Biomass and Bioenergy 81 (2015) 167–176

Contents lists available at ScienceDirect

Biomass and Bioenergy

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

Research paper

Assessing sustainable forest biomass potential and bioenergy implications for the northern Lake States region, USA

Sidhanand Kukrety [a,*], David C. Wilson [a], Anthony W. D'Amato [b], Dennis R. Becker [c]

[a] Department of Forest Resources, University of Minnesota, St. Paul, 55108 MN, USA
[b] Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, 05095 VT, USA
[c] College of Natural Resources, University of Idaho, Moscow, 83844 ID, USA

ARTICLE INFO

Article history:
Received 1 September 2014
Received in revised form
31 May 2015
Accepted 26 June 2015
Available online 8 July 2015

Keywords:
Bioenergy
Forest residue
GHG reduction
Lake states
Sustainable harvest
Biomass estimation

ABSTRACT

Forestlands in the United States have tremendous potential for providing feedstocks necessary to meet emerging renewable energy standards. The Lake States region is one area recognized for its high potential of supplying forest-derived biomass; however, the long-term availability of roundwood harvests and associated residues from this region has not been fully explored. Better distribution and temporal availability estimates are needed to formulate emerging state policies regarding renewable energy development. We used a novel predictive methodology to quantify sustainable biomass availability and likely harvest levels over a 100-year period in the Lake States region. USDA Forest Inventory and Analysis estimates of timberland were combined with published growth and yield models, and historic harvest data using the Forest Age Class Change Simulator (FACCS) to generate availability estimates. *Monte-Carlo* simulation was used to develop probability distributions of biomass harvests and to incorporate the uncertainty of future harvest levels. Our results indicate that 11.27–15.71 Mt y^{-1} dry roundwood could be sustainably harvested from the Lake States. Assuming 65% collection rate, 1.87–2.62 Mt y^{-1} residue could be removed, which if substituted for coal would generate 2.12–2.99 GW h of electricity on equivalent energy basis while reducing GHG (CO_2e) emission by 1.91–2.69 Mt annually. In addition to promoting energy security and reducing GHG emissions, forest residues for energy may create additional revenues and employment opportunities in a region historically dependent on forest-based industries.

1. Introduction

Ever increasing energy demands and scientific consensus on the risks associated with anthropogenically driven climate change [1] have stimulated global research into alternative energy resources. In the United States, fossil fuels contributed 88% of all electricity generated in 2012 with renewables accounting for the remainder [2]. Among fossil fuels, coal alone accounted for 43% of power generation, followed by natural gas (35%). Wind energy contributed 28% of total renewable energy while the woody biomass derived energy contribution was 10% [3]. Contemporary bioenergy research gained momentum with promulgation of the Biomass Research and Development Act (BRDA) of 2000 [4], and accelerated further with enactment of the Healthy Forest Restoration Act (HFRA) of 2003 [5], Energy policy Act of 2005 [6], and over 350 state level incentives and regulations [7]. Despite the push in the field of bioenergy research, the market share contribution of woody biomass towards energy generation actually fell from 11% in 2002 to 7.5% in 2012, largely due to expansion of natural gas production [2]. The absolute amount of wood energy production has remained relatively steady. At the same time, extracted biomass plus mortality 71% less than annual forest growth in most timberland areas [8–10].

Forestlands in the United States have been identified as holding tremendous potential for providing feedstocks necessary to meet emerging renewable energy goals. The updated Billion Ton study [8] indicated current availability of 291 Mt y^{-1} of dry biomass forest biomass in the US based on current rates of forest harvesting, which are depressed due to the recent recession [8]. However, there are

Abbreviations: BRDA, Biomass Research and Development Act; ESDT, Exponential Smoothing with Damped Trend; ERFMax, Extended Rotation Forest Maximum Age; FACCS, Forest Age Class Change Simulator; FIA, Forest Service Forest Inventory and Analysis; GEIS, Generic Environmental Impact Statement; GHG, Greenhouse Gases; GMHT, Growth to Maximum Harvest Trend; HFRA, Healthy Forest Restoration Act; LTSY, Theoretical Long Term Sustained Yield; MSE, Mean Squared Error; MN-IHT, Minnesota Increasing Harvest Trend; MN-DHT, Minnesota Declining Harvest Trend; MN-HHT, Minnesota historical harvest trend (1980–2010).

* Corresponding author.
E-mail address: sid.forester@gmail.com (S. Kukrety).

http://dx.doi.org/10.1016/j.biombioe.2015.06.026
0961-9534/

several areas of uncertainty regarding these and other estimates of feedstock availability [11,12]. First, landowner willingness and acceptance to harvest varies considerably within and across the public and private sectors indicating that the social availability of feedstocks will vary across different regions and ownerships [13–15]. Second, not all forested areas are accessible and open to harvest, which effectively reduces the total market availability [16]. Additionally, areas set aside within working forest landscapes to preserve unique natural and cultural resources and sustain biodiversity restrict the area available for harvest. Moreover, biophysical constraints further reduce the sustainable biomass harvest. For instance, the Billion Ton study indicated that equipment recovery limitations reduced the estimated 67 Mt dry logging residue by 37%, leaving only 41 Mt available for wood energy application [8]. Third, the need to retain residues in the forest for soil conservation and to maintain nutrient cycling processes imposes a necessary constraint [e.g., 17–19]. Fourth, since biomass feedstocks are less dense and have a lower heat value than fossil fuels, the economic and logistical constraints imposed by transportation infrastructure will also influence feedstock availability [8,20]. Lastly, the variation in delivered feedstock price will influence feedstock availability [11,12,20]. Collectively, these constraints must be rigorously incorporated into biomass availability estimates to inform policy development.

The northern Lake States region (encompassed by Minnesota (MN), Wisconsin (WI) and Michigan (MI)) is recognized as having a significant potential to supply forest-derived feedstocks [21] (Fig. 1). Harvest residues are among the largest unused feedstock [20] with annual growth far exceeding removals. This presents an opportunity to increase harvest rates for strategic, economic, and forest health reasons [22]. In most cases, harvest residues are left on the forest floor while only a limited quantity is collected from the landing point for energy purposes [23]. The northern Lake States region also collectively represents an important confluence of supporting policies, third-party forest certification, and an emerging wood energy sector that in recent years has seen a surge in demand [24]. However, further increases are dependent upon the economic, environmental, and social feasibility of residue collection on one hand, and the proximity of bioenergy facilities to these forests on the other.

Increases in the use of biomass for energy need to occur in ways that maintain the productivity, environmental sustainability, and quality of the forests to ensure sustainable production in the future. As such, a thorough assessment of the environmental impacts and benefits of expanded bioenergy development is needed, which is critical for refining existing harvest guidelines and associated policies for protecting environmental quality. The long term projections of roundwood harvests and associated residues predicted by previous studies have neither been verified for correctness [11,20,25,26], nor were the recorded harvests consistent. Better information about the distribution and temporal availability of forest feedstocks is needed to inform emerging state policies. Existing projections are fraught with uncertainties regarding future species composition and anticipated harvest levels.

Becker et al. [20] studied the existing and projected demand for residues in the Lake States region and concluded that total demand of 5.7 Mt dry residues exceeds the region-wide estimated and economically available 4.1 Mt [15]. There are other nation-wide studies that reflect the availability of timber and residue in the Lake States [8,9]. In Minnesota, a Generic Environmental Impact Statement [25] evaluated the long term availability, and harvest of forest biomass under different harvest scenarios. Jakes and Smith [27] similarly predicted biomass availability in Michigan from 1980 to 2010. Despite these previous works, there is a lack of comprehensive studies in the region using contemporary techniques, such as simulation methods, to approximate the long term availability of biomass and associated uncertainties. Such assessments are a critical improvement over sustainable feedstock harvest estimates derived from average trends in past timber harvesting, like done for the Billion Ton update. The purpose of this study was to examine the environmental sustainability and capacity for wood energy production in the northern Lake States region. We assessed the long term (2010–2110) availability of biomass derived from roundwood and harvest residues and attempt to project harvest patterns based on past harvest trends for each state. The implications of residue utilization for energy generation and GHG reduction were also evaluated. Fig. 2 shows the flow chart illustrating the sources and processes involved in the study.

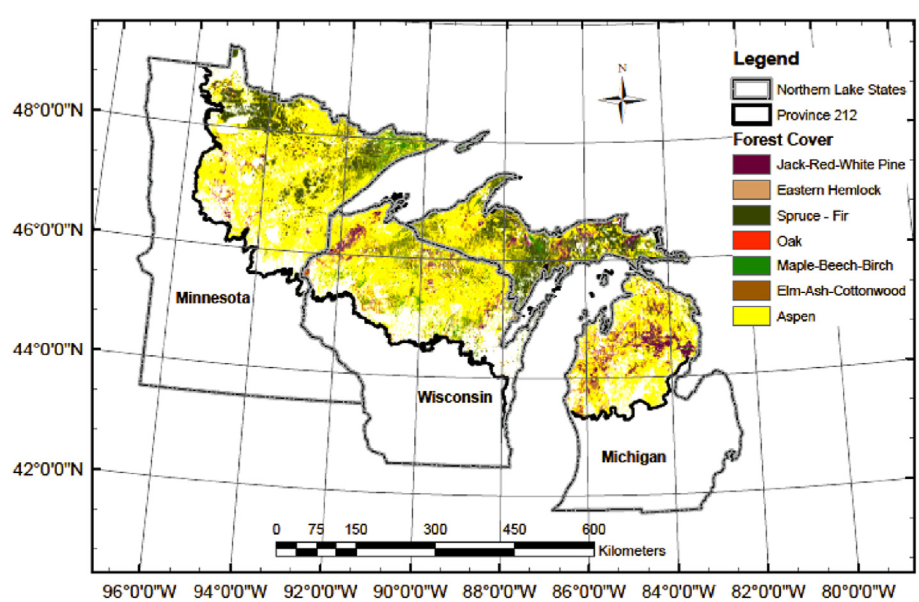

Fig. 1. Ecological Province 212 of the northern Lake States, USA with major forest types depicted. Forest type classification is based on GAP data.