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A FOREST PRODUCT/BIOENERGY MILL LOCATION AND DECISION SUPPORT SYSTEM BASED ON A COUNTY-LEVEL FOREST INVENTORY AND GEO-SPATIAL INFORMATION

By

Thomas Luke Jones

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A FOREST PRODUCT/BIOENERGY MILL LOCATION AND DECISION SUPPORT SYSTEM BASED ON A COUNTY-LEVEL FOREST INVENTORY AND GEO-SPATIAL INFORMATION

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The forest products industry is a major component of the economic base for many states in the southeastern United States. Forest inventories precise within a mill working circle and the availability of decision support tools for locating mills are important in attracting and sustaining the industry. This research focuses on the status of Mississippi's efforts to provide forest inventory information to attract forest industry. A pilot study is described that integrates a decision support system (DSS) in a 40-mile radius working circle with a geo-spatially based county-level forest inventory and a transportation network to determine the feasibility and optimal location of a case study Oriented Strand Board (OSB) mill. A linear programming (LP) model was constructed to minimize the cost of procuring and transporting wood to the case study OSB mill site. Net revenue (NR) was calculated to assess financial feasibility of placing the mill at the selected location.

DEDICATION

I would like to dedicate this research to my grandfather, Thomas E. Jones.

ACKNOWLEDGEMENTS

I would like to thank my parents, Ranny and Melissa Jones, for always encouraging me to do well in school and for molding me into the person that I am today. I would not have achieved much throughout my life if it was not for them. I want them to know that I appreciate everything and that I love them very much.

I would also like to thank Dr. Emily B. Schultz and Dr. Thomas G. Matney for giving me the opportunity to work on such a unique research project and the opportunity to further my education. I would like to thank Curt Collins, David Wilkinson, and Gan Li for their hard work in preparing data for the project. I would also like thank three of my true friends, Mike Jackson, Paul Jeffreys, and Cade Booth, for being there when I needed someone to talk to.

Last but not least, I would like to thank my wife, Lauren, for giving me the strength and the confidence to never give up on the project when things got frustrating. She always has a way of bringing the best out in me when I am at my worst. I want her to know that I love her more than anything in the world, and that I can not wait to spend the rest of my life with her.

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CHAPTER I

INTRODUCTION

Selecting an optimal location for a forest-based industry is a data intensive and costly exercise typically conducted by corporate and government decision-makers. The process involves the manual integration of analyses from numerous consultants and experts and can be error prone. Mill location studies can cost hundreds of thousands of dollars and can take months or years to complete. Since such a study takes a long period to complete, it also has to keep pace with changes that might affect the outcome of such an analysis. Included in the information that potential investors must know are: 1) the quantity, location, and type (i.e., species, size class) of woody feedstock available, 2) transportation networks and delivery costs of raw material to the mill and of finished product to the market, 3) sustainability of feedstocks (e.g., future growth, utilization), 4) competing utilization for raw materials, 5) product demand, and 6) various types of socio-economic data on education and the workforce. Without this information, investors will not be capable of making sound minimum risk investment decisions. This analysis is mandatory not only to establishing new facilities but also for planning modification or expansion of existing facilities. Computer-based decision support systems (DSS) are needed that efficiently coalesce geo-spatial information, forest inventory, transportation costs, and socio-economic factors to allow forest-based investors to rapidly assess economic viability and sustainability of proposed plant locations and capacities. These same tools can also be used to evaluate proposed plant expansions/modifications and predict future raw material availability and evaluate the impact of competing resource consumers (e.g., particle-based panels and lumber, plywood, sawtimber, poles, veneer, pulpwood, reconstituted solid wood products, and exports). Without these tools, poor decisions could be made resulting in mill closures or a lack of investment by industry because of uncertainty. The State of Mississippi has a unique opportunity to develop a DSS for selecting optimal mill locations and monitoring forest resource sustainability because of its current county-level forest inventory system. The construction of a DSS is the focus of this research.

A variety of industries compete for a limited forest resource that meets specific manufacturing requirements. Each product requires a minimum log diameter size class and quality. Any one forest-dependent plant must compete with all other product manufacturers and buyers within a targeted procurement area. Traditional forest products or emerging bio-energy plants must find sufficient volume/biomass among competing uses that is obtainable at a reasonable cost within a required product size class. The price and availability of feedstocks will depend upon supply and existing demand within the procurement area of a proposed plant. Multi-product forest product companies direct the flow of products to their various mills based on tree diameter, length, and quality. For example, representative pine merchantability specifications are 3.6 to 7.5 inches diameter at breast height (dbh) for pulpwood, 7.6 to 8.5 inches for chip-and-saw, 8.6 to 11.5 inches for peelers, and 11.6 inches and greater for sawlogs. Higher quality pulpwood sized trees are also utilized for particle-based panels and lumber [e.g., oriented strand board (OSB), engineered solid wood products]. Bio-fuels will most likely compete directly with mill and forest residues (e.g., logging slash) and pulpwood-sized trees, which can also be considered sawtimber growing stock.

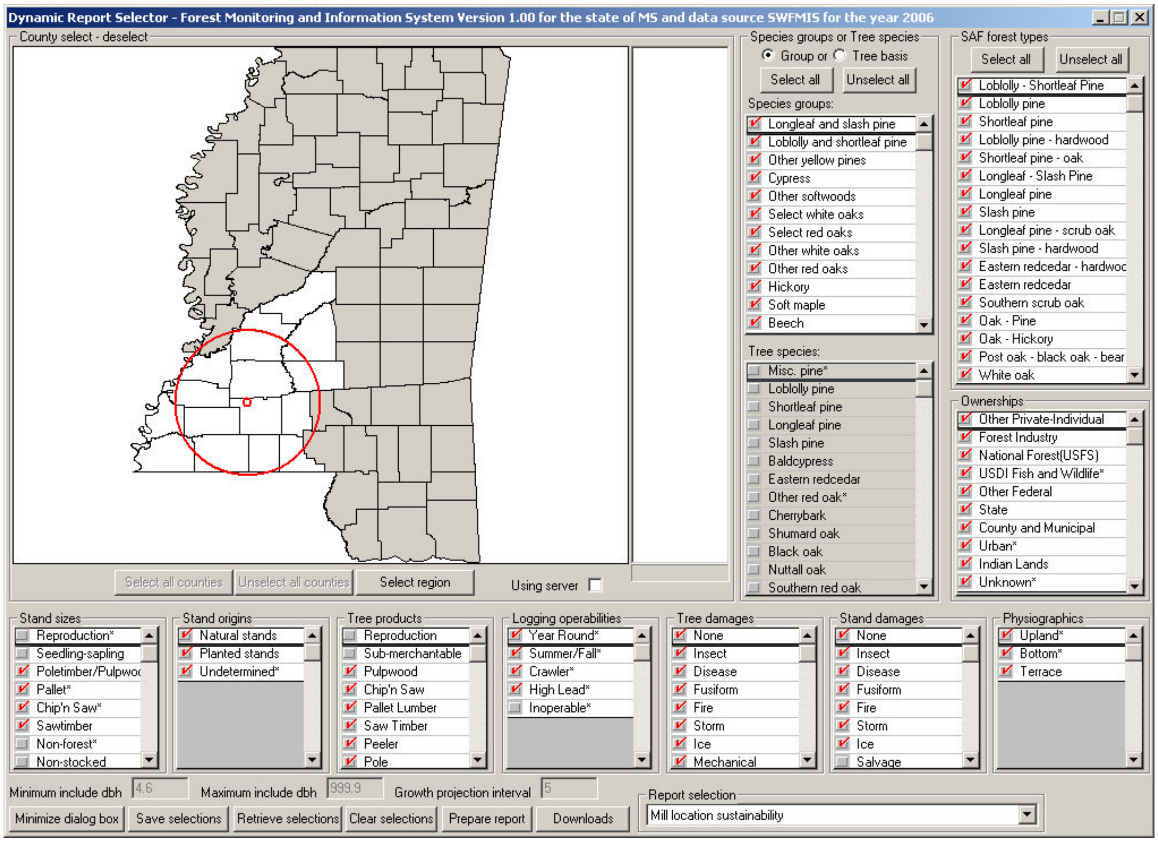
Thirteen southeastern states contain nearly one-third of the forest inventory and almost one-half of the timber harvested in the United States (U.S.) (Sun and Zhang 2001). Forest industries in these 13 states produce 45% of the softwood lumber, 56% of total paper production capacity, and 72% of total wood pulp production capacity. The forest products industry is a major component of Mississippi’s economic base, with timber one of the most valuable agricultural crops accounting for more than $1 billion of harvested forest products annually (Munn and Tilley 2005). In 2001, the amount of pine and hardwood stumpage utilized resulted in $801 million in payments to Mississippi landowners. The total (i.e., direct and indirect) output for aggregated forest-related sectors was approximately $13.4 billion with $5.3 billion of value-added (Munn and Tilley 2005). The early indications are that increased utilization of forest thinnings and logging residues for bio-fuels promises to add more value and importance to Mississippi's forest industry (Grebner et al. 2009). Mississippi has enough woody biomass residues to produce 280 to 400 million gallons of ethanol annually utilizing a range of currently available conversion technology or an equivalent of 6,500 to 9,300 MW of electricity. The development of a bio-fuel industry could translate into additional jobs, wages, expenditures, and regional production (Grebner et al. 2009). Forest lands, like those in Mississippi, provide an array of sources for woody biomass that could potentially be utilized for bio-fuels production. These sources include standing woody biomass, forest residues, and manufacturing residues. Growing demand for woody biomass from bio-fuel markets heightens the importance of obtaining forest inventory information and DSS tools on a scale fine enough for attracting and maintaining the industry and sustaining the resource.

This research addresses the current effort to provide the State of Mississippi with forest inventory information to attract forest industry and balance potentially increased utilization due to new markets with resource sustainability. A pilot study was conducted that integrates a DSS with a geo-spatially based county-level forest inventory to help determine the feasibility and location of forest products mills. The DSS was developed in phases, and background information important to the current work in optimal mill location and feasibility, forest resources assessment, transportation, and mill requirements are reviewed. The next DSS phase of the study will include the addition of socio-economic data to the spatial database and several timber supply regions in order to determine optimal mill location.

CHAPTER II

OBJECTIVES

A mill location and feasibility case study for the southwest Mississippi Institute for Forest Inventory (MIFI) inventory region was carried out based on inventory data and the MIFI Dynamic Reporter Interface DSS developed at the Forest and Wildlife Research Center (FWRC), Mississippi State University. The objective was to provide the basis for future enhancements to the existing MIFI DSS allowing users to choose options that determine the feasibility and optimal location of a forest products based mill (Figure 1). User inputs will include selecting the inventory region of Mississippi, type of mill and requirements, resource area size surrounding the proposed mill location, timber type and size class, and ownership class. The final outputs of the mill case study were an objective function value and a Net Revenue (NR) to determine location and feasibility of a proposed OSB mill. In future studies, optimal mill location and feasibility will be determined by comparing objective function values and NRs among proposed sites.


Dynamic Report Selector - Forest Monitoring and Information System Version 1.00 for the state of MS and data source SWFMIS for the year 2006

County select - deselect

Using server ☐

Species groups or Tree species: ● Group or ○ Tree basis

Species groups:
- ☑ Longleaf and slash pine
- ☑ Loblolly and shortleaf pine
- ☑ Other yellow pines
- ☑ Cypress
- ☑ Other softwoods
- ☑ Select white oaks
- ☑ Select red oaks
- ☑ Other white oaks
- ☑ Other red oaks
- ☑ Hickory
- ☑ Soft maple
- ☑ Beech

Tree species:
- ☐ Misc. pine*
- ☐ Loblolly pine
- ☐ Shortleaf pine
- ☐ Longleaf pine
- ☐ Slash pine
- ☐ Baldcypress
- ☐ Eastern redcedar
- ☐ Other red oak*
- ☐ Cherrybark
- ☐ Shumard oak
- ☐ Black oak
- ☐ Nuttall oak
- ☐ Southern red oak

SAF forest types:
- ☑ Loblolly - Shortleaf Pine
- ☑ Loblolly pine
- ☑ Shortleaf pine
- ☑ Loblolly pine - hardwood
- ☑ Shortleaf pine - oak
- ☑ Longleaf - Slash Pine
- ☑ Longleaf pine
- ☑ Slash pine
- ☑ Longleaf pine - scrub oak
- ☑ Slash pine - hardwood
- ☑ Eastern redcedar - hardwoc
- ☑ Eastern redcedar
- ☑ Southern scrub oak
- ☑ Oak - Pine
- ☑ Oak - Hickory
- ☑ Post oak - black oak - bear
- ☑ White oak

Ownerships:
- ☑ Other Private-Individual
- ☑ Forest Industry
- ☑ National Forest(USFS)
- ☑ USDI Fish and Wildlife*
- ☑ Other Federal
- ☑ State
- ☑ County and Municipal
- ☑ Urban*
- ☑ Indian Lands
- ☑ Unknown*

Stand sizes:
- ☐ Reproduction*
- ☐ Seedling-sapling
- ☑ Poletimber/Pulpwoo
- ☑ Pallet*
- ☑ Chip'n Saw*
- ☑ Sawtimber
- ☐ Non-forest*
- ☐ Non-stocked

Stand origins:
- ☑ Natural stands
- ☑ Planted stands
- ☑ Undetermined*

Tree products:
- ☐ Reproduction
- ☐ Sub-merchantable
- ☑ Pulpwood
- ☑ Chip'n Saw
- ☑ Pallet Lumber
- ☑ Saw Timber
- ☑ Peeler
- ☑ Pole

Logging operabilities:
- ☑ Year Round*
- ☑ Summer/Fall*
- ☑ Crawler*
- ☑ High Lead*
- ☐ Inoperable*

Tree damages:
- ☑ None
- ☑ Insect
- ☑ Disease
- ☑ Fusiform
- ☑ Fire
- ☑ Storm
- ☑ Ice
- ☑ Mechanical

Stand damages:
- ☑ None
- ☑ Insect
- ☑ Disease
- ☑ Fusiform
- ☑ Fire
- ☑ Storm
- ☑ Ice
- ☐ Salvage

Physiographics:
- ☑ Upland*
- ☑ Bottom*
- ☑ Terrace

Minimum include dbh 4.6

Maximum include dbh 999.9

Growth projection interval 5

Report selection: Mill location sustainability

Figure 1 The pilot version Mississippi Institute for Forest Inventory (MIFI) interface decision support system (DSS) that determines optimal forest product-based mill location in southwest Mississippi for the 40-mile radius working circle near Brookhaven, MS.

CHAPTER III

LITERATURE REVIEW

Optimal Mill Location

Optimal mill location and feasibility studies have been traditionally carried out by forest industry and, therefore, are usually proprietary and never published. As a result, there are few examples in the literature. An optimal mill location can be defined as a site that minimizes the sum of procurement and shipment costs from a processing plant to market (McCauley and Caulfield 1990). Distribution and market costs may also be considered (Lin et al. 1996). Important factors involved in an optimal location study include stumpage availability, furnish mix, wood costs, market distance, market penetration, species type, capital availability, timber supply, and product market demand (Lin et al. 1996; McCauley and Caulfield 1990).

McCauley and Caulfield (1990) divided Alabama into supply and demand points that consisted of 10 regions based on topography, species, and supply characteristics. Potential plant site locations were designated as each region's geographic center. A linear programming model was used with a base-level set of parameters to find an optimal plant location. The model's objective function value minimized the costs of procuring timber to potential sites and transporting finished products to demand points. Model variables included potential plant sites, supply regions, market locations, cost of procuring pine and hardwood timber, cost of transporting final product to market, amount of pine and hardwood available, demand for the final product, amount of wood required by the mill, amount of mill furnish consisting of hardwoods, amount of final product produced, number of plants located within the region, amount of pine and hardwood transported to the mill, amount of the final product transported to market from a plant site, and total amount of wood transported to a potential plant site. Supply information was obtained from the U. S. Department of Agriculture Forest Service (FS) Southern and Southeastern Experiment Station analyses that calculated growth minus natural mortality and pulpwood annual removals. Calculated surplus was assumed to be the only source of wood available. Timber cost was estimated from the sum of stumpage, logger profits, and harvesting and transportation costs. Transportation and harvesting costs were derived from prices of pine and hardwood stumpage provided by *Timber Mart-South*. To assess how changes in assumptions would influence the optimal location decision, a sensitivity analysis was conducted. While McCauley and Caulfield (1990) addressed a complex management problem, they separated capacity planning and location planning.

Lin et al. (1996) considered capacity and location simultaneously while including operating costs by using OSB/LOCATION software, a decision support program with financial and mixed integer linear programming (MILP) models for locating OSB mills in eastern Alabama. MILP determined the optimal location and size based on the most cost efficient set of options and considered factors such as capital availability, timber supply, and product market demand. Economic desirability was evaluated with a financial model developed under expenditure and capital investment assumptions and analyzed by discounted cash flows. The objective function of the Lin et al. (1996) MILP problem minimized the sum of costs for mill establishment, procuring timber for the potential mill, transporting products to markets, and mill operation. Model constraints were mill input, mill output, mill site and size, market target, timber supply, and budget. Input data required for the OSB/LOCATION program fell into six categories: model parameters, timber supply information, OSB market information, transportation data, financial data, and operating cost data. Model parameters accounted for the number of potential plant locations and sizes, timber supply regions, and product markets. These factors determined the size of the MILP model. Timber supply information was derived from FS Forest Inventory and Analysis (FIA) data and delivered mill prices were input by region. OSB market information estimated from demand quantities, predicted selling prices, and target market shares. Transportation data were distances and costs from plant locations to various markets, and financial data included the working capital of plants, the initial capital investment, and a minimum rate of return. The OSB/LOCATION program returned optimal plant location and size, timber resource use information, production-distribution cost information, investment return information, and marketing information (Lin et al. 1996).

Mill Feasibility

Optimal mill location is a component of determining financial feasibility which must be examined by calculating net present values (NPV) and internal rates of return (IRR). Blinn et al. (1986) calculated after tax NPV to determine economic and market feasibility of a proposed 1986 yellow-poplar (*Liriodendron tulipifera* L.) OSB mill producing 120 million ft^2 in a preselected area. Labor supply, geographical distribution of markets, resource quality and availability, and raw material costs were factors considered. Quantity of available resource and influences of landowner attitudes and accessibility were based on FS data. Assumptions for simulating a prototype OSB plant included capital requirements and costs for production, maintenance, engineering, energy, residue, supplies, and other fixed costs such as taxes, insurance, depreciation, and administrative salaries. A specified plant operating schedule was also assumed. Risk was included in the cash flow projection by inputting derived data in a computer-based Forest Products Investment Model (FPIM) that performed a Monte Carlo simulation and generated NPV probability distributions (Chambers et al. 1986). Other estimates and assumptions were made for depreciation and investment tax credits, gross revenues, and investment period. FS data estimated excess yellow-poplar growth and availability within a 75-mile radius of the plant site. A market analysis estimated the percentage of market penetration necessary to sell plant products within 300- and 500-mile radii (Blinn et al. 1986).

Forest Inventory, Growth, and Drain

All mill feasibility and optimal location studies require an accurate estimate of wood resources available to the mill. Several factors influence availability including land ownership, current growing stock, and projected yields. In Mississippi, 65% of the land is owned by nonindustrial private forest (NIPF) landowners, 18% by forest industry, and 17% by the state and federal government (Arano and Munn 2004). NIPF landowners generally own small and fragmented tracts of land and may have less capital to support management activities. Future increases in demand, like that from a new bio-fuel market, could necessitate less traditional or more intensive forest management practices to avoid timber scarcities (Arano and Munn 2004). Since NIPF landowners control a large proportion of Mississippi forest land and employ fewer management practices, there could be serious implications for future timber availability. Information on landowner attitudes and ownership patterns are important in estimating the proportion of forest resource availability to a mill and for planning sustainability of a potential mill. Ownership statistics for Mississippi have been collected by the Mississippi Institute for Forest Inventory (MIFI), and another study is currently being conducted at Mississippi State University to assess the willingness of different landowner groups to manage and sell timber.

Increased transportation costs of delivering raw materials to a mill have decreased procurement working circle radii and created a greater need for forest inventories that are precise for areas as small as a county. In 2002, MIFI was created to fulfill the need for a county-level forest inventory. This inventory together with a Web-based DSS tool is being used to assist statewide forest resource planning and mitigate the risk associated with decisions made in selecting a forest product-based mill location. Before MIFI inventory data were available, forest resource volume estimates were primarily based on FS FIA large area inventory data, which is currently sufficiently precise at only a 10 county or more area basis (USDA FS 2005). For FIA data, even at a 10+ county area, the percent sampling error at a confidence level of 95% is around 67%, and this sampling error is too large to secure funding from most financial institutions. Conversely, a five-county or larger area is typically larger than the maximum working circle required by most forest industries. Industry will be reluctant to invest in new facilities unless mill location analyses support the ability of the resource in a targeted area to sustain the mill throughout its expected life. The best way to estimate sustainability and delivered cost of raw material is through an integrated inventory growth and harvest projection system derived from a geo-spatial database reconciled with a precise geo-spatial inventory.

The MIFI inventory facilitates the estimation of growth and drain on a much smaller acreage basis than the FIA inventory. The State has been divided into five regions (i.e., north, central, Delta, southeast, southwest) with one region inventoried each year on a rotating basis. The inventory is spatially-based with sufficient sampling to be reliable at the county-level. Targeted sampling error levels are ± 15% at the 95% confidence level (Parker et al. 2005). Inventory plots are allocated within a county according to an optimal stratified random sampling scheme based on satellite imagery and forest GIS strata (i.e., pine, hardwood, mixed pine-hardwood).

Inventory data and spatial information are incorporated into the MIFI Inventory Dynamic Reporter DSS (Matney and Schultz 2008). This Microsoft Windows® based interface allowed users to obtain geo-spatial estimates of current and expected future forest volume and biomass within specified counties, working circles, or polygon bounded regions for combinations of nine forest and political selection attributes. Historical Landsat scenes are used to determine forested areas and change detection (i.e., afforestation, harvest detection, deforestation), and growth is obtained through stand table projection procedures.

Transportation

Transportation distances in acquiring wood, delivering products, and related costs are important factors in determining the feasibility and optimal location of a mill. The organization of vehicles for transportation of goods is a monumental challenge (Créput and Koukam 2007). Transportation networks are constantly changing such as railway realignment, new facilities, and rerouted roads (Han et al. 2003). McCauley and Caulfield (1990) measured transportation distance was from the supply region to a potential mill site as the straight line distance between two points on a road map (i.e., the center point of a region). The disadvantage of this method was that it underestimated the transportation distance and, thus, the transportation cost. Current geo-spatial road databases and GISs now present the opportunity for making more accurate distance calculations. There has been widespread adoption of GISs for spatial-related analysis tools for fields such as water resources, transportation, and environmental (Han et al. 2003).

Transportation systems contain spatial and temporal dimensions which make GIS suitable for analyzing these problems (Han et al. 2003). Many areas such as business analysis, transportation, urban planning, civil engineering, and facilities management have seen successful implementations (Li et al. 2003). Transportation systems have been researched in other application areas. Han et al. (2003) looked at using GIS platforms as techniques for developing a framework to allow spatial data sharing. This study outlined the importance of sharing multijurisdictional transportation data in order to account for changes in transportation networks to perform better transportation analyses in civil engineering (Han et al. 2003). Li et al. (2003) developed an internet based GIS system to find optimal routes for construction material procurement in China. The system allowed construction material buyers to determine costs of transportation from different areas (Li et al. 2003).

Grebner et al. (2005) found that the Microsoft Excel® (Microsoft 2003) based program Routechaser (Stuart and Grace 2008) was a useful tool in determining transportation costs from wood procurement areas to mills. The program takes into account the effects of operating costs, tract location, scheduling parameters, vehicle operating parameters, and other physical and economic inputs. Once the inputs are determined, the model produces a daily cost of operation by tract and market combination, delivered loads, per ton cost, per ton mile cost, delivered loads, volume per day, and outlays per day by expenditure type. Routechaser produces more realistic estimates of transportation costs than the straight line distance method.

Forest industries and local economic development organizations need reliable and precise forest inventory estimates based on a 50- to 80-mile mill working circle. This is critical to determining where forest manufacturing facilities can be located, as they need to be centrally positioned in areas where raw material supplies can be sustained at reasonable transportation costs over the manufacturing facility life. Since transportation costs are an ever increasing factor, for a facility to operate profitably the mill must be located in an area that has a transportation network sufficiently small to make the facility operation feasible. Since the MIFI DSS is the only large-scale inventory system in the U.S. that is designed to provide estimates at the county-level scale with the desired precision, it is a valuable asset for assessing the feasibility of proposed plant locations (Parker et al. 2005).

Feedstock Requirements and Capacities

Mill production capacities and annual wood, species, and age class requirements are important input factors in feasibility and optimal location studies. Blinn et al. (1986) reported on the production capacity for an OSB mill in Appalachia that was 120 million ft^2 on a 3/8-inch basis per year. Yellow-poplar was the required species because of its similar properties to the preferred species of aspen (*Populas* spp.). Annual solid wood requirements for the mill consisted of 7.5 million ft^3 based on industry data and manufacturer's specifications. Timber supplied to the mill was in 16-foot lengths and ranged from 4 to 20 inches in diameter (Blinn et al. 1986). The McCauley and Caulfield (1990) OSB plant required 110,000 cords of wood annually to produce 160 million ft^2 of 3/8-inch OSB. Species mixture included sweetgum (*Liquidambar styraciflua* L.), yellow-poplar, and southern pine (*Pinus* spp.). Current production statistics are confidential by nature within the industry and are not generally available. Operationally, however, an integrated DSS for evaluating optimal mill locations and their feasibility would allow industry users to input their own production statistics without fear of disclosure.

CHAPTER IV

METHODS

The pilot version of the mill location DSS utilized the 15-county 2004 - 2005 MIFI southwest forest inventory, where an average of 150, 0.2-acre fixed radius plots per county had been allocated and measured (Figure 2). Inventory data and spatial information were used to develop GIS layers for forest type, age, and volume. GIS layers for forest type (Figure 3) and age were supplied by the Spatial Information and Technologies Laboratory in the Forest and Wildlife Research Center at Mississippi State University. The age and forest type layer were constructed through change detection techniques using Landsat data from 1972 to 2006. For the purposes of this case study, a potential mill location was selected with geographic coordinates of Latitude: North 31 degrees, 39 minutes, and 8.01 seconds and Longitude: West 90 degrees, 34 minutes, and 2.4 seconds, near Brookhaven, MS (Figure 1). This location was the center of a 40-mile radius procurement working circle. A 40-mile radius working circle was the maximum size that would fit entirely within the southwest inventory region.

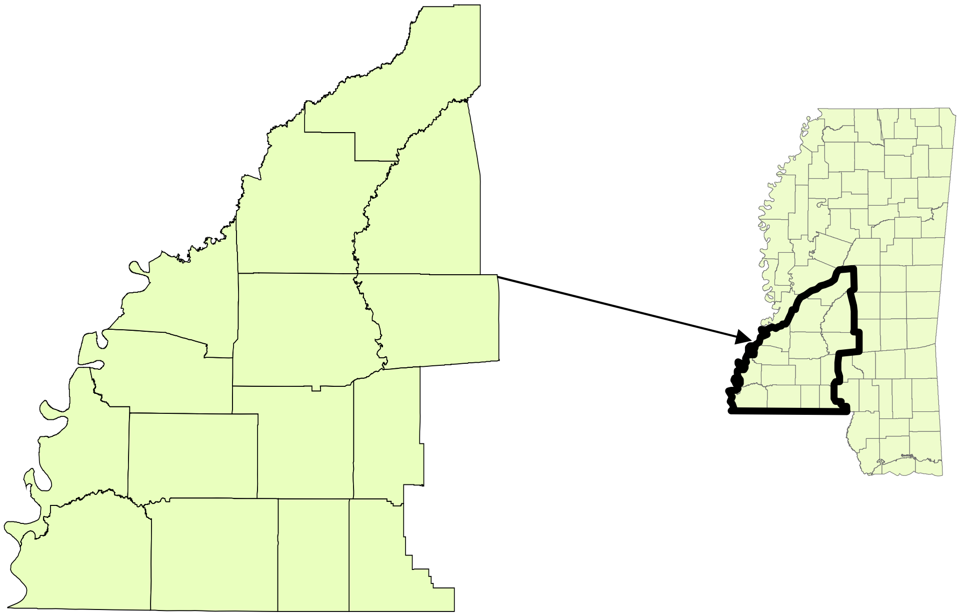


Figure 2 Fifteen-county southwest Mississippi study area inventoried by Mississippi Institute for Forest Inventory (MIFI) in 2004 and 2005.

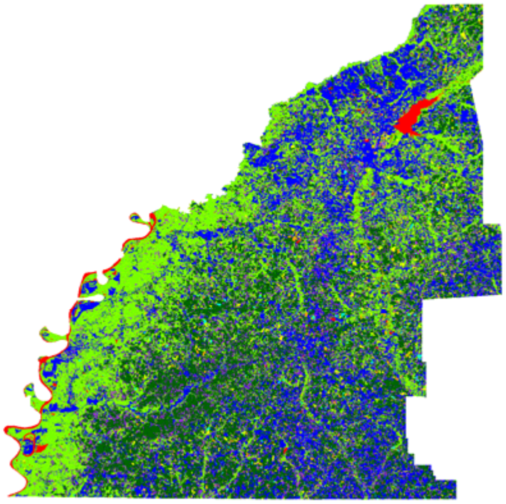


Figure 3 The 2004 geographic information system (GIS) forest type layer for the southwest Mississippi Institute for Forest Inventory (MIFI) inventory region developed from Landsat data and used as decision support system (DSS) input for calculating growth and drain volumes by forest type (Light green = hardwood, Dark green = mixed pine-hardwood, Blue = pine, and Red = water).

Regression Equations and Volume Layers

The 2004/2005 MIFI southwest forest inventory was used to develop regression equations to predict volume and produce the desired volume layers by the GIS forest type strata of pine, mixed pine-hardwood, and hardwood. Volumes were estimated in 11 different units (Table 1) from the regression of the natural log of volume on the inverse of GIS age and estimated for each image pixel in the user selected area. This can be expressed mathematically by equation (1):

$$ln(vol) = b_0 + b_1\left(\frac{1}{GIS\ age}\right) \qquad (1)$$

where ln = natural logarithm, vol = volume, and b_0 and b_1= regression coefficients.

Table 1 Eleven volume units used to estimate the amount of pine, mixed pine-hardwood, and hardwood volume within the southwest Mississippi Institute for Forest Inventory inventory region of Mississippi.

- Cubic foot inside bark pulpwood (cfibpw)
- Cubic foot inside bark to a pulpwood top (cfibpwtp)
- Cubic foot inside bark sawtimber (cfibst)
- Cubic foot inside bark to a sawtimber top (cfibsttp)
- Cubic foot outside bark pulpwood (cfobpw)
- Cubic foot outside bark to a pulpwood top (cfobpwtp)
- Cubic foot outside bark sawtimber (cfobst)
- Cubic foot outside bark to a sawtimber top (cfobsttp)
- Doyle sawtimber (doyle)
- International ¼ sawtimber (int14)
- Scribner sawtimber (scribner)

ERDAS Imagine's® spatial modeler (Leica Geosystems 2003) was used to create volume layers with 300m resolution from each set of regression equations. The forest type and age layers were model inputs and volume was calculated for each image pixel based on these factors. GIS volume was then reconciled with MIFI inventory volume for each stratum using contained least squares procedures.

Growth and Drain

Growth, the forest resource growing at the present rate projected to a specified time, volumes were calculated from growth curves based on the volume-age relation in Equation (1). Total growth included base volume growth plus ingrowth. Ingrowth for a pixel was determined through change detection techniques that indicated current forest cover where none had been previously. Drain, the forest resource removed or harvested within a given time period, volumes were removed from growth by comparing 2004 and

2006 Landsat images (Figure 4) to identify harvested areas and predicted removals. Removals were randomly allocated to procurement areas that matched volume, age, and forest type classes. The resulting growth to drain ratio indicated the sustainability of forest resources under current and future harvest demands.

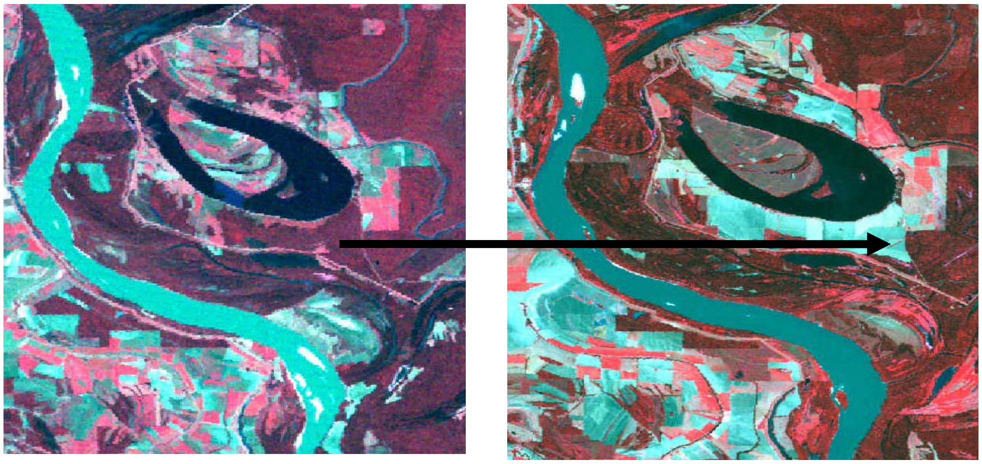


Figure 4 Portions of historical Landsat scenes of the Eagle Lake area located near Vicksburg, Mississippi, in 1972 (left) and 2004 (right) as an example of change detection techniques used to determine forested area and derive growth and drain ratios (Jones et al. 2009).

Transportation Network

Geo-spatial data for Mississippi's road network were obtained from the Mississippi Automated Resource Information System (MARIS) (MARIS 2006), and transportation network nodes and segment lengths were constructed from the primary, secondary, and county roads (Figure 5) using ArcGIS® software (ESRI 2005). The resulting network provided input to a Microsoft Visual C++® (Microsoft 2005) minimum route algorithm that accumulated volumes and weights by GIS forest type and calculated minimum route distances from each forested pixel for a selected 40-mile radius working circle to the proposed mill location. Forty miles was chosen as the case working circle radius because it was the maximum distance possible and still remain totally within the southwest inventory region. The southwest region was the first of five regions inventoried by MIFI.

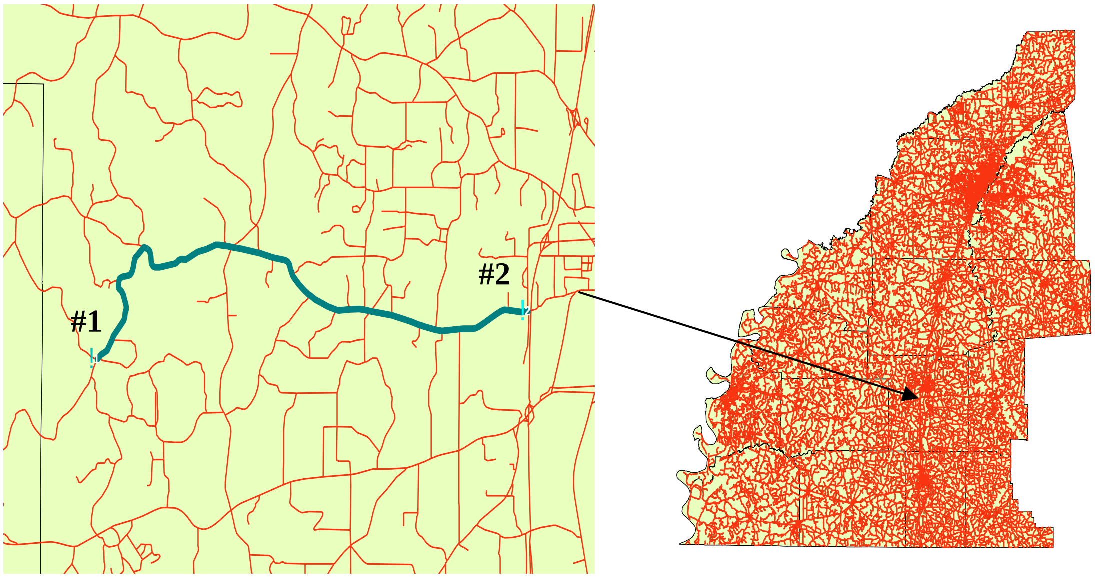


Figure 5 Example transportation network constructed for 15 counties in the southwest inventory region of Mississippi used to calculate the shortest distance between a procurement area pixel (#1) and a potential mill site (#2).

Volume Reports

Volume and transportation reports were obtained from the DSS for the 40-mile radius working circle for individual ages 16-years old and greater for pine and mixed pine-hardwood. The ages were 18-years old and greater for the hardwood forest type. For each GIS age in each GIS forest type, the minimum transportation distance, harvest volume, total growth volume, ingrowth volume (base volume equals zero and growth volume is greater than zero), base growth volume (volume in base year minus projected growth), base volume (volume in base year), base plus base growth volume, percent harvest, percent growth, and growth-to- drain ratio were reported for eleven volume types (Table 1). The same volume information was also reported for the 40-mile radius working circle accumulated over all ages. An OSB mill was chosen for the case study because a majority of requests for MIFI data analysis are for OSB mills (Glass 2005).

Case study OSB mill characteristics and requirements are given in Table 2. Since OSB mills only procure pine (tree length pulpwood, top pulpwood, and chip and saw) and soft hardwood (*Liquidambar styraciflua* and *Liriodendron tulipifera* tree length pulpwood, top pulpwood, and sawtimber), volumes for GIS forest types were proportioned by the amount of pine and soft hardwood species available. The MIFI Inventory Dynamic Reporter DSS (Matney and Schultz 2008) was used to determine the percentage of the available working circle volume composed of pine and soft hardwood in the appropriate tree product classes. The MIFI Inventory proportions were then applied to the total volume estimates in the 40-mile radius working circle. Volume reports across all ages by stratum were used together with the MSU FWRC Cutover Loblolly Pine Growth and Yield Model (Matney 1996) to proportion out product volume by age. To determine the proportion of soft hardwoods, 15 years were added to the pine ages. All volumes were converted to tons for calculating the procurement cost.

Table 2 Proprietary characteristics and requirements of case study OSB mill located in the southwest Mississippi Institute for Forest Inventory inventory region of Mississippi.

Annual Volume Requirement	Annual Production Requirement
600,000 tons (Pine) 200,000 tons (Soft Hardwood)	380,000,000 ft^2 (7/16”)

Procurement and Transportation Costs

Procurement costs associated with the raw material for the defined working circle procurement area were based on proprietary data from an actual OSB mill (Table 2). Procurement and transportation costs were obtained from Route Chaser software (Stuart and Grace 2008). This program allows the user to enter scheduling, equipment, and cost components. The scheduling component includes work days per year, hours per day, allowable extra hours, and overtime. The equipment component includes gross vehicle loaded weight (lbs) and vehicle tare weight (lbs). The cost component includes equipment purchase price, financing, labor, fuel, repair and maintenance, insurance, and overhead costs. Average haul distance was a required Route Chaser program input and was calculated for the 40-mile radius working circle and was determined to be two thirds of the radius of the 40-mile radius working circle (Matney 2009). Total transportation costs by GIS age and forest type were calculated by multiplying the associated OSB mill case study annual volume requirement by the per ton cost.

Linear Programming Model and Net Revenue

Once the growth-to-drain ratios, procurement, and transportation costs were determined, a linear programming (LP) model was constructed with C-Whiz software (KMS 2003). Procurement and transportation costs were input parameters to the LP model that minimized costs for the case study OSB mill. The LP objective function minimized the costs of procuring and transporting wood for a potential mill site. The problem may be more formally stated as follows:

Minimize: $\Sigma\alpha x + \Sigma\beta y$ (2)

Subject to:

$$\Sigma x = \Sigma\lambda \quad (3)$$

$$\Sigma y = \Sigma\mu \quad (4)$$

$$\Sigma x \leq \Sigma\varphi \quad (5)$$

$$\Sigma y \leq \Sigma\psi \quad (6)$$

$$\Sigma x + \Sigma y \geq 0 \quad (7)$$

Decision variables helped determine the minimized costs of procuring and transporting wood to the OSB mill case study, where:

x = Tons of pine procured and transported in the 40-mile radius working circle to the OSB mill case study located in the Mississippi Institute for Forest Inventory southwest inventory region

y = Tons of soft hardwood procured and transported in the 40-mile radius working circle to the OSB mill case study located in the Mississippi Institute for Forest Inventory southwest inventory region

Constants (coefficients) indicate the combined procurement and transportation cost, mill volume requirements, and the total amount of volume available from the 40-mile radius working circle, where:

α = Cost of procuring and transporting one ton of pine in the 40-mile radius working circle to the OSB mill case study located in the Mississippi Institute for Forest Inventory southwest inventory region

β = Cost of procuring and transporting one ton of soft hardwood in the 40-mile radius working circle to the OSB mill case study located in the Mississippi Institute for Forest Inventory southwest inventory region

λ = OSB mill case study pine volume (tons) requirement

μ = OSB mill case study soft hardwood volume (tons) requirement

φ = Total tons of pine available to the OSB mill case study from the 40-mile radius working circle located in the Mississippi Institute for Forest Inventory southwest inventory region

ψ = Total tons of soft hardwood available to the OSB mill case study from the 40-mile radius working circle located in the Mississippi Institute for Forest Inventory southwest inventory region

Equation (2), the objective function, minimizes the costs of procuring and transporting wood in the 40-mile radius working circle to the OSB mill case study. Equation (3) fulfills the pine volume requirement of the OSB mill case study. Equation (4) fulfills the soft hardwood volume requirement of the OSB mill case study. Equation (5) ensures that the total volume of pine available in the 40-mile radius working circle is not exceeded. Equation (6) ensures the total volume of soft hardwood available in the 40-mile radius working circle is not exceeded. Equation (7) sets the standard conditions of non-negativity.

Mill feasibility was assessed by calculating the net revenue (NR) of the case study OSB mill. The value of costs incurred by the mill was subtracted from the value of the mill's annual production revenue. If the resulting revenues minus costs produced an NR that was equal to or greater than zero, it was deemed feasible to locate the specified mill in the selected procurement area.

CHAPTER V

RESULTS

Regression Equations

Regression equations used to produce volume layers for the southwest region include 11 volume unit equations for each of the three GIS forest types. The equations and their fit statistics (coefficient of determination and standard error) are given by pine, mixed pine-hardwood, and hardwood forest types in Tables 3-5, respectively.

Table 3 Regression equations for the pine GIS forest type used as inputs to produce volume layers for the mill location DSS for the southwest Mississippi Institute for Forest Inventory inventory region of Mississippi.

Volume prediction equation	R^2	Syx
ln (cfibpw)* = 7.69059 - 8.6659(1/gis age)	0.2750	0.8648
ln (cfibpwtp) = 7.6063 - 8.6678(1/gis age)	0.2751	0.8648
ln (cfibst) = 7.1903 – 8.1452(1/gis age)	0.1221	1.0666
ln (cfibsttp) = 7.1909 – 8.147(1/gis age)	0.1221	1.0668
ln (cfobpw) = 7.8357 – 8.2645(1/gis age)	0.2710	0.8330
ln (cfobpwtp) = 7.8361 – 8.2662(1/gis age)	0.2711	0.8329
ln (cfobst) = 7.4127 – 7.9492(1/gis age)	0.1196	1.0535
ln (cfobsttp) = 7.4132 -7 .9509(1/gis age)	0.1196	1.0537
ln (doyle) = 8.4707 – 8.2666(1/gis age)	0.1165	1.1119
ln (int14) = 8.8595 - 8.9828(1/gis age)	0.1325	1.1228
ln (scrib) = 8.6793 – 9.5347(1/gis age)	0.1382	1.1627

*Volume units are defined in Table 1.

Table 4 Regression equations for the mixed pine-hardwood GIS forest type used as inputs to produce volume layers for the mill location DSS for the southwest Mississippi Institute for Forest Inventory inventory region of Mississippi.

Volume prediction equations	R^2	Syx
ln (cfibpw)* = 7.4141 – 11.234(1/gis age)	0.1752	1.0045
ln (cfibpwtp) = 7.4145 – 11.237(1/gis age)	0.1753	1.0045
ln (cfibst) = 7.0679 – 10.88(1/gis age)	0.1338	1.0019
ln (cfibsttp) = 7.0679 – 10.879(1/gis age)	0.1337	1.0019
ln (cfobpw) = 7.6169 – 11.01(1/gis age)	0.1734	0.9905
ln (cfobpwtp) = 7.62 – 11.013(1/gis age)	0.1735	0.9905
ln (cfobst) = 7.265 – 10.665(1/gis age)	0.1316	0.9914
ln (cfobsttp) = 7.265 – 10.663(1/gis age)	0.1316	0.9915
ln (doyle) = 8.4787 – 12.53(1/gis age)	0.1439	1.1058
ln (int14) = 8.8506 – 11.933(1/gis age)	0.1359	1.0890
ln (scrib) = 8.6912 – 12.222(1/gis age)	0.1318	1.1351

*Volume units are defined in Table 1.

Table 5 Regression equations for the hardwood GIS forest type used as inputs to produce volume layers for the mill location DSS for the southwest Mississippi Institute for Forest Inventory inventory region of Mississippi.

Volume prediction equations	R^2	Syx
ln (cfibpw)* = 7.4074 – 9.5252(1/gis age)	0.1484	0.9220
ln (cfibpwtp) = 7.4081 – 9.5256(1/gis age)	0.1485	0.9217
ln (cfibst) = 6.9438 – 7.8433(1/gis age)	0.0738	0.9843
ln (cfibsttp) = 6.9445 – 7.848(1/gis age)	0.0739	0.9846
ln (cfobpw) = 7.6035 – 9.4039(1/gis age)	0.1471	0.9148
ln (cfobpwtp) = 7.6041 – 9.4045(1/gis age)	0.1472	0.9145
ln (cfobst) = 7.1335 – 7.8423(1/gis age)	0.0746	0.9788
ln (cfobsttp) = 7.1342 – 7.8472(1/gis age)	0.0746	0.9791
ln (doyle) = 8.3613 – 8.7575(1/gis age)	0.0723	1.1115
ln (int14) = 8.7548 – 8.498(1/gis age)	0.0758	1.0515
ln (scrib) = 8.599 – 8.7699(1/gis age)	0.0771	1.0748

*Volume units are defined in Table 1.

Procurement and Transportation Costs

The average haul distance for a 40-mile radius working circle was 26.7 miles. The cost for transporting raw material from the working circle procurement area to the selected mill site was $5.48 per ton. The delivered price at the mill was $20.00 per ton for all species and products.

Volume Reports

Working circle growth-to-drain ratios were reported for by GIS forest type for each volume unit. For example, the Doyle volume unit for pine had a growth-to-drain ratio of 1.29 (Table 6) which means that the 40-mile radius working circle is growing 29% more Doyle volume than it is losing from harvesting, mortality, and other cases. Growth-to-drain ratios for pine, mixed pine-hardwood, and hardwood volumes are reported in Table 8, respectively. Overall, growth-to drain-ratios are high enough to show that the forest resource would be sustainable with an addition of a new OSB mill.

Table 6 Growth-to-drain ratios for the 2004-2006 time period in the selected 40-mile radius working circle of the Mississippi Institute for Forest Inventory's southwest inventory region for the pine, mixed pine-hardwood, and hardwood GIS forest types combined over all ages by volume unit.

Unit*	Pine	Mixed	Hardwood
cfibpw	1.27	1.00	1.30
cfibpwtp	1.27	1.00	1.30
cfibst	1.28	0.80	0.95
cfibsttp	1.28	0.80	0.95
cfobpw	1.27	0.98	1.28
cfobpwtp	1.27	0.98	1.28
cfobst	1.28	0.78	0.95
cfobsttp	1.28	0.78	0.95
doyle	1.29	0.89	1.03
int14	1.30	0.89	1.00
scrib	1.31	0.92	1.02

*Volume units are defined in Table 1.

The amount of pine tree length pulpwood, pine top pulpwood, pine chip and saw, soft hardwood tree length pulpwood, soft hardwood top pulpwood, and soft hardwood sawtimber volume that was available to the case study OSB mill was proportioned out of the total volume for each GIS forest type (pine and mixed pine-hardwood: 16-years-old and greater, hardwood: 18-years-old and greater) within the 40-mile radius working circle. The tons available for the case study OSB mill for pine and soft hardwood within the pine, mixed pine-hardwood, and hardwood GIS forest types are reported in Tables 7, 8, 9, 10, 11 , and 12, respectively. Age classification procedures led to low acre representation for some ages causing low volume representation. This occurred in ages 20 and 28 for the pine cover type and ages 20 and 32 for the mixed pine-hardwood and hardwood cover type. Since Landsat data is only available from 1972 forward, all ages beyond 34 were classified as age 45. Therefore, age 45 volumes are large for all cover types. The total available pine and soft hardwood across all GIS forest types is 84,657,078 tons and 18,502,956 tons, respectively. The case study OSB mill required 600,000 tons of pine and 200,000 tons of soft hardwood annually (Table 2). The current volumes of pine and soft hardwood together with growth-to- drain ratios, generally greater than one, indicate that there will be sufficient volume in the foreseeable future.

Table 7 Tons of pine pulpwood (PW) and chip and saw available for the case study OSB mill in the pine GIS forest type within the southwest Mississippi Institute for Forest Inventory inventory region 40-mile radius working circle.

	Tree Length PW	Top PW	Chip and Saw	
Age	•••••••••••••••••••••••••••	Tons	••••••••••••••••••••••••••	**Totals**
16	1,003,446	41,810	916,376	**1,961,633**
18	2,552,324	98,064	2,429,017	**5,079,406**
19	662,931	31,238	641,663	**1,335,832**
20	60,556	3,660	60,764	**124,980**
21	1,962,681	140,943	2,030,596	**4,134,219**
22	2,795,493	197,540	2,996,191	**5,989,224**
23	530,401	33,256	572,992	**1,136,649**
25	1,302,541	128,823	1,495,307	**2,926,671**
27	814,223	61,286	928,915	**1,804,424**
28	679	59	793	**1,531**
29	744,794	82,755	904,662	**1,732,211**
31	536,235	53,034	653,488	**1,242,758**
33	575,786	56,946	714,788	**1,347,520**
45	17,524,901	3,092,630	23,724,379	**44,341,909**
Totals	**31,066,991**	**4,022,043**	**38,069,931**	**73,158,965**

Table 8 Tons of soft hardwood pulpwood (PW) and sawtimber available for the case study OSB mill in the pine GIS forest type within the southwest Mississippi Institute for Forest Inventory inventory region 40-mile radius working circle.

	Tree Length PW	Top PW	Sawtimber	
Age	••••••••••••••••••••••Tons••••••••••••••••••••••			**Totals**
25	78,131	0	71,598	**149,729**
27	47,790	0	44,478	**92,268**
28	39	1	38	**78**
29	45,036	136	43,317	**88,489**
31	30,879	1,287	27,222	**59,388**
33	33,260	1,287	28,065	**62,602**
45	1,035,378	90,033	484,420	**1,609,831**
Totals	**1,270,513**	**92,734**	**699,137**	**2,062,385**

Table 9 Tons of pine pulpwood (PW) and chip and saw available for the case study OSB mill in the mixed pine-hardwood GIS forest type within the southwest Mississippi Institute for Forest Inventory inventory region 40-mile radius working circle.

	Tree Length PW	Top PW	Chip and Saw	
Age	•••••••••••••••••••••••••Tons•••••••••••••••••••••••••			**Totals**
16	4,781	199	15,283	**20,263**
18	25,927	996	70,827	**97,751**
19	10,465	493	28,388	**39,346**
20	754	46	1,936	**2,736**
21	29,990	2,154	73,897	**106,041**
22	48,726	3,443	109,924	**162,093**
23	22,150	1,389	47,815	**71,354**
25	14,886	1,472	31,250	**47,608**
27	42,057	3,166	83,759	**128,981**
29	42,896	4,766	83,008	**130,671**
31	37,089	3,668	69,321	**110,078**
32	184	10	318	**512**
33	41,812	4,135	75,574	**121,522**
45	1,727,130	304,788	2,739,791	**4,771,708**
Totals	**2,048,848**	**330,724**	**3,431,091**	**5,810,663**

Table 10 Tons of soft hardwood pulpwood (PW) and sawtimber available for the case study OSB mill in the mixed pine-hardwood GIS forest type within the southwest Mississippi Institute for Forest Inventory inventory region 40-mile radius working circle.

	Tree Length PW	Top PW	Sawtimber	
Age	••••••••••••••••••••••••Tons	••••••••••••••••••••••		**Totals**
25	4,106	0	17,201	**21,307**
27	11,351	0	46,104	**57,455**
29	10,767	1,196	45,691	**57,654**
31	9,309	921	33,196	**43,426**
32	46	2	147	**196**
33	10,495	1,038	34,111	**45,644**
45	433,510	76,502	643,107	**1,153,119**
Totals	**479,584**	**79,659**	**819,558**	**1,378,801**

Table 11 Tons of pine pulpwood (PW) and chip and saw available for the case study OSB mill in the hardwood GIS forest type within the southwest Mississippi Institute for Forest Inventory inventory region 40-mile radius working circle.

	Tree Length PW	Top PW	Chip and Saw	
Age	•••••••••••••••••••••••	Tons	•••••••••••••••••••••••••	**Totals**
18	13,435	560	63,301	**77,296**
19	3,740	144	17,360	**21,244**
20	1,159	55	4,834	**6,048**
21	7,023	425	26,942	**34,389**
22	23,638	1,697	78,803	**104,138**
23	11,908	841	37,454	**50,203**
25	11,629	729	32,688	**45,046**
27	19,204	1,899	53,387	**74,490**
29	28,867	2,173	70,880	**101,920**
31	37,971	4,219	93,282	**135,472**
32	699	69	1,616	**2,384**
33	23,362	1,230	51,620	**76,212**
45	1,734,239	171,518	3,052,851	**4,958,608**
Totals	**1,916,874**	**185,559**	**3,585,017**	**5,687,449**

Table 12 Tons of soft hardwood pulpwood (PW) and sawtimber available for the case study OSB mill in the hardwood GIS forest type within the southwest Mississippi Institute for Forest Inventory inventory region 40-mile radius working circle.

	Tree Length PW	Top PW	Sawtimber	
Age	••••••••••••••••••••••••••	Tons	•••••••••••••••••••••••	**Totals**
25	54,315	0	126,021	**180,336**
27	92,749	0	205,825	**298,574**
29	122,781	13,642	273,265	**409,688**
31	168,738	16,688	312,879	**498,305**
32	3,208	169	5,233	**8,610**
33	98,356	9,728	163,188	**271,271**
45	7,119,531	1,256,388	5,019,067	**13,394,986**
Totals	**7,659,678**	**1,296,615**	**6,105,478**	**15,061,770**

Linear Programming Model and Net Revenue

A simple LP model was constructed for the case study OSB mill. The objective function minimized the procurement and transportation costs. The objective function coefficients for the cost of procuring pine and soft hardwood were $25.48 per ton, the combined cost of procurement and transportation. The case study OSB mill required 600,000 pine tons and 200,000 soft hardwood tons annually to supply the mill. Constraints (Table 3) were placed in the model to ensure that this exact species mix was harvested and that the total amount of pine and soft hardwood volume available for the case study OSB mill was not exceeded. The LP model produced an objective function value of 20,384,000. This means it would cost the OSB mill $20,384,000 annually to procure and transport raw material to its facility. The annual production of the case study

OSB mill is 380,000,000 ft^2 on a 7/16” basis. A 7/16” 4-foot by 8-foot (32 ft^2) sheet of OSB is roughly $5.38 at any building supply store. To obtain the dollar amount the OSB mill makes on a single sheet, you can assume that roughly 60% of the $5.38 the building supply charges is for transporting the finished product, markup, etc. This leaves the OSB mill roughly making $2.15 per sheet. Therefore, the annual revenue is $25,531,250. This results in a NR of $5,147,250 which shows that it is economically feasible to locate the OSB mill in the 40- mile working circle in the southwest region of Mississippi.

CHAPTER VI

DISCUSSION AND CONCLUSIONS

The case study OSB mill demonstrated that the DSS was very effective in determining optimal mill location. The results of this pilot study indicated that the forest resources within the 40-mile radius working circle were sustainable and could support an OSB mill along with all other existing industries in the area. The NR of the case study OSB mill showed that it was feasible to locate the mill within the 40-mile radius working circle. For this study, only one working circle could be used because the southwest region was the first and only region to be inventoried by MIFI during the course of the research. As MIFI completes the inventories of the other four regions (north, central, Delta, and southeast), the newly acquired inventory data will allow the analysis of many different working circles or regions within the whole state. This will allow forest industry and state planners to compare the objective functions of different optimal mill location scenarios, allowing the evaluation of the sustainability, socio-economic infrastructure, and cost minimization of each area.

However, many challenges exist for the development of an automated geo-spatial mill location DSS, and enhancements will continue as additional data and research results become available. There are a number challenges and weaknesses in this methodology that should be addressed.

1) The inability to estimate volumes by product class directly from satellite imagery necessitates that surrogate variables such as forest age must be used to partition the aggregate volumes from an image into product classes. This means that the proportional partitioning of pixel volume must be taken from a growth and yield model or other inventory source of comparable age and timber type to that of the pixel. If in the future, methods are developed to accurately estimate pixel density in both trees and basal area, in addition to change detection age, then a more accurate partitioning of the pixel volume could be obtained from a growth and yield model. These estimates could also be greatly improved if a measure of pixel average tree height were available from a secondary source of data such as Light Detection and Ranging (LiDAR). 2) The pilot DSS cannot estimate volumes in adjacent state areas because of the lack of county-level inventory information. If mills are proposed for locations near state borders, then methods must be developed to estimate forest growth and drain ratios in those areas. Models are currently under development at Mississippi State University that allow volume and weight estimates by GIS forest type from satellite imagery of surrounding states. 3) DSS information for ownership category and associated willingness to sell timber was not complete and is essential for adjusting estimates of total volume available to a mill. MIFI was currently collecting ownership category information, and an associated FWRC project is evaluating points at which NIPF landowners are willing to sell their timber by merchandizing class. 4) Estimates of the errors associated with image interpretation propagated through the inventory must be added to the sampling error of the inventory to obtain a true estimate of error. Another FWRC project is investigating the propagation of errors associated with perturbations in image interpretation which will

help analyze classification errors in imagery and, in turn, help develop new classification methods. Good estimates of total error are required so investors can assess the true risk associated with locating a proposed mill.

Plans have been made to overlay socio-economic data such as demographics, education, income, housing, retailing, migration, and other economic metrics on MIFI's spatial inventory. These data are an important component of the industrial decision-making process where inadequate resources, such as educational facilities, can be the "deal killer" for local and state economic developers. Future DSS versions will include modules to access MIFI data and prepare mill location, feasibility information, and growth and drain. The transportation model required for the mill location and feasibility analysis and the growth and drain module are in place. Making these modules operational will require the preparation of age and GIS forest type layers for every year across the entire inventory since its operational beginning in 2004. Improved information on road and bridge weight limits for hauling wood is needed to obtain a better estimate of minimum transportation costs, and product demand information will allow the minimization of transporting finished products to market.

The MIFI DSS will fill a critical role in assessing the current and future availability and costs of procuring forest resources within user defined regions of Mississippi. Results of forecasting future raw material availability should be used to assess the need for forest landowner educational and incentive programs in reforestation, management, harvesting, and utilization, ensuring a sustainable supply and reducing the risk of mill failures. Lawmakers will have information upon which to base policy decisions guaranteeing the environmental and economic sustainability of the forest lands that support a major component of the State’s economic base. The forest products industry will possess the best possible information to evaluate economic risk for new and existing mills. An effective, Web-based, easy-to-use presentation of complex models associated with the DSS will empower its use. Without these tools, it will be difficult to entice industry investors to build or expand existing mills. No matter how technologically advanced a mill is, unless it is placed in a location with sustainable feedstock sources, it will fail.

The final product will be a monumental step forward in automating the process of evaluating forest-based resource supply and mill feasibility. The DSS will incorporate the most recent and precise inventory information and expert knowledge making that knowledge readily available to users in an effective, low cost, and timely manner. The ultimate impacts are: 1) promotion of stand management and reforestation, 2) more efficient utilization of the resource, and 3) prevention of over-utilization of the resource and environmental degradation.

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