Economics and Logistics of Biomass Utilization: The Superior National Forest

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Summary. Forest fires pose a great risk to nearby communities and dwellings. Many forest managers work to reduce such risks by managing fuels. Efforts are underway to understand the economics and the logistics required to extract harvested forest biomass for utilization instead of the conventional disposal method of piling and burning on-site. Benefits from biomass utilization are multiple and include reduced impacts to air quality, improved forest health, economic opportunities, local renewable energy production and climate change mitigation. Trials in the Superior National Forest examined the feasibility of using conventional equipment to extract and utilize forest biomass compared with disposal of biomass with pile and burn techniques. Factors that increase the costs of biomass utilization include: machinery down-time, distance to end users, low biomass price, size of the harvest unit, forwarding distance, the number of machines hauled to sites to complete small sized operations, the modest amount of biomass removed per acre and applying prescriptions that were not designed for extraction logistics. Interviews with forest machine operators during and after the trials helped clarify factors and logistical considerations which could be applied to help reduce the cost of future operations.

Keywords. *Biomass, Extraction, Utilization, Fuel, Economics, Forestry, Logistics*

Introduction

In 2005, the Institute for Agriculture and Trade Policy received a Healthy Forest Restoration Biomass Utilization Grant to conduct nine test biomass harvests in the Superior National Forest (SNF) in northeastern Minnesota. Partners in the project included teams of researchers from the University of Wisconsin-Stevens Point (UW-SP), and the University of Minnesota (UM), staff of the Superior National Forest, the Laurentian Energy Authority (LEA) - a partnership of two wood-burning public utilities in the area, and a cooperative of loggers - Forest Management Systems. Biological and physical research and analysis was led by the UW-SP team, while the economic analysis was led by UM researchers.

The study partners agreed to focus the biomass test harvests on sites that had no potential to produce positive revenue under traditional forest management for pulpwood or saw timber. Studies were designed to provide information on two sets of barriers to the development of biomass markets in the region: 1) economic and operational issues faced by loggers; and 2) environmental constraints of interest to land managers, scientists and policy-makers involved in developing and refining biomass harvest practices. In the course of the study, it was determined that administrative systems and constraints formed a third important set of barriers.

In this chapter we conduct cost benefit analyses of harvesting forest biomass for utilization versus disposal through conventional pile and burn. To make this a feasible operation, costs of

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harvesting are compared with alternative fuel treatment costs. Findings indicate that biomass harvesting and utilization alone is not cost effective. However, by running a sensitivity analysis, key factors were determined that could reduce costs below that of conventional disposal. Input from forest machine operators has helped explain some of these key factors that contribute to the feasibility of biomass extraction operations.

Study Background

In 1994, the Minnesota State Legislature desired to assist emerging renewable energy producers to find a secure market. The state required that one of its regulated power utilities buy 125 megawatts (MW) of power produced using biomass under 20 year contracts. (The quantity was subsequently reduced to 110 MW.) In 2005, the final 35 MW of this power was secured, with a contract between Xcel Energy and the Laurentian Energy Authority (LEA), a partnership of the Virginia and Hibbing public utilities (two communities in northeastern Minnesota).

The LEA proposed to utilize approximately 300,000 tons of green biomass annually from the region to provide at least 75% of the fuel necessary to produce the 35 MW of baseload power (power provided on a continuous basis throughout the year, regardless of demand). Other power producers in the region already utilized biomass as a fuel, and several palletizing operations and more power plants were being openly considered by other entities. Very little, however, was known about the full costs of harvesting biomass from small diameter material for energy. Existing studies have analyzed the cost of biomass harvesting as an added value to timber and forest management operations.

Many resource managers and members of conservation groups were concerned that existing forest management guidelines were developed without consideration of additional removal of biomass from small diameter material and residue. They were concerned that a strong interest in renewable energy might lead to overharvest of the smaller biomass material, with detrimental effects on forest soils and productivity, water bodies, wildlife and biodiversity.

In 2005, the Minnesota legislature required the Minnesota Forest Resources Council and the Minnesota Department of Natural Resources to prepare Forest and Brushland Biomass Harvest Guidelines. The LEA contributed $150,000 in funding towards this effort. The biomass test harvests in the SNF were conducted during the development of these guidelines, and provided some relevant information to the scientific committee developing them. The result was the publication in January of 2008 of the first-of-its-type Biomass Harvest Guidelines by the Minnesota Forest Resources Council. Subsequently, neighboring states and Canadian provinces have used the Minnesota Guidelines as a starting point for the development of their own versions.

The widespread certification of most public forestlands in Minnesota under either or both the Sustainable Forest Initiative (SFI) or the Forest Stewardship Council (FSC) standards, assured that millions of acres of public forest lands would be managed in accordance with these new "voluntary" biomass harvest guidelines.

Study Trials

Biomass removal was planned for 9 different sites in the Superior National Forest. Six of those sites were located along the Caribou Trail and three in the Pitcha Lake area (see figure 1). Removal was planned using different harvesting systems and techniques. Products removed from sites included wood chips, bundles and roundwood (pulpwood). Roundwood extraction was limited to only one treatment unit: 37-5. Most products were trucked to the LEA wood yard approximately 150 Miles from the Caribou Trails treatment units and approximately 85 miles from the Pitcha Lake treatment units, excepting roundwood, which was trucked to a pulp and paper plant. The SNF timber sales administrators and silviculturists monitored the trials. The study posed two main questions:

- First, concerning the economics of harvesting and selling biomass: *Can the production and sale of biomass for energy reduce the costs of mechanical fuel treatments for the Forest Service?; and*
- Second, concerning the logistics of biomass harvesting operations, from the perspective of the forest machine operators, *What can we learn to make the logistics of forest biomass production more efficient?*

To address the first economics-related question, the harvesting and delivery costs less the income from the sale of the biomass were compared with the conventional cut, pile and burn treatment costs. To address the second operations-related question, semi-structured interviews were carried out with forest machine operators involved in those trials. Triangulation of findings from other sources, observing the operations and follow up phone interviews complimented the on-site interviews. Research questions sought to inquire about three main areas: 1) How different were these operations from the operators' regular harvesting operations? 2) What adjustments were necessary? and 3) What lessons could be passed on to future biomass energy harvesting operations? Further detailed information about the economic methods, harvesting operations and the interviews could be found in Abbas 2007, Abbas et. al.2008 and Arnosti et. al. 2008.

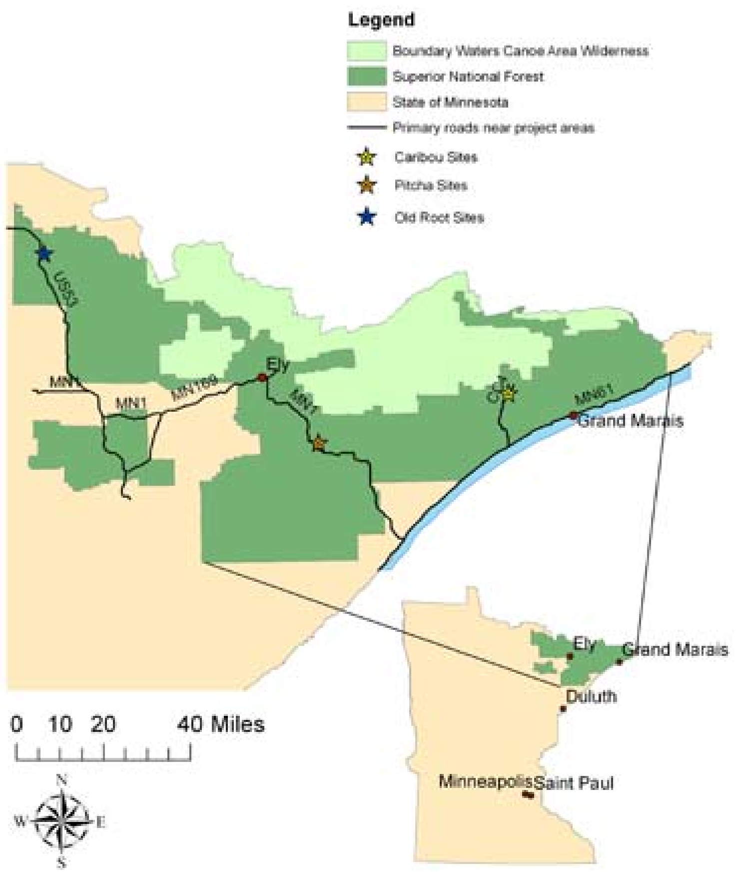


Figure one: Treatment units were in the Caribou Trails and Pitcha Lake areas

Economic Analysis

Cost methods

Harvesting and delivery costs less the income from the sale of the biomass removed were compared with the conventional cut, pile and burn treatments costs. Costs were calculated using the Forest Engineering Research Institute of Canada standard machine costing method. Input machinery costs were based on estimates for 2007 new machines. Data were collected from machine owners, manufacturers and dealers. Productive machine hours were calculated during the trials and collected from machine operators during and after harvest operations. Areas harvested were measured using handheld GPS units. Biomass tonnage recovered per unit of harvest was determined from weight slips measured in lbs. at the end users, and converted to U.S. short tons (1 lb. equals 0.0005 tons). Cost assessments were calculated on a per-acre basis for each treatment unit, and for the developed sensitivity analysis scenarios.

Systems

Three harvesting systems were designated in those trials:

• System one implemented in treatment units #13-10, 13-1W, 37-1, 37-5 and Pitcha South combined harvesting loose biomass for energy using a cut and pile, forward, loading grinder, grind, and truck-van sequence.

• System two implemented in treatment units # 38-69 and 13-1E and Pitcha North and Pitcha “C” sites combined bundling loose biomass for energy using a cut and pile, bundle, forward, and truck-trailer sequence.

• System three implemented in Treatment unit # 37-5 in the Caribou Trail site combined a roundwood option with system # 1, the option involved roundwood harvest using a cut and pile, forward, and truck-trailer sequence.

Revenue
Biomass delivered at the wood yard was sold for $21.00/ ton. Bundled materials were sold for $14.00/ton since $7.00/ ton were deducted for future grinding costs. In treatment unit 37-5, roundwood was removed in conjunction with prescription residue. Twenty tons of harvested roundwood were sold for energy, while 66 tons of roundwood were sold for $60.30/ton for pulp and paper. Table 1 shows the summary of the material removed per treatments unit.

Table 1: Description of study trials and products removed

Treatment Unit	Tons/acre
Unit 13-10 (woodchips)	8
Unit 13-1W (woodchips)	14
Unit 37-1 (woodchips)	7
Unit 13-1E (bundles)	6
Unit 38-69 (bundles)	4
Unit 37-5 (woodchips and roundwood)	13
PITCHA North (low density, bundles)	3
PITCHA C (high density, wood chips)	7
PITCHA South (medium density, wood chips)	10

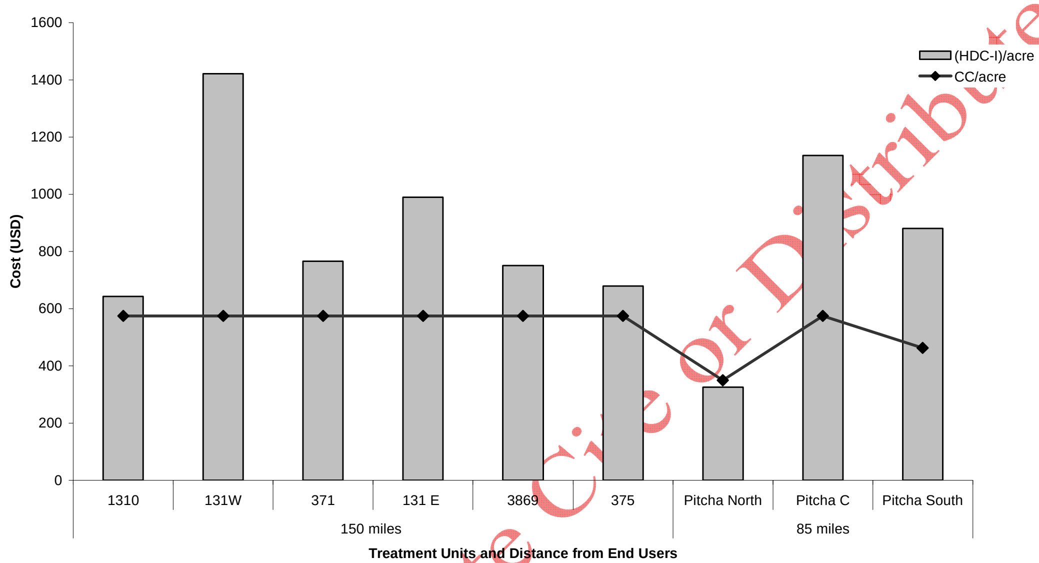
Analysis

The decision analysis compared per-acre harvesting and delivery costs (HDC) less income (I) from the sale of biomass with conventional treatment costs (CC). If (HDC – I) was larger than CC, then a biomass option was more costly than CC. If (HDC – I) was less than CC, then a biomass option reduced conventional treatment costs.

Figure 2 compares the harvest and delivery cost, less the income from the biomass sale, with the conventional treatment costs. Conventional treatment costs varied from one site to the other depending on the biomass density. Caribou Trails units (dense sites) were compared with a conventional cut, pile and burn cost of $575/acre. Pitcha Lake sites were classified as high-, medium and low-density sites. Conventional treatment costs were calculated at $575/acre, $462.5/acre and $350/acre, respectively. Unlike the Caribou Trails units, Pitcha Lake sites were of several sizes. The average unit size in Caribou was 11.5 acres; the range in unit size varied from 10-15 acres. Due to logistical and administrative constraints, areas treated in the three Pitcha Lake units ranged from 4 to 23 acres. Naturally, costs in the smallest units were very high, due to the significant harvesting and delivery expenses dedicated to small sized areas.

Average biomass removed from the Caribou trail units was 8.4 green tons/acre of biomass from small-diameter trees and roundwood versus 5.0 green tons/acre on the Pitcha Lake units. Machinery breakdown, distance to end users, low income from sale of material, prescriptions that were not designed for extraction logistics, size of the harvest treatment, forwarding distance, the number of machines trucked to sites to complete small sized operations and the modest amount of biomass removed pre acre, were all factors that contributed to the economic disparity shown in figure 2.

Figure two, per Acre Harvesting and Delivery less Income from Biomass Sale compared with Pile and Burn costs



Sensitivity Analysis

To examine conditions that would make biomass utilization economically favorable, six hypothetical scenarios were developed for the Caribou Trails treatment units to compare with the study trials. Three hypothetical scenarios were developed for the Pitcha Lake treatment units. Pitcha Lake units were located 85 miles from the biomass market whereas Caribou Trails units were as far as 150 miles away. The scenarios and sensitivity analysis made the following assumptions:

- Total biomass amount removed was not varied. This was assumed since the SNF predetermined the guidelines, which are likely to remain constant if no new prescriptions are designed and implemented.

- Hypothetical scenarios tested a variety of distances to biomass markets and for machine hauling ("mobilization"). In each scenario, biomass and machine traveling distances were assumed to be equal.

- Fully loaded biomass shipments were assumed for the sensitivity analysis scenarios. In study trials woodchip vans were loaded with chips from a single site, to clearly identify the tonnage

removed from each treatment unit. Thus, some trucks were not fully loaded. In an actual biomass harvesting operation, woodchip vans would be loaded to the maximum legal weight.

- All machines are hauled just once to the harvest site. (During the trials there were occasions when machinery broke down and was hauled from the site for repairs, and hauled back to the site to complete the experiments. In normal conditions, loggers felt that it was reasonable to assume that properly maintained machines, especially when new, would not break down.)

The result of the sensitivity analysis (see figures 3 and 4) indicated that under certain conditions biomass harvesting would indeed result in cost reductions for the land manager. Those cost reductions could be found even under site prescriptions that were not designed with biomass extraction operations in mind. All biomass harvest operations could be made more efficient with application of the lessons learned from these trials.

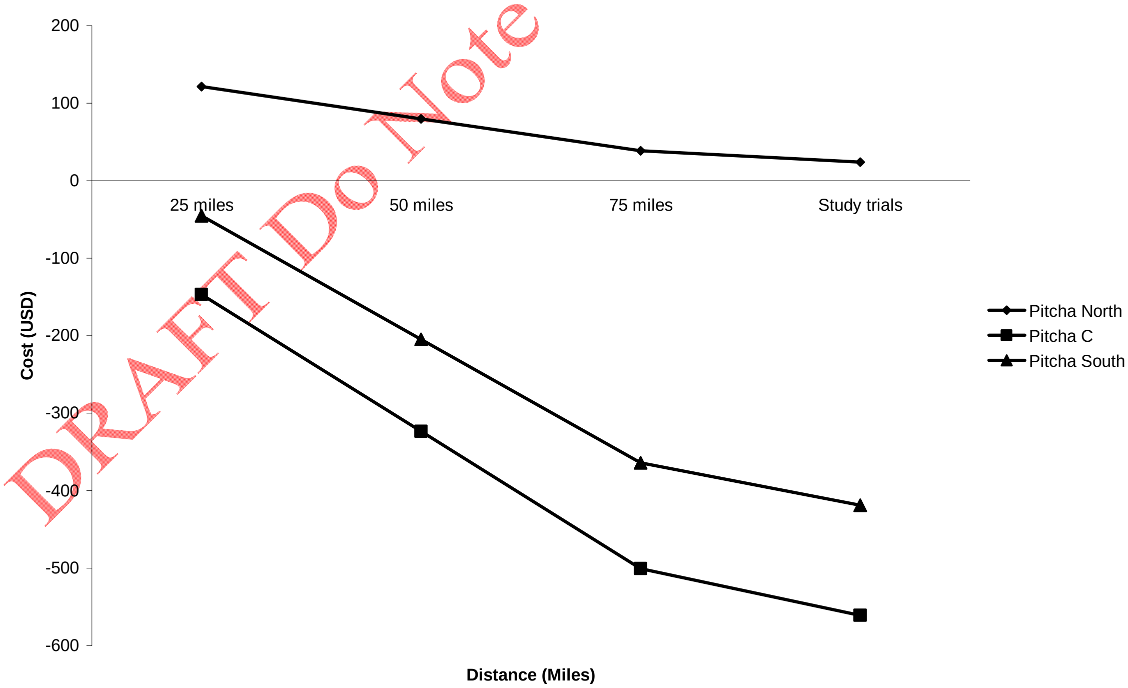
Sensitivity analysis results

Biomass treatment options in units 37-5 and 13-10 reduced conventional costs within a 100-mile radius of biomass markets. In the 75-mile scenario, the hand felling 38-69 treatment unit almost broke even with the conventional fuel removal treatment costs per acre showing just $2.00/acre difference between both analyses. The 50-mile scenario demonstrated that four out of the six units potentially would reduce treatment costs. Units 13-1W (chips) and 13-1E (bundles) did not demonstrate any cost reduction potential at any distance to market.

In the hypothetical scenario adjustments to the study trials, units 13-1W and 37-1 actually demonstrated higher costs in the 150-mile scenario versus actual trials, since the actual mobilization distances were shorter than 150 miles. Biomass treatment costs for the Pitcha Lake North site were slightly below conventional costs for the actual haul distance to market of 85-miles. With the small treatment unit sizes (four and six acres) in the other two Pitcha sites, cost reductions versus conventional treatment were not possible even within a modeled 25-mile distance to markets.

Figure 3, Caribou Trails Sensitivity Analysis. Per acre costs reductions from pile and burn costs

Figure 4, Pitcha Lake Sensitivity Analysis. Per acre costs reductions from pile and burn costs



Discussion and Analysis

Initial findings from the study recognized no economic benefit for the Forest Service to sell biomass to markets at tested distances (85 and 150 miles) in 8 out of the 9 trials. If an analysis of equi-distance in the Pitcha Lake treatments were calculated at the 150-Miles distance (i.e. Pitcha North at 150 miles from market) it would not have demonstrated cost effectiveness. Therefore, 100% of the results would have resulted in higher costs for the Forest Service than the conventional pile and burn treatment at 150 miles. The sensitivity analysis offered alternative scenarios, under which cost reduction opportunities were observed.

Findings from the economic analysis could be summarized as follows:

- Material cut and harvest in summer and under dry conditions generated the best cost reductions and biomass harvest conditions for the Forest Service.

- A single, combination of harvester/forwarder equipment was most cost efficient, particularly when paired with roundwood harvest, as tested in unit 37-5.

- Harvest and forwarding costs were highest on sites with steep terrain and rough ground conditions. Additional costs were incurred when the forwarding distance was longer, as tested in treatment units 13-1 E and 13-1 W.

- High biomass removal rates (tons/acre) did not automatically reduce costs. When harvesting and collecting low priced small diameter material under difficult harvest conditions, the operator could spend more time (expenses) collecting this material, than it was worth in the market, as tested in unit 13-1 W.

- Higher costs were attached to the one site that was forwarded in winter. Site 13-1 W was cut and piled in dry summer conditions, however, when material was forwarded in winter it was covered in snow which made it difficult for the operator to locate the piles.

- When biomass landing areas are too small to store all the material forwarded off a site, extra costs may be incurred. In treatment unit 13-1W the landing area was too small, and the operator had to return to the site to collect material, grind it and then gather more material from the site. This meant significant idle-time costs for the grinder.

- Cost reductions were observed when an operator lays out an organized pattern of skid trails similar to those used for traditional timber harvesting, as tested in unit 37-1.

Forest management implications

Treatment prescriptions for the test sites were prepared by the SNF. Consideration was given to all objectives mentioned in their management plan including wildlife, soils, productivity, biodiversity and fuels management. Harvest prescriptions utilized varied, but generally called for the removal of:

- Aspen less than 6 inches in diameter four feet off the ground (dbh),

- Balsam fir less than 5 inches dbh,

- Spruce less than 2 inches dbh; with
- Stumps no higher than 12 inches, and
- Crushing or removal of 80% of dead, downed and standing dead material.

Interviews with operators revealed two sets of considerations: *first*, harvesting and delivery, recommendations (physical and technical barriers) and *second*, planning and coordination recommendations (guidelines and people involved in designing the operations). Summary of recommendations include:

- **Practicality of prescriptions**: One of the key lessons learned from the interviews and during the trial observations was the importance of designing management prescriptions with biomass extraction in mind. Access necessary for conventional pile and burn is different than that required for the efficient entry, cutting and piling, and forwarding of biomass material.
- **Site conditions**: Additional care should be taken with rough rocky terrain. Damage to cutting chains can slow harvest and increase costs.
- **Seasonal conditions**: Dry conditions speed harvesting and forwarding. Snowfall can cover harvested biomass, making collection and forwarding difficult. Sites should be forwarded right after they are cut to use existing harvesting infrastructure and avoid unnecessary delays, as site conditions could change.
- **Material size and visibility:** Utilizing signs to locate biomass piles on the harvest site could improve visibility to locate piles and therefore improve collection and forwarding speed thereby reducing costs.
- **Site demarcation**: Harvesting area perimeters need to be clearly demarcated. Dense brush on a site could affect visibility. Using timber-harvesting conventional colors or flagging to mark the harvest boundaries is recommended.
- **Skid trails**: Laying out a clear skid trail, similar to those in a traditional timber sale, is recommended.
- **Material sizing and arrangement**: Forwarding and bundling efficiency is improved if material is sized (not too long for forwarding equipment) and arranged in piles.
- **Spearhead stems**: Stems should be cut straight and parallel to the ground, without a spearhead-like angle that can damage expensive machine tires.
- **Trails and operation space**: The workspace needs to be wide enough for a machine to enter and back up without affecting residual trees and vegetation.
- **Grinding**: Costly idle grinding time can be avoided if rootballs, rocks and soil residue is removed from biomass piles before the grinder arrives on site.

- **Landing**: Landing needs to be large enough to accommodate all material removed from a site.

- **Trucking**: A truckload of bundles weighs less than woodchips, increasing transportation costs/ton. Combining roundwood with bundles, when feasible, allows greater loading and reduced transportation costs.

- **Visiting sites**: It is recommended to visit a site prior to operations to assess operating conditions, biomass removal opportunities and potential profit.

- **Harvesting prescriptions**: Prescriptions need to consider recommendations that can overcome the operational barriers (technical and physical) and planning and coordination concerns (guidelines and communications) identified by machine operators.

- **Payment preferences**: Payments preferences (per ton, per load, on a moisture-adjusted weight basis) are going to depend on agreements between operators, forest managers and biomass energy utilities. Each system offers advantages and disadvantages to each partner.

- **Communication between operators**: Communication and coordination among operators, and with the forest managers and operators in early planning stages ensures a more efficient and effective implementation of biomass harvesting guidelines and operations. Operators need to know what type of machine follows or is in tandem, and how material can best be prepared and laid out to maximize efficiency for the whole operation.

Biomass policy implications

Economic and logistical considerations will prevent complete removal of biomass on most sites: this is a good thing. Harvest sustainability guidelines recommend that approximately 25% of biomass remain on most sites (Minnesota Forest Resources Council 2007). This dovetails with economically efficient harvest and collection practices which do not reward the gathering of smaller stems and smaller quantities of biomass. Residual biomass material is of importance for site nutrients, water quality and wildlife habitat.

Biomass removals are most likely to be considered economically viable if done in conjunction with other valued forest management "coproducts" or objectives, for which financial investment is required. Those objectives include timber stand improvement, fuels reduction, wildlife habitat improvement or ecosystem restoration. Biomass markets only pay for a fraction of the full cost of harvesting, forwarding and delivery of the biomass material; coproducts must be available to support some of the costs.

Based on the analysis, biomass utilization economics is sensitive to the mobilization costs and hauling distance to markets. The development, therefore, of well-distributed smaller local markets will better support economical extraction of biomass versus larger markets requiring biomass supplies drawn from longer distances.

Conclusion

Benefits of forest biomass harvesting are multiple and varied, depending on site conditions and local objectives. They can include climate change mitigation through provision of fuels for renewable energy, local energy production, rural jobs and economic development, catastrophic fire hazard mitigation through fuels reduction, ecosystem restoration, habitat improvement, and forest health or productivity improvements. In order for such benefits to materialize, consideration must be given to some of the key economic challenges related to biomass extraction as well as the technical and administrative logistics. Careful consideration of harvest needs and other operational concerns from the earliest stages of planning and preparation of management prescriptions can provide opportunities for biomass markets to reduce the cost of harvest through payments for delivered biomass.

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