Guidelines for Harvesting Forest Biomass for Energy: A Synthesis of Environmental Considerations

Dalia Abbas,[1] Dean Current,[2] Michael Phillips,[3] Richard Rossman,[4]
Kenneth N. Brooks[5] and Howard Hoganson[6]

ABSTRACT. Interest in the utilization of forest biomass for energy is growing. A search into existing forest biomass harvesting and regeneration guidelines was carried out to identify how biomass energy can be environmentally sustainable. Findings have shown that there are only a few guidelines that address harvesting and regenerating biomass for energy or any other uses. Of these few, there are guidelines developed for dedicated energy plantations, in addition to the Finnish and Swedish guidelines that recommend management guidelines for both timber and biomass extraction. Most of the existing guidelines emphasize the retention, disposal, redistribution, burning and mulching of biomass material on a site and are more focused than forest and timber management guidelines. This study synthesizes and classifies existing biomass related guidelines based on an in-depth literature review of existing guidelines and discussions with North American and European research institutions involved with biomass energy harvesting. Biomass guidelines are classified according to those that produce biomass commercially for energy versus those that manage this material for non-commercial purposes. The biomass guidelines are analyzed with respect to how they address issues of sustainability related to soil, water and habitat. Recommendations are offered for developing guidelines for biomass harvesting.

KEYWORDS. Guidelines, wood, forest, bioenergy, biomass, harvesting, sustainability, soil, hydrology, habitat.

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[1] Dr. Dalia Abbas is with the Department of Forest Resources, University of Minnesota. St. Paul, MN 55108-6112, USA
[2] Dr. Dean Current is a Research Associate and Program Director of the Center for Integrated Natural Resources and Agricultural Management, Department of Forest Resources, University of Minnesota, St. Paul, Minnesota, USA
[3] Dr. Michael Phillips is an Adjunct Assistant Professor and Site-level Program Manager, Minnesota Forest Resources Council, St. Paul, Minnesota, USA
[4] Mr. Richard Rossman is a soil scientist and Chair of the Minnesota Forest Resources Council Biomass Guidelines Technical Committee, Department of Natural Resources, Bemidji, Minnesota, USA
[5] Dr. Kenneth N. Brooks is a professor and Director of Graduate Studies, Department of Forest Resources, University of Minnesota, St. Paul, Minnesota, USA
[6] Dr. Howard Hoganson is a professor, Department of Forest Resources, North Central Research and Outreach Center, University of Minnesota, Grand Rapids, MN, USA

INTRODUCTION

Several international and national policies have been put in place to promote large-scale biomass utilization for energy (e.g., EC Communication Biomass Action Plan 2005, US Energy Policy Act 2005), because of growing energy needs, concerns for carbon dioxide emissions from burning fossil fuels, and the price of oil. However, the contribution that biomass can make to future global energy demand is not clear and has been inconsistently addressed (Berndes, Hoogwijkb and Broekc, 2003). An increase in demand for biomass energy has raised serious concerns about the long-term effects of forest residue removal on soil productivity (Grigal, 2004; Grigal and Bates, 1992); Belleau, Brais and Pare, 2006), water quality (Swank, Vose and Elliott, 2001; Sheppard, 2006) and habitat (Cook and Beyea, 2006; Stokland, 2001). This is because harvest and removal of biomass is expected to have a greater impact on soil, water and habitat than current traditional forest practices. Relying entirely on general forest management guidelines for the management of biomass harvest operations may not be prudent (Sheppard, 2006; Andersson, Asikainen, Bjorheden, Hall, Hudson, Jirgis, Mead, Nurmi and Weetman, 2002), and the development of specific biomass guidelines is necessary to ensure sustainability.

STUDY OBJECTIVE AND METHODOLOGY

This study investigates and evaluates criteria for harvesting biomass from forestlands for energy purposes. The objectives are to identify and classify existing forest biomass guidelines that promote sustainability, analyze existing environmental concerns and offer recommendations for developing biomass-harvesting guidelines.

This study synthesizes available biomass harvesting guidelines and literature and the opinions of forest biomass professions in North America and Europe via face-to-face and telephone discussions. Discussions held investigated current and potential guideline development efforts.

Study scope

Biomass from forests and plantations can be derived from above and below ground biomass material. For this synthesis, biomass includes forest residue extractions from forest management operations, stumps and biomass from dedicated plantations. In general, biomass for energy has lower bulk density and value than timber for pulp, paper and saw logs industries.

The supply chain of biomass energy from forests and plantations extends from activities at the harvest site to the power plant. Biomass energy guidelines can therefore address

recommendations for on-site and off-site activities. This study covers on-site harvest activities only. This does not include activities such as road transportation, energy used in extractions, and emissions. On-site activities cover biomass removal practices from harvest site to landing (the area dedicated to handing and processing material in a harvest site).

Purpose of guidelines

In general, guidelines are developed to protect the use of resources of interest and value for future generations through regulation of their use. Forest management guidelines offer a balanced framework to contribute to the goal of sustainability of forested lands and forest resources (Minnesota Forest Resources Council, 2005) by protecting soil productivity, water quality, habitat and ecosystem services. Potential for biomass harvesting is site specific. Utilization depends on the preferences of landowners and associated primary management goals for a site. Many site-specific management goals favor retaining forest residue over extracting. This is because forest residue serves several functions in providing site nutrients, maintaining physical properties, protecting water quality and providing habitat (Silkworth and Grigal, 1982; Harmon, Franklin, Swanson, Sollins, Gregory, Lattin, Anderson, Cline, Aumen, Sedell, Lienkaemper, Cromack and Cummins, 1986; McMinn and Crossley, 1993). However, if implemented properly, harvesting biomass and logging residue can improve conditions for site preparation. The quality of site preparation is improved, planting becomes easier and faster to carry out and regeneration can be improved (Halonen, 2004). Once biomass extraction is intended, biomass guidelines should apply and provide forest machine operators with recommendations for conducting specific biomass harvest operations. If there are no guidelines, harvesting biomass for energy is going to be up to the discretion of forestland owners and machine operators at the time of harvest.

BIOMASS GUIDELINES

With the rapidly increasing interest in biomass for energy, guidelines are necessary to ensure the sustainable use of this resource in a manner that does not impair both its commercial and non-commercial services. For example, over-extracting biomass can reduce soil productivity and hence reduce the sustainable supply of this material for future generations. On the other hand, if implemented properly, biomass removal can benefit overall forest management and energy goals.

There are only a few guidelines that have addressed removing biomass for energy, and practitioners have therefore often recommended guidelines for biomass harvesting based on

traditional forest best management practices (Sheppard, 2006), often known as forest management guidelines (USDA Forest Service - North Central Research Station, 2006). Basing biomass-harvesting guidelines on forest management guidelines is a logical starting point to develop biomass-specific guidelines. However, forest management guidelines alone may not be applicable in harvesting biomass because:

- Biomass harvest has the potential to have a greater impact on soil productivity, water quality and habitat than current traditional timber harvesting practices, due to the high nutrient concentration in branches, roots and leaves;
- Traditional guidelines offer guidance on how to conduct harvesting practices, largely for timber production, but do not address removing more of the residue and small material from a site. Guidelines offer recommendation for how to arrange logging residue material on skid trails to minimize soil compaction and damage, and in some cases the importance of redistributing biomass, if not extracted, on a site after harvest;
- There is a different mindset on how to handle residual biomass. Forest management guidelines recommend handing biomass by disposing of, re-distributing, burning, retaining, shearing and mulching this material for forestry and timber goals, but biomass guidelines need to address the repeated harvest of this material sustainably.

CLASSIFICATION OF EXISTING GUIDELINES

Existing biomass related guidelines address the management of biomass disproportionately, broadly classified into a) those that recommend the harvest and removal of biomass for commercial goals (production) as in classifications 1 and 2, and b) those that recommend the removal, disposal, retention, redistribution, shearing, mulching, or burning this material for non-commercial goals as in classification 3. In this next section existing guidelines are classified according to those that recommend biomass harvesting for commercial and non-commercial goals.

Classification 1: Energy plantation guidelines

Energy plantation guidelines recommend methods of harvesting a site for to maximize the amount of biomass harvested for energy. This included guidelines that address fast-growing short rotation woody crops such as hybrid poplars, willows and eucalyptus, which have been growing solely for energy generation. Such guidelines are developed with the understanding that the entire site yield is harvested every three to six years. Energy plantation guidelines are the only guidelines with biomass production as a primary rather than the secondary site management goal.

The Scottish Agricultural College guideline (Scottish Agriculture College, 2004), designed for intensive willow fuel wood systems in Europe, is a good example of an energy plantation guideline. Its goal is the management of plantations for sustainable development in rural communities. It also recommends biomass harvested from energy plantations as a fuel source that can be stored until needed, and used to generate heat or electricity.

Classification 2: Timber and biomass energy guidelines

Timber and biomass guidelines recommend the biomass handling manners in a timber extraction or stand improvement practice. Unlike energy plantations guidelines, the goal is not solely to recommend biomass energy harvesting, rather the essential integration of biomass extraction with timber harvesting goals to meet the market demand for bioenergy and timber.

Only two relevant guidelines have been identified: Finnish guidelines developed by Metsätalouden Kehittämiskeskus Tapio, and the Swedish guidelines developed by the Swedish Forest Agency (Skogsstyrelsen, 2001). Despite the potential usefulness of these two Scandinavian guidelines in providing insights into guideline development, both countries have high utilization rates of forest biomass energy that may not be comparable with less intensive forest biomass energy systems.

For example, both countries have already established large-scale biomass energy industries. To meet market demands, both Finland and Sweden have been exploring potentials for stump and root wood extraction (Hakkila, 2006), promoting new technology to utilize high energy content in spruce stumps and root wood (Hakkila and Aarniala, 2004). This stump extraction for energy is not an option in identified guidelines in North America, except in cases of site conversion (McCallum , Ryans, and Chisholm, 2006) and site sanitation and treatment, such as stump removals to control Armillaria Root Disease in Ponderosa Pine stands (Lewis, Shaw, Charles, Rolph and Leonard, 2000). At present, the biomass energy market has not attempted to explore stump and root extractions options for energy in North America. Concerns about soil disturbance and the removal of nutrients are more upheld concerns than expanding a market for extracting tree stumps and roots for energy. Furthermore, the pressing demand to utilize sites more intensively, because of a link between biomass extraction and energy consumption, is less critical in North America than in Finland and Sweden.

Classification 3: Forest residue removal in forest and timber management guidelines

Forest and timber management guidelines recommend how to deal with this biomass energy material, so that it does not interfere with present and future forest and timber harvesting goals (Minnesota Forest Resources Council, 2005; Sustainable Forestry Initiative, 2004). For

example, in situations where tops, limbs and slash material are not removed, forest and timber management guidelines recommend that the landowner/logger retain this material at the stump or return it to the logging site after processing extracted timber at the landing. In other cases, the visual importance of hiding or disposing of biomass piles after harvesting is pronounced (Minnesota Forest Resources Council, 2005). Within this classification there is little information about the potential usage for this material.

The goal of more focused forest residue management guidelines, as a supplement to forest management guidelines, is to manage this material to achieve specific forest management goals and objectives. Biomass energy production is not an objective. Forest residue management guidelines propose different management options for this forest residue. Cases of biomass management depend upon reforestation methods, slash-loading impacts on regeneration, site sensitivity to nutrients loss, wildlife habitat and travel, and potentials for escaped or spread fires (Manitoba Conservation, 2005). Unlike classification 2, potential for biomass removal is only one possibility next to retaining, burning, redistributing, windrowing, and mulching biomass on a site or infilling ditches (Manitoba Conservation, 2005; Frediksson, 2006).

Early biomass management guidelines include those developed in 1989 for the Blue River Ranger District residue guidelines in the State of Oregon (Eubanks, 1989). This set of guidelines was developed to regulate the amount of biomass that needs to remain on a site after yarding of unmerchantable material operations. Current efforts in Canada and the United States are developing similar guidelines. In Canada, efforts by Canadian Bioenergy Association, Forest Engineering Research Institute of Canada, and Stora Enso Company have developed draft interim biomass removal guidelines for the Maritime Provinces (McCallum, Ryans and Chisholm, 2006). In the United States, the State of Minnesota Department of Natural Resources (MNDNR) and the Minnesota Forest Resources Council (MFRC) was the first state sponsored effort to develop comprehensive forest residue and brushland biomass removal guidelines.

In summary, classifications 1 and 2 emphasize the commercial potentials for forest biomass for energy production. Both guidelines expand on forest biomass resources to include energy plantations and tree stumps. Classification 3 promotes leaving forest biomass resources in a site or managing this material so that it is burnt, redistributed, sheared, mulched or removed for timber and forest management goals which do not include commercial biomass extraction.

GUIDELINES AND THE SUSTAINABILITY CONCERNS OF BIOMASS ENERGY

Sustainability is an important, yet amorphous and overused term, which could only be defined within a context of interest. In other words, asking the questions, sustainability of what and for what purposes, can determine specific practices that sustain the resource of interest. For example, if sustaining biomass energy resources is a primary goal in a forestland, this goal is achievable when the forest is sustained, for the sustained supply of this resource. For plantations this can be more straightforward since sustainable biomass for energy production is the primary management goal on a site.

To protect the sustainability of forest-based ecosystems, and the multiple resources and products from these ecosystems, it is necessary to protect soil, water and habitat ecosystem services through forest related guidelines. Therefore, forest biomass energy production guidelines need to explain specific practices and protocols that serve both the sustainability of the forest environment and this product. Most of the existing guidelines address soil, water, and habitat services in relation to specific forest management goals. However, practices that allow preserving these environmental services are not linked with practices that would repeatedly allow the harvest, re-growth and produce of biomass for energy. It is necessary to make a distinction between guidelines that have the primary focus of addressing the repeated production of biomass energy and those that do not. Unless there are clear guidelines that can explain practices that make more material available, the link between woody biomass and energy generation may not be serious or sustainable. Therefore, if the intention is to produce biomass energy, specific guidelines should seek to identify key areas and practices that may lead to the long-term supply of biomass energy, whether from biomass energy plantations or by intentionally linking forest residue removal operations from different sites with different management objectives that can lead to a more stable biomass production supply.

This section addresses soil, water and habitat concerns that accrue to biomass harvesting, and analyzes how some of these concerns have been addressed in existing forest-related guidelines. Existing guidelines have dealt with each of these areas independently within a forest ecosystem. However, the integrated relationship between soil, hydrology, and habitat is complex and has been insufficiently addressed (Berndes , Hoogwijkb and Broekc, 2003). An understanding of this integrated relationship is necessary for evaluating the effects of large-scale biomass energy production. For example, if large-scale biomass production results in site compaction, runoff, soil erosion, and loading of sediments and nutrients to water bodies are likely to occur. This can result in a change in the habitat upon which many species of fish, reptiles and amphibians, large and small mammals, and birds depend (Brooks, Ffolliot, Gregersen and DeBano, 2003).

This section does not intend to detail in-depth soil, hydrology and wildlife and biodiversity habitat concerns. There are many studies that have looked in detail at these areas in relation to biomass material (Grigal, 2004; Heninger, Terry, Dobkowski and Scott, 1997; Christian and Hanowski, 1998; Angelstam, Mikusinski and Breuss, 2002; Neary, 2002). Furthermore, guidelines for harvesting energy plantations are not addressed. Environmental benefits of energy plantations are assumed to be a positive addition to the national and global ecosystems (Tolbert and Wright, 1998). If woody crops are grown instead of annual agricultural crops, they can work to restore some ecosystem functions and enhance biodiversity. However, if plantations replace native forests and wetlands, they are likely to cause a net loss in ecosystem functions and biodiversity (Cook and Beyea, 2000; Tolbert and Wright, 1998). This section analyzes existing guidelines, which have combined biomass and forest management goals.

Soil productivity

Soil productivity is the capacity of a soil to contribute to the production of forest biomass (Burger, 2002). Soil productivity is based on the natural capacity of unaltered soil to support plant growth, as measured by biomass yield in tones per hectare per year (Heninger, Terry, Dobkowski and Scott, 1997). Burger identifies three means to increase the productivity of a site. These are increasing: a) biotic potential of trees b) growth rate of trees, and c) site carrying capacity. On the other hand, soil productivity potential can be reduced as a consequence of chronic soil nutrient deficiencies, excessive water, puddling of soils, compaction, poor soil aeration, reduced water holding capacity and infiltration, disruption of soil pore space, fires and a reduction of the litter layer (Heninger, Terry, Dobkowski and Scott, 1997; Burger, 2002; Jurgensen, Harvey, Graham, Page-Dumroese, Tonn, Larsen and Jain, 1997).

The goal of sustaining soil productivity implies sustaining soil chemical, biological and physical properties. Chemically and biologically, the amount of slash biomass left on the forest floor and as standing dead material is a principal factor that can affect short- and long-term soil nutrient availability and microbial community characteristics (Belleau, Brais and Pare, 2006). However, in spite of the many functions of soil biological processes (e.g., nutrient cycling, energy cycling, water cycling, processing of potential pollutants, plant pest dynamics) the development of management guidelines that directly address soil biology protection has received little attention (Natural Resources Conservation Service, 2004). Protection of physical soil properties (e.g., texture, surface structure, drainage, depth) has been the principal focus for protecting soil productivity. The assumption has been that if the physical soil properties are protected during forest management operations, then impacts to soil biological properties will be minimized. For

example, minimizing site infrastructure and compaction, and maintaining adequate buffer strips adjacent to water bodies will favor maintenance of soil biological properties. To reduce chemical (e.g., nutrients retention and fertilizing) and physical (e.g., soil properties, site characteristics, species, and harvesting) effects on site productivity, guidelines recommend the following strategies:

Soil nutrients -

- Retain adequate quantities of slash on-site. There is no consensus in existing guidelines, however, over the exact amount of residue that should remain on a site after biomass extraction. Such quantities vary by soil types. Finnish guidelines recommend leaving up to 30% of residue or the same amount of nutrients on the forest floor (Metsätalouden kehittämiskeskus Tapio, 2005).
- Retain or leave tree foliage on-site for nutrients (Skogsstyrelsen, 2001; McCallum, Ryans and Chisholm, 2006) [20,23].
- Leave residue to dry on-site to maximize retention of nutrients, because foliage falls off (Metsätalouden kehittämiskeskus Tapio, 2005; Skogsstyrelsen, 2001).
- Distribute residue more evenly than during timber extraction only practices (Metsätalouden kehittämiskeskus Tapio, 2005; Skogsstyrelsen, 2001).
- Leave slash on a site to promote natural regeneration from seed bearing cones, and where removing debris affects soil fertility (Manitoba Conservation, 2005)
- Replace removed nutrients by fertilizing biomass sites with pure wood-ash. Swedish guidelines in particular emphasize the significance of maintaining certain ash standards to avoid atmospheric and soil complications (Metsätalouden kehittämiskeskus Tapio, 2005; Skogsstyrelsen, 2001).

Soil conditions -

- Leave slash on sites where long-term productivity can be impacted and on soil with low ground bearing capacity. For example, retain residue in shallow to bedrock, coarse or drought sand soil or deep organic soil, swamps, and nutrient-poor sites (Metsätalouden kehittämiskeskus Tapio, 2005; Minnesota Department of Natural Resources and Minnesota Forest Resource Council, 2007). On less rich sites, where vegetation cannot retain many nutrients, retain heavier branches for long-term nutrient release (Metsätalouden kehittämiskeskus Tapio, 2005). Also retain residue where it is important in forming new humus (Metsätalouden

kehittämiskeskus Tapio, 2005), and when understory stems are less than 250 stems per hectare (Sustainable Forestry Initiative, 2004).

- Harvest under suitable soil conditions. For example, enter lowlands and wet soil sites only under frozen or dry conditions to avoid displacing the soil (Minnesota Forest Resources Council, 2005).
- If stumps are removed, they should be shaken first so the soil from stump will drop into this same place after lifting and minimize soil disturbance (Metsätalouden kehittämiskeskus Tapio, 2005).
- If soil is damaged, stop harvesting immediately (Metsätalouden kehittämiskeskus Tapio, 2005; Minnesota Department of Natural Resources and Minnesota Forest Resource Council, 2007), for example, if evidences of erosion, compaction or rutting occur.
- Site characteristics and species.
- Do not skid, rather lift, biomass material on steep slopes to avoid erosion (Metsätalouden kehittämiskeskus Tapio, 2005).
- Retain cone-bearing slash under naturally growing pine regeneration goals (Manitoba Conservation, 2005).

Harvesting operations -

- Reduce soil compaction, rutting, exposure of mineral soil, soil removal, and erosion (Minnesota Forest Resources Council, 2005)
- Conduct biomass harvest operations only along with or following timber harvest operations (Minnesota Department of Natural Resources and Minnesota Forest Resource Council, 2007).
- Reduce the number of skid trails on a site (Minnesota Forest Resources Council, 2005; Metsätalouden kehittämiskeskus Tapio, 2005).
- Utilize existing infrastructure; reestablish water diversion structures, and soil erosion controls, if any re-access of a site is necessary for biomass harvest following site closure to avoid compaction (Minnesota Department of Natural Resources and Minnesota Forest Resource Council, 2007).
- Residue used to reinforce trails must not be used for wood energy (Metsätalouden kehittämiskeskus Tapio, 2005).

Most soil-related guidelines address soil nutrients, physical properties, site characteristics, species and harvesting operations. However, the main area of difference amongst guidelines is the potential amount of residue that is removed or retained on a site, which is identified according to guidelines management goals. Several studies have made assumptions associated with the degree of nutrient removal in timber harvesting (Grigal, 2004; Jurgensen, Harvey, Graham, Page-Dumroese, Tonn, Larsen and Jain, 1997; Powers, Sanchez, Andres Scott and Page-Dumroese, 2004). However, such assumptions need to be re-examined when harvesting the biomass material is considered (Grigal, 2004).

Hydrology

Soil hydrology is impacted by soil disturbances, harvesting operations, and mineral soil exposure (Minnesota Forest Resources Council, 2005). The main aim of water quality management is to reduce discharge of sediments and pollutants from a site to water bodies. Hydrology is affected by the ability of soil to hold and transfer water. Soil compaction impacts the size, number, and distribution of soil pores, which impacts water movement and increases surface runoff, erosion and water logging of soil (Greacen and Sands, 1980; McNabb, Startsev and Nguyen, 2001). Impaired soils can affect water quality in streams, rivers and lakes during and following forest management activities (Sheppard, 2006). Neary (Neary, 2001) summed up some of the hydrological process impacts caused by tree harvesting and litter removal as follows:

- Reduced interception reduces moisture storage and results in more runoff in small streams and increased water yield.
- Litter storage of water is impacted by changes in the amount of litter on site
- Temporarily eliminating transpiration increases baseflow and soil moisture
- Reduced infiltration increases overland flow and stormflow; whereas, increased infiltration decreases overland flow and increases baseflow.

To reduce the hydrological effects of residue removal, guidelines recommend the following strategies (Metsätalouden kehittämiskeskus Tapio, 2005; McCallum, Ryans and Chisholm, 2006; Minnesota Forest Resources Council, 2005):

- Keep ditches functional after energy wood harvest.
- Remove forest residue from riparian zones and all small water bodies after harvest.
- Minimize piling or storing of forest residue on ditches.
- Remove residue bridges after use, if they threaten water protection or hamper water flow in ditches.

- Minimize interference with natural drainage.
- Leave a continuous filter strip along ditches, small bodies of water and main waterways.
- Base the width and length of the filter strip on the slope, watershed, soil and properties of water bodies. For example, in Finland a filtering zone extends 2 – 3 meters from the edge of a ditch, 3 – 5 meters from the edge of small streams, and 7 – 10 meters from the edge of a major waterway.
- Avoid removing stumps from filter strips, streams, lakes or ditches.
- North American guidelines specify the avoidance of stump harvesting for utilization, except in woodland conversion sites.
- Avoid placing clearing debris in filter strips.
- Provide breaks in windrows to allow free water movement.

Most hydrology guidelines recommend riparian areas, ditches, filter strips and water-bodies protection goals. Management objectives emphasize the importance of protecting site hydrology pertaining to water quality and waterways. However, since biomass extraction sources may vary according to management objectives, guidelines specify conditions of biomass extraction from stumps and logging residue.

Habitat

Individual species vary in their dependence on forest biomass according to their habitat requirements. For example, factors such as coarse woody debris physical orientation, size, age, state of decomposition, tree species, overall abundance and physical distribution of debris influence how organisms utilize forest residue (Harmon, Franklin, Swanson, Sollins, Gregory, Lattin, Anderson, Cline, Aumen, Sedell, Lienkaemper, Cromack, Cummins, 1986). Additional functions of biomass energy material include sheltering, reproduction, resting, bedding, roosting, sunning, hibernating, preening, drumming, travel routes and lookouts (Thomas, 1979). In spite of the importance of coarse woody debris (woody material > 2.5 cm) in wildlife habitat, little is known of the importance of fine woody debris (woody material < 2.5 cm) to most small mammals, birds, reptiles and amphibians (Stokland, 2001; Aarhus and Moen, 2005). Recent studies have found that small residue biomass removals can affect the abundance and species richness of certain arthropods, and influence the microhabitat choice of arthropods (Nittérus, 2006). In addition, fine wood debris was found to have ecosystem effects in relation to species richness on logs in managed boreal spruce forests of northern Sweden (Kruys and Jonsson, 1999).

Many site-level studies have dealt with specific populations on specific sites and report conditions that promote management goals related to those populations on those sites. For a diversity of species, a landscape perspective and a strategy for a diverse habitat structure is necessary (Brown, Reinhardt and Kramer, 2003; Hutto, 1995). As a result guidelines have recommended general conditions necessary for wildlife and biodiversity protection. However, such conditions are insufficient in addressing this landscape scale. These habitat-related recommendations include (Minnesota Forest Resources Council, 2005; Metsätalouden kehittämiskeskus Tapio, 2005; Skogsstyrelsen, 2001; McCallum, Ryans and Chisholm, 2006):

- Do not collect or damage large dead stems.
- Do not remove breakable rotten stems.
- Move and pile rotten stems if they impede operations.
- Leave at least 2-5 bark-on down logs, such as hollow butt sections from conifer or hardwood logs, greater than 75 cm per ha.
- Maintain ground cover, shrubs, snags, naturally regenerating tree seedlings, and other live trees important for wildlife and stand regeneration.
- Reduce harvesting activities, which disturb sensitive sites, rare species, water features and unique habitats.
- Avoid damaging any nests.
- Retain naturally occurring and decayed wood debris on a site.

There is no answer to the question: "How much residue can remain on a site and still maintain ecosystem wildlife and biodiversity habitat resources?" (Tolbert and Wright, 1998; Brown, Reinhardt and Kramer, 2003). The optimum quantities of both standing and downed coarse woody debris are necessary in some situations to create habitat suitable for wildlife. In other situations, this is not necessarily the case. Eubanks found that in the Blue Ranger District in Oregon, most of the wildlife trees called for were live culls (green trees with defect) and not snags (standing dead trees) (Eubanks, 1989).

OTHER FACTORS CONSIDERED IN GUIDELINES

In addition to the environmental resources necessary to sustain a system, which generates biomass for energy, forest-related guidelines address other non-ecosystem related aspects such as social, cultural, aesthetics and biomass storage conditions suitable for biomass energy. Identified guidelines that address these areas include:

Social, cultural and aesthetics

(Minnesota Forest Resources Council, 2005; Metsätalouden kehittämiskeskus Tapio, 2005)

- Avoid damage to sites of valuable social and cultural significance.
- Protect ancient ruins and relics.
- Keep residue piles away from cultural resources.

Storage conditions

(Metsätalouden kehittämiskeskus Tapio, 2005)

- Store residue on dry, flat and open sites.
- Store residue on sites free of rocks, dirt, metal objects and other hard objects that can damage a chipper or grinder.
- Store biomass at a distance from other stems to avoid scarring during removal.
- Apply roadside round wood storage guidelines to biomass energy.
- Use a “warning of danger of collapse” sign to forbid climbing piles, in public access areas.
- Cover energy wood to control the moisture content.
- Clean residue storage sites of non-natural material.
- Remove small understory trees from storage site to prevent root clots from hampering chippers.
- Store biomass in the form of piles or bundles rather than chips to avoid hazardous combustion of chipped biomass materials.
- Store residue in high and narrow piles, so that no rain (or snow) enters into the storage piles.
- Avoid roadside piles within 30 meters of a watercourse
- Avoid piling residue within 3 meters of seed and protective trees to avoid their damage.

RECOMMENDATIONS

Harvesting of biomass for energy material can affect the sustainability of key environmental functions. On the other hand, if biomass is randomly sought, the potential contribution of this resource to a growing energy industry is at stake. Because of these concerns, it is necessary to regulate the process of sustaining environmental considerations alongside the supply of this resource. To overcome potential environmental complications, identified guidelines have listed recommendations in several of the essential environmental sustainability-

related areas: soil, water, and habitat. On a more process-oriented level, the following are recommendations to be considered when developing biomass energy harvesting guidelines.

- Start developing biomass energy specific guidelines now. Biomass is already being extracted to supply a growing energy market, with or without guidelines.
- General guidelines may not protect all sites, and a detailed and quantifiable description should be made of how much material should remain on different types of sites.
- Where scientific evidence does not exist, an informed estimate should be made. For example, Finnish guidelines estimate that 30% of residue needs remain on site. This estimate is there until a more scientifically informed estimate could be made (Frediksson, 2006).
- Prospective estimates are expected to explain both qualitatively and quantitatively the manner, and quantity, of biomass that should remain in a site while minimizing environmental concerns. Potential future removals, however, would have to be economical to make practical sense.
- Make guidelines simple, practical and well informed.
- Guidelines need to be science-based.
- Use common terminology and graphics when developing guidelines.
- Once a draft guideline is developed, this copy needs to be reviewed by operators, for additional considerations.
- Having well-thought-out guidelines is not enough. It is necessary to spend time explaining the objectives of guidelines to biomass harvesting operators.
- Monitor the implementation of guidelines to ensure the success of their objectives, and to explore additional areas for improvement.
- Update existing guidelines on a regular basis. Currently, forestry experts in Sweden are updating biomass energy guidelines according to the latest scientific knowledge.
- Identify future research questions and needs, while developing guidelines.
- Biomass harvesting guidelines should be site-specific based on site soil, water and habitat properties, with a landscape perspective in mind. This points to the importance of synthesising knowledge of relevance to each geographic area where biomass is extracted.
- Share global knowledge and case studies of biomass extraction guidelines.

CONCLUSION

This study has examined existing biomass guidelines and their classifications. If biomass energy is intended, it is important to have biomass energy production specific harvesting and removal guidelines. Most guidelines emphasize the site need for biomass material to remain on a site, as opposed to the removal potentials of biomass. Only guidelines developed for energy plantations and Scandinavian biomass energy guidelines address removal of this material for utilization. Biomass energy removal can impact soil, hydrology and water quality, and habitat resources. Therefore, specific and integrated guidelines need to look at these resources in relation to removing biomass material, and update this regularly based on scientific evidences and discoveries. Currently, efforts in Europe and North America are exploring these avenues.

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