BIOMASS AND BIOENERGY 52 (2013) 85–95

Available online at www.sciencedirect.com

SciVerse ScienceDirect

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Harvesting productivity and costs when utilizing energywood from pine plantations of the southern Coastal Plain USA

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ARTICLE INFO

Article history:
Received 20 April 2011
Received in revised form
18 February 2013
Accepted 20 February 2013
Available online 30 March 2013

Keywords:
Forestry
Logging
Biomass harvesting
Energy chips
Forest operations

ABSTRACT

For woody biomass to make a significant contribution to the United States' energy portfolio, harvesting contractors must economically harvest and transport energywood to conversion/processing facilities. We conducted a designed operational study in the Coastal Plain of North Carolina, USA with three replications of three treatments to measure harvesting productivity and costs when utilizing woody biomass. The treatments were: a conventional roundwood only harvest (control), an integrated harvest in which merchantable roundwood was delivered to mills and residuals were chipped for energy, and a chip harvest in which all stems were chipped for energy use. The harvesting contractor in this study typically delivers 2200–2700 t of green roundwood per week and is capable of wet-site harvesting. Results indicate that onboard truck green roundwood costs increased from 9.35 $ t^{-1} in the conventional treatment to 10.98 $ t^{-1} in the integrated treatment as a result of reduced felling and skidding productivity. Green energy chips were produced for 19.19 $ t^{-1} onboard truck in the integrated treatment and 17.93 $ t^{-1} in the chip treatment. Low skidding productivity contributed to high chip costs in the integrated treatment. Residual green biomass was reduced from 18 t ha^{-1} in the conventional treatment to 4 and 3 t ha^{-1} in the integrated and chip treatments, respectively. This study suggests that until energywood prices appreciate substantially, loggers are unlikely to sacrifice roundwood production to increase energywood production. This research provides unique information from a designed experiment documenting how producing energywood affects each function of a harvesting system.

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0961-9534/$ – see front matter
http://dx.doi.org/10.1016/j.biombioe.2013.02.038

1. Introduction

In recent years, concerns about America's dependence on fossil fuels and sustainability have led to increased interest in producing energy from renewable sources such as woody biomass [1,2,3]. Past research suggests there are sufficient forest resources available to support an expanded wood-energy industry [4,5,6]. As a result, state and federal governments have developed incentives and regulatory measures that promote renewable energy, including energy from woody biomass. For example, the Energy Independence and Security Act of 2007 requires that 136 hm^3 of renewable fuels be produced by 2022, of which 79 hm^3 must be produced from advanced biofuels such as cellulosic ethanol [7]. The Biomass Crop Assistance Program (BCAP) was designed to provide financial assistance for the harvest and transportation of eligible biomass to conversion facilities. However, this program had the unintended consequence of raising wood prices for traditional wood users such as the composite panel and pulp and paper industries [8]. Thirty-seven states have enacted renewable portfolio standards or goals that mandate or set goals for utilities to produce a certain amount or percentage of electricity from renewable sources by a target date [9]. The U.S. South has been less proactive in terms of both renewable portfolio standards and incentives for renewable energy than other states [10]; nonetheless, each southern state has at least one policy promoting bioenergy [3].

Wood that is used to produce energy is derived from one of three sources: 1) wood that is currently not used (i.e. harvesting residues, noncommercial stems, etc.) [6,11], 2) wood from dedicated bioenergy plantations [1,12], or 3) wood that is currently used for another purpose (i.e. traditional products such as pulpwood) [5,13]. Harvesting residues have the advantage of being commonly available with few or no modifications to silvicultural practices; however, these residues may be prohibitively expensive to process and transport in some areas [14,15], and may not be available in sufficient quantities to meet some government renewable energy goals/mandates [16,17]. Hardwood bioenergy plantations are of interest because hardwoods have better physical attributes for producing energy than pine (*Pinus spp*.) [12,18]. However, pine plantations have lower establishment costs and can be productive on a wider range of sites than hardwood plantations [12].

Past research indicates that a substantial expansion of the wood-energy market may create competition between the forest products and wood-energy industries [16,19,20]. Galik et al. [16] suggested that wood-energy demand exceeding the availability of harvesting residues could cause a sudden increase in roundwood prices, which could displace some current wood users. To date, no such competition has been documented at the state level. For example, Virginia has a wood-energy market that is comparable in size to other southern states [21]. It has an 80 MW wood-fired power plant, at least three wood pellet producers [22], and it produced 2.22 TWh of electricity from biomass in 2010 [21]. However, Virginia has experienced minimal competition between the forest products and wood-energy industries [23], and most of the loggers harvesting energywood in the state are concentrated around a single market [24]. Virginia did lose one of its largest paper mills in 2010; however, this closing was a result of reduced paper demand, not competition from the wood-energy industry [25]. Nonetheless, Conrad et al. [19,20] found that a majority of consulting foresters, wood-energy facilities, pulp and paper mills, composite mills, sawmills, and private landowners surveyed in the U.S. South expected wood-energy facilities and forest industry mills to compete for wood in the future. If these expectations come to fruition, landowners and harvesting contractors may decide whether to sell pulpwood-sized material to a paper mill or to an energy facility. This decision may take the form of selling roundwood pulpwood to a paper mill versus chipping the pulpwood-sized material and selling it to a wood-fired power plant for energy production.

When deciding between selling roundwood pulpwood and energy chips, landowners and loggers should consider the harvesting costs associated with the two products. For example, if green energy chips can be produced for 1 $ t^{-1} less than roundwood pulpwood, then the market price of roundwood pulpwood must exceed the market price of energy chips by at least 1 $ t^{-1} in order for the landowner or logger to be indifferent between selling the two products. Past research investigating the cost of producing energywood has assumed that roundwood pulpwood would be of higher value than energy chips, and therefore did not estimate the cost of chipping this material. Research by Westbrook et al. [26] in the Coastal Plain of Georgia suggested that green energy chips could be produced from limbs and tops for 12 $ t^{-1}, while green energy chips can be produced from limbs, tops, and understory stems for 13 $ t^{-1}. Research in the Coastal Plain and Piedmont of Georgia by Baker et al. [27] found that green energy chips could be produced for between 8.67 $ and 14.44 $ t^{-1} in clearcuts, depending on the harvest prescription, while green roundwood production costs in these treatments varied between 8.04 $ and 9.36 $ t^{-1}. In thinnings, roundwood harvesting costs varied between 11.15 $ t^{-1} and 15.48 $ t^{-1} while chipping costs varied between 8.63 $ t^{-1} and 10.59 $ t^{-1}. This study found that adding a chipper to a traditional southern pine harvesting operation reduced roundwood production during thinning.

It is critical that harvesting costs be taken into account when determining the viability of wood-energy projects. Past research indicates that the market price of energywood and the cost of adopting energywood harvesting technology are important barriers for harvesting firms considering harvesting energywood [28]; therefore, accurate estimates of energywood harvesting costs will enable harvesting contractors to make informed decisions about whether to purchase equipment for harvesting energywood. The overall purpose of this study was to investigate harvesting productivity and costs under three harvest prescriptions in the Coastal Plain. The specific objectives were to: 1) quantify the difference in roundwood harvesting costs between harvesting roundwood only and integrating roundwood and energy chip production, 2) quantify the difference in hourly production rates and energy chip harvesting costs for stand-alone energywood production versus integrated roundwood and energy chip production, 3) investigate whether adding a chipper to a tree-length southern pine harvesting operation reduces hourly and per ha roundwood production, 4) compare woody biomass utilization between roundwood only harvesting, energy chip