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Cost estimates of post harvest forest biomass supply for Canada

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ABSTRACT

This study estimates the potential physical amounts and financial costs of post-harvest forest residue biomass supply in Canada. The analyses incorporate the locations of harvest activities in Canada, the geographical variation of forest productivity patterns and the costs associated with the extraction and transportation of residue feedstock to bioenergy facilities. We estimated the availability of harvest residues within the extent of industrial forest management operations in Canadian forests. Our analyses focused on the extraction of biomass from roadside harvest residues that involve four major cost components: pre-piling and aggregation, loading, chipping and transportation. The estimates of residue extraction costs also included representation of basic ecological sustainability and technical accessibility constraints. Annual supply of harvestable residual biomass with these ecological sustainability constraints were estimated to be approximately 19.2–23.3 Tg·year^{-1} and 16.5–20.0 Tg·year^{-1} in scenarios that included both ecological and technical accessibility limitations. These estimates appear to be less than other similar studies, due to the higher level of spatial details on inventories and ecological and operational constraints in our analyses. The amount of residual biomass available in baseline scenarios at a supply cost of \$60 ODT^{-1} and \$80 ODT^{-1} were 1.08 and 1.38 Tg year^{-1} and 7.82 and 10.14 Tg year^{-1} respectively. Decreasing residue extraction costs by 35% increased the amount of residues available at a \$60 ODT^{-1} and \$80 ODT^{-1} supply price by ~5.5–5.7

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and ~1.5–1.6 times respectively. The assessment methodology is generic and could be extended to examine residue supplies for specialized biomass markets such as lignocellulosic ethanol production.

1. Introduction

Production of renewable energy from biomass requires feedstocks to be sustained over extended time periods at a competitive cost. In Canada, forests have been recognized as a potential stable and abundant source of biomass supply for bioenergy [1–3], however the costs of forest biomass extraction and the long-term availability of sustainable feedstock are two key issues which limit the adoption of residual forest biomass for bioenergy production. With recent advances in biomass combustion technologies [4,5] the utilization of woody biomass in energy production systems could be expected to expand [6]. For renewable energy production, residual forest biomass left after harvest operations could be a cost-effective source of biomass supply [7]. Harvest operations typically remove only the commercially viable (merchantable) portion of wood from the harvest areas. The remaining biomass is left to decay or be burned. Potentially, this residual biomass could be extracted using standard machinery and common silvicultural practises. Determining supply costs in a geographically large and diverse country like Canada is difficult because of the significant variation of transportation distances and wide range of biophysical conditions and economic circumstances (including bioenergy markets). Nevertheless policy-makers and investors require such estimates to gain insights as to the competitive position and opportunities residual biomass presents.

Forest harvesting operations in Canada produce three general classes of residual biomass feedstock: post-harvest residues (such as tree tops, limbs, foliage and stumps), non-merchantable timber (such as cull trees and pre-commercial thinning material) and standing dead wood (such as residual snags and trees killed by fire and insect outbreaks). Stumps are commonly not considered as a source of residue supply due to high removal costs. Standing dead wood accounts for a significant portion of residual material [8,9], but is not likely to provide a stable feedstock supply over time. For example, the accumulation of dead wood usually follows natural disturbances such as fires or insect outbreaks. The stochastic nature of these events makes the long-term planning and allocation of large-scale biomass supply from standing dead trees problematic. Alternatively, non-merchantable round wood and other residues left after timber harvest operations provide a potentially more consistent feedstock over time [2,10]. Industrial harvest operations create significant amounts of woody residues and are typically planned well in advance, allowing sufficient lead time for planning the extraction of residues from the harvested sites. The unused portion of the tree biomass has been historically considered a waste product and, as noted above, disposed of through on-site burning practises or left for decay. Burning of slash piles is regulated by provincial forest management guidelines. Operational decisions depend on a multitude of local conditions (such as weather and moisture conditions, proximity to unharvested stands and personnel availability).

Supply costs are arguably the biggest constraint to widespread use of residual forest biomass in bioenergy systems [2,3,11–14]. The costs of biomass supply include the fixed and variable costs of biomass extraction and aggregation and the variable costs of transportation to final end-users. Recent estimates of biomass extraction costs for Ontario and Quebec [2,15] were estimated as between \$53 and \$59 ODT^{-1}. Hauling costs typically show significant geographical variation [16–20], depending on the location of biomass processing facilities, hauling distances, quality of the access roads and physical conditions of residues extracted from the harvest sites.

In this paper, we provide a nationwide assessment of the supply costs of post-harvest residual biomass from the managed forests of Canada, an area of approximately 230 million ha [21] to a set of 89 existing bioenergy facilities. We include consideration of variation of hauling distances and general road conditions (i.e., paved vs. unpaved roads), which can affect hauling times and costs. Our analysis proceeds as follows. First, we used a spatially refined version of Canada's National Forest Inventory, recent volumes of forest harvest in Canada and, as noted, existing locations and current capacities of wood processing facilities (such as pulp, paper and saw mills) to establish the spatial extent of industrial harvest operations across the country. We then developed and applied a geographic model that estimates the amount of post-harvest residual biomass from these locations utilizing biomass accumulation models. Biomass supply costs were generated by adding the fixed and variable costs associated with the extraction and transportation of the residues to the nearest mill location. We aggregate these results to provide provincial and national summaries and residue cost supply curves. A depiction of the overall modelling process is provided in Fig. 1.

2. Material and methods

2.1. Step 1. Assessing the geographical distribution of merchantable timber volumes

The analysis begins with a broad-scale geographic assessment of current amounts of timber volumes in Canadian forests. In Canada, spatial details on these attributes (such as merchantable timber volume and stand age) are stored in operational forest inventories based on photo-interpretation