In: Hartsough, Bruce; Stokes, Bryce, compilers. 2009. *Proceedings, Environmentally Sound Forest Operations*. 32nd Annual Meeting of the Council on Forest Engineering, held June 15-18, 2009 at Kings Beach, California. Proceedings published on CD-ROM by the University of California, Davis, California.

Updating FRCS, the Fuel Reduction Cost Simulator, for National Biomass Assessments

Dennis Dykstra[1], Bruce Hartsough[2], and Bryce Stokes[3]
[1]*Research Scientist, Pacific Northwest Research Station, Portland, Oregon*
[2]*Professor, Biological and Agricultural Engineering, University of California, Davis, California*
[3]*Senior Advisor, Golden Field Office, Department of Energy, Golden, Colorado*
Email: ddykstra@fs.fed.us

Abstract

In 2005 the USDA and DOE jointly published a report (Perlack et al. 2005) concluding that it would be technically feasible to supply a billion dry tons of biomass annually from farms and forests throughout the United States in support of an emerging bioenergy and bioproducts industry. The report was criticized because it defined "supply" largely in terms of physical availability without a formal evaluation of economic feasibility. As a result, during 2008 and early 2009 the two agencies conducted a follow-up study in an effort to assess the potential biomass supply economically by deriving county-level supply curves for farm and forest biomass. This paper describes the forest harvesting model that was used to estimate the costs associated with collecting and preparing forest biomass for transport to processing facilities. The model was updated from an earlier version that was limited to forest conditions in the Interior West. The revised model has been designed for use in all regions of the contiguous United States. Actual results from the study are not provided in this paper because they have not yet been cleared for release by the USDA and DOE.

Introduction

In 2007 the US Congress passed the Energy Independence and Security Act (EISA), which revised the 2005 Renewable Fuel Standard (RFS) upward to specify that, by 2015, the US as a whole is mandated to produce 20.5 billion gallons of biofuels annually from renewable sources, and that by 2022 this should grow to 36 billion gallons per year (Renewable Energy World 2008). At the current average yield of 67 gallons of ethanol per dry ton of biomass (DOE 2009), these targets imply the need for biomass supplies of around 305 million tons by 2015 and 540 million tons by 2022. Such quantities represent ambitious targets, and it seems unlikely that they could be met solely from crop-based biomass. Additional biomass sources could include logging and mill residues, small trees from thinnings, wood from energy plantations, urban wood waste, and possibly even repurposing of conventional forest products such as pulpwood.

In an effort to estimate the technical feasibility of supplying the large quantities of biomass needed to meet the RFS mandates, in 2005 the Departments of Energy and Agriculture jointly published a report on potential biomass supplies from both agriculture and forestry (Perlack et al. 2005). The report concluded that more than a billion tons of biomass are "potentially available" each year from US farms and forests. However, the study was criticized because it relied heavily on data related to physical availability without comprehensively evaluating biomass supply in an economic context. As a result, a new study was commissioned in late 2007 to derive county-level supply curves, using economic data, for both farm and forest biomass. Counties were selected as the basic unit of area for the assessment because that is the level at which the Agricultural

Research Service collects agricultural data. Both the farm and forestry components were to be modeled at that level in order to facilitate aggregation of supply curves. The county-level supplies can then be aggregated at the state level and summarized according to regional groupings that are commonly used in assessments of this type. For this study, “supply” refers not to a fixed quantity but rather to an economic supply curve indicating the estimated quantity of biomass that might be made available at a given price. In general, as the price of biomass increases, the quantity made available by landowners should increase as well, up to some limit imposed by the long-term productivity of the land and the propensity of landowners to sell biomass.

Acknowledgments

Overall coordination of the Forest Service contribution to the biomass supply study was managed by Bryce Stokes, then at the Forest Service Washington Office. The forest biomass supply assessment was led by Kenneth Skog at the Forest Products Lab in Madison, Wisconsin, with programming and statistical assistance from Patricia Lebow, who is also at the Lab. Consultation on data from the Forest Inventory and Analysis Program of the Forest Service was provided by Patrick Miles, an FIA scientist at the Northern Research Station in St. Paul, Minnesota. Estimation of biomass harvesting and collection costs was the responsibility of Dennis Dykstra at the Pacific Northwest Research Station in Portland, Oregon, who updated and revised a simulation software package developed originally by Bruce Hartsough at the University of California, Davis (Hartsough et al. 2001).

Methodology

The procedure used in this study involved estimating biomass stumpage prices and harvesting costs nationwide on a county-by-county basis. The assessment relied on data from the Forest Service’s permanent Forest Inventory and Analysis (FIA) plots located throughout the US. For this study, Alaska and Hawaii were excluded. Forest biomass supply curves were determined by simulating thinning operations on each FIA plot to estimate the costs of:

a) Felling and extracting whole trees to a roadside landing.

b) Chipping or grinding the limbs and unmerchantable tops of pulpwood and sawlog trees. The merchantable stems of such trees would be utilized in the normal way as pulpwood or sawlogs and would not form part of the biomass supply.

c) Chipping or grinding whole trees that are too small to be used for conventional forest products but are scheduled to be removed in the thinning. Larger unmerchantable trees that are scheduled to be removed may also be processed in this way.

d) Loading the biomass chips or ground particles onto trucks in preparation for transport to a processing facility. We assume that the particles are blown or conveyed into a chip van directly from the chipper or grinder. Transportation costs are not included so that we can combine supply curves for forest biomass with those for agricultural biomass, which is modeled as being supplied at the farm gate without accounting for road transport cost.

e) Paying landowners a stumpage price for small biomass trees and the limbs and tops of larger trees. We used a base stumpage price of $4/dry ton as a rough national average, derived from an informal national assessment of biomass stumpage prices. We recognize that stumpage prices tend to be dynamic and location-specific, so we regard this only as a starting point. We assume that as the biomass stumpage price increases in a locality, the amount of biomass offered for sale would also increase. We model the biomass stumpage price as increasing to a maximum of 90% of the pulpwood stumpage price when the total biomass harvest reaches its maximum level as limited by the level of harvest for conventional forest products. Limiting biomass collection according to the level of conventional harvest is described under point 4 of the assumptions below.

f) We do not include the cost of moving logging equipment to and from each harvesting site. Because our forestry data are taken from the FIA database, including moving costs would require us to make assumptions about both the moving distance and the physical area of each harvesting operation. Using assumed averages for these values would shift the supply curves upward slightly but the effect would be the same for the entire country.

Assumptions

To develop the supply curves for forest biomass, we made the following assumptions:

1. Forest biomass is considered to be supplied at the point where it is loaded onto trucks or other vehicles for transport from the farm gate or forest roadside to a processing facility. Thus, road transportation costs are not considered in the analysis. This is consistent with the treatment of farm biomass in the analysis.

2. Forest biomass is assumed to come from thinning treatments on overstocked timberland as described in point 3 below, except that federally managed forests are not considered as contributing to the renewable biomass supply as mandated under the RFS. The thinning treatments simulated are consistent with those used for the West-wide reports by Rummer et al. (2003) and Western Governors' Association (2008).

3. Simulated thinnings to recover biomass are devised so that they remove trees across all size classes, based on the stand density index (SDI) of the timber stand. The simulation methodology assumes that stands will be treated only if their SDI exceeds 30% of the maximum SDI for their forest type and ecoregion. The methodology used to identify the fraction of trees within each size class to be removed in a simulated thinning is described in Shepperd (2007). In short, beginning with 1-inch dbh trees, the simulated treatment removes successively fewer trees from each larger diameter class. The removals in aggregate reduce the stand density to 30% of the maximum SDI. Thinning operations are assumed to be scheduled so that they occur over a 30-year period, with 1/30th of the total SDI reduction across the US being removed each year.

4. Unmerchantable, small-diameter trees (1-5 inches dbh) and larger cull trees are considered available for potential use as biomass feedstocks for energy or biofuels. Trees 5-7 inches dbh in the East and 5-9 inches dbh in the West are considered pulpwood trees, and larger trees are considered sawlog trees. The biomass supply is assumed to come

from the unmerchantable trees and from the limbs and unmerchantable tops of pulpwood and sawlog trees. The harvest of all raw materials is assumed to be integrated, so the supply of limbs and unmerchantable tops is limited by the level of sawlog harvest for conventional forest products, and by a recovery factor recognizing that not all limbs and tops can be recovered (see point 6 below). We also assume that the supply of non-merchantable trees is limited by the level of conventional harvest; i.e., we assume that most biomass harvesting will be done in conjunction with conventional harvesting operations.

5. We assume that there is a slight cost premium for harvesting hardwoods as compared to softwoods. For the West this differential is 20% and for the North Central/Northeast and South it is assumed to be 5%. The figure for the West is a default that has been programmed into the simulation model and was based on experience with poorly formed hardwoods such as oak, tanoak, and madrone in California. The 5% figure for other regions is based on a suggestion from Greene (2008).

6. Not all limbs and unmerchantable tops of pulpwood and sawlog trees will make it to the landing in a whole-tree harvesting operation. One study (Stokes 1992) reported a wide range of recovery percentages averaging about 60% for biomass recovery in association with conventional harvesting operations. Currently we are using a recovery percentage of 65%, which is constant for all regions.

7. We assume that the cost of harvesting pulpwood and sawlog trees is fully allocated to the pulpwood and sawlogs that are recovered. Thus the limbs and unmerchantable tops of those trees are free at the landing except for the stumpage cost, and only the additional costs of chipping and loading are allocated to them. Unmerchantable trees that are harvested, however, bear all costs of felling, extraction, chipping, and loading in addition to the stumpage cost.

8. We separate the unmerchantable trees from pulpwood and sawlog trees only by dbh, without considering species. This is a recognized oversimplification in situations where larger trees of certain species, such as basswood in Wisconsin, might be used for biomass but not for conventional products.

Operations Simulated

We are not attempting to simulate all possible types of harvesting operations that might be used to collect biomass. Instead we consider only the following:

- Manual felling and whole-tree extraction, either with conventional skidders or with cable systems. The simulator uses cable systems if the average ground slope on the FIA plot is 40% or more.

- Mechanized felling and whole-tree skidding or forwarding. We assume that mechanized felling is not used with cable yarding even though we recognize that this is not a fully accurate assumption.

For ground-based logging, the simulation model calculates the production rates and costs for both of the possible alternatives (manual felling and mechanized felling). It then selects the lower-cost alternative for use in deriving the supply curve.

We recognize that harvesting systems other than these are likely to be used for biomass collection, such as harvesters and forwarders, slash bundlers, mobile chippers or grinders, or yet-to-be-developed technologies that could offer financial advantages in this type of operation. At present we have not identified publications providing production rates and related information for these other systems when they are used for collecting biomass, and therefore simulating them would involve more guesswork than we were willing to accept in doing this assessment.

Cost Estimation

The harvesting-cost simulation model used for this study is an adaptation of the Fuel Reduction Cost Simulator, or FRCS (Fight et al. 2006), which in turn was based on an earlier model called STHARVEST, for Small-Tree Harvest (Hartsough et al. 2001). FRCS is a Microsoft® Excel® application with auxiliary modules written in Visual Basic for Applications (VBA). It was originally designed to simulate fuel-reduction treatments in the Interior West, where wildfire is a significant problem. The model was substantially revised for this study, including the development of new procedures to simulate harvests in the North (North Central and Northeast), the South, and the coastal West as well as the Interior West. Cost data used in the original FRCS had several baselines: December 2000 for wages, December 2002 for equipment costs, and December 2004 for fuel costs. We updated all costs to December 2007 for this assessment. This represents the latest month for which all data were available when we were beginning to make production runs in early 2008. Furthermore, we have disaggregated the costs regionally, as described below.

Logging wages differ for each state, and are taken from the Bureau of Labor Statistics (2008), which publishes an online census of employment and wages by state and county for a wide variety of occupations, including logging (NAICS code 1133). We assume a nationwide average of 35% for benefits and other payroll costs because the BLS series do not include these costs.

Fuel prices differ by subregion (New England, Central Atlantic, Lower Atlantic, Midwest, Gulf Coast, Rocky Mountain, West Coast, California) and are taken from the diesel price series published by the Energy Information Administration (2008). We have not attempted to account for wholesale prices or off-highway savings in fuel costs because these vary widely and we have not identified a reliable source from which we could obtain the necessary information for all states. In any case, fuel prices are extremely volatile.

Equipment costs have been updated from the December 2002 base by using the producer price index for construction machinery manufacturing (Bureau of Labor Statistics 2008). We use a single national average cost for each category of equipment. The costs include estimates for all of the standard categories such as depreciation, repair and maintenance, interest, insurance, and taxes, but do not include an allowance for profit. Utilization rates are assumed to vary from 50% to 75% depending on the type of equipment but are constant throughout the country for any particular type of equipment.

No doubt the cost data could be improved if information were available for specific locations. However, the goal is to provide reasonable cost estimates for the country as a whole. Our assessment involves projections to 2022, and for simplicity we assume that different types of costs will remain about the same relative to each other as they are now.

Simulated production rates. To simulate harvesting operations, FRCS uses published production rates that typically vary according to the size of the trees being harvested and other factors such as slope and skidding distance. Most of the published studies are specific to a particular area of the country; hence, the simulated production rate for whole-tree harvesting with ground skidding in Alabama would differ from the simulated production rates for the same type of operation in Massachusetts or Wisconsin. In part this is due to different timber types and conditions, but also the published production rates for skidding operations in Alabama differ from those in Massachusetts and Wisconsin. A major part of the effort in this project was developing three new variants for FRCS that could be used to estimate logging and biomass collection costs in the West, North, and South respectively. More than 40 new production-rate equations were identified and implemented in the different variants of FRCS in order to support this effort.

FIA data. Parameters used to drive the simulation are taken from the 2007 Resource Planning Act database available from the Forest Inventory and Analysis National Program at http://www.fia.fs.fed.us/program-features/rpa/. This database includes all types and ownerships of forests in the United States. Each plot in the database represents a certain area of land that varies in different parts of the country and is influenced by local ownerships and other factors. Plots are identified in the database by county and state so it is possible to assign the harvesting operation simulated on each plot to a particular county.

Simulation results. The harvesting simulation runs involve calculations for about 125,000 permanent field plots located throughout the United States that have been established and are maintained by the FIA. For each plot, one of the following types of results is provided:

a) **No treatment—**the trees on the plot do not meet the requirements for thinning. Such plots do not contribute to the biomass supply curves. This is true also of plots on federally managed forest land due to restrictions in the EISA related to the RFS mandates.

b) **Treatment scheduled but inoperable—**if the average plot slope is greater than 40% and the distance to the nearest road as recorded in the FIA database is greater than 1,300 feet (the simulation limit for cable yarding), the plot is considered inoperable. For such plots, a harvesting cost of $100/green ton of biomass is recorded, indicating that the costs associated with collecting biomass from the plot are so high that it is very unlikely the trees on the plot will contribute to the biomass supply. No such limitation is imposed on ground-skidding or forwarding operations, although those with very long operating distances will inevitably enter the biomass supply at an extremely high cost.

c) **Treatment scheduled and feasible—**the simulation model was able to calculate estimated harvesting costs for the site. The following are recorded for use in putting together the biomass supply curves:

(i) Estimated total harvesting cost (the sum of felling, yarding/skidding, chipping, and loading costs) for all unmerchantable trees, pulpwood trees, and sawlog trees, expressed in $/CCF of logs recovered, $/green ton of logs and chips recovered, and $/acre of treatment area.

(ii) Estimated volume of chips recovered from unmerchantable trees, in green tons/acre.

(iii) Estimated volume of residue chips recovered (from the limbs and tops of pulpwood and sawlog trees), in green tons/acre.

(iv) Estimated volume of pulpwood logs recovered, in CCF/acre.

(v) Estimated volume of sawlogs recovered, in CCF/acre.

(vi) Estimated total collection cost for unmerchantable trees (the sum of felling, yarding/skidding, chipping, and loading costs), expressed in $/green ton of chips recovered.

(vii) Estimated total chipping and loading cost for residue chips produced from the limbs and unmerchantable tops of pulpwood trees and sawlog trees, expressed in $/green ton of residue chips recovered. Felling and yarding/skidding costs are not included for these trees because those costs are allocated to the production of logs from pulpwood and sawlog trees.

Limitations of the Model

One of the major difficulties in undertaking this type of analysis is the fact that FIA plot data do not include a robust measure that can be used as a surrogate for average skidding distance. The only plot-based measure related to distance is the estimated distance to the nearest road. Although we used this measure in our analysis, it is a poor surrogate for average skidding distance. A better approach, given sufficient time, would be to develop average skidding distance values for each county or group of counties.

Another limitation of the model is that it makes no effort to incorporate the cost of building or upgrading roads where that might be necessary in order to harvest forest biomass. The importance of this limitation would differ by region, but the general result is that our estimates of biomass supply are probably optimistic.

As mentioned earlier, our approach assumes that the thinning operations from which the forest biomass supply would be drawn are to be spread out evenly over a 30-year period. However, we use FIA data from the most recent measurement so the anticipated treatments are based on these data without incorporating future growth or other changes in forest area or timber conditions that might occur over the 30 years.

Concluding Remarks

Forest harvesting simulators are imperfect predictors at best, and we make no claim that the Fuel Reduction Cost Simulator is the best of all possible models to use for estimating harvesting costs throughout the United States. Even so, given the very short amount of time that was available to adapt the model for national use, the flexibility and robustness of FRCS permitted us to make the necessary adaptations and to successfully complete the analysis on time. On average, the general shapes of the supply curves derived from the analysis appear to be reasonable and at levels that are consistent with those independently derived for agricultural biomass.

The three regional FRCS variants and documentation for the original FRCS model can be obtained from a Forest Service website, http://www.fs.fed.us/pnw/data/soft.htm. Notes on formatting and methodological changes that were needed to accommodate the national assessment are also available on the website.

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