously, Pennsylvania's guidelines make a case for small-scale (less than 2,000 tons of biomass per year) biomass utilization facilities.

5. Recommendations

The following recommendations for the development of future biomass guidelines are based on the existing guidelines and available science and will change as more is learned about biomass removals:

- Develop guidelines that are based on sound science and include wide stakeholder engagement. As the Minnesota guidelines describe it, "provide the best scientific judgment, tempered by the consensus process among a broad group of forest management interests, related to practices that will sustain a high level of biodiversity."
- Define "woody biomass" and other important terms clearly. In some cases, the definition of biomass appears at odds with its usage. For instance, Maine carefully differentiates between "biomass" (i.e., all organic material) and "energy wood" (i.e., woody material used in a bioenergy facility).
- Base biomass harvesting recommendations on local ecology. They should recognize state or local natural communities, disturbance regimes, and other ecological traits. Technical committees and scientific literature provide a firm base for harvest recommendations.
- Consider developing guidelines for each of the subtopics listed in Appendix I—though not all subtopics will be appropriate for every location.
- Make clear and specific recommendations for the retention of standing dead trees, existing CWM, CWM generated by the harvest, FWM, and forest floor and litter layer. Because reduction of dead wood is one of the key differences between biomass removal and traditional harvest, it should be a focus of future guidelines. Nutrients removed from the site should be replenished. For even-aged systems, nutrients should be replenished to adequate levels by the end of the rotation. Uneven-aged systems should maintain nutrient levels close to the optimum. Nutrient levels may be temporarily reduced after each entry, but should return to adequate levels by the next cutting cycle.
- Make biomass guidelines practical and easy to follow. Where biomass guidelines supplement existing forestry rules and guidelines, the new guidelines should provide clear references to the relevant sections of the existing rules and guidelines both for convenience and to increase the likelihood of implementation.
- Take advantage of the opportunity to create new forestry recommendations that encourage excellent forestry: forestry that goes beyond minimum BMPs and enhances the full suite of ecological values. For example, biomass guidelines may be an opportunity to suggest alternatives to high grading and other practices that damage the long-term health of the forest. Similarly, biomass guidelines can present the chance to advocate for appropriately scaled biomass utilization, as Pennsylvania guidelines already do.

6. Acknowledgments

This report benefited from the comments of Don Arnosti, Amber Ellering, Kathryn Fernholz, Ehrhard Frost, Brad Hutnik, Ken Laustsen, Darcie Mahoney, Eunice Padley, Michael Palko, David Ray, Christopher Riely, Paul Trianosky, and Pieter van Loon.

Special thanks to Doug Enyart, Clearwater Forestry Consultants, LLC, for help with developing the section addressing the Missouri guidelines and to Brian Titus, Research Scientist, Natural Resources Canada, for his help with the Canadian section.

7. References

Arnosti, D., D. Abbas, D. Current, and M. Demchik. 2008. Harvesting Fuel: Cutting Costs and Reducing Forest Fire Hazards through Biomass Harvest. Institute for Agriculture and Trade Policy, Minneapolis, MN.

Åström, M., M. Dynesius, K. Hylander, and C. Nilsson. 2005. Effects of Slash Harvest on Bryophytes and Vascular Plants in Southern Boreal Forest Clear-Cuts. *Journal of Applied Ecology* 42(6):1194-1202.

Boyle, J. R., J. J. Phillips, and A. R. Ek. 1973. "Whole Tree" Harvesting: Nutrient Budget Evaluation. *Journal of Forestry* 71(12):760-762.

Briggs, R. D. 1994. Site Classification Field Guide. Maine Agricultural and Forest Experiment Station, Orono, ME.

Briggs, R. D., J. W. Hornbeck, C. T. Smith, R. C. Lemin, and M. L. McCormack. 2000. Long-Term Effects of Forest Management on Nutrient Cycling in Spruce-Fir Forests. *Forest Ecology and Management* 138(1-3):285-299.

Butts, S. R., and W. C. McComb. 2000. Associations of Forest-Floor Vertebrates with Coarse Woody Debris in Managed Forests of Western Oregon. *The Journal of Wildlife Management* 64(1):95-104.

Carey, A. B., and M. L. Johnson. 1995. Small Mammals in Managed, Naturally Young, and Old-Growth Forests. *Ecological Applications* 5(2):336-352.

Ellefson, P. V., and A. S. Cheng. 1994. State Forest Practice Programs: Regulation of Private Forestry Comes of Age. *Journal of Forestry* 92:34-37.

Ellefson, P. V., M. A. Kilgore, and J. E. Granskog. 2006. State Government Regulation of Forestry Practices Applied to Nonfederal Forests: Extent and Intensity of Agency Involvement. *Journal of Forestry* 104:401-406.

Environmental Protection Agency. 2007. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005. USEPA #430-R-07-002, Washington, DC.

Evans, A. M., and G. McKinley. 2007. An Evaluation of Fuel Reduction Projects and the Healthy Forests Initiative. Forest Guild, Santa Fe, NM.

Grigal, D. F. 2000. Effects of Extensive Forest Management on Soil Productivity. *Forest Ecology and Management* 138(1-3):167-185.

Grigal, D. F. 2004. An Update of Forest Soils. A Technical Paper for a Generic Environmental Impact Statement on Timber Harvesting and Forest Management in Minnesota. Laurentian Energy Agency, Virginia, MN.

Grisez, T. J. 1960. Slash Helps Protect Seedlings from Deer Browsing. *Journal of Forestry* 58(5):385-387.

Gunnarsson, B., K. Nittérus, and P. Wirdenäs. 2004. Effects of Logging Residue Removal on Ground-Active Beetles in Temperate Forests. *Forest Ecology and Management* 201(2-3):229-239.

Gurnell, A. M., K. J. Gregory, and G. E. Petts. 1995. The Role of Coarse Woody Debris in Forest Aquatic Habitats: Implications for Management. *Aquatic Conservation: Marine and Freshwater Ecosystems* 5(2):143-166.

Hacker, J. J. 2005. Effects of Logging Residue Removal on Forest Sites: A Literature Review. Resource Analytics and West Central Wisconsin Regional Planning Commission, Eau Claire, WI.

Hagan, J. M., and S. L. Grove. 1999. Coarse Woody Debris: Humans and Nature Competing for Trees. *Journal of Forestry* 97(1):6-11.

Hallett, R. A., and J. W. Hornbeck. 2000. Managing Oak and Pine Stands on Outwash Sands: Protecting Plant Nutrients. *Northern Journal of Applied Forestry* 17(2):57-61.

Harmon, M., J. Franklin, F. Swanson, P. Sollins, S. Gregory, J. Lattin, N. Anderson, S. Cline, N. Aumen, J. Sedell, G. Lienkaemper, K. Cromack Jr., and K. Cummins. 1986. Ecology of Coarse Woody Debris in Temperate Ecosystems. Pages 133-302 *in* A. MacFadyen and E. D. Ford, editors. *Advances in Ecological Research*. Academic Press, London, UK.

Hendrickson, O. Q. 1988. Biomass and Nutrients in Regenerating Woody Vegetation Following Whole-Tree and Conventional Harvest in a Northern Mixed Forest. *Canadian Journal of Forestry Research* 18(11):1427–1436.

Hornbeck, J. W., C. T. Smith, Q. W. Martin, L. M. Tritton, and R. S. Pierce. 1990. Effects of Intensive Harvesting on Nutrient Capitals of Three Forest Types in New England. *Forest Ecology and Management* 30(1-4):55-64.

Hunter, M. L. 1990. *Wildlife, Forests, and Forestry*. Prentice-Hall, Englewood Cliffs, NJ.

Huntington, T. G., and D. F. Ryan. 1990. Whole-Tree-Harvesting Effects on Soil Nitrogen and Carbon. *Forest Ecology and Management* 31(4):193-204.

Johnson, D. W., and P. S. Curtis. 2001. Effects of Forest Management on Soil C and N Storage: Meta Analysis. *Forest Ecology and Management* 140(2-3):227-238.

Kelty, M. J., A. W. D'Amato, and P. K. Barten. 2008. Silvicultural and Ecological Considerations of Forest Biomass Harvesting in Massachusetts. Department of Natural Resources Conservation, University of Massachusetts, Amherst, MA.

Mahendrappa, M. K., C. M. Pitt, D. G. O. Kingston, and T. Morehouse. 2006. Environmental Impacts of Harvesting White Spruce on Prince Edward Island. *Biomass and Bioenergy* 30(4):363-369.

Mallory, E. C. 2008. Collation of On-Going Canadian Research on Biomass Harvesting and Biodiversity. in *Proceedings of The Scientific Foundation for Sustainable Forest Biomass Harvsting Guidelines and Policies*. Sustainable Forest Management Network, Edmonton, AB.

Martin, C., J. Hornbeck, G. Likens, and D. Buso. 2000. Impacts of Intensive Harvesting on Hydrology and Nutrient Dynamics of Northern Hardwood Forests. *Canadian Journal of Fisheries and Aquatic Sciences* 57(S2):19-29.

McGee, G. G. 2001. Stand-Level Effects on the Role of Decaying Logs as Vascular Plant Habitat in Adirondack Northern Hardwood Forests. *The Journal of the Torrey Botanical Society* 128(4):370-380.

McInnis, B. G., and M. R. Roberts. 1994. The Effects of Full-Tree and Tree-Length Harvests on Natural Regeneration. *Northern Journal of Applied Forestry* 11(4):131-137.

MFRC. 2007. Biomass Harvest Guidelines. Minnesota Forest Resources Council, St. Paul, MN.
MFS, U of ME, and TCNF. 2008. Biomass Retention Guidelines for Timber Harvesting in Maine. Maine Forest Service, University of Maine, and the Trust to Conserve Northeast Forestlands, Orono, ME.
New Brunswick DNR. 2008. Forest Biomass Harvesting. New Brunswick Department of Natural Resources, Fredericton, New Brunswick.
Nord-Larsen, T. 2002. Stand and Site Productivity Response Following Whole-Tree Harvesting in Early Thinnings of Norway Spruce (Picea Abies (L.) Karst.). *Biomass and Bioenergy* 23(1):1-12.
Norton, G., S. Abraham, and A. Veneman. 2003. Memorandum of Understanding on Policy Principles for Woody Biomass Utilization for Restoration and Fuel Treatments on Forests, Woodlands, and Rangelands. U.S. Forest Service and Bureau of Land Management, Washington, DC.
Olsson, B. A., H. Staaf, H. Lundkvist, J. Bengtsson, and R. Kaj. 1996. Carbon and Nitrogen in Coniferous Forest Soils after Clear-Felling and Harvests of Different Intensity. *Forest Ecology and Management* 82(1-3):19-32.
PA DCNR. 2008. Guidance on Harvesting Woody Biomass for Energy. Pennsylvania Department of Conservation and Natural Resources, Harrisburg, PA.
Patrick, D. A., J. Hunter, Malcolm L., and A. J. K. Calhoun. 2006. Effects of Experimental Forestry Treatments on a Maine Amphibian Community. *Forest Ecology and Management* 234(1-3):323-332.
Pierce, R. S., J. W. Hornbeck, W. C. Martin, L. M. Tritton, T. C. Smith, A. C. Federer, and H. W. Yawney. 1993. Whole-Tree Clearcutting in New England: Manager's Guide to Impacts on Soils, Streams, and Regeneration. GTR-NE-172, Forest Service, Northeastern Forest Experiment Station, Radnor, PA.
Ralevic, P., J. Karau, T. Smith, and J. Richardson. 2008. IEA Bioenergy Task 31 Country Report: Canada. International Energy Agency, Ottawa, Canada.
Richardson, J., R. Björheden, P. Hakkila, A. T. Lowe, and C. T. Smith, editors. 2002. *Bioenergy from Sustainable Forestry: Guiding Principles and Practice*. Kluwer Academic Publishers, Hingham, MA.
RISI Inc. 2008. Emerging Biomass Industry: Impact on Wood Fiber Markets.
Titus, B. D., S. M. Berch, D. M. Morris, R. L. Fleming, P. W. Hazlett, D. Pare, and P. A. Arp. 2008a. Synopsis of on-Going Canadian Research on Biomass Harvesting and Site Productivity. in *Proceedings of The Scientific Foundation for Sustainable Forest Biomass Harvsting Guidelines and Policies*. Sustainable Forest Management Network, Edmonton, AB.
Titus, B. D., C. T. Smith, D. Puddister, J. R. Richardson, and C. Young. 2008b. Notes from Facilitated Discussions. in *Proceedings of The Scientific Foundation for Sustainable Forest Biomass Harvsting Guidelines and Policies*. Sustainable Forest Management Network, Edmonton, AB.
Tritton, L. M., C. W. Martin, J. W. Hornbeck, and R. S. Pierce. 1987. Biomass and Nutrient Removals from Commercial Thinning and Whole-Tree Clearcutting of Central Hardwoods. *Environmental Management* 11(5):659-666.
Woodall, C. W., and V. J. Monleon. 2008. Sampling Protocol, Estimation, and Analysis Procedures for the Down Woody Materials Indicator of the Fia Program. NRS-GTR-22, U.S. Forest Service, Newtown Square, PA.

8. Appendix I: Summary Table of Biomass Guidelines

	ME	MN	MO	PA	WI	FSC
Dead Wood						
Coarse woody material	√	√	√	√	√	√
Fine woody material	√	√	√	√	√	√
Snags	√	√	√	√	√	√
Wildlife and Biodiversity				√		
Wildlife	√	√	√	√	√	√
Sensitive wildlife species	√	√	√	√	√	√
Biodiversity	√	√	√	√	√	√
Plants of special concern	√	√	√	√	√	√
Sensitive areas	√	√	√	√	√	√
Water Quality and Riparian Zones						
Water quality	√	√	√	√	√	√
Riparian zones	√	√	√	√	√	√
Non-point source pollution	√	√	√	√	√	√
Erosion	√	√	√	√	√	√
Wetlands	√	√	√	√	√	√
Soil Productivity						
Chemical (Nutrients)	√	√	√	√	√	√
Physical (Compaction)	√	√	√	√	√	√
Biological (Removal of litter)	√	√		√	√	
Silviculture						
Planning	√	√	√	√		√
Regeneration		√		√	√	√
Residual stands	√	√	√	√	√	√
Aesthetics			√	√	√	√
Post operations	√	√	√	√	√	
Re-entry		√	√	√		
Roads and skid trail layout	√	√	√	√	√	√
Disturbance						
Insects		√	√	√	√	√
Disease			√	√	√	√
Fire		√	√	√		√
Fuel reduction		√		√		√
Pesticides		√		√		
Invasives		√	√	√		
Conversion from forest			√	√		√

9. Appendix II: Links to Biomass Harvesting Guidelines

- Minnesota: Biomass Harvesting Guidelines for Forestlands
  http://www.frc.state.mn.us/FMgdline/BHGC.html

- Missouri: Best Management Practices for Harvesting Woody Biomass
  http://mdc4.mdc.mo.gov/applications/MDCLibrary/MDCLibrary2.aspx?NodeID=2055

- Pennsylvania: Guidance on Harvesting Woody Biomass for Energy
  http://www.dcnr.state.pa.us/PA_Biomass_guidance_final.pdf

- Wisconsin Council on Forestry: Use of Woody Biomass
  http://council.wisconsinforestry.org/biomass/

- Forest Stewardship Council
  http://www.fscus.org/standards_criteria/

- Canada: The Scientific Foundation for Sustainable Forest Biomass Harvesting Guidelines and Policies
  http://www.sfmnetwork.ca/html/biomass_workshop_e.html

- New Brunswick: Forest Biomass Harvesting Policy
  http://www.gnb.ca/0078/Policies/FMB0192008E.pdf