An Analysis of Woody Biomass Harvesting Guidelines (BHGs) for North Carolina Forestry

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Introduction

Rising fuel costs, the sensitive geopolitics of fossil fuels, and climate change from rising emissions are pushing the US towards renewable-based energies such as wind, solar and biomass. Bioenergy from Southeastern forests, specifically woody biomass, is an important topic in this debate, as it is expected to play a vital role in how the nation will meet its future energy needs. With increasing pressure on forests to provide the raw material to replace coal and gas, however, forestry practices need to be re-evaluated to consider a variety of elements to maintaining healthy forests. The goal of this paper is to aid North Carolina's best management practices technical committee in the development of guidelines for the sustainable harvest of woody biomass in the state.

What is Woody Biomass?

Woody biomass is the traditionally un-merchantable product left on-site following a roundwood harvest and includes all the limbs, tops, needles, leaves, stumps and other above-ground woody parts of trees. This left-over wood (logging residue) is either chipped on-site or bundled for transport to an energy facility where it is burned to generate electricity or heat, or both. Northern European countries such as Finland, Sweden, the Netherlands, and Denmark have a long-standing tradition of harvesting woody biomass for use in district heating systems or combined heat and power (CHP) facilities and the practice is increasingly being adopted in Canada and the United States as an alternative to fossil fuel sources.

What are the concerns that have been raised about woody biomass harvesting?

Concerns have been raised about the intensive harvesting of woody biomass on forested sites for energy, including the increased removal of dead wood, threats to wildlife and biodiversity, the loss of nutrients and soil productivity, and the protection of water quality and riparian zones (Evans and Pershel, 2009). In response to these concerns, various US states have either adopted woody biomass harvesting guidelines or are in the process of developing them. States have amended their existing forestry best management practices (BMPs) or developed new biomass harvesting guidelines (BHGs) for reasons similar to why forestry has become regulated: public anxiety over environmental protection, correction of misapplied forestry practices, the need for greater accountability, the growth of local ordinances, landscape-level concerns, and following the lead of others (Ellefson et al. 2004, Evans et al. 2010). Most forestry best management practices were not written at a time when energy from forests was being considered and therefore do not address how much woody biomass can be sustainably harvested from forests (Evans et al. 2010).

What does NC already have in place as it relates to the harvest of woody biomass?

North Carolina currently lacks guidelines on the harvesting of woody biomass other than those related to water quality. However, the state has well-crafted, specific recommendations in place to maintain water quality in forests, and research has shown that when forestry Best Management Practices (BMPs) are properly implemented they protect water quality (Shepard 2006). North Carolina foresters show relatively frequent use of voluntary protection measures and a high compliance rate (85%) of implementing BMPs (*North Carolina Forestry BMP Implementation Survey Final Report: 2006-2008).* Although NC forestry BMPs effectively mitigate the potential consequences of forestry practices, they may fail to adequately address concerns over intensive woody biomass harvesting.

Scientific Literature and State BHGs

Effects of Woody Biomass Harvests

With so much regulation and guidance already in place in the form of forestry best management practices, some have questioned the need for additional guidelines covering woody biomass. A review of the most recent literature on woody biomass harvesting effects suggests that concerns are related to the timing, duration and location of a harvest. In response to these concerns, six states have developed biomass harvesting guidelines since 2007 that suggest how to mitigate the consequences of more intensive woody biomass harvesting—Minnesota (2007), Wisconsin (2009), Maine (2010), Pennsylvania (2008), Missouri (2008), and Kentucky (2011).

Table 1. State Biomass Harvesting Guidelines and References

Kentucky

Recommendations for the Harvesting of Woody Biomass (KDF 2011) (http://forestry.ky.gov/Pages/WoodEnergyTopics.aspx)

Maine

Considerations and Recommendations for Retaining Woody Biomass on Timber Harvest Sites in Maine (Benjamin 2010) (http://www.maine.gov/doc/mfs/pubs/biomass_retention_guidelines.html)

Minnesota

Biomass Harvesting on Forest Management Sites (MFRC 2007a)

The Minnesota Forest Resources Council (MFRC) also developed a set of guidelines for woody biomass harvesting from brushlands and open lands.

Woody Biomass Harvesting for Managing Brushlands and Open Lands (MFRC 2007b)

(http://www.frc.state.mn.us/documents/council/site- level/MFRC_forest_BHG_2001

- 12- 01.pdf)

Missouri

Missouri Woody Biomass Harvesting Best Management Practices Manual (Enyart 2008)

(http://mdc4.mdc.mo.gov/Documents/18043.pdf)

Michigan

Michigan Woody Biomass Harvesting Guidance (MI DNRE 2010)

(http://www.michigan.gov/documents/dnr/WGBH_321271_7.pdf)

Pennsylvania

Guidance on Harvesting Woody Biomass for Energy In Pennsylvania (PA DCNR 2008)

(http://www.dcnr.state.pa.us/PA_Biomass_guidance_final.pdf)

Wisconsin

Wisconsin's Forestland Woody Biomass Harvesting Guidelines (Herrick et al. 2009)

(http://council.wisconsinforestry.org/biomass/pdf/BHG- FieldManual- lowres090807.pdf)

This review examines the literature on the effects of intensive biomass harvesting and how states have addressed those concerns through their BHGs. The review is divided into sections based on the common elements addressed by states' biomass harvesting guidelines. A complete list of the topics and subtopics of states' biomass harvesting guidelines is shown in Table 2. This review summarizes key findings from the literature and from the existing state BHGs to assess how biomass guidelines might be considered and applied in the South.

Table 2. Summary of Standards included in State Biomass Harvesting Guidelines.

	KY	ME	MN	MO	PA	WI
Dead and Downed Wood						
Coarse Woody Debris	√	√	√	√	√	√
Fine Woody Debris	√	√	√	√	√	√
Snags	√	√	√	√	√	√
Wildlife and Biodiversity						
Wildlife		√	√	√	√	√
Sensitive Wildlife Species	√	√	√	√	√	√
Biodiversity		√	√	√	√	√
Plants of special concern		√	√	√	√	√
Sensitive areas		√	√	√	√	√
Water Quality and Riparian Areas						
Water Quality		√	√	√	√	√
Riparian Zones		√	√	√	√	√
Non-point source pollution		√	√	√	√	√
Erosion	√	√	√	√	√	√
Wetlands	√	√	√	√	√	√
Soil Productivity						
Nutrients		√	√	√	√	√
Compaction	√	√	√	√	√	√
Removal of Litter Layer	√	√	√		√	√
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	√	√

Adapted from Evans 2010

Dead and Downed Wood

Dead and downed wood is important for both wildlife and biodiversity in forested stands. It comes in a variety of forms, including snags, stumps, logs, tops and limbs, twigs and forest floor (duff, litter, organic layers) and can be categorized by its size: coarse woody debris (CWD; stumps, logs, and other woody material greater than 3 inches), fine woody debris (FWD; leaves, needles, the tips of branches, forest floor that is less than three inches), and dead, standing trees (snags) (Harmon et al. 2004).

How Is Coarse Woody Debris Formed?

The cyclical nature of coarse woody debris accumulation (the stumps, and logs and other woody material greater than 3 inches) is often referred to as a “U-shaped” pattern (Harmon et al. 1986) (see Figure 1). At stand initiation in naturally regenerating stands, a large amount of coarse woody debris remains as a legacy from the previous stand. This CWD gradually decays as the new stand grows, but new CWD is formed through self-thinning. As the stand continues to age, much of the CWD legacy from the previous stand has decayed but the stand is still too young to generate CWD through self-thinning (trough of the curve in Figure 1). As the stand increasingly diversifies in height, increasing amounts of coarse woody debris are generated. The decomposition of increasingly larger pieces of coarse woody debris and increasing die-off leads to an increase in dead wood in the now old forest.

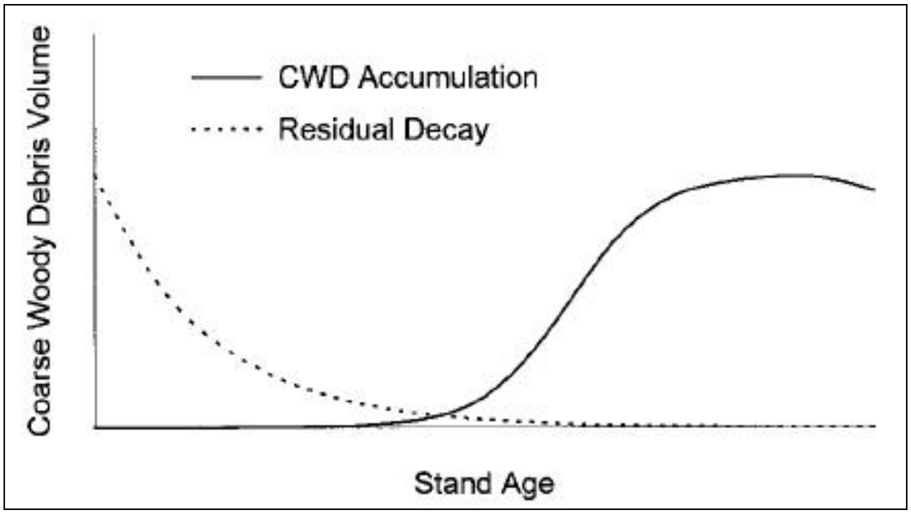

Figure 1. Conceptual relationship between coarse woody debris (CWD) and stand age, showing the decay of residual debris following harvest disturbance, followed by the accumulation of debris from the regenerating stand (reproduced from Sturtevant 1997)

Research about Coarse Woody Debris

Despite the abundance of literature on the benefits of CWD, limited research has been conducted on its presence in forests of the Southeastern U.S. Historically, the Southeast has had much less coarse woody debris than other parts of the US (See Figure 2). This is a reflection of large-scale land conversion practices following European colonization as well as rapid decomposition rates. In the 19th to 20th century, clear-cutting of largely forested areas and conversion to agricultural lands by settlers led to soil degradation and the return of marginal farmland to naturally regenerated stands.

Many areas now covered in pine forests were once depleted agricultural lands fallowed by the depletion of soil nutrients. Forests that were once agricultural lands have much less coarse woody debris than areas that were previously forested (Bragg and Heitzman 2009). National average levels of coarse woody debris range from 0.4-6.3 tons/acre, whereas averages for the Southeast are 0.4-2 tons/acre (Woodall and Liknes 2008). "Ecology of Dead Wood of the Southeast" (Evans et al. 2011) provides a thorough summary of the research on dead wood in the specific forest types of the Southeast, including the Southern Appalachians, Piedmont, Upper Coastal Plain-Mixed Hardwood, Coastal Plain and Bottomland Hardwoods.

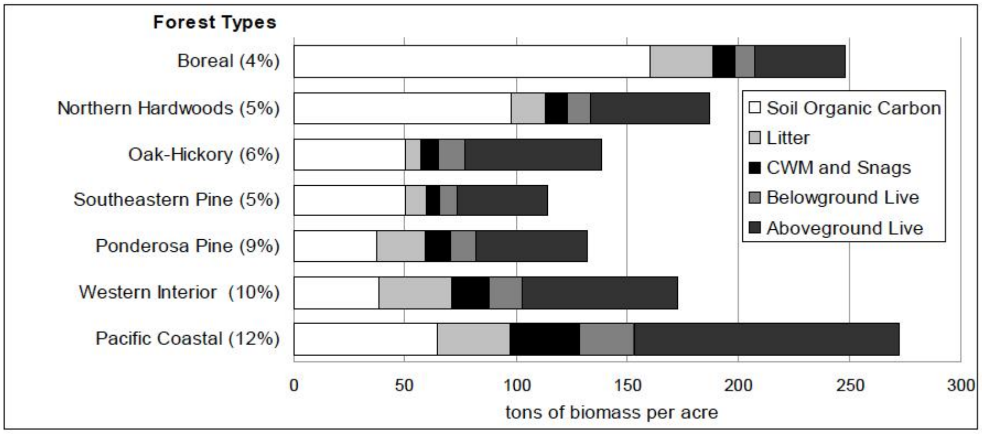

Figure 2. Estimates of biomass by forest type per acre, with percentage made up by CWM[1] and snags in parenthesis (EPA 2010 Table A-211, Evans 2011)

State BHGs for Coarse Woody Debris

State biomass guidelines have similar definitions of coarse and fine woody debris as Harmon et al 2004. Pennsylvania, Minnesota, and Missouri BHGs all define coarse woody debris as the stumps, fallen trunks or limbs of trees greater than 6 inches in diameter at the large end,[2,3,4,5] whereas fine woody debris are the tops, limbs and woody debris of less than 6 inches in diameter.[6,7,8] Regardless of its size, woody biomass serves

[1] CWM, or coarse woody material, is defined as down dead wood with a small-end diameter of at least 3 inches and a length of at least 3 feet. FWM, or fine woody material, is defined as having a diameter of less than 3 inches (Woodall and Monleon 2008).

[2] Sustaining Minnesota Forest Resources p. 447

[3] Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 40

[4] Missouri Woody Biomass Harvesting BMPs Manual p. 32

[5] Wisconsin BHGs defines CWD as greater than or equal to 4 inches diameter inside bark at the small end. (Wisconsin's Woody BHGs 2008 p. 6)

[6] BHGs for Forestlands, Brushlands and Open Lands p. 37

a vital role in any healthy forest ecosystem. Wisconsin and Missouri BHGs both provide good introductions to the benefits of coarse woody debris[9]. Minnesota's BHGs state that inputs of coarse woody debris and fine litter to riparian areas, "helps to create and maintain pools, reduces stream velocity, forms eddies where food organisms concentrate, provides protection from predators, shelter during winter run-off, traps and stores forest debris, and leads to natural levee formation"[10]. Minnesota's BHGs cite studies saying that FWD provides shelter, reduces wind velocity and fluctuations in ground temperature, provides habitat for small mammals and ground-active beetles, and that it may shelter plants from desiccation following clearcuts.[11]

BHGs for the most part stress that all coarse woody debris be left on-site, whereas they assign percentages to the amount of fine woody debris that should be retained on-site. Minnesota's BHGs are clear that all pre-existing coarse woody debris should be left on-site, undisturbed, except in skid trails and landings, and especially in filter strips. Additional exceptions cited for removing CWD are specific silvicultural applications (such as insect pests) and visual quality issues.[12] Wisconsin's BHGs also suggest retention of all coarse woody debris present, except on skid trails and landings.[13] Additionally, Wisconsin's BHGs suggest retaining additional amounts of CWD in forests that lack woody debris because of past management practices.[14] Pennsylvania's BHGs

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[7] Missouri Woody Biomass Harvesting BMPs Manual p. 33
[8] Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 40
[9] Wisconsin's Forestry BMPs for Water Quality p. 51; Missouri Woody Biomass Harvesting BMPs Manual p. 4-5
[10] Sustaining Minnesota Forest Resources p. 91
[11] BHGs for Forestlands, Brushlands and Open Lands p. 10
[12] Sustaining Minnesota Forest Resources p. 80
[13] Wisconsin's Woody BHGs 2008 p. 3
[14] Wisconsin's Woody BHGs 2008 p. 3

recommend to, "Leave 15 to 30 % of harvestable biomass as course [sic] woody debris."[15]

State BHGs for Fine Woody Debris

Minnesota's BHGs suggest that, "for soils with 8-20 inches of soil over bedrock and droughty sands, consider that the recommended retention of one third or more of fine woody debris."[16] This goal is achieved by "intentionally retaining 20% of the FWD (tops and limbs from one "average sized" tree out of every five trees harvested), with an additional 10-15% achieved by incidental breakage during skidding."[17] The guidelines show a diagram adapted from Grigal 2004 ("Comparison of Biomass and Nutrient Removal Levels with Natural Nutrient Inputs") which presents various harvesting scenarios and their corresponding nutrient removal levels. In the scenarios presented, the retention of one third of FWD represents a nutrient removal level similar to a whole tree harvest in which tops and limbs are retained as a result of breakage.[18] Additionally, removal of fine woody debris resulting from incidental breakage of tops and limbs in the general harvest area should be avoided.[19] Missouri's BHGs also suggest leaving as many leaves and twigs (fine woody debris-FWD) on a site as possible to encourage nutrient cycling and habitat for small animals.[20]Wisconsin's BHGs suggest to "retain and scatter tops and limbs (<4" diameter) from 10% of trees in the general harvest area (e.g. one

[15] Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 36
[16] BHGs for Forestlands, Brushlands and Open Lands p. 24
[17] BHGs for Forestlands, Brushlands and Open Lands p. 29
[18] BHGs for Forestlands, Brushlands and Open Lands p. 15
[19] BHGs for Forestlands, Brushlands and Open Lands p. 28
[20] Missouri Woody Biomass Harvesting BMPs Manual p. 5

average-sized tree out of every 10 trees harvested)".[21] In general, Pennsylvania's guidelines suggest whole tree harvests should be limited; however, when performed slash should be retained on 10% of the site.[22]

In cases where a stand might not have enough coarse woody debris, both Minnesota and Wisconsin BHGs suggest creating more. For selecting which trees to fell, Minnesota's guidelines refer to the state's BMPs (under "Providing Coarse Woody Debris" in General Guidelines):

- Create at least 2 to 5 bark-on down logs greater than 12 inches in diameter per acre, if fewer than this number already exist.
- In choosing candidates for leave logs, consider that hollow butt sections or other defective lengths of at least 6 feet are preferred.
- Sound logs and 6-inch to 12-inch diameter logs may be used if they represent the best available candidates.
- Hardwood logs have more hollows or cavities and are favored by certain amphibians.
- Conifer logs decay more slowly and thus remain present as structure on a site longer than hardwoods.
- Using pines as down logs, especially in summer, increases the risk of bark beetle damage to adjacent healthy pines.
- Scatter leave logs across the site, including a few near wetlands. [23]

State BHGs for Snags, Leave Trees and Cavity Trees

Snags have a similar function to coarse woody debris in that they serve as shelter, nesting, and feeding sites for many species. Missouri's BHGs define a snag as:

1. A standing dead tree from which the leaves and most of the branches have fallen.[24] 2) A standing section of the stem of a tree, broken off

[21] Wisconsin's Woody BHGs 2008 p. 3
[22] Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 19
[23] Sustaining Minnesota Forest Resources p. 79-80
[24] NOTE: for wildlife habitat purposes, a snag is sometimes regarded as being at least 10 inches in diameter at breast height and at least 6 feet tall; a hard snag is composed primarily of sound wood, generally merchantable; a soft snag is

usually below the crown. 3) A sunken log or submerged stump or tree. 4) The projecting base of a broken or cut branch on a tree stem[25]

As with coarse woody debris, state-based BHGs place numbers on the amount of snags to retain. Pennsylvania's guidelines say to retain 1 to 5 snags per acre[26] and that all snags possible should be left in harvest areas. Those cut for safety reasons should be left where they fall.[27] Minnesota's BHGs refer to the state's BMPs and say that as many snags as possible should be left standing in harvest areas. Exceptions to leaving all snags may be made for reasons related to visual quality or safety reasons. When leaving snags in areas classified as most sensitive or moderately sensitive, then snags should not be left in the foreground. Scattered snags should be hidden within vegetative islands, or located around the edge of an opening to allow for camouflage by background trees of similar color and texture.[28]

Minnesota's BHGs have additional advice for retaining snags when doing a biomass harvest for fuel reduction or when harvesting biomass on a non-clear cut site. When conducting a biomass harvest for fuel reduction, retain only larger snags and pre-existing CWD, because these larger fuels do not contribute as much to the initial speed and flame length of a wildfire.[29] On non-clear cut sites (including selection or partial-cut), "be sure

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composed primarily of wood in advanced stages of decay and deterioration. (Missouri Woody Biomass Harvesting BMPs Manual p. 35)

[25] Missouri Woody Biomass Harvesting BMPs Manual p. 35
[26] Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 19
[27] Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 38
[28] Sustaining Minnesota Forest Resources p. 33
[29] BHGs for Forestlands, Brushlands and Open Lands p. 30

that the remaining stand includes a minimum of 6 cavity trees, potential cavity trees and/or snags per acre."[30]

Wisconsin's BHGs refer to the state's Silviculture Handbook (Chapter 24) on retaining snags, whereas Missouri's BHGs provide a table showing recommended number of den and snag trees to leave per acre, based on habitat type (heavily forested, riparian corridor, or bottomland hardwoods).[31] They also recommend not leaving snags near recreational use areas.[32]

Wildlife and Biodiversity

Research Findings

The effects of increased woody biomass harvesting on wildlife are similar to the effects of increased removal of biomass for fuel reductions. The effects of woody biomass harvesting on wildlife, just as they are for fuel reductions, are highly variable. In general, species which prefer open or early successional habitats will benefit from biomass harvesting whereas species which prefer closed canopy or dense understory vegetation will be negatively impacted by biomass harvests (Pilliod et al. 2006). Research on some specific species is more extensive than others. Gunnarson et al. (2004), for example, found the effect of woody residue removal adversely affected populations of ground-dwelling beetles. Every species has unique habitat requirements which vary depending on the geographic range, home range, patch size, and habitat elements (e.g. logs or cavity trees) found within habitat patches (McComb 2008). High

[30] BHGs for Forestlands, Brushlands and Open Lands p. 32
[31] Missouri Woody Biomass Harvesting BMPs Manual p. 4
[32] Missouri Woody Biomass Harvesting BMPs Manual p. 24

quality habitat is found near the center of a species' range, with lower quality on the outer edges. Larger species with greater home ranges tend to be less adversely impacted by disturbances than smaller species with smaller ranges. Natural stands, in contrast to intensively managed stands, have higher quality habitat in the form of vertical and horizontal complexity, dead and downed wood, understory vegetation, cavity trees and a rich forest floor (Hunter 1990).

Research on the effects of woody biomass harvests on biodiversity is also still in the development stages. Concerns have been raised about the biodiversity loss from large-scale land conversion from native forests to short rotation biomass plantations or intensive harvesting within native stands (Hesselink 2010). Biodiversity is affected the most among species that are dependent on the material removed by harvesting (dead wood, coarse woody debris, fine woody debris, non-merchantable trees).

Decomposers such as invertebrates, fungi and microorganisms use coarse woody debris for habitat (McComb 2008). Logs and stumps are used by amphibians and reptiles for cover and to regulate their temperature (Butts and McComb 2000). Small mammals nest in logs and use them for shelter as well as travel corridors (Bowman et al. 2000). Large, hollow logs are used for denning and resting by larger mammals (Bull et al. 2000).

The effects of woody biomass harvesting on biodiversity varies by species, harvest area, and duration of the harvest. Although dead and downed wood is critical to forested systems, there have been few studies so far which quantify the amount of dead wood or biological legacies needed to sustain wildlife populations.

State BHGs for Wildlife and Biodiversity

Pennsylvania's BHGs mention the potential benefits that biomass harvesting could have for wildlife. Biomass harvesting provides habitat for certain species reliant on early successional habitat and can revitalize habitat-deficient, high-graded stands.[33] The guidelines, however, also include a summary of the latest research on the potential adverse impacts of biomass harvesting.[34] They also include that biomass harvesting should not be done along stream or riverbanks or along bodies of water, because riparian vegetation is important for wildlife habitat, and biodiversity, amongst other benefits ("Situations and settings in which biomass harvesting may be harmful/unacceptable").[35] The guidelines include a list of wildlife BMPs to follow when harvesting biomass. Most importantly, however, is to leave 15-30% of harvestable biomass on site:

- Inventory habitat features on the property, and be aware of their relationship to surrounding lands.
- Protect sensitive habitats such as spring seeps, vernal ponds, riparian zones, cliffs, caves, and rubble lands.
- Develop missing special habitats, such as herbaceous openings for grouse and other species, through planting, cutting, or other manipulations.
- Protect cavity trees, snags, and food-producing shrubs and vines.
- Maintain overhead shade along cold-water streams.[36]

Furthermore, retain slash piles that look like they have been used by wildlife, as well as slash piles that are difficult to access by humans.[37]

Minnesota's BHGs stress that silvicultural practices (such as biomass harvesting) should resemble as closely as possible natural disturbance or natural stand development.

[33] Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 17
[34] Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 18
[35] Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 28
[36] Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 36
[37] Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 38

What is most lacking between harvested stands and those disturbed by Nature is the increased removal of woody debris in roundwood harvests. Minnesota's guidelines, therefore, try to minimize this gap by leaving biological legacies[38] in the form of leave clumps, snags, down CWD and slash (or FWD).[39]

Missouri's guidelines for preserving wildlife in a biomass harvest read like traditional forestry Best Management Practices. In many cases they don't specifically address biomass harvesting. The guideline's "Best Management Practices for Wildlife" suggest:

- leaving trees of various sizes and species for mast production
- using directional felling to avoid damaging mast trees
- gradually transitioning from heavily cut areas to lightly cut areas.
- Leaving travel lanes for wildlife in clear cuts
- Seeding logging decks, skid trails, and haul roads with green browse food plots.[40]

Before harvesting in High Conservation Value Forests (HCVFs), the guidelines suggest to do an on-site survey and to look for unusual wildlife and plants, and to look especially for:

- Unusual karst or geologic features.
- Types of wildlife or plants you rarely see or have never seen before.
- Large nests in the tops of trees, especially near water.
- More than the normal amount of very old or large trees. P.2 (In High Conservation Value Forest)

[38] defined as, "anything handed down or carried over from a pre-disturbance forest ecosystem, including green trees, patches of undisturbed forest ecosystem, surviving propagules, and organisms (e.g. buried seeds, seeds stored in serotinous cones, surviving roots, basal buds, mycorrhizal fungi and other soil microbes, invertebrates and mammals), dead wood, and certain aspects of soil chemistry and structure. (Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 37)

[39] BHGs for Forestlands, Brushlands and Open Lands p. 10

[40] Missouri Woody Biomass Harvesting BMPs Manual p. 3-4

Even if there are threatened or endangered species present, the guidelines say that a well-designed and supervised harvest may be possible and may even improve habitat for species.[41]

State BHGs for Endangered, Threatened, or Rare Species

Wisconsin's BHGs also allow for biomass harvesting where there are federal or state endangered or threatened species but only when it improves their habitat. In this case, management guidelines that maintain endangered or threatened species' habitat should be followed. Before harvesting, the guidelines instruct to determine the location and potential impact on any:

- State Special Concern Species and Species of Greatest Conservation Need (those not listed as Federal or State Endangered or Threatened)
- Element Occurrences (EO) of Wisconsin Natural Heritage Inventory (WNHI) Community Types
- Designated High Conservation Value Forests (HCVF)
- Communities demonstrating exceptional composition or structure, and sensitive sites (those not listed as WNHI EO or HCVF), including:
  Relict forests, old-growth forests, old forests, large bogs, vernal pools, seeps, cliffs, rock outcrops, ravines, and caves.[42]

Minnesota's BHGs suggest reviewing existing guidelines- especially those related to threatened, endangered, special concern (ETS) species, sensitive plant communities or cultural resources. Additionally, they suggest avoiding native plant communities (listed in Appendix J in the state's forestry BMPs). Biomass harvesting can take place in these areas if management plans include ways of keeping rare species habitat or if harvesting will restore degraded native plant communities.[43]

[41] Missouri Woody Biomass Harvesting BMPs Manual p. 2-3
[42] Wisconsin's Woody BHGs 2008 p. 4
[43] BHGs for Forestlands, Brushlands and Open Lands p. 19-20

Water Quality and Riparian Zones

Research Findings

In some biomass harvests, such as short-rotation woody biomass plantations, more fertilizers may be needed to boost production. In this case, water quality BMPs may need to be revised to ensure that these fertilizers don't enter surrounding water bodies (Shepard 2006). In most cases, however, the impacts of woody biomass harvesting on water quality and riparian zones are similar to the impacts of more intensive forestry practices. The continued implementation of well-researched and empirically-based forestry best management practices (BMPs) will be necessary and sufficient to protect water quality in forestry operations with a woody biomass component (Shepard 2006). Roads and landings continue to be the greatest source of sedimentation in a forestry operation so limiting the impact that these elements have on water quality is essential, yet unrelated to woody biomass harvests.

Riparian zones within forests are important because they slow floodwater, filter sediment and create bottomland soil. They need special care when harvesting timber/woody biomass in order to protect streambanks from erosion and to provide shade to cool water temperatures. Maintaining riparian buffers during a forestry operation prevents fluctuations in stream temperature that would otherwise occur if riparian sites were harvested (Bragg et al. 2009). Except when large amounts of woody debris are left in streams, thus limiting oxygen availability, biomass harvesting was not shown to degrade water quality within riparian zones (Chiono 2011). Traditional forestry practices limit harvesting along stream corridors and should continue to be followed in the face of more intensive biomass harvests. As long as existing, appropriate forestry best management practices are followed, increased removal of residues from a site should not adversely impact stream temperatures or water quality.

State BHGs for Water Quality and Riparian Zones

States with biomass harvesting guidelines have forestry best management practices which constrain forestry practices within riparian zones. The harvesting of biomass from within riparian zones is generally limited in the six existing state biomass harvesting guidelines. Missouri's BHGs, however, suggest leaving a variety of tree species of different sizes in a riparian zone (at least one third should be left, although one-half to two-thirds is recommended). Trees left in place along stream banks protect water and soil quality and serve to cool water temperatures. Heavy equipment should be used with caution within a SMZ, and any logs or woody biomass should be cabled out of the first 25-foot primary zone. The pre-harvest plan should include which trees to leave standing.[44]

Soil Productivity

Nutrient Impacts

Most of the research on the effect of nutrient removal from increased woody biomass harvesting comes from studies comparing whole-tree harvesting to stem-only harvesting (Saarsalmi et al., 2010). In stem-only harvesting, significant woody material is left on-site and only the tree bole is removed. Studies show that stem-only harvests

[44] Missouri Woody Biomass Harvesting BMPs Manual p. 8

have minimal impact on soil nutrient loss, as material left on-site allows for soils to replenish (Clinton et al., 1996). Whole-tree harvesting removes more nutrients, but this depends on the nutrient content and type of material removed, as well as the tree species and the season in which the harvest occurs. Foliage has the greatest above-ground nutrient content, followed by small twigs, branches, and stems (Kimmins, 1977). The removal of even a large amount of nutrients from a site, however, may also only be a fraction of the total amount of nutrients on a site (Van hook et al., 1982). Depending on the type of material and decomposition rates, woody biomass nutrients may either be taken up by trees or leach from the site.

Compared to other regions, the South has low soil carbon and nitrogen concentrations, in part a reflection of the history of an intensive agricultural production past and also the nature of soils of the region. (see Table 1).

Region	Carbon percent	Nitrogen percent
Northeast	4.61	0.27
North Central	3.17	0.201
South	2.11	0.108
Interior West	3.14	0.141
Pacific West	3.86	0.173

Table 3. Average soil carbon and nitrogen concentration in the upper 10 cm in forest soils, measured by Forest Inventory Analysis (FIA) crews (reproduced from Chiono 2011)

In Southern mixed hardwood forests, warm temperatures and high humidity levels lead to rapid decomposition rates in comparison to Northeastern hardwood forests. Studies comparing clear-cut mesic (wet) sites to clear-cut xeric (dry) sites found that mesic sites had higher levels of potassium than either xeric or control sites after one year (Abbott and Crossley 1982), but that calcium levels did not vary between the sites, suggesting higher residue decomposition rates on wetter sites. A Southern Appalachian study by Clinton et al. 1996 found that forest floor nitrogen levels recovered to nearly pretreatment levels (90%) within 2 years of cutting and burning. Elliot et al (2002) studied the rapid recovery of a Southern Appalachian forest following a clearcut and found that after twenty years, there were slightly lowered levels of calcium, potassium and magnesium than either nitrogen or phosphorus. Johnson and Todd (1998) compared stem-only harvested sites to whole-tree harvested sites after 15 years and found that although higher soil and foliar concentrations of calcium, potassium and magnesium were in the stem-only harvested sites, there was no decreased biomass accumulation on the whole-tree harvested site or the sign of deficiencies of these nutrients. No differences in soil nitrogen, foliar nitrogen or phosphorus were found between treatments. As in many forest types of the South, high temperature and humidity led to the almost complete decomposition of forest residues over the 15-year study period. From an atmospheric carbon balance perspective, the authors of the study argue that it would have been better to have used forest residues as an alternate energy source instead of allowing them to rot on-site, as this would have resulted in a net savings in the amount of carbon dioxide released.

In southern loblolly pine plantations, the research is less conclusive about the nutrient effects of woody biomass removal during or following an intensive harvest. Carter et al (2002) found a significant drop in soil carbon and nitrogen in both whole and stem-only harvesting but he noted that both returned to pre-treatment levels after two growing seasons. Vitousek et al. (1992) found that practices such as site preparation had a greater impact on nitrogen levels than the intensity of the harvest and that after 5 years there was a negligible difference in nitrogen levels between whole-tree and stem-only harvests. Scott and Dean (2006) found that on marginal soils or soils poor in phosphorus that biomass accumulation decreased after 10 years but that adding phosphorus restored biomass levels.

The limited number of long-term studies on the effects of increased woody biomass removal on nutrient levels as well as the lack of a standardized research approach makes it difficult to draw any strong conclusions. However, the suggestion is that for the near future, forest nutrients are sufficient for woody biomass harvesting. Numerous meta-analyses have found few long-term effects of increased woody biomass harvesting (Johnson and Curtis 2001).

Physical Compaction

Heavy foresty equipment compacts soil particles, limiting the exchange of gases, water and nutrients in forest soils. (Adams1981). The risk of soil compaction in a biomass harvesting operation depends on the type and use of forestry equipment. Harvests with a biomass component have no added water quality or compaction effect than a traditional harvest if whole trees are brought by skidder to the landing site. If additional equipment is used to gather tops, branches and small trees that are left in the forest, a logging site will be traversed more frequently, but these vehicles cause less compaction than log-moving equipment. Recent technological advances and revised practices have reduced the negative impact that harvesting has had on soil and water impacts.   There is some concern that biomass harvesting will increase stand re-entry resulting in increased negative effects on soils.

State BHGs for Soil Productivity

The main soil productivity precaution presented in state biomass harvesting guidelines is to not remove the litter layer, stumps, or root systems. Wisconsin's guidelines limit FWD harvesting on shallow soils (lithic bedrock within 20 inches of the surface), dry, nutrient-poor soils, and dysic histosols.[45] In Minnesota, when their current site-level guidelines are followed, biomass harvesting is seen as no more of a threat to soil health than conventional forest harvesting. Where it does have an increased effect is with nutrient removals, because removing biomass inevitably removes more nutrients. Nevertheless, long-term research studies suggest however that for most soils, there are enough nutrients to support a large number of biomass harvests without causing undue harm[46].

A secondary concern with biomass harvesting affecting forest soils is with harvesting on steep inclines.   Minnesota BHGs caution to not harvest on steep slopes (>35% incline), "over and above the tops and limbs of trees that are usually taken out in a roundwood harvest under existing guidelines".[47] Biomass should be harvested when the soil is dry to avoid rutting, compacting, and erosion. (Forest Wildlife and Soil Management).[48]   Pennsylvania BHGs stress that woody debris, brush and shrubbery are

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[45] Wisconsin's Woody BHGs p.9
[46] BHGs for Forestlands, Brushlands and Open Lands p. 15-16
[47] BHGs for Forestlands, Brushlands and Open Lands p. 23
[48] Missouri Woody Biomass Harvesting BMPs Manual p. 1

important at slowing the rate of run-off from rain, ice or snowmelt, and in preventing rain-splash erosion. [49]

Forest soils can also be affected when loggers re-enter a site following a harvest. After a forestry operation, residue often remains piled on-site. The preference is to remove this biomass at the time of harvest. BHGs are unanimous in cautioning against re-entry. Minnesota's BHGs warn that, "any re-entry onto a site may impact regeneration and disturb rehabilitated infrastructure". If re-entry is necessary, it should be along existing infrastructure (roads and landings).[50] After re-entering a site, re-install erosion control measures on roads and landings, including vegetative cover and water diversion devices. Avoid re-entering sites across non-frozen wetlands.[51]

State BHGs for Silviculture

States' biomass harvesting guidelines in general recognize the potential that woody biomass harvests have to meet a variety of silvicultural goals, including site preparation, salvage operations, fuel reduction, and the maintenance of forest health and aesthetics. Missouri's guidelines have recommendations for the number of trees to retain during a biomass harvest[52]. Wisconsin's guidelines suggest leaving 5% of the area in reserve patches that include dead wood, cavity trees and green trees[53]. Missouri's guidelines note that prescribed fire can be used after a biomass harvest for site preparation or fuel management[54]. Minnesota, Missouri and Pennsylvania caution

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[49] BMPs for Pennsylvania Forests p. 29
[50] BHGs for Forestlands, Brushlands and Open Lands p. 16
[51] BHGs for Forestlands, Brushlands and Open Lands p. 24-25
[52] Missouri Woody Biomass Harvesting BMPs Manual p. 1
[53] Wisconsin's Woody BHGs p.4
[54] Missouri Woody Biomass Harvesting BMPs Manual p.4

against re-entering a harvested stand to remove biomass. Additionally, once regeneration has begun, stands should not be re-entered. If re-entry does occur, brush piles that are in use by wildlife should be avoided and any erosion control measures should be put back in place.

The visual quality of sites that have been harvested for biomass can sometimes be as important (in terms of public perception) as the harvesting practices themselves. An aesthetically harvested site is less likely to engender public criticism, improves recreational value and also presents less of a safety hazard. Pennsylvania's BHGs offer guidance on improving the visual effects post-harvest:

- Cut all broken trees, leaners, and badly scarred trees except where they are being retained for a specific purpose.
- Locate landings away from public view.
- Design cutting areas to take advantage of natural contours; avoid straight lines when possible.
- Lop tops of harvested trees near a public road, frequently used trails, recreational areas, and residential sites.
- Clean up all refuse daily.
- Regrade and seed landings, using native grasses wherever possible.
- Keep mud off public roads and out of streams.
- Consider leaving a visual buffer along traveled roads.[55]

Missouri's BHGs also offer advice on practices that protect or improve views and recreation values. In areas near roads and other places where harvesting may be visible to the public, they advise to slash tops within 100 feet of public roads or visually sensitive areas, so that debris is 3 feet or less off the ground. They also suggest locating landings out of sight of the public, and to leave a forested buffer strip between the landing and public roads. Additionally, Missouri guidelines suggest:

[55] Guidance on Harvesting Woody Biomass for Energy in Pennsylvania p. 37

- Shape cutting areas to shorten line of sight, and minimize the area that can be seen from one viewpoint. Use group selection harvesting rather than regeneration cutting (clear cutting).
- Leave scattered groups of trees and clumps of woody vegetation in large cut areas.
- Create visual screens along roads and streams with irregular-shaped borders, uncut or partially cut buffer strips, and feathered forest edges.

Abrupt changes from harvest areas should be avoided, as well as leaving safety hazards next to recreational areas (snags, large dead limbs, etc.) People object when they see piled trash, snapped trees, wasted logs, rutted roads, and exposed eroding soil. A well-conducted harvest will leave the landscape looking tidy. [56]

Disturbance

Forest disturbances, including by wildfire, insect or storm, present an opportunity for increased woody biomass harvests that must be balanced with sustainable levels of harvest following these occurrences. Biomass harvesting can in some cases reduce the risk of catastrophic fires, as harvests remove ladder fuels (e.g. small trees, shrubs, shade-tolerant trees with crowns extending to the forest floor) which would otherwise carry fires into the forest canopy.

Climate change is leading to an increasing number of insect epidemics as warmer winters are allowing pests such as the hemlock woolly adelgid to survive to impact the carbon cycle (Nuckolis 2007). The role of biomass harvesting needs to be considered in the event of the increasing number of these catastrophic forest events. Biomass harvesting can be seen in a positive light as an opportunity to reduce the susceptibility of

[56] Missouri Woody Biomass Harvesting BMPs Manual p. 24

forests to pests and disease, provided it is site-specific and conducted in compliance with existing best management practices.

Conclusion

North Carolina woody biomass guidelines should be based on the best research on the region-specific effects of harvesting on dead wood, biodiversity and wildlife, water quality, and soil productivity. Key to the guidelines should be the retention of dead and downed wood (Evans 2010). Optimal dead and downed wood retention levels will vary by ecosystem, nutrient availability, species of conservation concern, and area of harvest. Southern pine forests, for example, have less dead and downed wood than southern Appalachian hardwood forests, partly a reflection of past intensive agricultural practices.

Guidelines need to address how the retained wood should be distributed across a site (e.g. evenly or in clumps—piles or rows), which will depend on the various species present, as some species prefer clumped formations while others benefit from distribution. A single target retention level, such as dry tons/acre, is not advised due to the site variation needed to sustain ecological functions (Hagan and Whitman 2006).

Biomass guidelines should consider the type, amount and distribution of dead wood used by wildlife. Some species are more reliant on these structures and more research needs to be conducted on harvesting's effects on these species, especially those listed as rare, threatened or endangered by the federal or state government. The trade-off between maintaining wildlife habitat and mitigating CO2 emissions from high residue decomposition rates needs to be carefully considered in Southern forest types. As some studies note, it can be preferable to harvest woody biomass as an alternate energy source to fossil fuel, rather than allow it to continue releasing atmospheric CO2 through decomposition on-site (Johnson and Todd 1998).

Although at present there is little concern that existing forestry best management practices would be insufficient at protecting water quality during a biomass harvest, guidelines should address the amount and type of harvesting allowed within riparian zones. North Carolina's BMPs for Water Quality address soil productivity, however biomass guidelines should include recommendations on how much fine woody debris and forest floor should be retained to prevent soil erosion. Specifically, NC's guidelines should consider off-limits to intensive harvesting any areas with poor nutrients or highly erodible soils.

Like other states' guidelines, North Carolina biomass harvesting guidelines should caution against re-entering a stand to collect biomass, as multiple entries increases the amount of compaction, rutting, and disturbance to retained structures. Additionally, guidelines should acknowledge the potential benefits of harvesting, including fire risk reduction, lowered site prep costs, slash management, and reduced insect and disease levels. Furthermore, guidelines should address the appropriate amount of biomass that may be removed during a salvage operation.

The NC Forest Service indicates that they may have to soon (within four to five years) revise forestry BMPs to include woody biomass for energy or fuel production due to changing political, regulatory, social, and market-driven forces, and special interests representing specific forestry activities or forestry-related objectives (Gerow 2011). Although silvicultural practices vary from state to state depending upon species distribution, harvesting practice and site characteristics, similarities lie between harvesting recommendations regardless of geographic region. The recommendations presented here should serve as a background for NC's BMP technical committee in developing guidelines for the state.

The Southern US is a biologically diverse region of the nation that is being increasingly threatened by development. Habitat loss is the main cause of species loss as lands have been converted to agriculture, industry and urbanization[57]. North Carolina's population is expected to increase by 54.6% between 2000 and 2030 (US Census Bureau 2000). With natural areas increasingly encroached upon by development, forests remain as one of the last refuges for wildlife. If done sustainably, managed forests can maintain biodiversity, meet our renewable energy goals, and provide an additional source of income for those whose lands would otherwise be developed.

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[57] Twenty-two species of birds, 33 of mammals, 7 amphibians, and 17 reptiles are listed as threatened or endangered in the South (Trani 2002).

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