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Biomass retention following whole-tree, energy wood harvests in central Maine: Adherence to five state guidelines

Julia I. Briedis, Jeremy S. Wilson, Jeffrey G. Benjamin, Robert G. Wagner*

School of Forest Resources, 5755 Nutting Hall, University of Maine, Orono, ME 04469, USA

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ABSTRACT

The expansion of the bioenergy industry in Maine has led to an increase in integrated roundwood and energy wood whole-tree harvesting. A better understanding of the amounts of logging residue left unrecovered on whole-tree harvested sites will enable the refinement of available forest residue estimates for Maine and the assessment of the potential effect of such harvesting on forest health. Several states have developed biomass harvesting guidelines in response to concerns generated from an expanding bioenergy industry. In this study downed wood and snags were inventoried on twelve sites in central Maine that had recently been whole-tree harvested for roundwood and energy wood. The percentage of harvested material retained as residue on the study sites was determined. On average, 45% of the energy wood generated during the harvest was left on site. This removal efficiency must be considered when developing forest residue availability estimates. Additionally, the volumes of logging residue were compared to measurable criteria from biomass and biodiversity guidelines of several states. We found that enough fine woody material (<15 cm diameter) remained on the harvest sites to meet the guideline criteria; however, the quantities of coarse woody material (≥15 cm diameter), large logs (≥38 cm dbh), and snags (≥25 cm dbh) were insufficient to meet the guideline criteria. These deficiencies likely resulted from prior forest practices rather than from the current energy wood removal. Retaining more trees of larger sizes in the future can address this concern.

1. Introduction

Environmental, economic, and renewable energy policy incentives have prompted an increase in woody biomass harvesting in recent years. The current level of biomass harvesting in Maine is the highest recorded to date [1] with a three-fold increase in the green weight of harvested biomass chips in the last decade [2]. As the incidence of such harvesting has escalated, the integration of woody biomass extraction with traditional roundwood timber harvesting has become increasingly common throughout the United States. Woody biomass that is harvested directly from the forest, referred to in this paper as energy wood, may become particularly important in the Northeast as a bioenergy feedstock [3]. Energy wood, termed according to its end use, is the material generated in a harvest operation that is ultimately chipped and used for energy generation [4]. A significant portion of this energy wood is in the form of tree tops and branches; however, additional sources may include small diameter stems, downed coarse woody material (CWM), snags, cull trees, and depending on market dynamics, occasionally pulp and sawlog quality logs. Whole-tree harvesting

* *Corresponding author.*
E-mail addresses: juliabriedis@gmail.com (J.I. Briedis), jeremy.wilson@maine.edu (J.S. Wilson), jeffrey.g.benjamin@maine.edu (Jeffrey G. Benjamin), robert.wagner@maine.edu (R.G. Wagner).
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is an efficient and economical method for simultaneously extracting logging residue and roundwood, which is one reason for its widespread use in Maine.

For the bioenergy and bioproducts industry to expand in the state, Maine forests must be able to sustainably supply the industry with logging residue and other energy wood material. A crucial step to sustainably managing Maine's forests with the addition of the bioenergy and bioproducts markets will be to recognize the present and future availability of the energy wood resource within the state so that the potential growth and limits of the industry's expansion can be further understood. Several availability estimates have been generated in recent years. The Maine Forest Service [3] and the University of Maine's Margaret Chase Smith Policy Center [5] have each developed estimates of sustainable forest residue availability specific to the state of Maine, while the Oak Ridge National Laboratory has produced a report suggesting a nationwide sustainable level of available logging residue [6].

The mechanical inefficiencies associated with biomass removal result in a portion of the total residue left in the woods. It is important for the accuracy of the supply estimates that the percentage of unrecovered logging residue be accounted for; otherwise, the results could potentially overestimate available residue. The estimates in the above mentioned reports did account for unrecoverable residue; however, since there are no recent studies that have determined the percentage of residue being left on the forest floor during harvest operations, their predictions for the percentage of unrecovered material are based on biodiversity guidelines suggestions for retention [3] or readjusted percentages from outdated studies [6]. Thus, a more recent study is warranted to determine the amount of logging residue left on harvest sites where biomass is extracted simultaneously with roundwood.

Not only are unrecovered residue amounts important for state- and nationwide biomass availability estimates, but they are also important for assessing if enough material is being left behind to sustain a healthy forest ecosystem. As the incidence of energy wood harvests has increased [2], so too have concerns over the additional removal of logging residue, snags, and downed wood from harvest sites [7,8]. These materials, when left on-site, provide important ecosystem values, including providing wildlife habitat, nutrient cycling, and the protection of water quality.

Snags and large downed woody material are critical to many species of wildlife by providing foraging habitat, shelter, transport, and denning or nesting sites. Hagan and Grove reported that in the Northeast, 18 mammal species, 23 reptile and amphibian species, 28 bird species, and hundreds of invertebrate species rely on snags and downed wood during some part of their life [9]. Thus, the importance of these structural features within a forest is considerable. Many animals select deadwood of a particular species, size, and stage of decay [10]. Therefore, maintaining an array of sizes and types of deadwood could be helpful in preserving biodiversity. Large diameter snags and downed logs, however, are of particular importance. This larger material is most persistent in the environment [11] and is host to wildlife whose habitat requirements are limited to large diameter deadwood [12]. As such, it provides habitat for a greater diversity of species than material of smaller sizes [13,14].

Nutrients that get recycled into the soil from the decay of fine woody material (FWM) are an essential component of a site's nutrient pool. Because the fine branches and foliage contain a high proportion of a tree's nutrients [15–17], they are particularly important to a site's fertility. Excessive removal of nutrient inputs could lead to reduced long-term site productivity. It is, therefore, imperative that excessive amounts of these fine branches are not removed from the forest. The impact of forest residue removal on the productivity of a site will likely depend on the initial fertility of the site and the extent of FWM removal. Nutrient poor sites have the potential to be the most negatively affected by energy wood harvesting [18,19]. Fine wood can also play a vital role in protecting soil from erosion and rutting during harvest operations. Since skid trails are subject to the highest degree of forest floor disturbance [20], the placement of logging residues on the trails helps to minimize sedimentation and excessive rutting from machine traffic [21]. Scattered residues on the forest floor also reduce erosion by slowing the movement of surface runoff [22].

Several states including Minnesota [23,24], Maine [25], Missouri [26], Wisconsin [27,28], and Pennsylvania [29], have been prompted by the rapid increase in energy wood harvesting to develop biomass harvesting guidelines that address the ecological importance of forest residue and other material potentially harvested for energy wood. These guidelines, specific to harvests involving energy wood extraction, are intended to be used in conjunction with pre-existing biodiversity and water quality harvest guidelines. Each of the guidelines address state-specific concerns particular to special features or protected areas in addition to general site guidelines. Included in the general site guidelines are suggestions pertaining to riparian areas, soil productivity, skid roads, and the retention of ecological features including snags, mast trees, wildlife trees, and downed wood. Of particular interest in this study, however, was the proportion of logging residue remaining on the harvest site, and the retention of snags and large downed woody material.

It is not well understood how integrated roundwood and energy wood whole-tree harvesting affects the presence of downed wood and snags, and consequently how this harvesting method impacts their associated ecosystem values. While it is evident from scientific literature that fine and coarse downed woody material and snags are essential attributes in a healthy forest, existing studies have not quantified the amount of each material that should be present on site to maintain healthy ecosystem functioning [30]. The diversity of forest communities, each of which may require a different amount of woody material, complicates the development of general site attribute criteria. The creation of general site guidelines, therefore, will most likely satisfy the requirements of some communities while maintaining deficiencies in others [14]. It would be impractical to create guidelines for every forest type; therefore, general guidelines are created as an attempt to satisfy the requirements for most forest conditions. With an understanding of these limitations, the biomass harvesting guidelines of Missouri, Wisconsin, Pennsylvania, and Minnesota set target residual quantities for downed wood and snags. Though the target quantities differ slightly among these state