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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Abstract: The forest products industry is a major component of Mississippi's economic base. The need for a county-level forest inventory and the availability of decision support tools for locating forest product mills are of primary importance in attracting and sustaining the industry. The objective of this paper is to describe the pilot study, currently under development, for an integrated decision support system (DSS) that determines the feasibility and optimal location of a forest products mill based on geo-spatial information and a county-level forest inventory. The DSS will aid economic development decisions for state planners, forest industry, and forest and wildlife managers. Geographic Information System (GIS) layers were constructed for a 15-county southwest Mississippi study area for type, age, ownership, and volume. Growth and drain ratios will be calculated from volume-age relations and historical Landsat multi-spectral images. Raw material and finished product haul distances and costs will be determined from a transportation network of the primary, secondary, and county roads. The user will enter mill specific input parameters through a Microsoft Visual C++ interface, and a linear programming (LP) model minimizes the costs of procuring wood to the potential mill site and transporting the finished product to market.

Introduction

Industry location is of great interest to corporate and government decision makers (Sun and Zhang 2001). Thirteen southeastern states contain nearly one-third of the forest inventory and almost one half of the timber harvesting in the United States. Forest industry in these states produces 45% of the softwood lumber, 56% of the total paper production capacity, and 72% of the total wood pulp production capacity (Sun and Zhang 2001). The forest products industry is a major component of Mississippi's economic base (Munn and Tilley 2005). Timber is one of Mississippi's most valuable agricultural crops and accounts for more than $1 billion of harvested forest products annually. The amount of pine and hardwood stumpage utilized in 2001 resulted in $801 million in payments to Mississippi landowners. The total (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). Since the forest and the wood products industry is a major component of Mississippi's economic base, the need for a county-level inventory and the availability of decision support tools for locating forest product mills are of primary importance

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in attracting and sustaining the industry. The need for a county-level inventory was fulfilled by the creation of the Mississippi Institute for Forest Inventory (MIFI) in 2002. MIFI has broken the state into five regions (north, central, Delta, southeast, and southwest) and inventories one region each year. MIFI's procedure employs an optimal stratified random sampling scheme based on satellite imagery, forest type, and age classification.

The components of a decision support system (DSS) for locating a forest products mill include: 1) spatial information for transportation, ownership, and inventory data, 2) growth and drain estimates, and 3) mill specific input variables. Spatial information is combined with inventory data in a stratified area to estimate volume by cover, species, ownership, and origin. Growth and yield equations and historical Landsat scenes (Figure 1) can be used to derive growth and drain ratios for a selected area. Growth and drain estimates are important to: 1) determining the sustainability of the forest resource, 2) the future availability of feedstocks to mills, 3) reforestation planning, 4) landowner education, 5) policy implementation, and 6) wildlife habitat assessments. Transportation data will be acquired from geo-spatial networks. Optimal mill location and feasibility studies are traditionally carried out by forest industry who needs information upon which to base decisions concerning investments for new manufacturing facilities. These studies are usually proprietary and, therefore, are never published. As a result, there have been few examples in the literature.

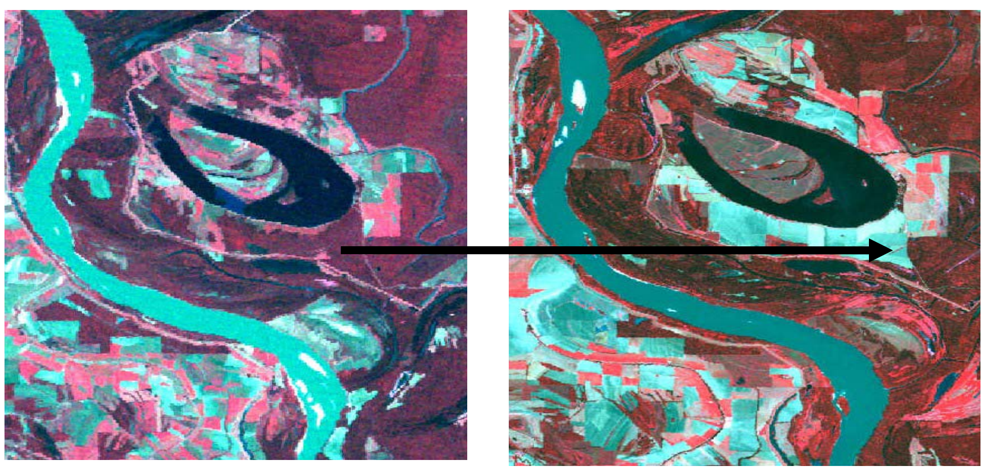

Figure 1. Example of historical Landsat scenes of Eagle Lake located in Vicksburg, MS, in 1972 and 2004 and are used to determine forested area and change detection to derive growth and drain ratios.

Objectives

The objective of this paper is to describe a pilot project for a Web-based decision support system (DSS) currently under development at Mississippi State University. The DSS determines the feasibility and optimal location of a forest products mill based on geo-spatial information and a county-level forest inventory. This tool will aid economic development decisions for state planners and forest industry. System inputs such as a region of Mississippi, the type of mill, resource area located around the proposed location, size class, timber type, and ownership class need to be specified by the user. The final product will be an optimal mill location based on specified criteria. The project will also determine the feasibility of a hypothetical mill in southwest Mississippi.

Methods

The pilot version of the DSS will utilize the 15-county 2004 - 2005 MIFI southwest forest inventory where approximately 150 0.2-acre fixed radius plots per county were allocated (Figure 2). Inventory data and spatial information were used to develop GIS layers for forest type, age, ownership, and volume (Figure 3).

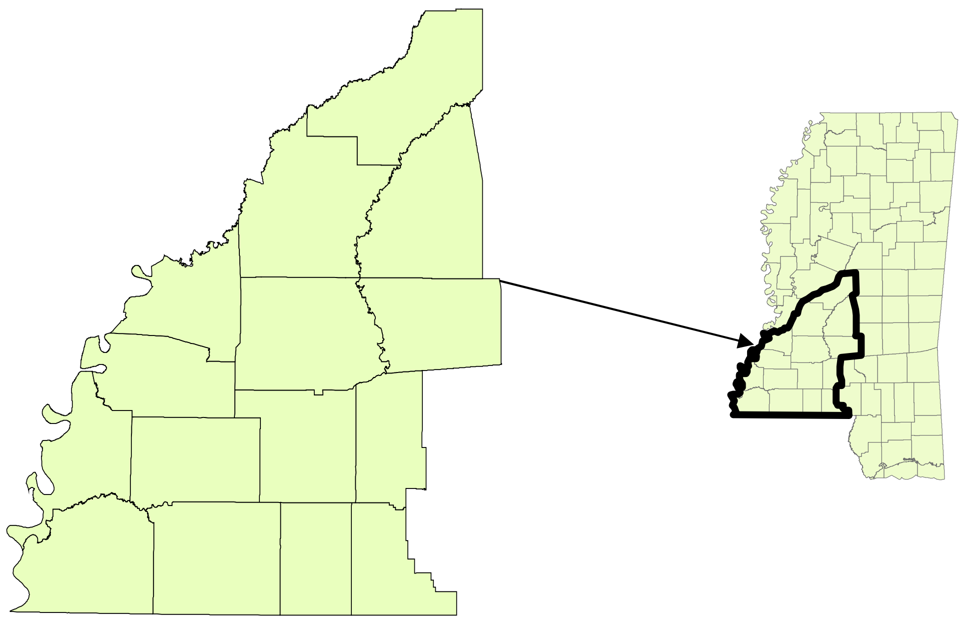

Figure 2. Study area located in southwest Mississippi consisting of 15 counties inventoried by Mississippi Institute for Forest Inventory in 2004 and 2005.

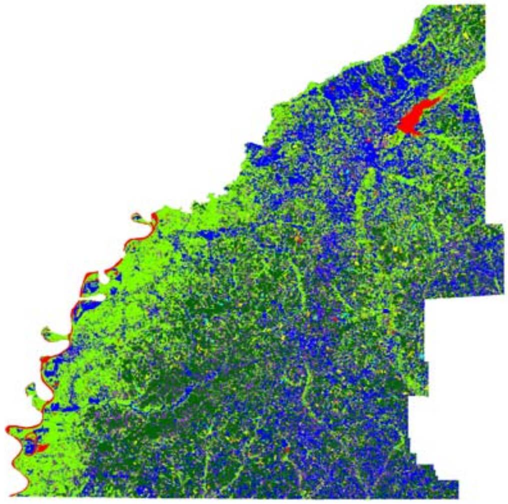

Figure 3. Example of a forest type layer developed from Landsat data that will be used as an input GIS data layer for the DSS.

Volumes for pine, mixed pine-hardwood, and hardwood forest types (in 11 different volume units) were estimated from the regression of the natural log of volume on the inverse of age (Equation 1) and allocated to each image pixel in a user selected area.

$$ln(vol)=b_0 + b_1(1/age) \tag{1}$$

The spatial modeler in ERDAS Imagine (2003), a type of remote sensing/GIS software, was used to create the volume layers from the appropriate regression equations.

Growth (the forest resource growing at the present rate projected to a specified time in the future) will be calculated from growth curves based on the volume-age relation in Equation 1. Volumes will be removed from the growth component based on the existing resource and new mill requirements. Drain (the forest resource that has been removed within a given time period) will be estimated by comparing 2004 and 2006 Landsat images to identify harvested areas and predicted removals. Removals will be randomly allocated to procurement areas that match volume, age, forest type, and ownership classes. The resulting ratio of growth to drain will determine if the forest resource in the selected area will be sustainable under current or future harvest demands.

Another important component of the decision support system is the transportation network constructed from the primary, secondary, and county roads for the 15 counties in the southwest region of Mississippi (Figure 4). Road data were obtained from the Mississippi Automated Resource Information System (MARIS) (2006). ArcGIS software (2005), which is composed of ArcMap, ArcInfo, ArcCatalog, and ArcToolbox, was used to construct the transportation network. Minimum cost path will be the criterion used to determine transportation haul distances. ArcGIS Network Analyst will calculate the road distances from procurement area(s) to the potential mill site.

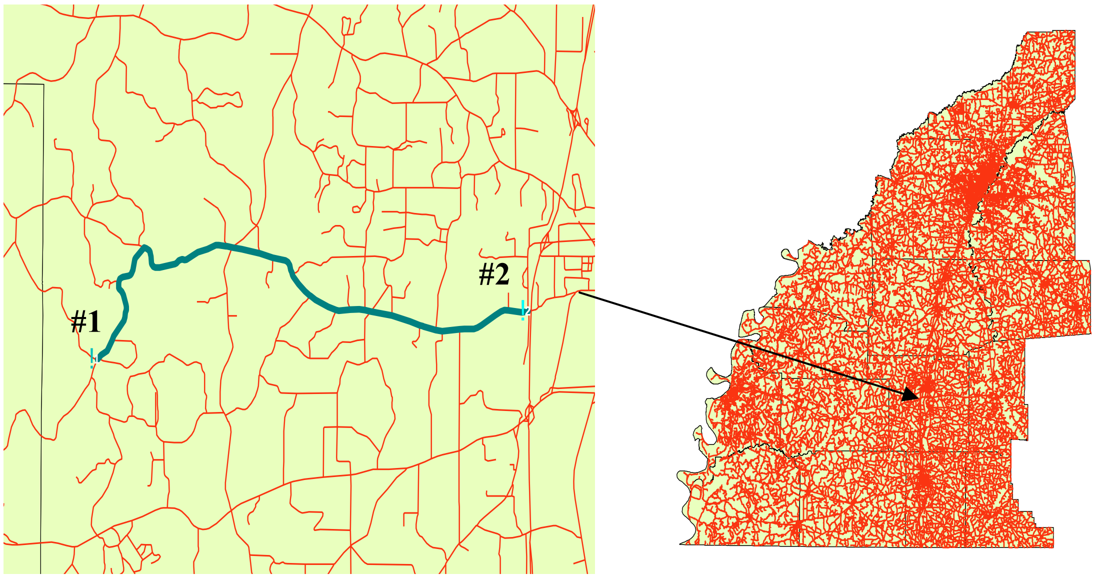

Figure 4. Example of the transportation network constructed for 15 counties in the southwest inventory region of Mississippi that will calculate the shortest distance between a procurement area(s) (#1) and a potential mill site (#2).

Once the growth and drain ratio, procurement costs, and transportation costs are determined, a linear programming model for determining the optimal location of a mill to minimize costs will be constructed using C-whiz software (2003). The objective function will minimize the costs of procuring wood for a potential mill site and transporting the finished product to market. Input variables and constraints that will be used are those used by McCauley and Caulfield (1990) (Tables 1 and 2, respectively). Sensitivity analyses will identify the LP factors with the greatest influence on mill location, such as stumpage volume, timber type, size class, and ownership class. Mill feasibility will be assessed by calculating net present values (NPV). All the components of the optimal mill location and suitability DSS will be combined in a seamless Microsoft Visual C++ (2005) interface and linked to the current MIFI interface, http://www.mifi.ms.gov/mission.htm, (Figure 5).

Table 1. Constraints that will be used in the LP model that minimizes the costs of procuring wood to the potential mill site and transporting the finished product to market (after McCauley and Caulfield 1990).

-A binary constraint to show that a certain number of plants are located -A wood requirement -One that makes sure the mill does not exceed the amount of timber available in a region -One that shows the production requirement of the proposed mill -One that does not let the quantity of the finished product shipped to a specific market location exceed the demand -One that limits the proportion of mill furnish (pine/hardwood) used in production -A nonegativity constraint

Table 2. Input variables that will be used in the LP model that minimizes the costs of procuring wood to the potential mill site and transporting the finished product to market (after McCauley and Caulfield 1990).

-Potential plant sites, timber supply regions, final market demand locations
-Cost of procuring a given amount of pine/hardwood cords from a given timber supply region to a given demand point
-Cost of transporting a given amount of finished product to a given market location from a potential plant site
-Cords of pine/hardwood available to a mill from a given supply region
-Demand for the finished product at a given market
-Total cords of wood required by a mill
-The proportion of mill furnish consisting of hardwoods
-The amount of finished product produced by a mill
-The number of plants located (integer)
-A binary variable for selecting or not selecting a site
-Cords of pine/hardwood transported to a given site from a given supply region
-The amount of finished product transported to a given demand point from a given plant site
-Cords of hardwood transported to a given plant location

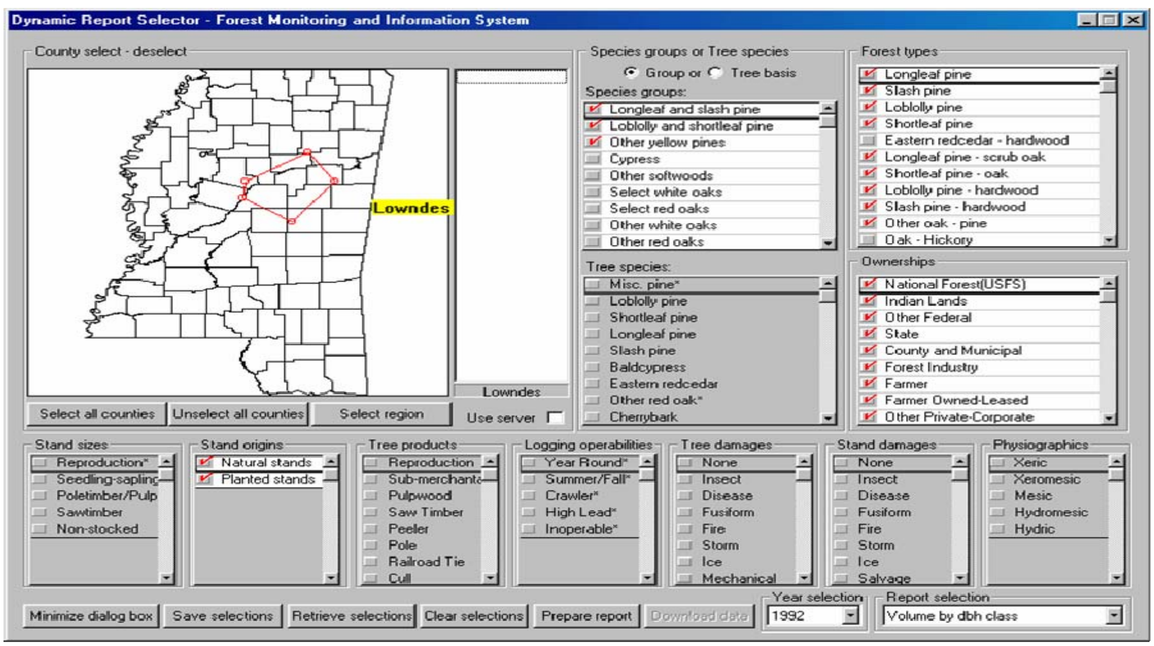

Figure 5. Current MIFI interface that will be linked to the DSS to determine an optimal mill location.

Anticipated Impact

The DSS will fill a critical role in assessing the current and future availability and costs of forest resources within user defined regions of Mississippi. The results of forecasting future raw material availability should be used to assess the need for forest landowner educational and incentive programs in reforestation, management, 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. Forest land managers will possess the best possible information to evaluate economic risk for new and existing plants. An effective, Web-based, easy-to-use presentation of the complex models associated with the DSS will empower its use by forest managers, policy makers, and foresters.

The final product will be a monumental step forward in automating the process of evaluating forest-based resource supply and mill feasibility. The system will provide a framework for gathering and organizing the essential data that has, in the past, been manually prepared. Manual preparation involves numerous consultants (experts), and is very costly and error prone. This 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) the promotion of stand management and reforestation, 2) more efficient utilization of the resource, and 3) the prevention of over-utilization of the resource and environmental degradation.

Literature Cited

ESRI. 2005. ArcGIS Software, Version 9.1. Redlands, CA.

KMS Optimization Products, The Bionetics Corporation. 2003. C-whiz, Version 4, Linear Programming Optimizer. Arlington, VA: Ketron Management Science User's Reference Manual, 126 pp.

Leica Geosystems GIS and Mapping. 2003. ERDAS Imagine, Version 8.7. Norcross, GA.

McCauley, K.C. and J.P. Caulfield. 1990. Using mixed-integer programming to determine the optimal location for an oriented strandboard plant in Alabama. Forest Products Journal. 40(2): 39-44.

Microsoft. 2005. Microsoft Visual Studio 2005. Redmond, WA

Mississippi Automated Resource Information System. 2006. Primary, Secondary, and County road files, Acquired electronically May 2006. Jackson, MS

Munn, I.A. and B.K. Tilley. 2005. Forestry in Mississippi: The impact of the forest products industry on the Mississippi economy, an input output analysis. Forest and Wildlife Research Center, Bulletin FO301, Mississippi State University. 27 pp.

Sun, C. and D. Zhang. 2001. Forest resources, government policy, and investment location decisions of the forest products industry in the southern United States. Forest Science. 47(2): 169-177.