Woody Biomass Feedstock Supplies and Management for Bioenergy in Southwestern Mississippi*

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Abstract: Mississippi's forests cover approximately 20 million acres distributed in hardwood, softwood, or combination of both forest types. This timberland acreage represents a source of woody biomass for potential bioenergy consumption derived from four processes: (1) residues associated with the harvesting and managing of conventional forest products such as sawlogs, pulpwood, and veneer logs, in which material is often left on-site or piled and burned at an additional cost; (2) biomass generated from thinning to improve forest health and reduce fire hazard risks; (3) residues from mills; and (4) urban waste. Although there are many studies of woody biomass use for bioenergy consumption, few have analyzed the economic feasibility of utilizing woody biomass as a feedstock to produce ethanol in Mississippi. In this study, using forest inventory data from the Mississippi Institute for Forestry Inventory, we estimate woody biomass supplies by county, evaluate their availability for potential use in bioethanol facilities, and analyze major production costs. Results show that more than 975,000 dry tons are available for use as a potential feedstock to produce ethanol. Logging residues and small-diameter trees make up the majority of these stocks (89%) with much less from mills and urban waste (11%). However, small-diameter biomass was the most expensive feedstock due to the high costs of delivery which included the price paid to the owner for the right to harvest. In general, transportation costs account between 50 and 60 percent of total production costs.

Keywords: Ethanol, forestry residues, production costs, supply curves, thinning woody biomass

Introduction

Bioenergy can be converted from a wide variety of agricultural and forestry resources, including corn, sugarcane, wood, industrial processing residues, and municipal solid and urban wood waste (Perlack and others 2005). Cellulosic ethanol, one of several bioenergy outputs, is fuel ethanol made from cellulose, hemicellulose, and lignin. Cellulose is the inedible fiber that forms the stems and branches of plants and represents the main component of plant cell walls (Crooks 2006). Since cellulose is the most common organic compound on earth, it is one of the most promising feedstocks for conversion into liquid transportation fuels (Coleman and Stanturf

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2006). Among these feedstocks, forestry residues and removals from fuel treatments (hereafter, woody biomass) have attracted special attention due to their abundance, relatively low-cost production, and environmental benefits (Cook and Beyea 2000; Bartuska 2006; Gan and Smith 2006).

Woody biomass for use as a feedstock to produce ethanol is mainly derived from four processes: (1) residues associated with the harvesting of conventional forest products such as sawlogs, pulpwood, and veneer logs; (2) biomass generated from thinning to improve forest health and reduce fire hazard risks; (3) mill residues; and (4) urban waste. Due to value-added differences, we have differentiated between woody biomass and total woody biomass. The former includes low economic value material, frequently left on site or piled and burned at an additional cost. This type of material represents the focus of this study. The latter refers to all types of biomass including forest products with higher aggregated value such as lumber, veneer, and pulpwood.

Forest resources are a major component of Mississippi's economic base, covering over 18 million acres, or 62% of the state's total land area. Over $1 billion worth of forest products are harvested from Mississippi's forest lands annually and delivered to mills and other manufacturing plants, making timber one of Mississippi's most valuable agricultural crops (Munn and Tilley 2005). The value of these forest resources can be multiplied through integrated woody biomass utilization, efficient product conversion, and because of the larger production scales, reduction of major production costs (Cook and Beyea 2000). However, the development of industries to process woody biomass has been relatively slow, due to economic and resource uncertainty (Coleman and Stanturf 2006).

The purpose of this study is to quantify woody biomass resulting from the four processes mentioned above and analyze the most important production costs. Analysis and results are presented for the southwestern area of the state, which includes 15 counties and comprises 5.8 million acres of which 77 percent is forest. Hardwoods and pine are the main forest types with a low proportion of mixed forests (Figure 1).

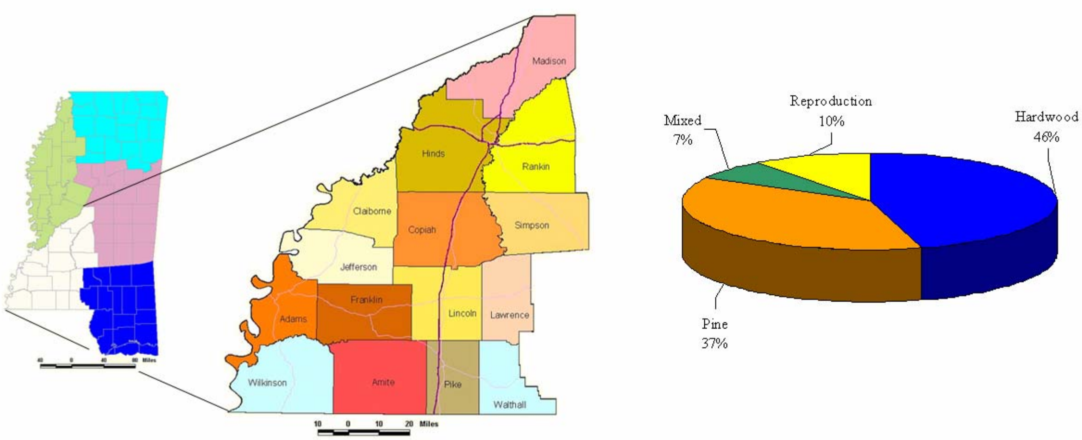

Figure 1. Location of the southwestern area and forestland distribution.

Methods

Data come from a recent forest inventory, timber production reports, and state surveys. The Mississippi Institute for Forest Inventory (MIFI) was created in 2002 to inventory the forest resources of the state. The inventory began in 2004 and currently the southwestern and southeastern portions of the state have been completed. The remainder of the forest inventory is expected to be completed by mid 2008. To gain experience and evaluate the consistency of the information for ethanol production, we are presenting results for the southwestern area as a preamble for a comprehensive study of all five regions.

Data processing and reporting are done through a computer software, called the MIFI Dynamic Inventory Reporter [http://www.mifi.ms.gov/mission.htm], which captures and report both current and historical (US Forest Service) forest inventory information. The current forest inventory integrates a satellite-based remote sensing and stratified sampling design that produces near real-time inventory of the status of forest resources. Through a combination of band analysis and mathematical modeling, primary classifications of water, non-forest, pine, hardwoods, and mixed pine-hardwood classes are obtained from remote sensing. Ground-based measurements include four types of plots: (1) a one-fifth acre fixed radius plot located randomly within forest cover classes on which conventional products (saw timber, pole) along with stand dynamics attributes are measured; (2) a one-tenth acre plot on which all trees oriented for the pulp industry are recorded; (3) a one-twentieth acre plot for trees from 1 to 4.5 inches in diameter at breast height; and (4) a one-hundredth acre regeneration plot. From this inventory and timber production reports (Howell and others 2005), we calculated total inventories, growth, and removals. Total inventories include existing biomass from all types of species, natural and planted stands, conventional products, cull trees, and small diameter trees. Growth rate is the percent of biomass growing annually and is calculated from MIFI stand table projections. Removals refer to the amount of timber produced in any year and include conventional products such as sawlogs, pulpwood, and veneer logs.

The availability of logging residues was obtained by estimating the proportion of branches to stem biomass. It was assumed that leaves are left on site for soil nutrient compensation (Sanchez and Eaton 2001). The branch-to-stem ratio was then multiplied by the amount of timber produced in 2002 based on Howell and others (2005). Small-diameter biomass was calculated by applying a rate of thinning of 60 percent over total biomass and a recovery rate of 80 percent (Harrington 2002; Perlack and others 2005) for all trees less than 8 inches in diameter at breast height. The harvest frequency was set at 30 years (Perlack and others 2005). Mill and urban waste were processed from USDA Forest Service Forest Inventory Analysis (FIA) data, state surveys (Garrard and Leightley 2005), and the Mississippi Department of Environmental Quality (information available at http://www.deq.state.ms.us/MDEQ.nsf/page/SW_Home?OpenDocument).

Production costs include cutting, skidding, loading, and transporting woody biomass to the processing plant as well as payment to the owner for the right to harvest[1]. These costs can be divided in three types: harvest (cutting, skidding, and loading), transportation, and stumpage

[1] Other plant processing costs such as equipment, installation, engineering, financing, labor, and marketing were not included. The scope of this project is to address only costs associated with processing, managing, and transporting woody biomass feedstocks to the converting facilities.

prices. Delivered prices, which are a reasonable proxy for the sum of all three, and stumpage prices, are reported in Timber Mart-South (Norris 2006).

Production costs for mills and urban waste included separation and transportation. Although still not a dominant practice, some industries are considering disposal of excess wood by selling this by-product to other industries for power generation (McNeil Technologies 2003; Garrard and Leightley 2005). In anticipation of higher demand for mill residues, we consider reuse of residues as another cost.

Table 1 shows the costs assumed in this study and the sources of information. Given the fact that there is no current commercial production of woody biomass-based ethanol, it has been difficult to simulate real production costs. In this case, we considered various sources of information and, for some processes, took pulpwood production costs as the closest product/process that resembles woody biomass production. We also assumed that the same proportion of landowners who sold forest products in 2002 (33%), would sell again in the next five years (Birch 1997).

Table 1. Summary of cost assumptions for the southwestern region of Mississippi.

Costs	Logging residues	Small-diameter trees	Mill residues	Urban waste
Harvest ($/dry ton) [a]	5.82	12.66	n/a	n/a
Transportation				
Fixed ($/dry ton) [b]	6.96	6.96	6.96	6.96
Incremental ($/dry ton/mile) [a,b]	0.14	0.14	0.12	0.12
Product value ($/dry ton) [a,c]	4.81	6.33	n/a	n/a
Selling / separating ($/dry ton) [b,d]	n/a	n/a	4.2	5.51

Source: [a] Timber Mart-South (after converting to dry tons).
[b] McNeil Technologies, Inc (2003).
[c] The final price paid to the owner. It is the stumpage price for small diameter trees
[d] Garrard and Leightley (2005).

To analyze different procurement distances, we estimated the associated production costs for different intervals from 25 to 150 miles. We then constructed a graph representing the relationship between costs and quantity of biomass produced (i.e., a supply curve). We assumed that the centers of the supply areas are the GIS-derived centroids of the counties and woody biomass is transported one-way from this center to various destinations, including off-state demand centers. Production costs were also estimated from the centroids of each county to the outer boundary of the circle for a specified radius.

The supply curves were constructed using an Excel-designed tool that plots cumulative biomass on the *x*-axis and cumulative costs on the *y*-axis. This tool allows visualization of the width and height of each bar which represent the relationship between costs versus quantity supplied. Units were expressed in terms of dry tons of woody biomass, although they could have been expressed as gallons of ethanol.

A sensitivity analysis to assess the variations in production costs was performed by reducing the stumpage price of logging residues. Since logging residues are generated during normal harvest operations, one could assume that they do not have value and their final product value should be removed from total operation costs. Thus, we considered various product values including no payment to the landowner. A second variation of the sensitivity analysis was the assignment of different transportation costs and distances.

Results

Adjusting data for 2002[1], the year of timber production data used in this study (Howell and others 2005), there are 134.4 million dry tons of standing forest inventories in the 15-county southwestern region of Mississippi. The heaviest concentrations of timber resources are found in Wilkinson, Copiah, Hinds, Amite, and Rankin (Figure 2). The annual growth for all counties and species is 12.6 million dry tons, which represents 9.3 percent of inventories. Annual removals total 5 million dry tons (year 2002), which represents 3.7 and 39.6 percent of inventories and forest growth, respectively.

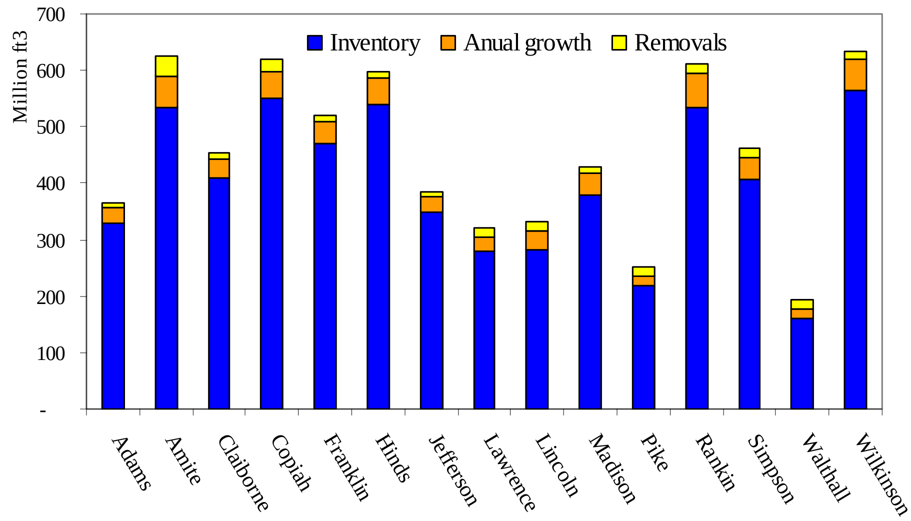

Figure 2. Inventories, annual growth, and removals for the southwestern area of Mississippi (2002).

Woody biomass availability

The annual woody biomass availability for the 15-county area is 975,000 dry tons. Of this amount, 74 percent are logging residues, 15 percent are small-diameter trees, 5 percent are urban waste, and 6 percent are produced from mill residues. Logging residues and small-diameter trees combined yield between 4.5 to 8.5 dry tons/acre/year (in this case, yield is dry tons divided by forest area), with an average of 6.8 dry tons/acre/year. The ratio of timber production to logging residues is 6.7, which means that 6.7 tons of conventional timber production generates one ton of

[1] Data were adjusted by discounting the accumulated growth with respect to 2007. Growth rates for each county were obtained from the MIFI reporter.

logging residues. Assuming 80 gallons of ethanol per dry ton of woody biomass (DOE 2007, http://www1.eere.energy.gov/biomass/ethanol_yield_calculator.html) and a manufacturing plant energy efficiency of 35 percent (Hamelinck and others 2005; Gan and Smith 2006) the total production of ethanol can reach up to 27 million gallons per year or, in energy units, 2.3 millions of MMBtu, which is equivalent to the 0.0002 percent of the total US energy consumed in 2005 (EIA 2005). The southwest Mississippi counties with the greatest ethanol potential are Amite, Copiah, and Rankin (Figure 3).

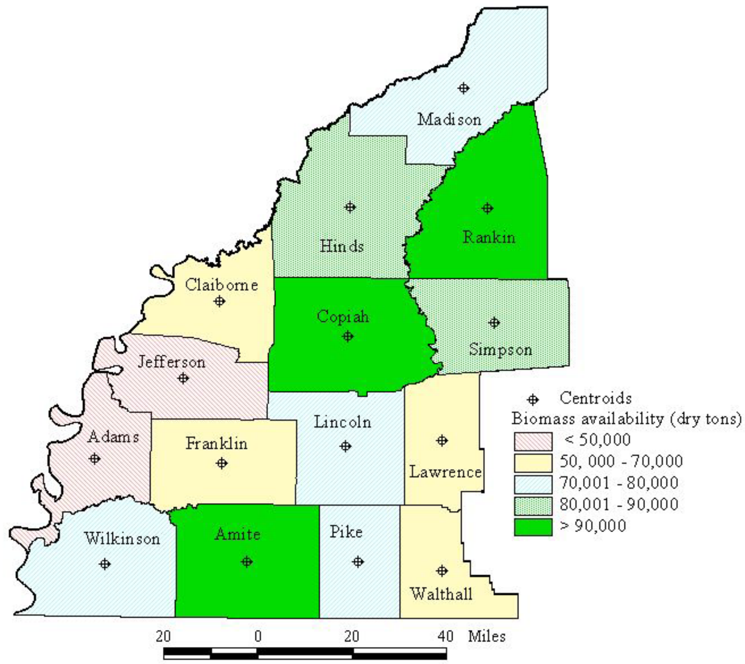

Figure 3. Biomass availability for the southwestern MIFI inventory region of Mississippi.

We conducted a temporal analysis of small diameter trees availability using stand table projections of gross growth from the MIFI Dynamic Inventory Reporter. Since logging residues basically depend on the amount of timber harvested, they were not included in these data projections. Instead, we used a percent change of timber harvested from 2000 to 2005 and applied the 2002 timber production to logging residues ratio to estimate the trends for the following years (Gan and Smith 2006). The percent change r_w was calculated as follows:

$$r_w = 1 - \left(1 - \frac{A_1 - A_2}{A_1}\right)^{1/t}$$

where w is species group (pine or hardwood), A_1 is the timber production at time 1, A_2 is the timber production at time 2, and t is the number of years for the period of analysis. Based on timber severance data (Mississippi State Tax Commission, http://msucares.com/forestry/economics/reports/index.html), the percent changes for this period were: pine -0.013, hardwoods -0.094, for a combined rate of -0.042. We assumed no substantial variations in the amount of mill residues and urban waste. The results of the projections for the next five years are shown in Figure 4.

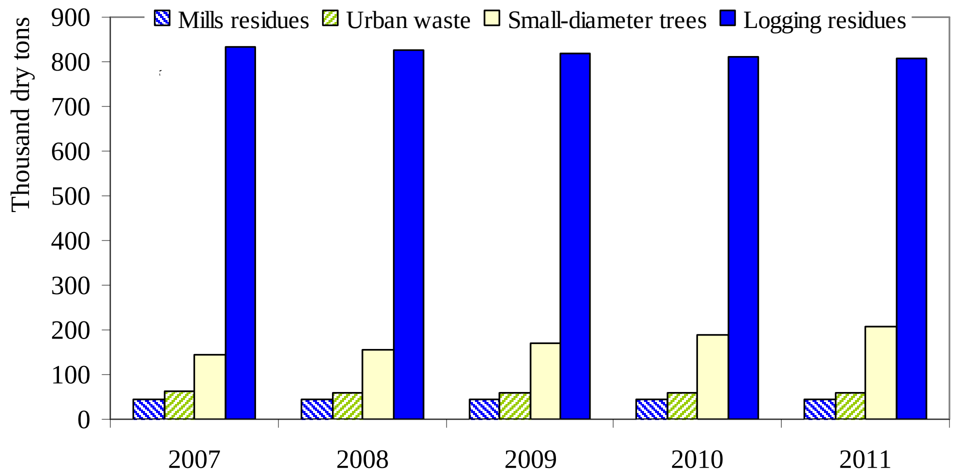

Figure 4. Annual woody biomass supplies for the southwestern MIFI inventory region of Mississippi.

Accordingly, Figure 4 shows a slight decrease in the availability of logging residues driven by a reduction in harvests of pulpwood, mostly from hardwoods. In 2000, production of pulpwood from hardwoods was 398 million ft^3 whereas in 2005 production was only 240 million ft^3 (Mississippi State Tax Commission, information available at http://msucares.com/forestry/economics/reports/index.html). In contrast, small-diameter biomass shows a significant increase due to a higher growth rate and reduced harvesting.

Production costs

The resulting supply curves suggest that woody biomass from small-diameter trees are more costly than the other sources of biomass. In fact, mill residues and urban waste from distances up to 150 miles can compete with closer, more expensive biomass. However, mill residues and urban waste make up a small percentage of total supply. Reducing the product value of logging residues (while keeping constant all other costs) produced no significant results until it is equal or less than one. For any product value between $1 and 14, logging residues are the second most expensive feedstock, only behind small-diameter trees. When the product value is equal or less than one, logging residues becomes the second less expensive, only behind mill residues.

For all woody biomass types, transportation costs accounted for the majority of production costs (50–60%). Based on the weighted average for all woody biomass, total production costs per dry ton are: $25.1 for a 50-mile radius, $27.6 for 100-mile radius, and $33.2 for 150-mile radius. Individual costs by woody biomass source are shown in Figure 5.

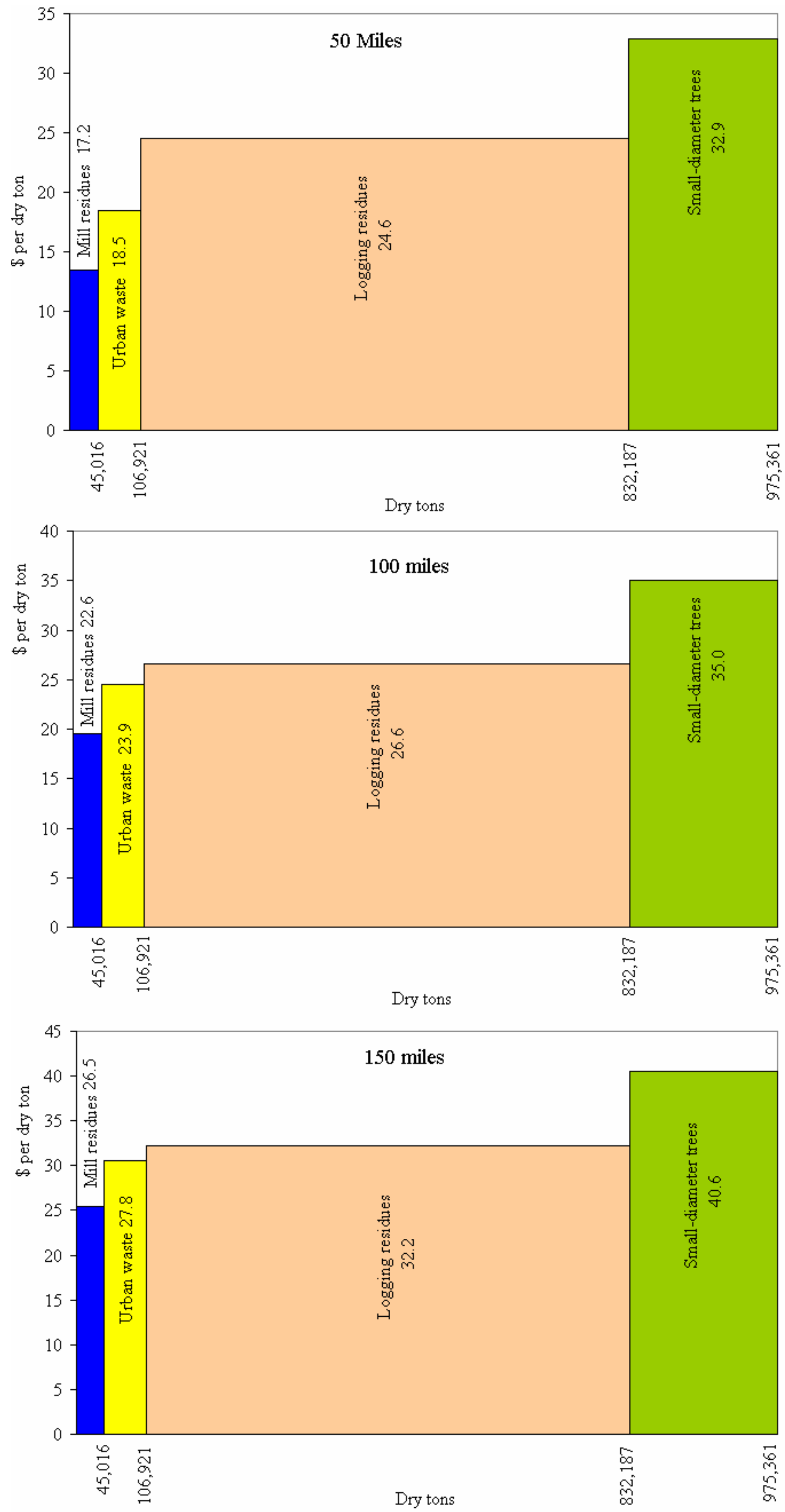

Figure 5. Woody biomass supply curves for distances 50, 100, and 150 miles.

Conclusions

This research was conducted to estimate woody biomass availability from logging residues, small-diameter trees, mills residues, and urban waste sources as a feedstock to produce ethanol in the 15-county southwestern MIFI inventory region in Mississippi. We used MIFI's recent forest inventory and Dynamic Inventory Reporter to provide accurate information on the distribution and quantity of timber resources. Other sources of information included state reports on woody biomass and USFS FIA data. Results showed that the annual woody biomass available in the Mississippi's southwestern 15-county area is 975 thousands dry tons (excluding conventional forest products such as sawlogs and veneer logs which have higher aggregated value). These stocks can produce up to 27 millions gallons of ethanol per year. The counties with the highest biomass potential are Amite, Copiah, and Rankin. Logging residues and overstocked stands (small-diameter trees) make up the majority of woody biomass supplies (89%) whereas the non-used portion of mill residues and urban waste contributed to 5 and 6 percent, respectively. However, small-diameter biomass was the most expensive feedstock due to the high cost of delivery, including the price paid to the owner for the right to harvest and transportation. Langholtz and others (2006) found similar results for the high costs of small diameter trees. The study also confirms that transportation is one of the major factors influencing ethanol production. Transportation costs account between 50 and 60% of total production costs. Future research should include input-output studies to assess the impacts of developing cellulosic ethanol biorefineries on Mississippi's economy and ecology.

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