Biomass and Bioenergy 93 (2016) 97–106

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

Processing and sorting forest residues: Cost, productivity and managerial impacts

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ARTICLE INFO

Article history:
Received 23 January 2016
Received in revised form 17 June 2016
Accepted 24 June 2016

Keywords:
Integrated harvesting methods
Northern California
Shovel logging
Standardized comparison
Timber harvesting
Wood biomass

ABSTRACT

Feedstocks generated from processing forest residues have traditionally been considered as a low value product. The economic potential of these materials can be enhanced by emerging biomass conversion technologies, such as torrefaction, briquetting, and gasification; however, these systems require higher quality feedstock. The objective of this study was to determine the cost of processing and sorting forest residues to produce feedstock, so that the best comminution machines (i.e. chipper vs. grinder) could be used to better control feedstock size distribution. The tree tops left from sawlog processing and small-diameter trees were delimbed and separated from the slash pile. Three harvest units were selected and each unit was divided into three sub-treatment units (no-, moderate, and intensive sorting). Results showed that the cost of operations were higher for the sorted sub-units when compared to the non-sorted. The total cost of operation (felling to loading) for sawlogs was lowest at 40.81 $ m^{-3} in the nosorting treatment unit, followed by moderate (42.25 $ m^{-3}) and intensive treatment unit (44.75 $ m^{-3}). For biomass harvesting, the cost of operation (felling to delimbing and sorting) ranged from 27 to 29 $ oven dry metric ton^{-1}. The most expensive operational phase was primary transportation; therefore, cost of treating the forest residues had less impact on the overall cost. The cost increase (1150 $ ha^{-1}) of sorting forest residues could offset cost savings from avoided site preparation expenses (1100 $ ha^{-1}), provided that the forest residues were utilized.

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1. Introduction

Forest residues generated from timber harvesting operations, in the form of dead trees, branches, tree tops, chunks (offcuts), non-merchantable tree species and small-diameter trees, have traditionally been regarded as economically low value products. These by-products are generally utilized as feedstock for energy production, as they are widespread, renewable, and can be used to offset the use of fossil fuels and reduce greenhouse gas emissions [1].

In regions where there are markets for biomass or pulp, a variety of treatments, including debarking stems, removing foliage, field drying, etc. are carried out [2,3]. Such treatments have been found to accelerate drying, reduce contamination, and eventually enhance the quality of the feedstock [4]. The cost associated with these treatments, while documented, often cannot be compared, because the harvest operations are species, site, and practice specific [5]. However, documenting these operations can help in formulating specific strategies that can be adopted in regions with limited bioenergy markets.

In northern California, approximately 157 and 110 oven dry metric tons (ODMT) ha^{-1} of forest residues can be recovered from a typical even-age managed ground-based and cable yarding operations, respectively [6]. However, the markets (primarily restricted to wood based power plants) for these woody biomass are limited by the transportation distance due to the low price [7]. This means, forest residues generated from most of the timber harvest units out of the power plant procurement regions are piled and burned on-site. These slash burning are additionally restricted to specific burn windows of the year [8]; and can have a negative impact on air quality and human health [9].

One of the greatest barriers for utilizing traditional feedstock is due to the low price paid by the prevailing markets such as power plants. This price (approximately 50 $ BDT^{-1}) in large prohibits from implementing any commercial biomass removal projects [10,11]. Emerging biomass conversion technologies (BCT) such as torrefaction, briquette, and gasification can increase the economic

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http://dx.doi.org/10.1016/j.biombioe.2016.06.021
0961-9534/Published by Elsevier Ltd.

potential of these residues. However, to meet the feedstock specifications set by BCTs, the forest residues will have to be treated to minimize contamination, facilitate comminution via chipper, reduce moisture content, and improve handling/transportation efficiency [12]. As the conventional practice of biomass removal in the region stacks all forest residues into one pile, the only form of comminution is limited to grinding which produces non-homogenous sized feedstock (hog fuels) [13]. Hog fuels has inherent low quality in terms of size distribution (typically having larger particle size compared to that from chipper) and can negatively affect fuel conveyance and productivity of the follow up conversion processes [14]. Additionally, piling tree stumps and chunks along with other forest residues (like tree-tops) can introduce soil contaminants in to the feedstock [15]. All these become major barriers in the economic feasibility of conversion into value added forest products.

The overall goal of this study was to produce high quality (i.e., less contamination from dirt, and uniform in size) feedstock through sorting and processing (delimbing) tree tops generated from integrated timber harvesting operations, which could be further chipped rather than grinded to produce uniform size feedstock (Fig. 1). The specific objective of this study was to evaluate and compare the cost of treatment (i.e., sorting and processing forest residues) with the conventional harvesting practice of piling all forest residues together. The study also investigated the differences in cost associated with varying degrees of processing and sorting forest residues and evaluated the impacts of the treatments from a managerial perspective.

2. Methodology

2.1. Defining terminologies used in this study

- Forest residue: Materials generated from timber harvesting operation other than sawlogs that are typically of lesser or no economic value. These were further classified into non-merchantable trees, small-diameter trees, slash, and tree tops.
- Non-merchantable tree species: Trees species which are currently not in demand in the sawlog market in northern California; for e.g., hardwood species, such as tanoak (*Notholithocarpus densiflorus* (Hook. & Arn.) Manos et al.). They are used as feedstock for energy purpose, or firewood.
- Small-diameter trees: Trees of both non-merchantable and sawlog species having a diameter at breast height (dbh) less than 20 cm and are not generally accepted by sawmills for lumber manufacturing in northern California. The size of the merchantable timber varies from region.
- Slash: The component within the forest residues generated from sawlog processing typically consisting of chunks, foliage, branches and other broken material not appropriate to be comminuted by a chipper.
- Tree tops: The wood material within bole (main stem) from 15 cm diameter level onwards to the tip of the crown for both conifer and hardwood trees. The tree tops were further divided into two sections:
  - Processed tree tops: Tree tops delimbed (foliage removed along the entire length) to the top 15 cm length.
  - Unprocessed tree tops: The intensive sorting treatment had an unprocessed tree top sort for conifer and hardwood trees, which were not delimbed and had branches with leaves and needles still attached to them.
- Sawlog component: Merchantable trees with a diameter at breast height (dbh) of 20 cm or greater which will be eventually processed to lumber at a saw mill. In northern California, only softwoods had sawlog markets.

2.2. Stand and site description

The study site comprised of three even-age managed stands on

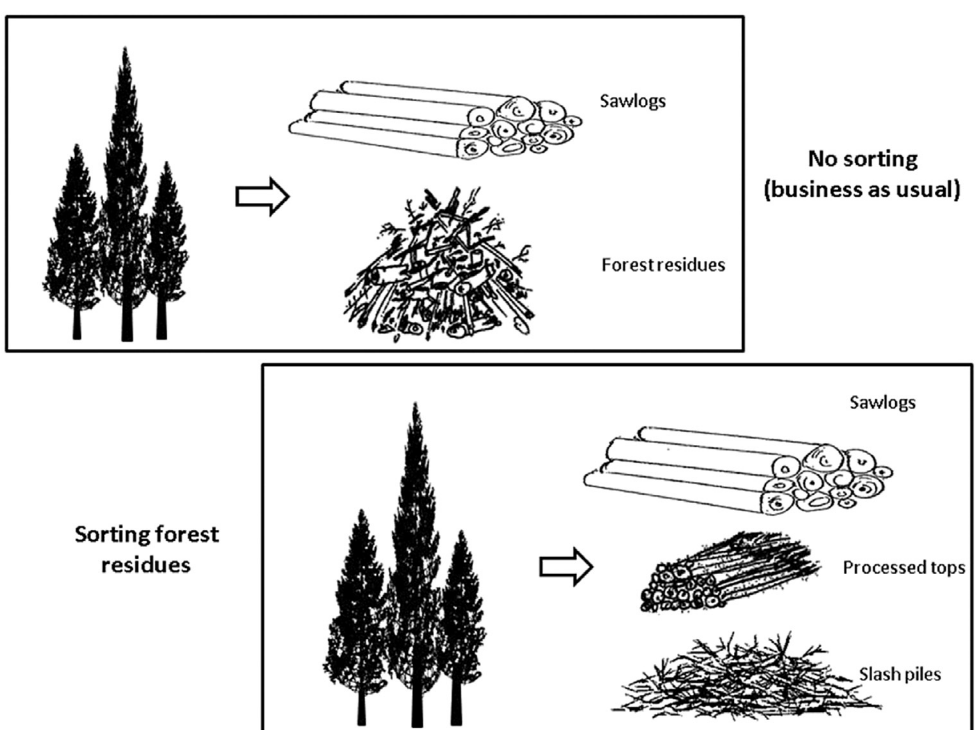

Fig. 1. Demonstrating processing and sorting treatment for forest residues from timber harvest units.