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Biomass energy production in Louisiana: a GIS study on the supply chain

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BIOMASS ENERGY PRODUCTION IN LOUISIANA: A GIS STUDY ON THE SUPPLY CHAIN

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ABSTRACT

One major drawback of biomass fuel is its bulky nature and the resulting high cost of transporting the fuel to the facility where the energy is being produced. Hence, supply chain of biomass residues plays a crucial role in determining the financial viability of bioenergy production. Transporting biomass for energy purposes more than 50 miles (80 km) is not considered economically feasible in most conditions. In the wood energy scenario, the maximum distance is more often restricted to distances of less than 200 km between production and consumption (via road). A study was done to determine logging residues and agricultural residues production for the 64 parishes in Louisiana and to compare the three different modes of transportation (freight) for wood biomass, namely rail, road and water. The average annual production for logging residues in the state from 2000 to 2010 was estimated around 3,073,978 bone dry tons (BDT) and for agricultural crop residue it was approximately 6,773,985 BDT annually (2005- 2011).

The greatest production of logging residues was in the western and northern parishes of Louisiana, away from the population centers. The road network was the most extensive means of transportation. For long distances (greater than about 150 km), the Mississippi/Red River complexes could provide a very cheap source of transportation, followed by rail, but they had their own set of logistical problems. The river or rail networks were limited for the major logging residues producers (such as Winn, Vernon, Bienville, Union, etc.) and utilizing parishes.

For agricultural residues, north-eastern and central parishes like Morehouse, Madison, Franklin, East Carroll and Pointe Coupee were the major producers. Soybean, rice, corn and sugarcane constituted the majority of the agricultural residue production. All the major agricultural parishes were in close proximity to ports in the state, which opened them to the waterway system.

PART I - LOGGING RESIDUES

CHAPTER 1: INTRODUCTION

Energy is a key factor that determines a nation‘s growth and sustainability. High oil prices have today put the spotlight on the nation‘s increasing dependency on imported energy. In 2011, United States consumed over 6,874,900,000 barrels of oil. That is about 18,835,000 barrel per day, making US the world's largest petroleum consumer. But the production for the same year was only 7,841,000 barrels/day. We had to import 8,436,000 barrels/day. However, the good news is that the U.S. dependence on imported oil has dramatically declined since peaking in 2005. This trend owes to multiple reasons including a decline in consumption, shifts in supply patterns, the economic downturn after the financial crisis of 2008, improvements in efficiency, changes in consumer behavior and patterns of economic growth, etc. Another factor of this decrease was the production of domestic biofuels (EIA 2012). People have been burning wood for energy purpose for more than thousands of years. Wood was the major source of energy in the world until mid-1800s. Even today, wood biomass continues to be a major source of energy in much of the developing world. Fuel-wood and charcoal, together with other biofuel such as bagasse, provide 10-15 percent of the world's total annual energy. They are mainly used for the production of thermal energy in both developing countries and developed countries (Hillring and Trossero 2006).

In the United States, wood and wood waste (bark, sawdust, wood chips, and wood scrap) provide only about 2 percent of the energy we use today. About 81 percent of wood and wood waste fuel used in this nation is consumed by industry and commercial businesses (EIA 2005). The rest, mainly wood, is used in homes for heating and cooking. Historically, wood combustion processes were dirty, with uncontrolled emissions of smoke, ash, carbon monoxide, nitrogen oxides, hydrocarbons, etc. But today with modern combustion systems, emissions are reduced making it more environmental friendly and more efficient in power generation (Hughes 2000). In

general, wood energy today, can be used to reduce greenhouse gas emissions, improve forest health, and provide economic benefits to rural communities (Langholtz *et al.* 2006).

Wood energy is an economic source of power when the fuel is very low cost or free. For this, it should be available as a residue or byproduct. Wood utilized for energy production in the United States primarily comes from the forest products industry, logging and municipal wastes. Wood residues are created at all points on the wood product supply chain. Logging residues can be partially collected at logging sites. Sawdust and wood cutoffs are perpetual residues from sawmills and pallet plants in the primary wood products industry. The secondary industry provides sawdust, sander dust, and cutoffs, all of which are typically kiln-dried. All these wood residues can be viewed as a sustainable source for energy production (Slaven *et al.* 2008). Wood can also be converted to other usable forms of energy like methane gas or transportation fuels like ethanol, biodiesel etc. As a waste or residue of forest product industries, biomass could become a resource large enough to provide about 3-5 percent of the electric energy generated in the United States.

In order to increase its share in biomass energy, Louisiana has adopted several policies like a number of clean energy bills and tax incentives to tap its biomass resources for energy production. This provides the state ample opportunities for renewable energy expansion and helped it in developing a renewable portfolio standard. The state has announced plans for a wood pellet plant, worth $124 million that would produce 450,000 metric tons per year of wood pellets to be shipped as bioenergy to Europe. The facility is projected to create up to 100 new direct jobs and 273 new indirect jobs and is also projected to generate $12.9 million in new, state tax revenue and $9.6 million in new, local tax revenue over the next 10 years. Louisiana ranks third in forest residue with 3,384 metric tons per year and ninth in primary mill resources with 3,577

metric tons per year. The state has a cumulative resource of 143,054 metric tons per year (ACRE 2011 p52).

1.1. Beneficials

From a production economics point of view, wood residue for energy production has a lot of advantages. It is typically a by-product or residue of the main product and helps to cover marginal costs (Lunan 1997). Thereby biomass is cheap and can compete with unstable gas price, lowering cost of production.

Moreover, this sort of power production plays a vital role in waste management system, as it finds an economical value for the residual products, which is otherwise considered as waste. When hurricanes Katrina and Gustav hit the state of Louisiana in 2005 and 2009 respectively, tons of wood debris was sent to landfill. Hence, the future wood residue energy production could be combined with projects in waste disposal management (Hughes 2000).

Many studies have been done to investigate the influence of fuel on total costs and also on utilization of waste wood (like industrial waste wood, demolition wood and wood products (Dornburg *et al.* 2001). Multiple environmental, ecological and socio-economic bottlenecks can be addressed by increasing the use of biomass power generation (PIU 2001 and Upreti 2004). The biomass energy infrastructure can also help to strengthen industrial economies or speed the decline of rural communities (Paine *et al.* 1996).

In the environmental scenario, wood energy is usually superior to coal in terms of its concentrations of sulfur, nitrogen, ash, and other toxic metals. Exceptions exist, but can be identified and controlled. But when wood biomass compared to natural gas, it cannot claim any inherent advantage in terms of emissions, except for greenhouse gas emissions.

Another perception problem for biomass power, besides combustion, is the use of forests. The forests are expanding in the United States. Net forest biomass is currently increasing at

about 3 percent per year. In Louisiana alone, landowners (industrial and non-industrial) reforest the land each year with over 128 million seedlings, an average of 410,000 trees per day (six-day week), and at least 29 trees for each Louisiana citizen (official 2000 census shows a state population of 4,468,876) (LFA 2011).

1.2. Forests in Louisiana

Louisiana has 14 million acres of forest cover, which constitutes about 50 percent of the state‘s land area, making it the greatest single land use. Almost, 59 of the state‘s 64 parishes contain land capable of producing sufficient timber to support its forest products industry. This makes forest industries the second largest manufacturing employer, providing about 12,694 jobs in 2010. In addition to this, around 8,000 people are employed in the harvesting and transportation of timber. There are an estimated 148,000 Louisiana forestland owners. Private non-industrial landowners own 81 percent of the state‘s forestland; forest products industries own 10 percent and the public owns 9 percent (LFA 2011).

In 2010, 811.9 million board feet of sawtimber and 6.3 million cords of pulpwood were produced. Louisiana forest landowners received $396.8 million in stumpage revenues. Louisiana timber contractors and their employees received $426.6 million in gross revenues. Forestry accounted for 57 percent of the total value of all plant commodities grown in the state, including cotton, feed grain crops, fruit, soybeans, sugarcane, and others. The impact of forestry and forest-products industries on the economy in 2010 was $3.1 billion (LFA 2011).

The state has about 180 primary forest products facilities, including sawmills, plywood mills, panel mills, veneer mills, and pulp/paper mills. A natural byproduct of this industry is the biomass waste in the form of bark, wood chips and saw dust. Together they produce more than fifteen million tons of wood residues annually. This is mostly utilized by the producers for their own energy needs (such as lumber, drying kilns or veneer driers) and the rest is sold to other

mills, often to pulp and paper mills that co-generate electricity. Still, some 8,255 tons annually go unutilized.

There are about 750 secondary forest products facilities (which includes furniture manufacturers, cabinet makers, millwork plants and others that use the products produced by primary wood-using industries), producing about 7,655 tons of wood residues annually. These include dry wood trimmings, sawdust, and sanderdust, making them ideal for energy or to modify and glue together into other products. Results from 2008 forest products industry showed that the majority of wood being produced in the industry went un-utilized. Most of the primary forest products industry used their residue in energy production. However, in the secondary sector, nearly ninety percent of residue went to landfills. The major reason for non-utilization of wood residue in the secondary sector was due to comparatively small production that was distributed widely across the state. Furthermore, the cost of transportation restricted them from being a viable option. Lack of information about producers and consumers also played a role. By contrast, there were industries that had a great demand for wood residue as a fuel within the state. However, a drastic increase in utilization of wood residue was seen in the forest products industry from 1994 to 2008 (Kizhakkepurakkal 2008).

The wood biomass fuel used for energy today is essentially all from wood wastes and residues, the majority of which originate in forest industrial and other logging operations conducted for other purposes. In some cases, wood biomass is provided from forest management (thinning) operations that are conducted for the specific purpose of improving forest health and value. Harvesting of these forest residues, left after forest operations, may be considered. But this harvest may cause nutrient depletion and affect long-term productivity of forestland. Again, such activities may not be economically feasible. As regards to the residues collected from the forest products industry, it is assumed that only three quarters of the felled roundwood is turned into

final products. The remaining quarter consists of by-products like, bark, sawdust, wood chips and black liquor, which can serve as potential fuels for energy purposes. This fraction of available by-products, i.e. 25 percent of felled roundwood, is a rough approximation. In reality, it varies from region to region depending on the type of forest products industry, its structure, degree of technological development and other factors. For example, in mechanical pulp-making some 95–97 percent of the debarked wood raw material is converted into product, whereas in the chemical processes the figure is about 50 percent, with most of the other half of the wood being used for energy in the form of black liquor. In Louisiana there are 8 pulpmills that produce more than 14,000 tons of pulp annually (Table 1). At sawmills about 25–30 percent of the sawn logs become available for energy purposes (Savolainen and Berggren 2000 and, Ericsson and Nilsson 2006 p4).

Table 1. Louisiana pulpmills, by process and capacity, 2009 (Johnson and Steppleton 2011)

Location	Company	AP	S	GM	SC	SS
DeRidder	Boise Cascade Corporation	1975	1300	675	-	-
Bogalusa	Temple-Inland, Inc.	2383	2383	-	-	-
Port Hudson	Georgia-Pacific Corporation	1920	1920	-	-	-
St. Francisville (2011)			800 All from Gloster MS chipmill			
Mansfield	International Paper Company	2958	1957	2	1001	-
West Monroe	Graphic Packaging International, Inc.	1831	1630	-	201	-
Hodge	Smurfit-Stone Container Corporation	1500	1500	-	-	-
Campti	International Paper Company	1134	1134	-	-	-
Total		14501	11284	675	1202	-

(All processes- AP, Sulfate-S, Groundwood and other mechanical-GM, Semichemical-SC, Soda & sulfite-SS)

1.3. Concerns

There are a number of factors that hinder the growth of the wood energy production, moisture content being a very significant one. As wood contains water, its moisture content determines the gross heating value that is available from a given wood fuel. Moisture content is

expressed in two ways. Some researchers, particularly engineers and chemists, use the wet basis while others, including wood scientists, use the dry basis. With wet basis, the moisture content is calculated by dividing weight of water by the total weight including weight of wood and water. With dry basis, moisture content is calculated by dividing weight of water by dry weight of the wood (Westphal 1983, and Patterson and Zinn 1990).

The value of wood waste thus depends on whether it is green (wet) or dry. Most of the wood waste is usually green, including the chips supplied by primary logging mills. Pelletized chips are drier but are less widely available. Use of wood pellets, which have been compressed and dried prior to combustion, nearly doubles the amount of British Thermal Units (BTUs) per ton compared to raw wood waste. The cost of producing electricity from wood waste is a function of the price of wood and the cost of transporting it, plus the generating equipment and associated maintenance costs (Kent and Risch 2006).

In Europe, most of the unused wood residue resources are in small private holdings, making their mobilization difficult (Commission of the European Communities 2005). This coincides with the condition prevailing in secondary forest products industry in Louisiana too, where the major reason for non-utilization of wood residue was identified as the comparatively small production and the fact that the wood residue produced was distributed widely across the state. Lack of information about producers and consumers also played a role. Once the market is organized, these may benefit facilities or points with unexploited wood residue resources (Kizhakkepurakkal 2008).

1.4. Transportation

One major concern when looking into the financial viability for energy production from wood biomass is the transportation price. When transportation costs are taken into account, more costly resources in close proximity may be economically competitive than cheaper resources

farther away, and vice versa (Langholtz et.al. 2006). Lindholm and Berg (2005) showed that in the wood supply chain, from raising seedlings through timber delivery, long-distance transport of the timber to processing sites (secondary transport) accounts for the largest proportion of energy used (54percent, compared with 35percent by logging and 11percent by silviculture). This is quite similar to the wood residue energy market. In countries like, Sweden approximately 20percent of all domestic transport by truck is related to the forest industry (Swedish Institute for Transport and Communications Analysis 2004 and Lindholm and Berg 2005). There are several important factors that must be considered to enhance trucking productivity. These include (Bolding 2008):

1) Haul distance

   A typical cut-and-haul rate ranges from $12 to $16 per ton based on the requirements and difficulty of the harvest. This rate may include a minimum haul of 50 miles. If products must be delivered outside of the 50-mile threshold, a some extra incentive may be provided at $0.10–$0.12 per ton for each additional mile.

2) Payload

   This is defined as the actual weight of wood residues being transported and is calculated, as gross vehicle weight (loaded weight) minus tare weight (empty weight)

3) Loading time

   This time can be managed by the contractor and must be minimized to improve efficiency.

4) Unloading time

   Truck drivers often have to wait long time to unload, which results in an increment of truck turnaround time. This can drastically lower trucking productivity and increase the hauling costs.

5) Load weight variation

   Highway weight regulation laws govern the weight allowances for trucks. Weight allowances differ by state, and can change often, as these laws are dynamic. The current maximum Gross Vehicle Weight (GVW) for unmanufactured forest products in most states are 80,000 pounds with some states having percentage overage allowances. To improve trucking efficiency, efforts are underway to increase maximum GVWs.

Other factors that play a critical role in the truck transportation are selecting and matching trucks to perform most efficiently. Some important ones in this section would be: type of load, weight of truck and load and weight restrictions, type of terrain—flat, mountainous, switchbacks, etc., type of road- public, private, etc., haul distance, frequency of volume- consistent flow, periodic, or scattered; safety requirements- braking. In the case of wood residue, usually chip vans are preferred.

But then there are many other productivity criteria that are outside the control of contractors, such as rising fuel prices and hauling distances. However, many determining factors such as maximizing payload, minimizing loading time, and reducing loadweight variability are controllable and must be considered to improve the efficiency of road transportation in the sector (Bolding 2008).

Initially, transporting raw wood residues more than 80 km (50 mile) by road were not considered to be economically feasible (Brower *et al.* 1993 and Paine *et al.* 1996). Moreover, the markets are geographically limited (Lunan 1997). Therefore, supply in remote locations may not be suitable for exploitation due to high access costs (Fischer and Schrattenholzer 2001). Hence, it is always better to find a local market for the biomass; if possible, so that the energy consumption associated with wood fuel transportation over long distances can be reduced.

Today, the findings that production of electricity from wood biomass was not economically competitive that prevailed was underscored by a December 2005 report for the American Forest and Paper Association that examined costs of biomass vs. coal generated energy nationwide (Bowyer *et al.* 2006). From 1987 onwards, the cost of wood residues was lower than that of the other fuels when compared on an equivalent British thermal unit (Btu) basis (in 1987, the cost of one million Btu was $1.12 for dry wood residue, $5.63 for natural gas, and $7.50 for oil) (Brock *et al.* 1987 and Patterson and Zinn 1990). In 2011, the Pellet Fuel Institute reported that wood pellets are more price and energy efficient when compared to other fuel resources such as fuel oil, natural gas, coal etc. Hence wood fuel is a cost stable and price competitive fuel. A similar conclusion was made by a German study that compared environmental parameters from agricultural or forest residues, liquid fuels and solid bioenergy carriers like short rotation forest. It found that considering all parameters examined, like emissions of greenhouse gases, wood products are to be favored, while liquid biofuels tend to be less advisable since the overall efficiency rate is lower (Forsberg 2000). At present, due to the ever-increasing demand for energy, wood biomass fuels are being shipped across continents.

For this reason 80 percent of wood pellets manufactured in Canada are exported to Europe, even though, 800,000 tonnes of wood pellets are produced in Europe annually (Magelli *et al.* 2009). Consequently, due to this high demand, wood pellets are being shipped from North America to Europe over a distance of about 15,500 km. This shipment from an environmental standpoint has been substantiated, provided modern carriers are used; bioenergy can be considered a traded item over long distances (Forsberg 2000).

However, in the United States almost all of the 800,000 tons of wood pellets produced are consumed domestically (Magelli *et al.* 2009). Here truck and railroad are the most available

and convenient mode of transportation. In Louisiana, owing to the Mississippi river, water transportation is also one potential option. But the fact that the road system in the state is very efficient makes it the popular choice of transportation. The road transportation system also plays a major role in generating government revenue. It is estimated that each loaded log truck pays the equivalent of $835 in local, state and federal taxes (LFA 2011).

1.5. Geographical distribution of demand and supply

Efficient integration of increasing shares of renewable resources into energy generation requires information about spatial and temporal variations in the availability of energy carriers. The site selection and resource availability of the wood residues within a certain distance from the plant site has been the focal point of various optimizations (Faaij *et al.* 1997 and Voivontas *et al.* 2001). As regards to wood biomass, the spatial variation is crucial for estimating the potential of specified area and costs of biomass for energy production (Gehrung and Scholz 2009).

Geo information studies (GIS) are considered to be an efficient and useful tool for evaluating woodshed procurement areas and transportation costs (Young *et al.* 1991, Brewington *et al.* 2001, and Chalmers *et al.* 2003). In a study done at Crete, Greece, the biomass supply and characteristics were evaluated for estimating the transportation cost as well as the site selection for energy crop developments (Sidiras and Koukios 1996, and Voivontas *et al.* 2001). The study showed that spatial knowledge of the different entities is crucial for estimating the transportation cost and thus determining the most cost effective options. GIS was also applied to identify potential sites for bringing up industries that utilized wood to produce energy in Southern Thailand (Krukanont and Prasertsan 2004). Mathematical models were also developed in this study, to determine the maximum affordable fuel cost and optimum capacity of the power plant for a given location of known area based on fuel availability. GIS can also be used as a tool for standardized assessment of locally available biomass potentials. In Andalusia (Spain), the ideal

site for a biomass plant was identified by estimating biomass potentials on community level and by calculating the total biomass available for every pixel within a radius of 25 km of the pixel (Domı´nguez and Marcos 2000, and Gehrung and Scholz 2009).

Similar research that involved the use of GIS was done in Europe, wherein the Institute of Technical Thermodynamics of the German Aerospace Center (DLR) made an inventory of solar, wind, biomass, geothermal and water energy resources, in order to find out which renewable energy mix can satisfy electricity demand most cost-efficiently. This inventory with high spatial and temporal resolution required extensive use of GIS (Gehrung and Scholz 2009). The US also has an extensive forest inventory database, and this data for the forests are readily available on the Internet at various levels of detail. Methods have also been developed for converting US inventory volume data to above and belowground biomass (Cairns *et al.* 1997, Schroeder *et al.* 1997, Brown and Schroeder 1999, and Brown *et al.* 1999). GIS data of the forest resources that supplied materials were even used to locate the appropriate sites and determine the size of the power plants.

In general, the GIS environments are used to create, store, retrieve, update and present geographical objects, attributes and methods. The geographical entities are modeled within a GIS environment as point, line, or polygon objects. These attributes are then stored as database fields and are referenced to the corresponding geographical objects. Each geographic object and its attributes represent a database record. A set of records referring to objects with the same attributes represents a table, which can be presented either as a map (geographic objects) or a browser (data fields). Maps thus produced can provide a visual representation of the pattern of wood residue densities and pools over space that can be critical in decision-making and management of these resources (Brown *et al.* 1999). The maps can be used to estimate wood residue production and utilization. The methods available in a GIS environment provide the tools

to handle geographic operations, set a minimum connectivity between different sets of objects and perform database calculations with the aim to expand the interactions of objects. The user can create different sets of objects defined based on common characteristics and develop models for extensive calculations using the built-in framework of object behaviors. It is obvious that GIS environments are not just extensions of the capabilities of conventional database systems but a dynamic environment able to accommodate and handle complicates geographic data structures and provide comprehensive information (Clementini and Di Felice 1994, Voivontas *et al.* 1998, and Voivontas *et al.* 2001 p.107).

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CHAPTER 2: OBJECTIVES AND METHODOLOGY

GIS was the employed for achieving the objectives, however the information utilized for obtaining the data was compiled from different sources.

2.1. Objective I

To determine the logging residue production in the state of Louisiana.

2.1.1. Methods adopted

For accomplishing this objective, timber production data was derived from the severance tax data compiled by the Louisiana Department of Agriculture and forestry. The Louisiana Timber and Pulpwood Production Report, published by the Louisiana Department of Agriculture and Forestry (2012) - Office of Forestry, was an annual report of total forest products severed and tax receipts received by parish and species plus estimated stumpage values. The Office of Forestry, the Louisiana Forestry Commission, the Louisiana Department of Revenue and Taxation and the Louisiana Tax Commission gathered data in a cooperative effort.

The data utilized for this study was from 2000 to 2010. Logging residues (limbs and tops) are basically the left behind materials in the site after harvesting pine (*Pinus* spp.) and hardwood for timber and pulpwood. In this case, they were derived from the timber production data. Pine sawtimber (Board feet, Doyle scale) was converted into bone dry tons (BDT). Although the residues were green at the site, this was done to get its dry mass. For pine, these values were calculated by multiplying annual pine roundwood production (as reported through severance tax data) by 13.98 percent (Johnsson 2001) and then it was converted to dry tons. 1 MBF Pine Doyle Scale weighed 8 tons and every cord of Chip-N-Saw weighed 2.7 tons (Louisiana Dept. of Agriculture and Forestry 2010). Moreover, the fresh timber had 50 percent moisture content (half water).

Similarly for estimating the logging residue left behind in woods from harvesting hardwood (broadleaf) timber and pulpwood, the hardwood sawtimber (Board feet, Doyle scale) was first converted to bone dry tons equivalent. Values were calculated by multiplying annual hardwood roundwood production (as reported through severance tax data) by 59.65 percent (Johnsson 2001) and converted to dry tons. It was assumed that a thousand board feet (MBF) of hardwood sawtimber weighed 9.5 tons and a cord of hardwood pulpwood weighed 2.85 tons and they had 50 percent moisture content tons (Louisiana Dept. of Agriculture and Forestry 2010). These were the equation used for estimating the logging residue production (Table 2).

Table 2. Equation for logging residue (de Hoop and Clement 2008)

	Equation
Pine BDT	[(Pine sawtimber MBF.doyle) x 8] + [Pine pulpwood cord x 2.7] * 0.5
Hardwood BDT	[(Hardwood sawtimber MBF.doyle) x 9.5] + [Hardwood pulpwood cord x 2.85] * 0.5
Pine Chip-N-saw BDT	Chip-N-saw cord x 2.7 * 0.5
Pine Residue BDT	(Pine sawtimber BDT + Pine pulpwood BDT + Chip-N-Saw BDT) * 0.1398
Hardwood Residue BDT	(Hardwood sawtimber BDT + Hardwood pulpwood BDT) * 0.5965
Total logging Reside BDT	Pine Residue BDT + Hardwood Residue BDT

BDT – Bone Dry Tons

In order to find the pine and hardwood logging residue production for the different parishes in the state, both types of timber were treated separately and plotted on a map. Further, for estimating the state's total logging residues production, the pine and hardwood logging residues from each parish were totaled. The annual production for each parish from 2000 to 2010 was later averaged to get the total average production. This average total production was used to estimate the maximum logging residue producing regions (parishes) in the state.

2.2. Objective II

To compare the three different mode of transportation (freight) namely rail, road and water

2.2.1. Data gathered

For comparing the three different modes of transportation (freight) namely rail, road and water, which were the most widely used transportation system in the state and determining the most effective mode of transportation among them, the following GIS data were included in the study:

- Digital map of administrative boundaries for the 64 parishes in Louisiana.
- Digital map of town, location and other demographic data.
- Digital map of the forest products industry in the state.
- Digital map of roads, rail and water transportation.

The different data sets that were used for this research were collected from the http://lagic.lsu.edu, http://www.atlas.lsu.edu/ and other websites. All the files were vector data. Some of the prominent files and their purposes are described below:

- National Waterway Network - This data set was a comprehensive network database of the nation's navigable waterways in and around the United States. It was primarily used for analytical studies of waterway performance, for compiling commodity flow statistics, and for mapping purposes. The data was compiled by the Vanderbilt Engineering Center for Transportation Operations and Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA/BTS). It was published in 2006.
- Ports (USACE) - This dataset contained physical information on commercial facilities at the principal U.S. Coastal, Great Lakes and Inland Ports. The data consisted of listings of port area's waterfront facilities, including information on berthing, cranes, transit sheds, grain elevators, marine repair plants, fleeting areas, and docking and

storage facilities. The US Army Corps of Engineers and RITA/BTS published the data in 2006.

- Deep Draft Ports - The data was compiled by the Louisiana Department of Transportation and Development (LA DOTD) in 2007. The dataset provided general location of Deep Draft Ports in Louisiana.
- Shallow Draft Ports - Compiled by the LA DOTD in 2007, the dataset provided general location of Shallow Draft Ports in Louisiana.
- Intermodal Terminal Facilities - The data was compiled by the RITA/BTS. This public database consisted of intermodal facility, cargo, commodity and directionality. The database was based on the requirements from the Commodity Flow Survey and with the different modes of DOT, supervised by RITA/BTS. The database would extend its design to support all of the modes within the DOT and in reference to modes involved with Intermodal transfer. It was published in 2006.
- Railroads of the United States - This map layer include railroads in the conterminous United States and Alaska. The National Atlas of the United States compiled it in 2005.
- Railroads in Louisiana - Railroads in Louisiana compiled by the LA DOTD in 2006.
- National Rail Network - The data was compiled by the RITA/BTS in 2006.
- State Highways - This dataset represents the state maintained road network of Louisiana compiled by the LA DOTD in 2007.
- Inter-state road system in Louisiana
- Major cities in Louisiana
- Coastal water in Louisiana
- Major water bodies in Louisiana

2.2.2. Methods adopted

All federal government data were in Geographic Coordinate System (GCS), while the state government preferred Universal Transverse Mercator (UTM). Since the study area was in Louisiana, all GCS shapefiles was "projected" to UTM. All their coordinate systems were checked in ArCatalogue before they are loaded into ArcGIS map. Following this, the data was further checked to find the area they covered. The various forms of Federal shapefiles had data for the entire nation, such as railway, navigational waterway and the port shapefiles. These were clipped using the Louisiana parish map (LA Map). This helped us to obtain the data for the study area.

Certain shapefiles like federal Railways polylines were later merged with the polylines from the state. However the deep-water ports shape files were not merged with the shallow water ports. This was done to abstract information on the interstate and international trade routes for biomass fuels. The following shapefiles was clipped.

1. National Waterway Network
2. Ports (USACE)
3. Intermodal Terminal Facilities
4. Railroads of the United States

These clipped files were later compared with similar shapefile datasets of different origins. The ones that showed major difference were closely examined. Metadata proved to be very helpful at this stage. Certain shapefiles were then merged with the state data (e.g. Ports (USACE) and National Waterway Network was be renamed Merge Ports).

Followed by this, the wood residue spreadsheet was compiled from the forest products industry survey done in 2008 and the logging residue table prepared for each parish. The industry survey contained information for the wood residue being produced, utilized and sold in the state

of Louisiana. The table had even more information regarding the industries that produced them. For this study, parish data was given importance. The data was organized in a fashion to fit attribute table of Louisiana Parish (LA_parish) shapefile. Later the excel sheet was joined with LA_parish file. The fields that are not pertinent to the study were removed. This included columns like age group, education, income, etc. Finally, the new attribute table was exported to create a new shape file called Wood_LA for permanent records. The Wood_LA shape file was also developed to analyze per parish wood residue production, utilization and the amount being discarded. All the transportation data, like, navigable waterway, road system and the railway network in the state would be overlaid. In order to make all other features clear, the Wood_LA layer would be given a 25 percent transparency. The Wood_LA was also labeled by name of the parishes.

2.3. Objective III

To identify the hotspots for wood residue utilization

2.3.1. Methods adopted

In order to find the hotspots for wood residue utilization the addresses of pulpmills in the state were gathered from the 2008 forest products industry survey (Kizhakkepurakkal 2008). Using these addresses, the pulpmills were later geo-coded to find the exact location in the map. The addresses that did not match were rexamined online. A 60-mile buffer was later added to the pulpmill location to show the areas from where these firms procured their raw materials.

2.4. Data analysis

Simple descriptive statistics were used to describe, estimation of production and utilization of logging residue material for woody biomass energy. ANOVA was used to show if there was a significance difference in the production of the logging residue between years and between parishes.

The data obtained were coded and entered into computer. Excel based statistical packages were used to manage and analyze data through variable relationship testing. The data entry was closely monitored to ensure accuracy. The statistical techniques were used to discern differences in responses among stakeholders and two types of forest products industry, analyzing data, and aided in reporting conclusions and recommendations.

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CHAPTER 3: RESULTS

3.1. Average logging residue production

The average total production for logging residue from 2000 to 2010 was approximately 3,073,978 Bone dry tons (BDT). Parishes like Winn (158,404 BDT), Vernon (154,955 BDT), Bienville (142,258BDT), Union (141,772 BDT), Beauregard (133,322 BDT) and Sabine (130,248 BDT) topped the logging residue production in the state. These parishes in combination produced around 28 percent of the total logging residue. All of these parishes were located in the Western and Northern parts of the state (Fig. 1).

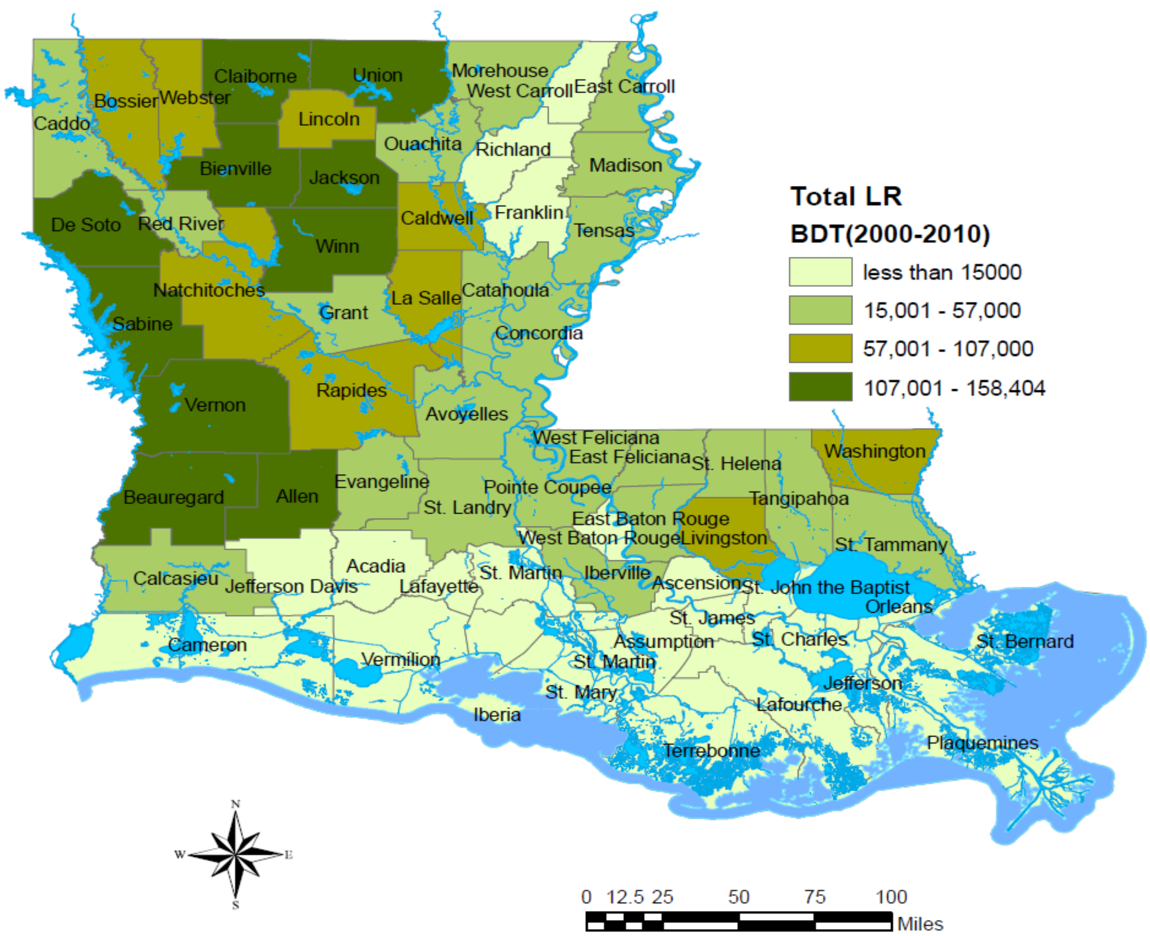

Figure 1. Total average logging residue production in Louisiana (2000-2010)

When it came to pine logging residue, the average total production was estimated around 1,464,831 BDT. Yet again the highest producers were Vernon (113,417 BDT), Winn (96,990

BDT), Beauregard (97,383 BDT), Sabine (92,753 BDT) and Bienville (83,348 BDT). They produced around 33 percent of the pine wood logging slash. However, hardwood logging residue constituted about 52 percent of the total logging residue being produced in the state. For hardwood logging residue the total average production in the state from 2000 to 2010 was 1,609,147 BDT, and the major producers were Union, Claireborne, Winn, Bienville and De Soto.

3.2. Statistical analysis

ANOVA done on the average total logging reside production revealed there was no significant difference (P= 0.92) between the years. The total production over the years from 2000 to 2010 when plotted on a graph (Fig. 2) showed an overall decrease, however there was a peak during 2003 and 2006. The logging residue production is directly proportional to the timber production in the state. Furthermore the timber production is driven by market, economy, policies, weather etc.

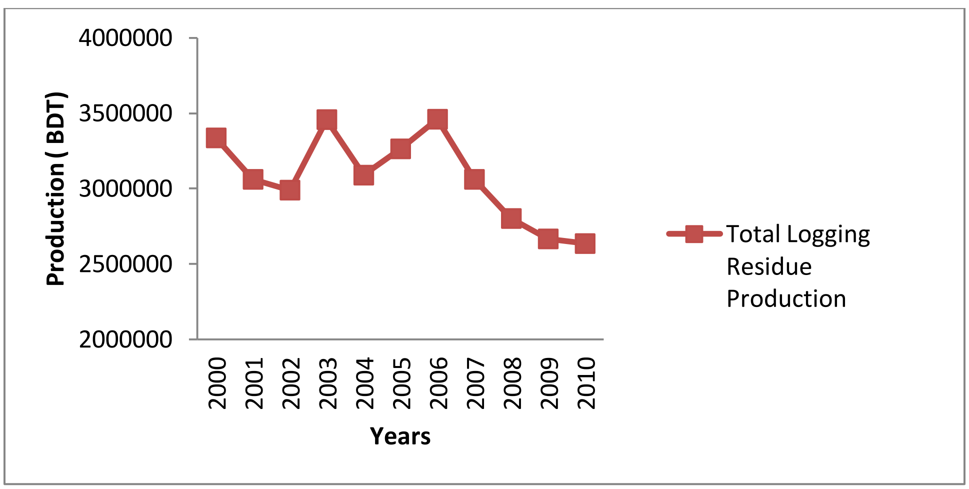

Figure 2. Logging residue produced in Louisiana (2000-2010)

However, ANOVA done between the parishes showed a significant difference (P ∞ 0) for all the parameters analyzed, such as average total logging residue, hardwood logging residue and pine logging residue. These results indicate that a fairly consistent supply can be assured from the top producing parishes, such as Vernon, Winn, Beauregard, etc. This data can also be used to

locate a collection center to gather logging residue produced in those parishes. The optimum location of the collection center can be derived from the maps. Factors like production points, distance to the nearest transportation point, availability of a reliable transportation mode, cost of overall transportation etc., can be considered when determining the location of the collection point. The point will facilitate the transportation of the logging residue to the final utilization point.

The GIS results comprised of various maps, which showed the logging residues being produced for all the parishes in the state, the three different transportation options for the logging residue and the industrial wood residue utilization. Additional maps included the transportation options for the parish producing and utilizing the highest wood residue and a 60-mile buffer zone on pulpmills in the state.

In order to find the pine and hardwood logging residue production for the different parishes in the state, both types of timber were treated separately and plotted on a map. The map (Fig. 3) showed the tree distribution in the state, according to which, the western part of the state had a good density of pine trees whereas the north eastern and south central part was dominated by hardwood species.

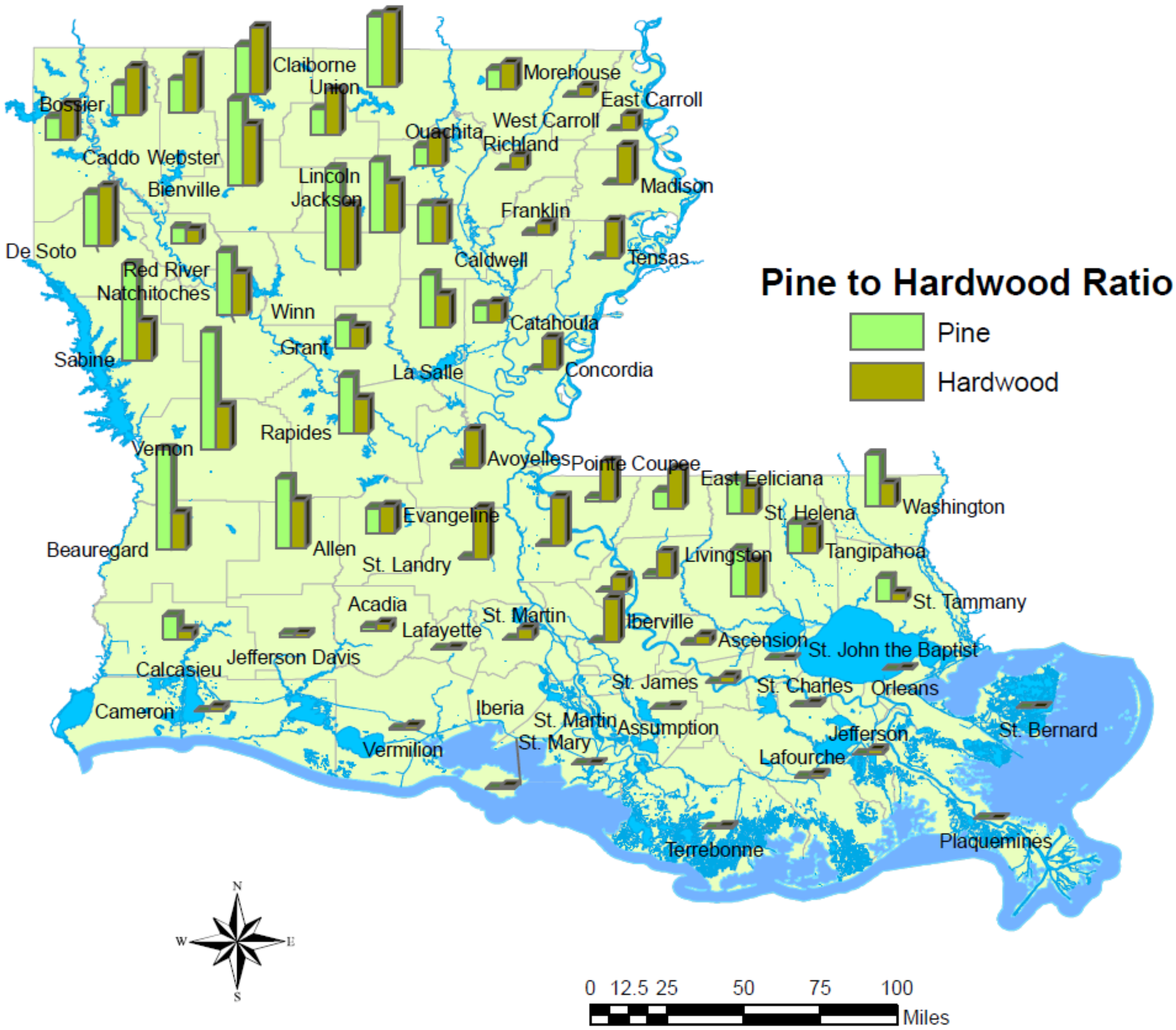

Figure 3. Pine to hardwood logging residue ratio in Louisiana (2000-2010)

3.3. Transportation

Once the logging residue was extracted from the forest it must be transported in some form to a facility for energy conversion. This leads us to the next objective of the study - to evaluate the most efficient means of transportation. When transportation costs are taken into account, more costly resources in close proximity may be economically competitive with cheaper resources farther away, and vice versa (Langholtz *et.al.* 2006). Again, the markets are

geographically limited (Lunan 1997). Therefore, supply in remote locations may not be suitable for exploitation due to high access costs (Fischer and Schrattenholzer 2001).

The three primary mode of transportation in Louisiana was the roads, rail and waterways system.

3.3.1. Roads

The road system in the state was by far the most extensive form of transportation. The state featured a total of 60,900 mi (98,009 km) of public roads, over 75 percent of them rural (Citidata 2000). The roads connected all the major logging residue producing parishes in the state (Fig. 4). The State had 6 primary interstates or 2dis: 10, 12, 20, 49, 55, 59; and 6 secondary or 3dis: 110, 210, 310, 510, 610 and 220.

But the road system also came with some limitation, it was considered to be the most energy consuming among the three transportation systems considered. More over 47 percent of Louisiana's major roads were in poor or mediocre condition and 28 percent of major urban highways were congested. This can be critical in determining the cost of transportation.

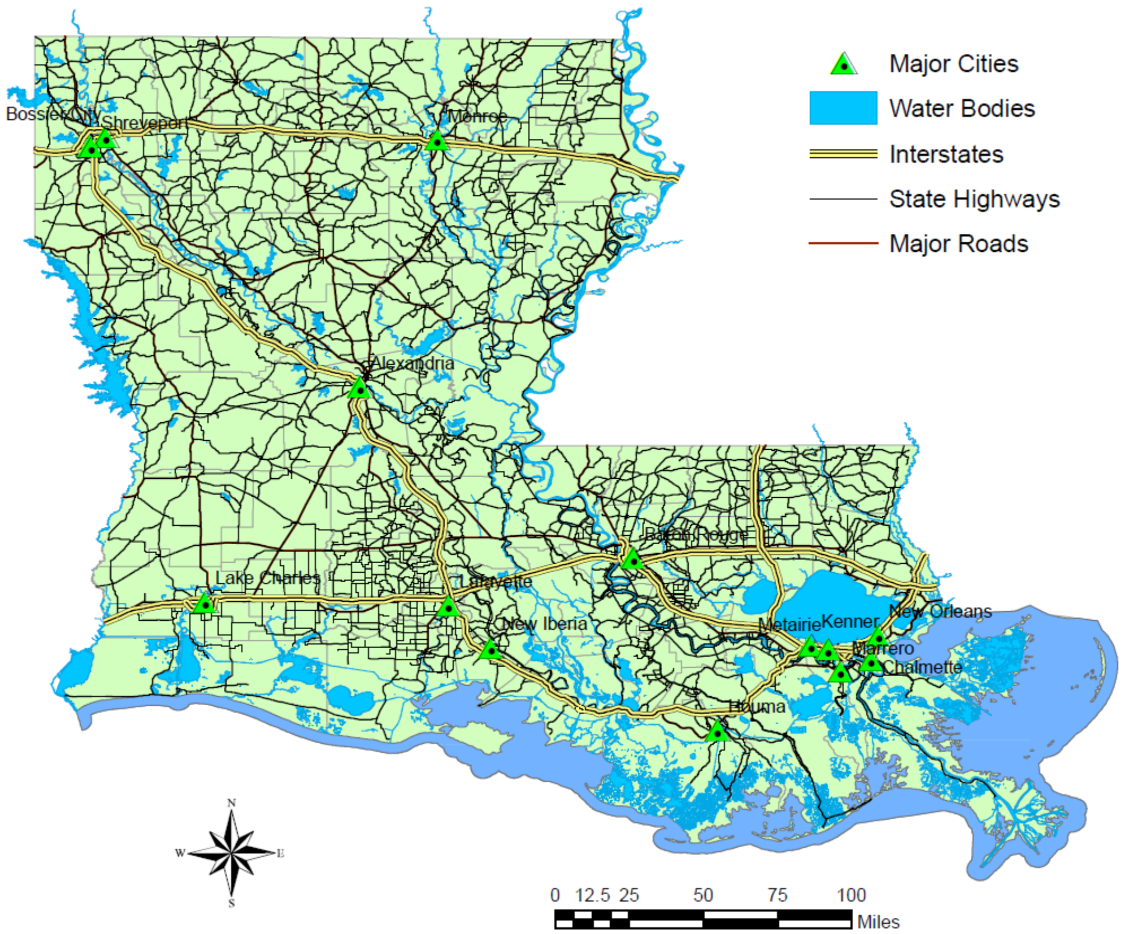

Figure 4. Road systems in Louisiana

3.3.2. Railroads

The state had about 2699 miles of railway tracks in freight service and there were 17 freight railroads operating. Unfortunately, like most other states, Louisiana was also losing its railway mileage. In 1999, lumber and wood products accounted merely for 3.4 percent of the total tonnage being transported, but pulp, paper and allied products made up 6.8 percent of the states rail traffic (Wilbur Smith Associates 2003). Even though railways were considered as the most cost effective mode of land transportation, only a few of the top producing parishes had access to them. But most these parishes had a railway terminal with in 50 mile of their boundary (Fig. 5). The major rail terminals in the vicinity of to these parishes were:

1. Yellow Shreveport LA Terminal
2. Murphy Bonded Warehouse
3. Caddo Bossier Port
4. Yellow Alexandria LA Terminal
5. Monroe Warehouse LA Terminal
6. Port of Lake Charles
7. Lake Charles Harbor Terminal

This was the primary mode of transportation 25 years back. But then later the timber industry switched from railway to the roads transportation. The major problems associated with the rail systems were

- Lack of availability of railcars
- Timing of delivery
- Cost of building railroads

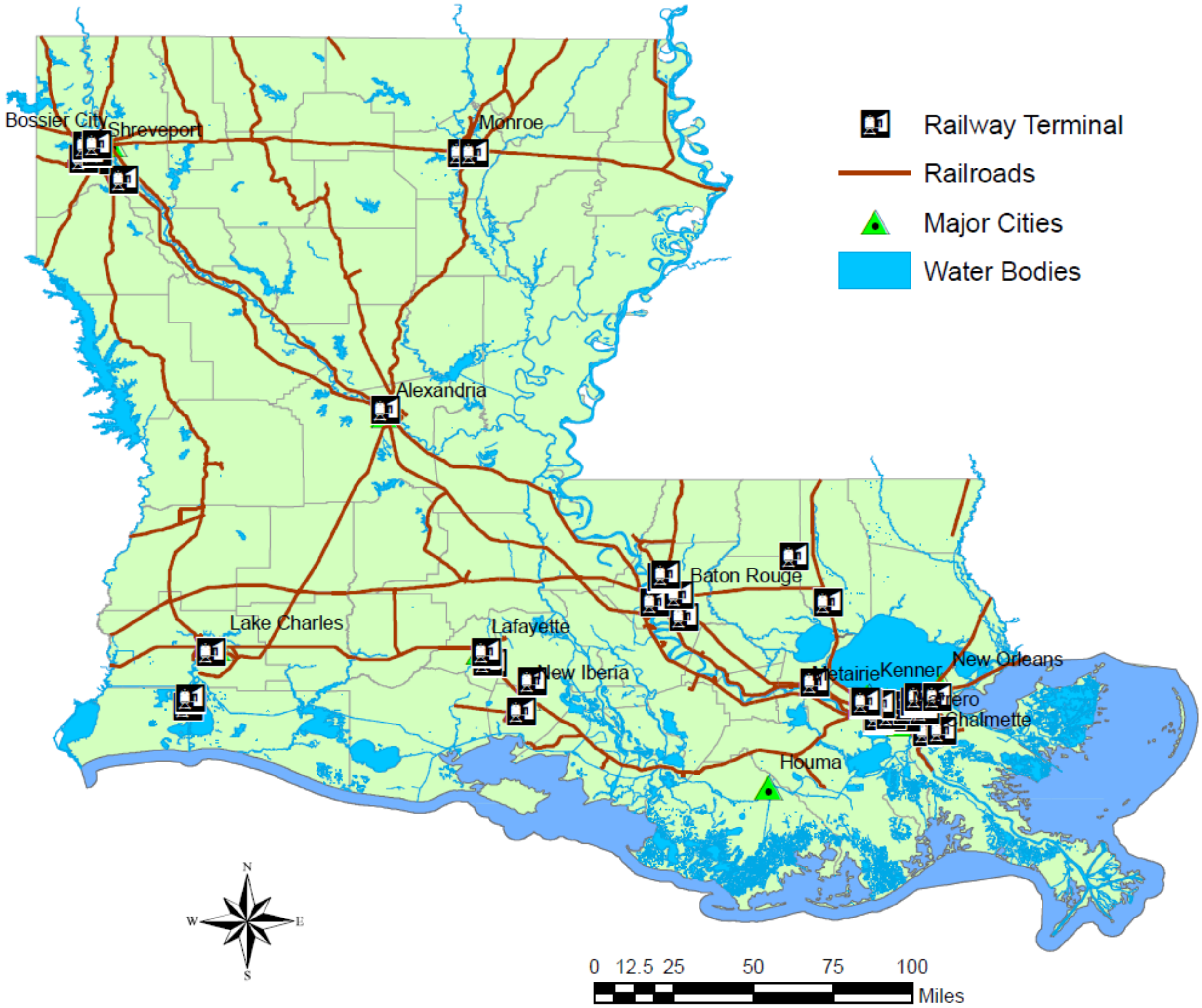

Figure 5. Railroads in Louisiana

3.3.3. Waterway system

This is considered to be the most cost effective mode of transportation system and Louisiana blessed with very good navigable waterways. The states navigable water consisted of over 2,800 miles of navigable water making it the next only to Alaska and a wide port network comprising 39 public entities and several private dock and terminal. Of 64 parishes in the states, 44 had navigable water system (Shaw Environmental and Infrastructure 2007). But here again most of the logging residue producing parishes had little connection to waterways. The Red

River was the principal waterway that ran through the high timber-producing belt in the state (Fig. 6). Some of the ports located near the highest logging residue parishes were (Table 3)

- Deep Ports-Lake Charles Harbor and Greater Baton Rouge Port
- Shallow Ports- Caddo Bossier Port, Red River Parish Port, Natchitoches Parish Port, Alexandria Regional Port Authority and Columbia Port

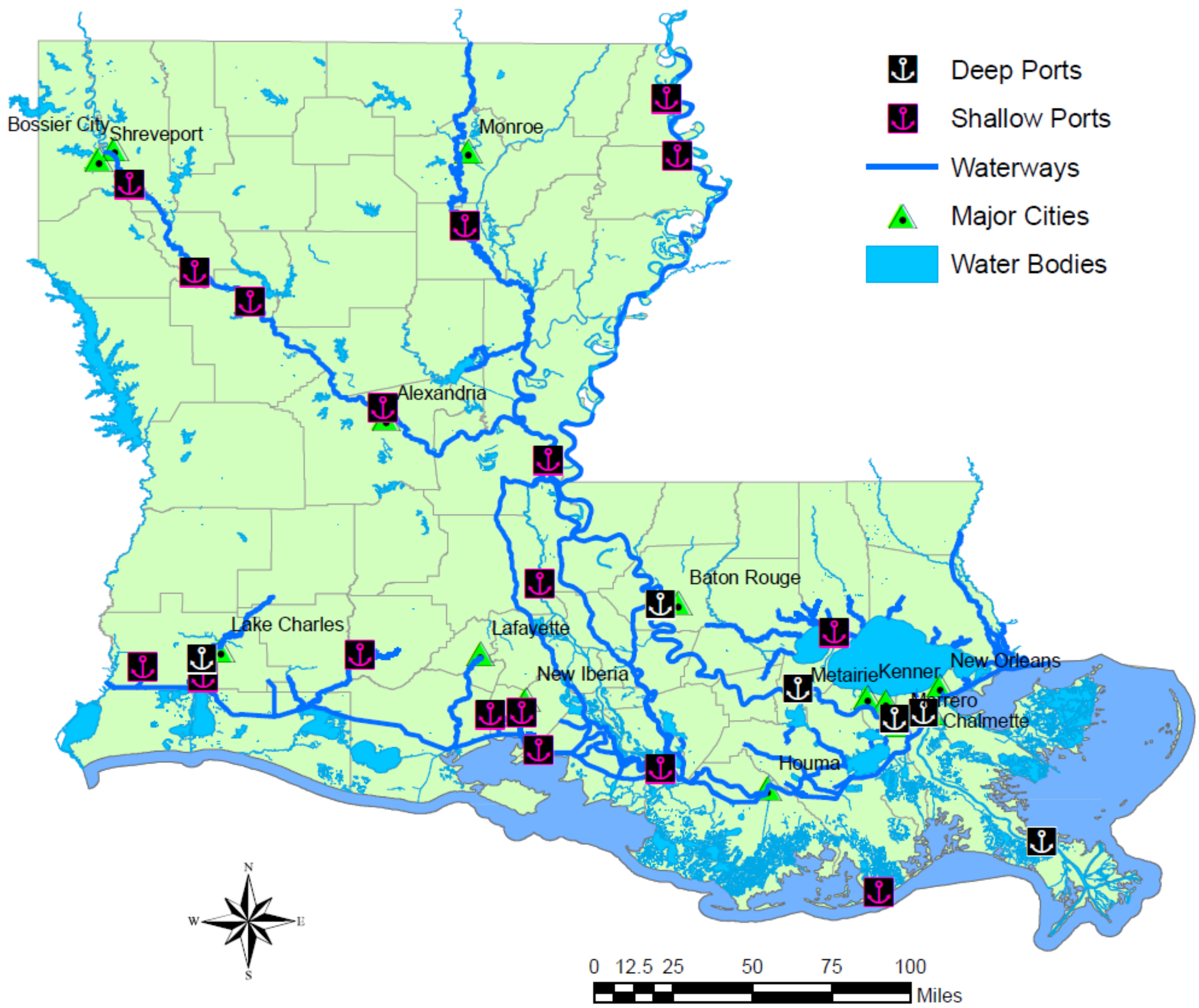

Figure 6. Navigable Waterways in Louisiana

Table 3. Ports in proximity to the timber producing belts (Shaw Environmental and Infrastructure 2007)

Port Common Name	Legislated Name	Waterway
Port of Greater Baton Rouge	Greater Baton Rouge Port Commission	Lower Mississippi River
Port of Lake Charles	Lake Charles Terminal and Harbor District	Calcasieu River
Port of Alexandria	Alexandria Regional Port Authority	Red River
Port of Shreveport-Bossier	Caddo-Bossier Parishes Port Commission	Red River
Port of Columbia	Columbia Port Commission	Ouachita/Black Rivers
Natchitoches Parish	Port Natchitoches Parish Port Commission	Red River
Red River Parish	Port Red River Parish Port Commission	Red River

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CHAPTER 4: DISCUSSION

The United States is one of the world's top producers and consumers of forest products. The total US consumption of timber products has increased since the mid-1960s, by 43 percent in lumber, 32 percent in plywood, 45 percent in pulpwood, and 33 percent in fuelwood. However, US per capita consumption of timber products has remained relatively steady, oscillating between 60 to 83 cubic feet per person per year from 1965 through 2005. Production grew 44 percent during this period. Currently, US consumption of timber products exceeds US production by 4.2 billion cubic feet (Alvarez 2007).

Meanwhile the forest industry in the nation also provides other benefits in addition to the timber supply. Today biomass feedstocks from forests are available in various form of logging residues, such as unsalable small stems, understory plants, and wood fiber used for other products (e.g., pulpwood). A globally competitive wood supply system is already in place producing traditional roundwood products such as pulpwood and sawtimber as well as clean pulp chips. Wood pellets, electricity from wood and liquid fuels are sectors that are developing that can utilize tree biomass not used by conventional markets (Greene *et al.* 2011). At present, the largest domestic source of renewable energy is biomass, of which 75 percent comes from forests (Perlack *et al.* 2005). Woody biomass can be used in a number of forms to produce energy, which includes firewood, pellets, cellulosic ethanol, and a feedstock in co-firing and cogeneration facilities. In general, using wood for energy has the following advantages over coal and other fossil fuels: it is renewable, releases 90 percent less carbon dioxide when burned, contains minimal metals and sulfur, contains minimal ash, and can be inexpensive compared with fossil fuels (Bergman and Zerbe 2004**)**. In fact, projections have shown that US could produce 10 percent of its energy from wood, which would be a threefold increase over wood's current contribution (Zerbe 2006 and Conrad and Bolding 2011).

At the same time, as the demand in wood-to-energy increased, the traditional forest products industry has weakened. The US South has seen falling prices for its timber products in recent years as a result of weak demand and excess supply (Wear *et al.* 2007 and Conrad and Bolding 2011). The timber industry in Louisiana has also followed similar trend, where timber production has been falling ever since 2006 (Fig. 2).

The forest products industries in the United States have adapted to these changing market situations as economic conditions has changed since 2007. Mill closures and job losses throughout the forest products sector have had significant local impacts. About 1,009 sawmills, 15 pulpmills, and 148 other mills have closed since 2005: nearly, 19 percent of all mills in the forest sector. These closures resulted in slowdowns or closures in hundreds more secondary wood-manufacturing facilities, resulting in an overall loss of 294,000 full-time jobs over the past five years (Smith and Guldin 2012 p 1). However, the loss by decreasing number of mills in the United States has been partially compensated by the enhancement in mill capacity and improvements in efficiency (Spelter *et al.* 2007 and Collins *et al.* 2008).

However, the problem can be further aggravated if a competition comes into play for the raw materials by pulpwood industry and industries intending to produce energy from wood biomass. This would eventually result in a further hike in the price of wood biomass, which would damage both. Such a situation was nearly experienced in Virginia, where 75 percent of pulpmills were located within 50 miles of a wood-to-energy facility, and all pulpmills were within 75 miles. Even though recent trends in pulpwood prices, fuel chip prices, and Virginia law indicated that competition for raw material was unlikely to happen in the near future, studies pointed out that it would in the long run, depending on government policies and technological progress in conversion technologies, competition between forest industry and wood-to-energy companies was possible (Conrad and Bolding 2011). In general, the market for wood residue

energy production was heavily influenced by the price of alternative energy resources and the supply of raw materials for the pulpwood market (Energydata *et al.* 2005 p.8).

Taking this situation in mind, a 60-mile buffer was drawn to the sites of pulpwood industries, which were the region from where the pulpmills in most cases procured their raw materials. Any logging residue collection centers or energy production utilities located in those regions could result in a heads on competition between the two industries. Since most of the pulpwood industries fetch their raw material from a 50-mile radius, these would be the points that would not preferable for the forest logging residue collection center to be situated. However in Louisiana the pulpmills were widely distributed with majority of them in the highest timber producing belts (Fig. 7).

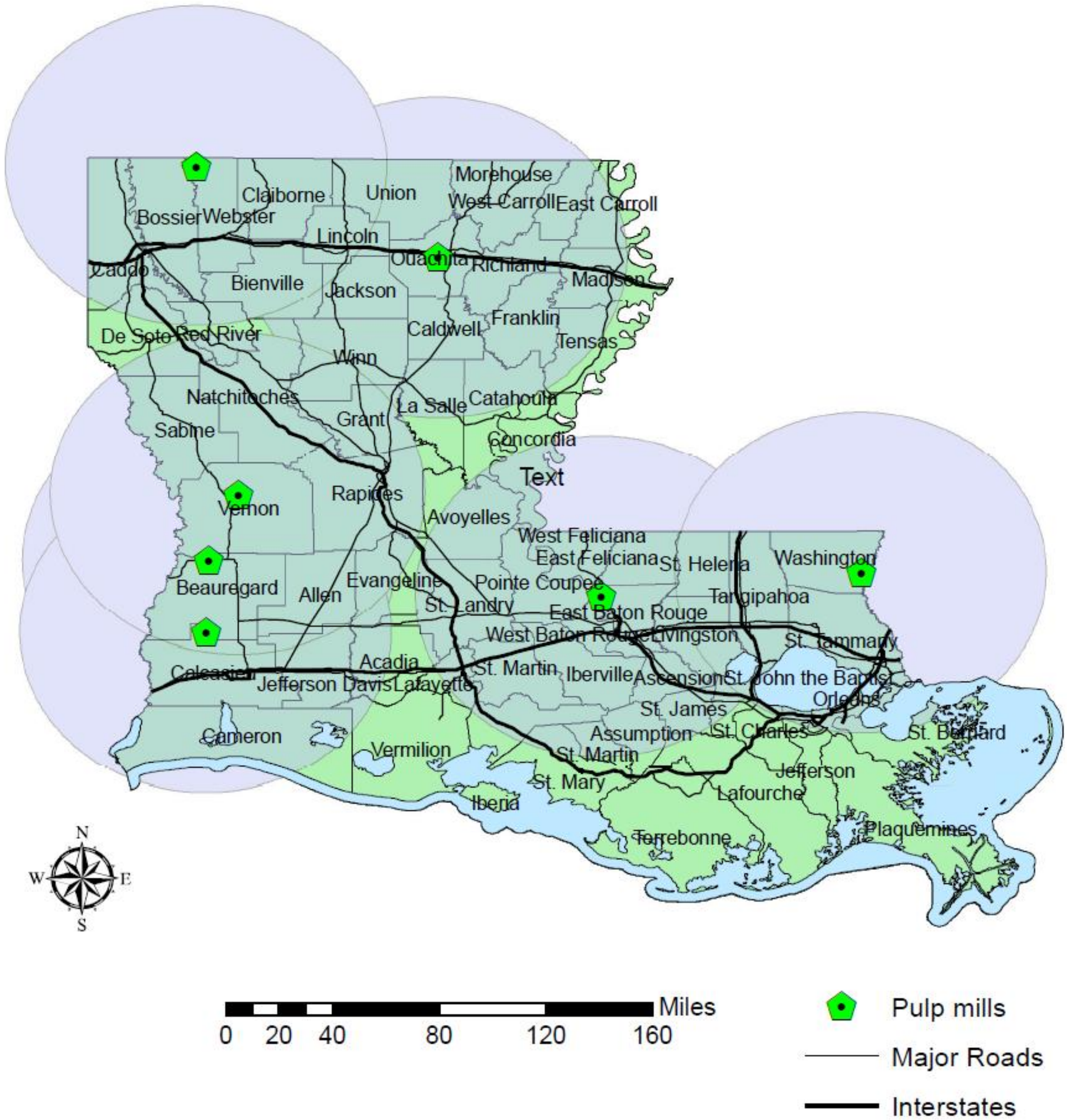

Figure 7. Raw material gathering region for pulpmills, Louisiana

This led us to the next phase, where we evaluated the production of logging residue for the state. Conventional forms of forest inventory did not provide an accurate estimate of the potential amount of forest biomass resulting from fuels reduction silviculture. Generally, maximum forest residue production occurred in harvesting operation that generated biomass as a by-product of producing higher valued logs. Another ground for production were fuels reduction

projects specifically targeting the removal of small diameter trees in high fire hazard stand with dense, tightly spaced under-stories (Kellogg *et al.* 2006).

In order to estimate the logging residue production for this study, we adopted an equation developed by de Hoop and Clement (2008), as this was the most suitable one for the conditions that prevailed in Louisiana. A number of studies have tried to quantify the forest residue production for the nation (e.g., Perlack *et al.* 2005, Southern States Energy Board 2006, Western Governors' Association 2008, and Encyclopedia of Southern Bioenergy Resources 2006) (Table 4). In fact, a volume to weight conversion factor of 17.22 dry tons per thousand cubic feet was derived for softwood and 17.99 dry tons per thousand cubic feet was derived for hardwood using cubic feet/cubic meter and cubic meter/green ton conversion factors listed in Timber Mart-South (2007). However not all forest residues available can be used. Technically only 40 percent of the residues can be recovered (Walsh *et al.* 2000). Increased harvest efficiency is important to the future economic viability of forest residues (Grushecky *et al.* 2007 and Galik *et al.* 2009)

Table 4. Different estimates for quantifying of logging residue and other removal from timber harvesting regions

Source	Region	Logging residue	Other removal
		(Percent of total roundwood harvested)	
Johnsson (2001)	Northeast	29	1
	North Central	25	7
	South	12	10
	Rocky Mountains	18	2
	Pacific Coast	11	1
	Entire Nation	16	7
	Louisiana	13.98 and 59.65 (Pine and hardwood)	5.79 and 26.88 (Pine and hardwood)
Smith et al (2005)	Entire Nation	16	6
WGA (2008)	Entire Nation	30 (Forest residue)	

On the other hand, according to the last full RPA assessment (Haynes 2003), logging residues have been a declining portion of the total removals from the growing stock inventory

decreasing from 9.8 to 6.4 percent of softwood removals and 22.2 to 12.4 percent of hardwood removals between the years 1952 and 1997. This trend is projected to continue with logging residues as a percent of softwood removals declining to 6 percent and to 9 percent for hardwood removals by 2050. However certain other studies showed the opposite trend for reason such as increased price for logging residue, which made it more economical to remove lower quality material, changed harvesting methods, and increased use of fuelwood (Walsh 2008).

The conversion factor (roundwood to logging residue) for this study was derived from a report, wherein the logging residue production for Louisiana was estimated around 14 percent of the pine roundwood timber being harvested and nearly 60 percent for hardwood (Johnsson 2001) (Table 4). Even though the production of logging residue was estimated, little was known regarding their utilization in the state. The average total production for logging residue from 2000 to 2010 was approximately 3,073,978 bone dry tons (BDT).

Since certain buyers of wood biomass were interested in specific tree species, we also described the logging residues for pine and hardwood timber separately. This was done to help the industries that utilized either one of them. Moreover it helped in giving an idea of tree species distribution in the state (Fig. 3).

To generalize the wood residue industry in the south, a study conducted by Greene *et al.* (2011) came up with these findings

- Pulpmills are the major market for wood residue in the South.
- Biomass is usually purchased on a green ton basis, which is out of the comfort zone for both logging contractors and forest landowners, because these residues tend to dry soon after harvest.
- The size of residue material used for woody biomass markets appeared to be directly related to the demand and competition for pulpwood by pulpmills in a region

- Most operations chipped or ground their biomass in the field prior to transportation. This was done to improve product quality and maximize truck payloads.
- Transportation efficiency was critical to the success of biomass harvesting operations and maximizing truck payloads was a key factor. This was a challenge in the South where most state weight laws limited vehicle gross vehicle weight to 40 tons (often with 5-10 percent allowances).

4.1. Transportation

The next phase of the study was to evaluate the economics of delivered product, which was one of the major barriers to the utilization of forest biomass (Kellogg *et al.* 2006). In one case, costs for a four hour transportation was nearly equal to the forest management costs to grow a 17 year-old pine; Studies have accounted that transportation can comprise up to 50 percent of the total delivered harvesting cost (Richardson *et al.* 2002). Due to these challenges, many harvesting contractors are currently opting to subcontract their transport to specialized transportation companies. Even though this seemed to take care of the limitation, it also introduced another "middleman" which further ate revenues.

Transportation can be minimized by optimal utilization of vehicle payload and by choice of shortest travel paths. Both means are determined by behavior and geography. The behavior of truck drivers was not accounted in this study. Instead, from a geographical point of view, it is attractive to find the least possible transport efforts to meet a given wood fuel demand with available resources. This least cost approach, together with actually recorded transport volumes, can then be used to bench-mark intended improvements (Moller and Nielsen 2007).

Over all, cost-effective harvesting and transportation was particularly significant to delivering biomass feedstocks at a competitive market price (Aguilar and Garrett 2009). The Department of Energy recently identified $47 per dry ton (approximately $23.50 per green ton)

as a target delivered feedstock price for 2012 to make biomass-based processes competitive (Wilkerson *et al.* 2008). Of this, they targeted $10 per dry ton for the landowner ($5 per green ton), leaving $37 per dry ton ($18.50 per green ton) available for collection and transportation (Greene *et al.* 2011). By contrast, Travis Taylor of Travis Taylor Logging and chipping Goldana, Louisiana, stated in September 2005 that it cost him $27/green ton to cut, skid and chip wood (no transportation cost included).

The primary transportation systems adopted in the state were water, rail, and road transport. Transporting forest products by water, through barging or rafting, was the oldest form of transportation, utilizing large payloads and long distances. Rail transport was the next important phase in transportation, which was also characterized by large payloads and long distances. But today, in the southeastern U.S., approximately 90 percent of wood is transported by truck, while 10 percent arrives through a combination of water and rail (Bolding 2008).

4.1.1. Road transportation

Road transportation was the most extensive form of transportation in the state (Fig. 8). In fact, truck transportation had taken over the rail transportation in the state due to several factors, including flexible scheduling, a relatively low investment compared to other modes of transportation, and speed of delivery. However, fuel costs were reducing the profit margins on the logging residue industry. In most cases, the maximum hauling distance for timber may be 100 miles to 150 miles and varied based on economic factors such as product value and hauling costs. However when economic feasibility of wood residue transportation was accounted, the hauling distance was further reduced. To conclude, the more valuable the product, that is, sawtimber vs. pulpwood, the farther it could be hauled economically.

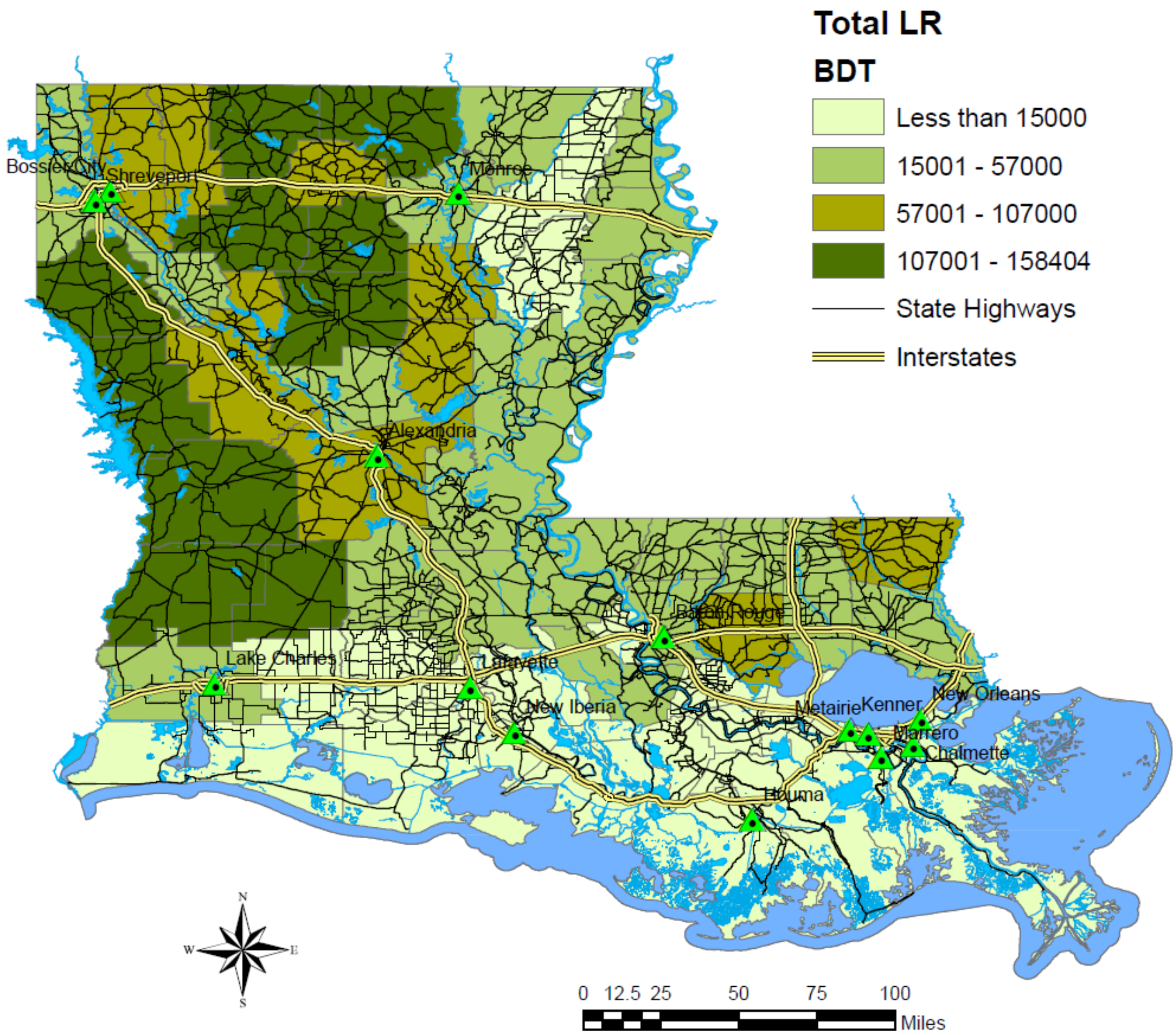

Figure 8. Road transportation compared to logging residues production in Louisiana

In fact in the real world, a typical cut-and-haul rate ranges from $12 to $16 per ton depending on the requirements and difficulty of the harvesting contract. This rate might include a minimum haul of 50 miles. If commodity was to be delivered outside this 50-mile threshold, a $/ton-mile incentive might be provided at $0.10–$0.12 per ton for each additional mile (Bolding 2008). But due to its relatively low energy density, the economical transport distance for wood fuel was a fraction of that for other energy sources; typically, wood fuel must be gathered from a radius of 62 miles (100 km) or less (Richardson *et al.* 2002). Even at 50 miles or less,

transportation costs alone can rise as high as $10 to $30 per dry ton (Galik *et al.* 2009). Other earlier studies showed still lower distance, like 80 km (50 mile) (Brower *et al.* 1993 and Paine *et.al.*, 1996). The increment in hauling distance from then to today was a direct consequence of the demand for this raw material in energy production.

Since the trucking industry had a prominent role in determining the efficiency of road transportation, there are several imperative factors to be considered in enhancing trucking productivity. Certain aspects like the loading time played an important role. The loading time was to be minimized to improve efficiency. Coming to the unloading time, truck drivers often had to wait long time to unload, which resulted in an increased truck turnaround time. This would drastically lower trucking productivity and rise hauling costs.

Further issues were regarding the highway weight regulation laws that governed the weight allowances for trucks. Weight allowances varied by state, and changed often, as these laws are dynamic. The current maximum Gross Vehicle Weight (GVW) for unmanufactured forest products in most states are 80,000 pounds with some states having percentage overage allowances. To improve trucking efficiency, efforts were still being done to increase maximum GVWs (Bolding 2008).

Yet again, the state road network, especially, the interstates ran all the way through the state and connected most of the logging residue belts. I-49 had a significant role to play because it more or less ran through this zone (Fig. 8). However, the state highways and other roads were more accessible important function in connecting the rural harvesting sites.

Other factors that affected truck transportation were selection and matching of the trucks to perform most efficiently. Some important points to be taken remembered in this section would be: type of load, weight of truck and load and weight restrictions, Type of terrain—flat, mountainous, switchbacks, etc., Type of road—public, private, etc., Haul distance, Frequency of

volume—consistent flow, periodic, or scattered, Safety requirements—braking. In the case of wood residue, usually chip vans were preferred.

But then there are many other productivity criteria that are outside the control of contractors, such as rising fuel prices and hauling distances. However, many determining factors such as maximizing payload, minimizing loading time, and reducing load weight variability are controllable and must be considered to improve the efficiency of road transportation in the sector (Bolding 2008).

4.1.2. Railway system

When compared to road transportation the primary and process energy requirements were lower for rail, except for the train powered by electricity from coal power. In an environmental point of view, potential impact of acidification and eutrophication was also lower for rail powered by electricity than for road. Although the maximum load on a train as a proportion of the overall vehicle weight is larger, and trains are more efficient than truck when the transportation distance is farther (Lindholm and Berg 2005).

Despite all these advantage trains were not often preferred since most of the harvesting locations had little access to railway terminals. But railways could be a potential option for shipping the wood residues from wood residue collection centers to the final utilization point. For this the collection center should be located nearby a railway intermodal terminal. From this map (Fig. 9) we could locate some of such potential collection centers for gathering the wood residue being produced at the harvesting site and for transporting it through railroads.

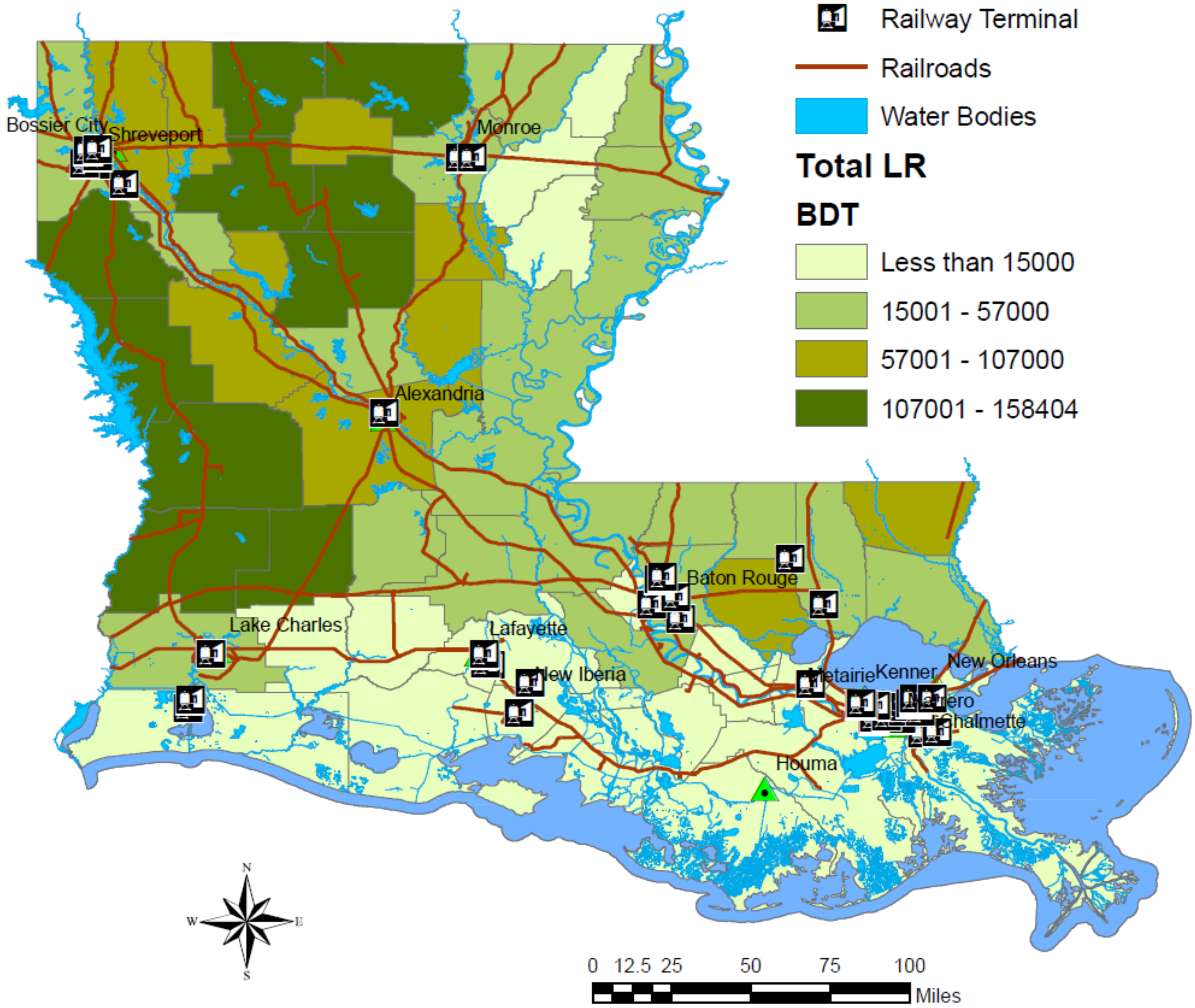

Figure 9. Railway transportation compared to logging residues production in Louisiana

In general, 37.1 million tons of commodities were transported by rail originating in Louisiana and terminating outside the state, in which pulp, paper, or allied products constituted 11.7 percent, whereas, lumber and wood products were at 4.8 percent. In the aggregate (all movement types), pulp, paper, and allied products made up 6.8 percent of Louisiana rail traffic.

Moreover rail freight originating in Louisiana predominantly terminated in Texas. The next largest areas were California, Illinois, Georgia and Florida. Altogether, these states accounted for 18.1 million tons or 48.7 percent of cargo that originated in Louisiana by volume.

The shipments to California were mainly chemicals and pulp/paper products (Wilbur Smith Associates 2003).

However for the past 25 years the dependency by timber industry on the rail has declined. In a survey conducted on shippers, in general, using the rail, a majority (53 percent) indicated that the service had deteriorated either somewhat or significantly over the last 10 years. The main reason for this was untimely and inaccurate (poor car placement) switching, short line service cutbacks, poor customer service, lack of storage tracks on carriers and the high costs. Again, the state's 11 small railroads, which connected to the national freight rail system, had unmet capital needs totaling up to $102.6 million, of which 39 percent were related to 286 track improvement projects required to handle heavier car weights. There were also abandoned railroads seen on the map, scattered throughout the state (Fig. 9). For improving the railway transportation some of the practical solutions by Wilbur Smith Associates (2003) were

- Improved rail facility access.
- More and larger rail cars.
- The establishment of private (shipper-owned and controlled) car fleets

4.1.3. Waterway system

Overall, the navigable waterway system provided a safe, environmentally sound transportation network. The water transportation, generally, consumed approximately 2.2 times less energy than transportation by rail (Magelli *et al.* 2009). It also served as a sustainable economic resource base that could be continuously harnessed for the benefit of economic growth and diversification.

Since there was an international market growing for biomass residue, the water system would play a major role in the future. There are firms coming up in Baton Rouge, LA, which were planning to ship their wood pellets to Europe. Currently, Louisiana waterways network

handled approximately 485 million tons of cargo a year, of which 200 million tons was foreign trade. Louisiana's marine transportation system was a highly integrated transportation system that connected the domestic markets of America's heartland with the international marketplace (Shaw Environmental and Infrastructure 2007).

Most of the logging residues' water transportation in the state was associated with the Red River, because the river flowed through some of the high wood residue producing belts in the state (e.g. Natchitoches, Rapides and Winn) (Fig. 10). However, since the highest logging residue producing parishes (Vernon, Beauregard, Bienville, Sabine) had little accessibility to the ports, transportation of these biomass through boats have not been an option, at least for meeting the domestic demands. But once trucks were employed to transport the commodity to the ports, this could be a potential option for long distance travel, interstate even perhaps intercontinental freights. Another restriction here would be the "reshipment" of the biomass from the trucks or small barges (as the ports in the Red river were inland/ shallow water ports that did not accommodate large ships) to containers at major ports. This would further increase the cost of transportation.

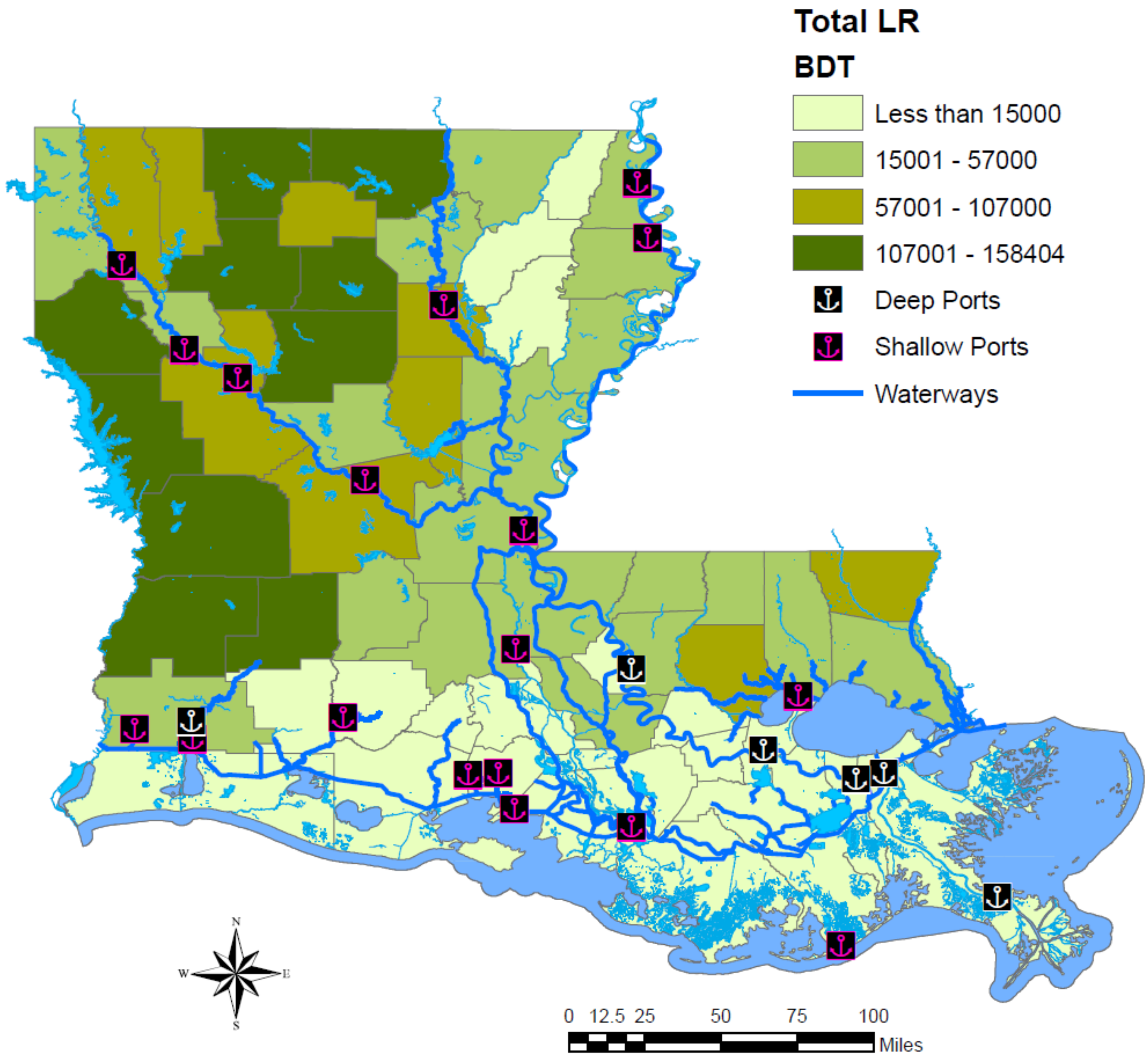

Figure 10. Water transportation compared to logging residues production in Louisiana

Overall, the ability to receive cargo from inland areas was vital to the water transportation of logging residue. This was largely dependent on the port's ability to access hinterland markets by other transportation modes, such as roadways, waterways and railroads. Generally, trucks were the primary mode within a 500 mile radius of a port. Rail connectivity at a port became increasingly important in attracting containerized cargo when the origin-destination pairs are more than 500 miles apart (Shaw Environmental and Infrastructure 2007).

In general, some steps that can be adopted to enhance the water transportation of logging residue would be (Ashar and Swigart 2007):

- To construct Inter-terminal modals inside the dock
- To combine the handling of marine and domestic containers to achieve better utilization of the IM facilities and enhance rail services

4.2. Combination of transportation modes

Today, as new markets are being opened for wood residue in Europe, more sophisticated logistic supply chains are coming into place. These employ different combinations of transportation modes, which would not only serve long distance freight but also reduce cost (Fig. 11). Furthermore, these permutations of freight have also been proved to be environmentally friendly. Such scenarios have been already in place in Europe and Canada, were wood biomass is in great demand. Usually these transportation methods make use of more than one mode of freight. A major revenue concern here would be the “reshipment” of the commodity from one mode to another, which would significantly increase the shipment cost. However these methods are usually employed for long distance shipment.

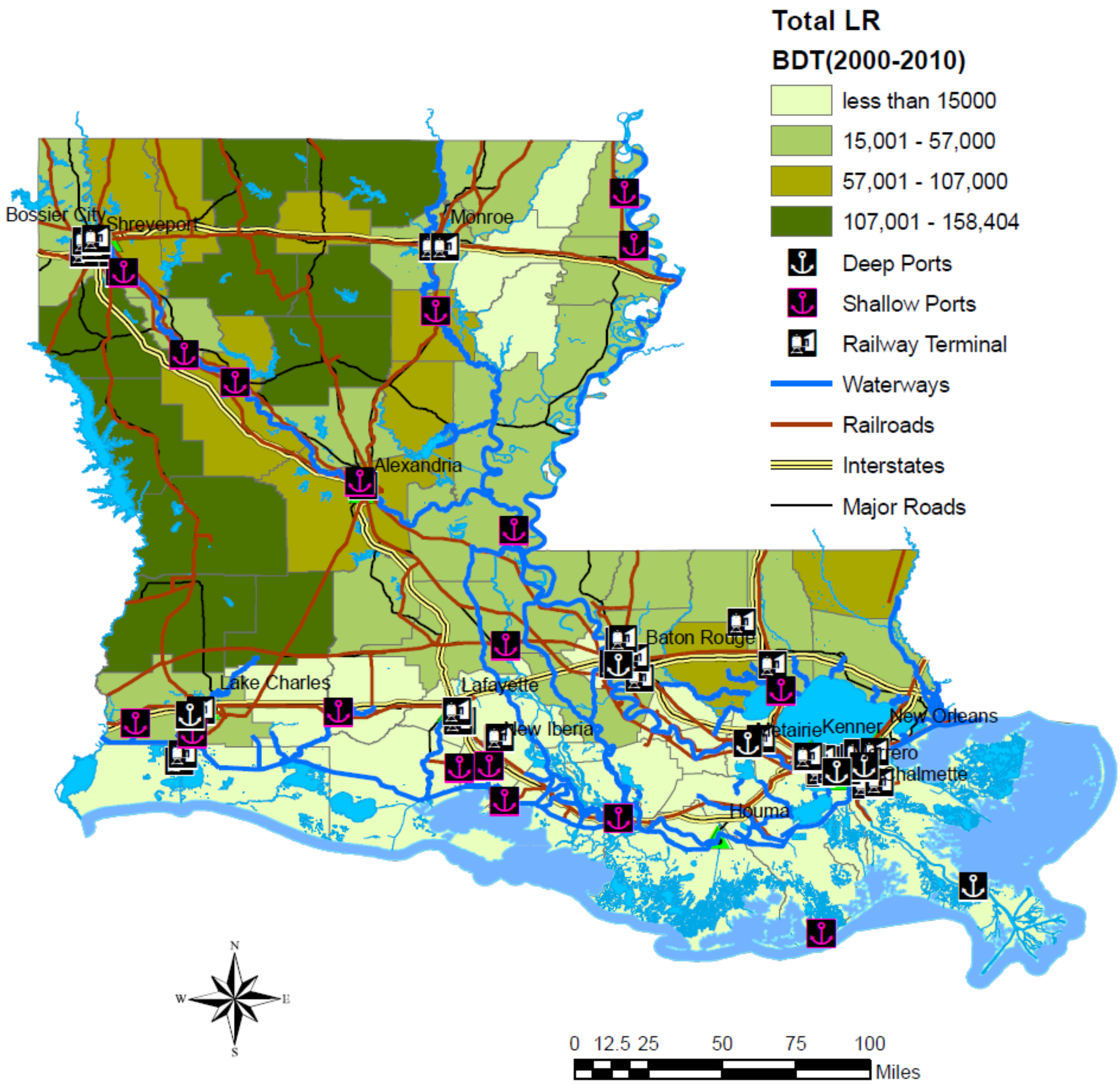

Figure 11. Transportation options for logging residues production in Louisiana

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PART II - AGRICULTURAL CROP RESIDUE

CHAPTER 5: INTRODUCTION

Agricultural and natural resource industries have been contributing significantly to our state's economy and have always carried the potential for increased economic benefits and job creation through value-added processing in urban and rural communities throughout Louisiana (LSU AgCenter 2012). Some natural byproducts of agriculture were biomass waste in the form of cotton gin trash, rice hulls and sugar bagasse. Disposing of these wastes has always posed a problem. One popular waste management solution was to use them for fuel known as biofuels.

Today, biomass energy is critical in accomplishing the energy demand in the nation. In 2010, biomass fuels provided about 4percent of energy used in the United States (EIA 2011). In fact about 10-15 percent of the world's total annual energy came from fuel-wood and charcoal, together with other biofuel such as bagasse. These were mainly used for the production of thermal energy in both developing and developed countries (Hillring and Trossero 2006).

Biomass resources used for energy production can be broadly grouped into wood residues, (generated from forest products industries, timber harvesting sites and municipal waste); agricultural residues, (generated by crops, agro-industries and animal farms); energy crops, i.e. crops and trees dedicated to energy production; and municipal solid waste (Easterly and Burnham 1996, and Voivontas *et al.* 2001 p.1).

The significance of this category of energy was directly visible in the US energy perspective. Biomass constituted the largest source of renewable energy that provided 3.2 quads of energy, which was 47 percent of all renewable sources of energy, in which 43 percent came from biofuels (mainly ethanol), and about 11percent from municipal waste (EIA 2005). A recent study indicated that the U.S. had the potential to produce almost 1.2 billion dry tones of biomass per year in addition to current food and fiber production (Perlack *et al.* 2005, and Castellano *et al.* 2009). In the most biomass-intensive scenario, studies showed that by 2050 modernized

biomass energy would contribute to about half of the total energy demand in developing countries (IPCC 1997).

Other figures regarding crop residue productions showed, the amount of crop residue produced in the US was estimated at 367×10^6 Mg/year for 9 cereal crops, 450×10^6 Mg/year for 14 cereals and legumes, and 488×10^6 Mg/year for 21 crops. The amount of crop residue produced in the world was estimated at 2802×10^6 Mg/year for cereal crops, 3107×10^6 Mg/year for 17 cereals and legumes, and 3758×10^6Mg/year for 27 food crops. Furthermore, the fuel value of the total annual residue produced was approximately 1.5×10^{15} kcal, about 1 billion barrels (bbl) of diesel equivalent, or about 8 quads for the US; and 11.3×10^{15} kcal, about 7.5 billion bbl of diesel or 60 quads for the world (Lal 2005).

But on the other hand, even with today's high oil prices, biofuels cost more than conventional fuels. To encourage the supply of biofuels and their feedstocks, aids were available for cultivation of raw materials and for the capital cost of biofuel processing. These aids were designed to promote demand for biofuels to play a larger role. The main approaches were (Demirbas 2008):

- Tax reductions/exemptions for biofuels
- Biofuel obligations

As a matter of fact, most of the states in the US have adopted several policies to promote renewable energy production and to control its price. Nineteen states have established targets for renewable energy production. Sixteen states have formulated initiatives to encourage production of ethanol, and seven more have enacted laws to encourage its use. Thirty states have installed wind generated electricity capacity and many more were pursuing possibilities of electricity from various forms of biomass (Bowyer *et al.* 2006). Policies adopted by the state played a crucial role in enhancing the financial attractiveness of biofuel production and trade, and many such policies

influenced biofuel costs and prices, e.g. subsidies, tax breaks, tariffs (Doornbusch and Steenblik 2007).

Louisiana has also adopted several policies like, a number of clean energy bills and tax incentives to tap its biomass resources for energy production. This provided the state ample opportunities for renewable energy expansion and helped it in developing a renewable portfolio standard. However further, market expansion of bioenergy can only result from combination of factors such as new energy and environmental policies, high international fossil fuel prices and low production and transportation costs (Hillring and Trossero 2006).

In Europe, the European Union (EU) has implemented energy and climate policy, which aimed by 2020 to reduce energy consumption by 20 percent, with a similar cut in CO_2 emissions, while raising the share of renewable energy in the EU‘s energy mix to 20 percent. At present, more than half of EU‘s renewable energy came from biomass (EU 2006). To support this, the European Union had put in some policies that were meant to promote the renewable energy in heating (Commission of the European Communities 2005 p7). Some of the prominent ones were:

- To ensure biomass fuels supplies were available
- Establishment of efficiency criteria for biomass and the installations in which it was to be used
- Equipment labeling which enabled people in buying clean and efficient devices
- The appropriateness of setting targets and other technical measures
- Voluntary agreements with industry
- Amendment of the directive on the energy performance of buildings to increase incentives for renewable energy

- A study of how to improve the performance of household biomass boilers and reduce pollution, with a view to setting requirements in the framework of the eco-design directive
- To support research and development of technologies for energy production

5.1. Features affecting biomass residue production

The biomass residue being produced in the agricultural field was one of the most prominent source of biomass which could be used for energy production. There were several features that determined the quality of the biomass being produced. Moisture content was the most significant feature that affected quality of biomass fuel for thermal processes like combustion, gasification and pyrolysis. Materials with lower moisture content, had a lesser cost of transportation, since it reduced size of handling, processing and energy conversion equipment needed for biomass power. Reason for this being that a smaller volume of feedstock would be required to meet fuel requirements for the facility (ODE 2003).

In addition to this, the amount of agricultural residues that could be sustainably removed was directly influenced by a number of factors including grain yield, crop rotation, field management practices (e.g., type and timing of tillage and other management practices), climate, and physical characteristics of the soil (soil type, erodibility index, topography, etc.). The methodology required to estimate agricultural crop residue supplies involved estimating the quantities of residues produced, the quantities that must remain on the field to maintain soil quality characteristics and long-term productivity, and the cost of collecting/harvesting available residues (Walsh 2008).

5.2. Beneficials

From a production economics point of view, agricultural crop residue for energy production had a lot of advantages. It was typically a by-product or residue of the main product.

Since, the main product was the crop or other fiber product, this would cover the fixed costs and the by-product only had only to cover marginal costs (Lunan 1997). Moreover, agricultural crop residues (the non-grain, above ground component of crops) being a complementary product to the production of crops, and had the same factors that drove the production of these crops driving the quantities of crop residues produced too (Walsh 2008). Besides this, it also played a vital role in waste management system, as it found an economical value for the residual products, which was otherwise considered as waste.

Today biomass is considered as an important source of renewable energy which is widely accepted for its potential to satisfy environmental compatibility. The third assessment report of the Intergovernmental Panel on Climate Change (IPCC) supported the emissions and removals of greenhouse gases, including carbon dioxide, and showed that most of the observed global warming over the last 50 years was likely to have been due to the increase in greenhouse gas (GHG) concentrations in the atmosphere (M'ollerstena *et al.* 2003). This was where biomass energy turns out to be one of the promising options to reduce green gas emission. The carbon component in plants, removed from the atmosphere, had only a recent past, but the carbon locked in fossil fuels ranges over millions of years. Hence, here the comparison was between emissions of CO_2 into atmosphere, from biomass generated in recent years, to the fossil fuels, which had taken millions of years to evolve.

Coming to the other advantages, use of crop residue as a possible source of feedstock for bioenergy production also have a positive impact on soil Carbon sequestration, soil quality maintenance and ecosystem functions.

5.3. Concerns

The major concern regarding the biomass market was associated with the organization of the trade (Commission of the European Communities 2005). The organization of the biofuel

market was characterized by the fact that there were no central, regional or local marketplaces. Consequently, prices of immediate and future supplies were not transparent. This made it very complicated for consumers to make choices about the use of bioenergy, and furthermore it was more difficult to gain a complete overview of every condition relevant to an investment. Hence, it was safe to conclude that the biofuel market relied on the involvement of government or others authorities in order to establish a more functional market, which could initiate the expansion of the market. The possibilities for a marketplace and its organization for bioenergy were to be considered to create efficient logistics chains.

The development of the future price level for competing energy sources (e.g. hydropower, oil and gas) defined a critical framework for a long-term utilization of bioenergy. Furthermore, the development of bioenergy was affected by energy policy (e.g. more renewable energy, increased flexibility), agriculture policy objectives (e.g. increasing the industrial base in the districts, the overgrowing of arable land), environment policy (climate, tourism) and infrastructure (the overgrowing of roads). These objectives were reflected in laws and regulations, e.g. taxes and subsidies, which in turn affect future production and utilization of bioenergy (Energydata *et al.* 2005 p.8).

The other issues were mold, rot and fire damage. This could be dealt effectively by converting crop residue into densified fuel. The next major constraint was regarding the transportation issues of crop residues. Transportation cost turned out to be a major factor that determined the economic viability of the whole operation.

5.4. Transportation

Transportation was one of the most important elements in the logistic chains, in which the distribution of the demand and the supply in the area had to be taken into account. Again, statistics for local distribution of biomass resources in the area was to be procured, and several

assumptions had to be made. It was assumed that a relation existed between the quantity of harvesting and the quantity of resources available.

Some countries have tackled this problem by setting up supply chains coupled to existing plants, and by supporting the organization of logistics systems. The performance of a logistics chain depended on a large number of variables. The three primary elements on which the cost of a logistic in chain were (Energydata *et al.* 2005 p.32-35):

- Production: the quantity of agricultural residue being produced or treated
- Size of the task: the factor of work that has to be done with the biomass, e.g. transporting the biomass from one place to another, treatment, etc.
- System: the component employed to solve the task. This would include the unit costs per task unit and production unit. The unit cost depends on the technology, capacity etc.

A more comprehensive economic assessment of biomass residue resources takes into account other costs varying with biomass type, distance, and transportation infrastructure (Langholtz *et al.* 2006). In order to explore the possibility for improvements and find an efficient logistics chain, the effects of these variables must be calculated. For this, different options should be embed in the context. Different scenarios determining the demand for bio-heat and the supply of bioenergy in the actual area has to be developed for evaluating logistic chains, possible efficiency and synergy effects. In such evaluations, it is appropriate to differentiate between four major effects (Energydata *et al.* 2005 p.9):

- Scaling effects- This is a situation that exists when the unit cost of supplying a product is reduced by increasing the volume of supply. This increase of volume can be achieved by higher demand, centralization of production to larger units, or cooperation/fusion with similar companies.

- Unit effects exist when there is a possibility of eliminating functions. This can be achieved through cooperation/fusion between companies, either within the same industry, between different industries or with suppliers or customers.
- Dispersion effects exist when the cost of supplying several products together is lower than supplying them separately. This can be achieved through cooperation/fusion between companies producing or supplying different products.
- Efficiency effects exist when the unit cost for supplying a product is reduced without volume increase. This can be achieved through increasing the efficiency of the processes in the chains.

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CHAPTER 6: OBJECTIVES AND METHODOLOGY

6.1. Objective I

To determine the Parish wise residue production for major agricultural crops

6.1.1. Methodology

The biomass residue created from agricultural sectors was obtained from LSU AgSummary- Parish totals Summary created by the LSU AgCenter (2012). This provides parish wise data on crops being produced, number of producers, number of acres cultivated, yield per acre, production gross farm value, etc. The data from 2005 to 2011 was utilized for this study. For studying the agricultural residue production in the state, the 9 crops selected were rice, sugar cane, cotton, oats, soybean, potato, peanut, wheat and sorghum. The prime reason behind the selection was because these crops constituted the major agricultural production in the state.

This was later plugged into the following equation (Milbrandt 2005) depending on the crop being cultivated to estimate the crop residue that can was produced in each Parishes in the state.

For crops in which production was reported in pounds, such as peanuts, cotton, rice, and potatoes:

BDT residue = (crop production * crop to residue ratio * Dry Matter %) / 2205

For crops reported in BU such as corn, oats, sorghum, soybeans and wheat:

BDT residue = crop production * crop to residue ratio * Dry Matter % / K

For crops reported in short (US) tons (sugar cane):

BDT residue = crop production * crop to residue ratio * Dry Matter % * 0.9072

Here, BDT – Bone dry tons, BU – Bushel, 1 metric ton (MT) = 2205 pounds and K - BU to MT conversion or 2205 / Bushel weight (in Lbs). 0.9072 – conversion from short (US) tons to metric tons. The crop to residue ratio is given in Table 5.

Table 5. Crop to residue ratio and moisture content of selected crops (Milbrandt 2005)

Crops Selected	Ratio of Residue to Crop Volume	Moisture Content (Percent)	Bushel Weight (lbs)
Barley	1.2	14.5	48
Corn	1	15.5	56
Cotton	4.5	12	32
Oats	1.3	14	32
Peanuts	1	9.9	22
Potatoes	0.4	13.3	60
Rice	1.4	15	45
Sorghum	1.4	12	56
Soybeans	2.1	13	60
Sugar Cane	1.6	62.8	50
Wheat	1.3	13.5	60

6.2. Objective II

To compare the three different mode of agricultural residue transportation (freight) namely rail, road and water

6.2.1. Methodology

The information obtained from all this data set was utilized to create biomass pools, which can was further developed into a map in a geographic information system (GIS) by parish. The transportation information was further plugged in to this, to get the most cost efficient product for biomass energy production in the state.

To construct the maps which showed the production and transportation modes for the agricultural residues in the state, utilizing GIS, was similar to the procedures employed in making the logging residue maps, except for the fact that agricultural residue production data was plugged into the points instead of logging residue. Here again ANOVA was utilized to find the significance between the different parishes in the state.

6.3. References

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CHAPTER 7: RESULTS

Agriculture is a highly sophisticated segment of the national and world economy and it becomes increasingly more every year (LSU AgCenter 2012). The agricultural production in the state was concentrated in the eastern and the central strip of the state. There were 7 parishes in the state which had no agricultural cultivation; these were Lincoln, Sabine, Vernon, Orleans, Jefferson, Plaquemine and St. Bernard.

The 9 crops selected were rice, sugar cane, cotton, oats, soybean, potato, peanut, wheat and sorghum (Fig. 12). In which soybean, rice corn and sugarcane constituted more than of the crop grown in the state in production (Table 6). The average agricultural residue produced in the state was 6,773,985 BDT and was concentrated in the North Eastern and central regions of the state. Morehouse, Madison, Franklin, East Carroll and Pointe Coupee were among the major producers in the state (Fig. 13).

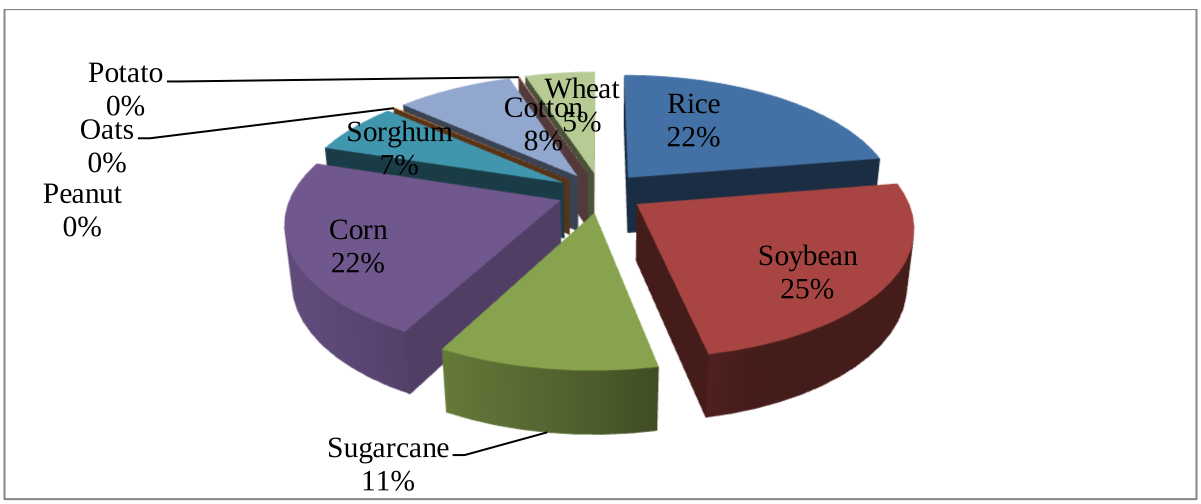

Figure 12. Total production (percentage) of major agricultural crops cultivated in Louisiana

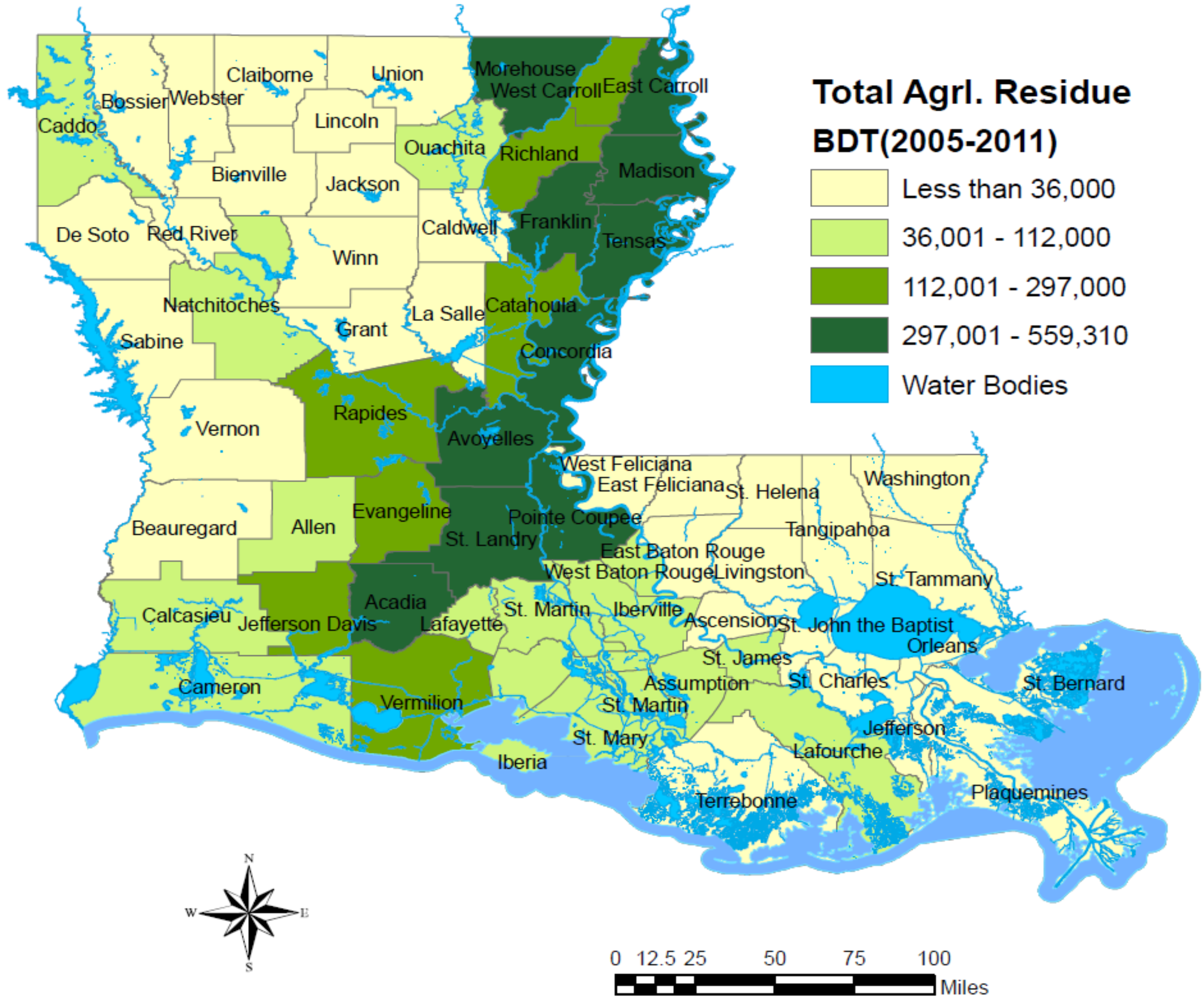

Figure 13. Total agricultural residue production in Louisiana (2005-2011)

Table 6. Average residue production of major crops cultivated in Louisiana (2005-2011)

Crop	Average Residue Production (BDT)
Soybean	1,656,814
Rice	1,514,797
Corn	1,502,670
Sugarcane	738,982
Cotton	564,332
Sorghum	446,398
Wheat	337,025
Oats	6,830
Potato	5,828
Peanut	309

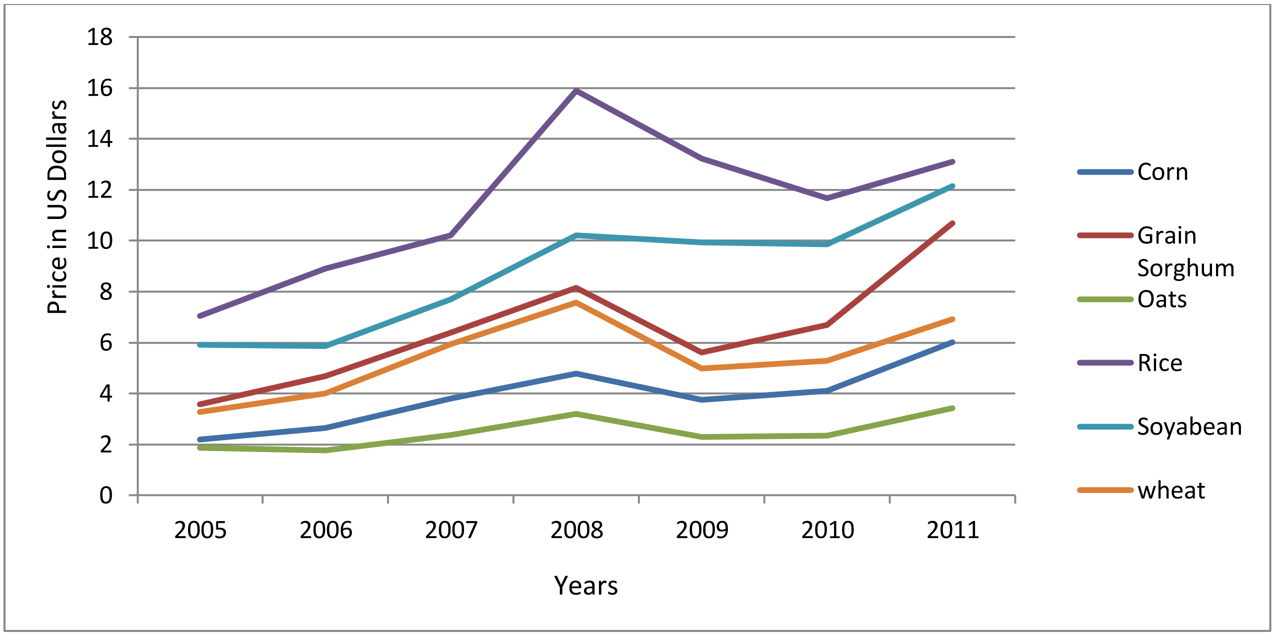

Figure 14. Unit price fluctuation for major agricultural crops in Louisiana (2005-2011)

There has been on average 105 percentage increase on the price for all the major crops selected, except for potato which showed 57 percent decrease. The greatest increase was seen in 2007- 2008 (28 percent increase) except for peanut and sugarcane (Fig. 14). But then in 2008-2009 almost all the crops had a set down in price (17 percent).

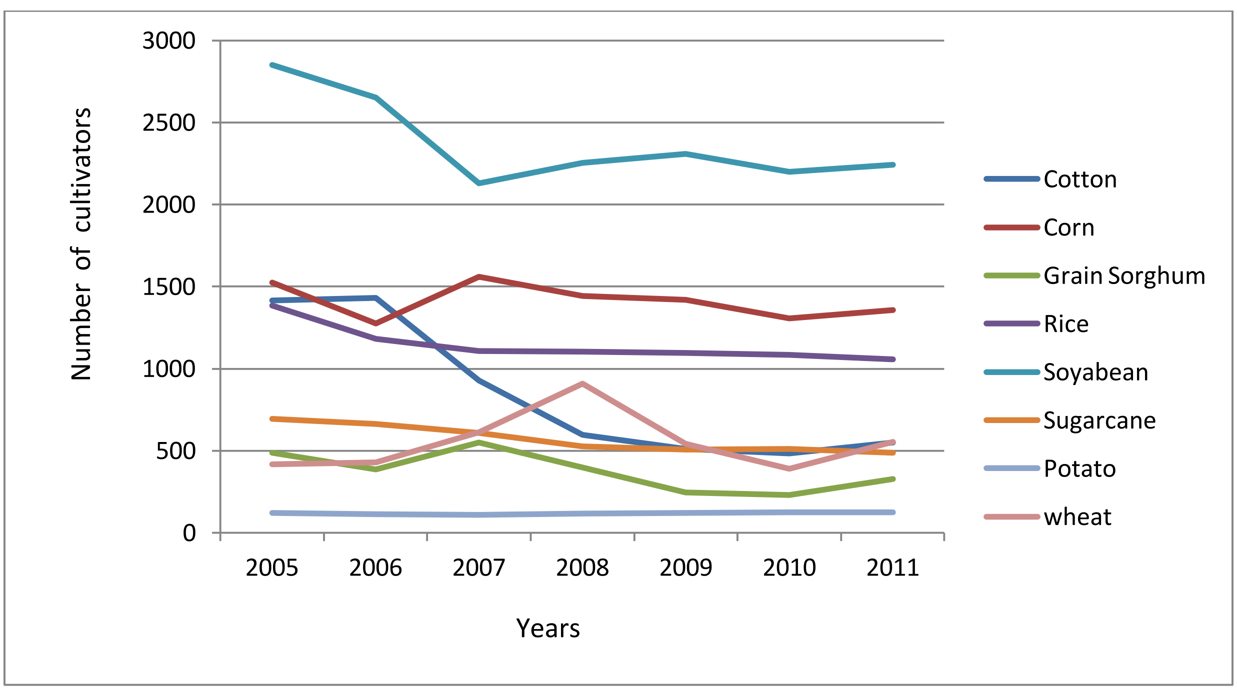

Figure 15. Number of cultivators for major agricultural crops in Louisiana (2005-2011)

In general the number of cultivators has been steadily decreasing for these selected crops (Fig. 15). The greatest decrease was seen in cotton (61 percent). Only potato and wheat, showed an increase in the number of cultivators.

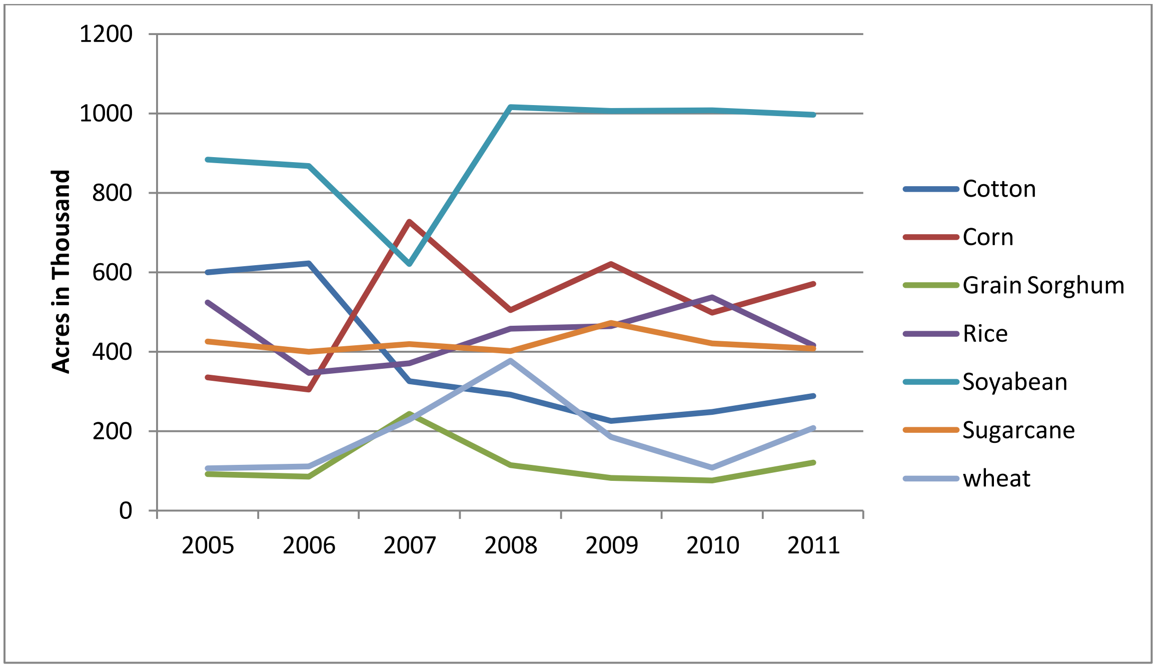

Figure 16. Area for major agricultural crop cultivation, Louisiana (2005-2011)

Coming to the cultivated land, a drop in the area of cultivation was seen for cotton (52 percent) and rice (20 percent) from 2005 to 2011 (Fig. 16). But there was a high increase in wheat (95 percent) and corn (70 percent) area in the state.

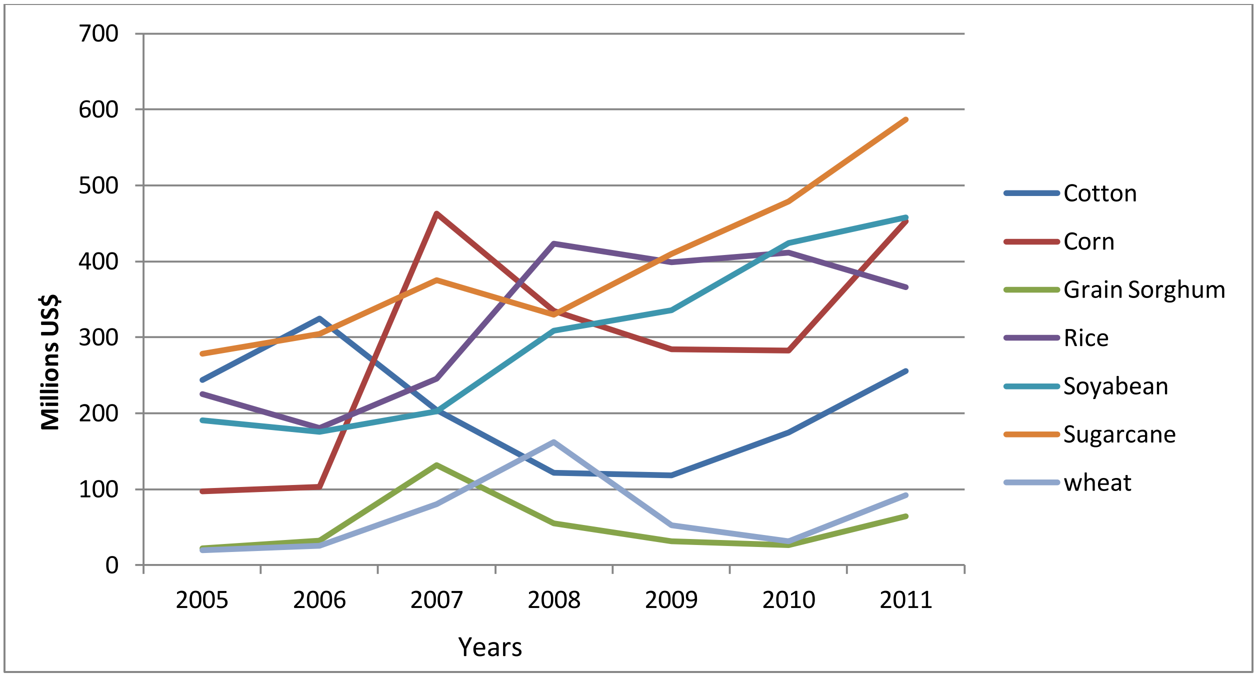

Figure 17. Gross farm value for major agricultural crops in Louisiana (2005-2011)

The Gross Farm Value for almost all crops selected showed an increase throughout this period (Fig. 17). A partial credit goes to the inflation in price for the agricultural products

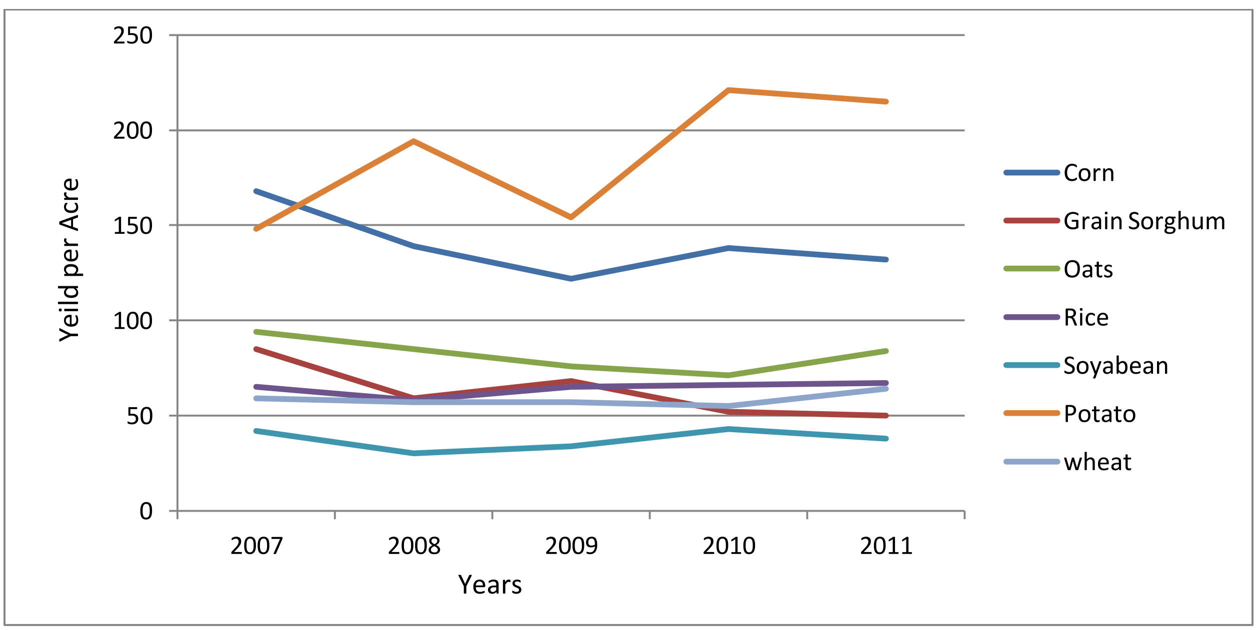

Figure 18. Yield per acre for major agricultural crops in Louisiana (2005-2011)

In spite of the major technological advancements in the region every year, interestingly the yield per acre was decreasing for all the major crops in the state except potato and rice (Fig. 18).

7.1. Analysis of variance

The statistical test was conducted in the data obtained to see whether there was a significant difference between various features studied. The results showed that there was no significant difference between the years for crops (except cotton and sorghum). But when it came to between parishes, there was a significant difference between them for every parish. There was also a significant difference between the productions of the crops.

7.2. Production of crop residues

7.2.1. Rice

The average total production for rice residue from 2005 to 2011 was 1,514,797 Bone Dry tons. Acadia, Jefferson Davis, Vermillion, Evangeline and Morehouse topped production. There were 30 parishes, which produced rice in the state of Louisiana (Fig. 19). Most of them were situated in the northeastern and the central region of the state. On an average, 30 parishes cultivated rice. The average rice produced per acre during this period was 64 cwt. and there was around 445,308 acres of land used for rice cultivation in the state. The major forms of residue were hulls, straw and bran.

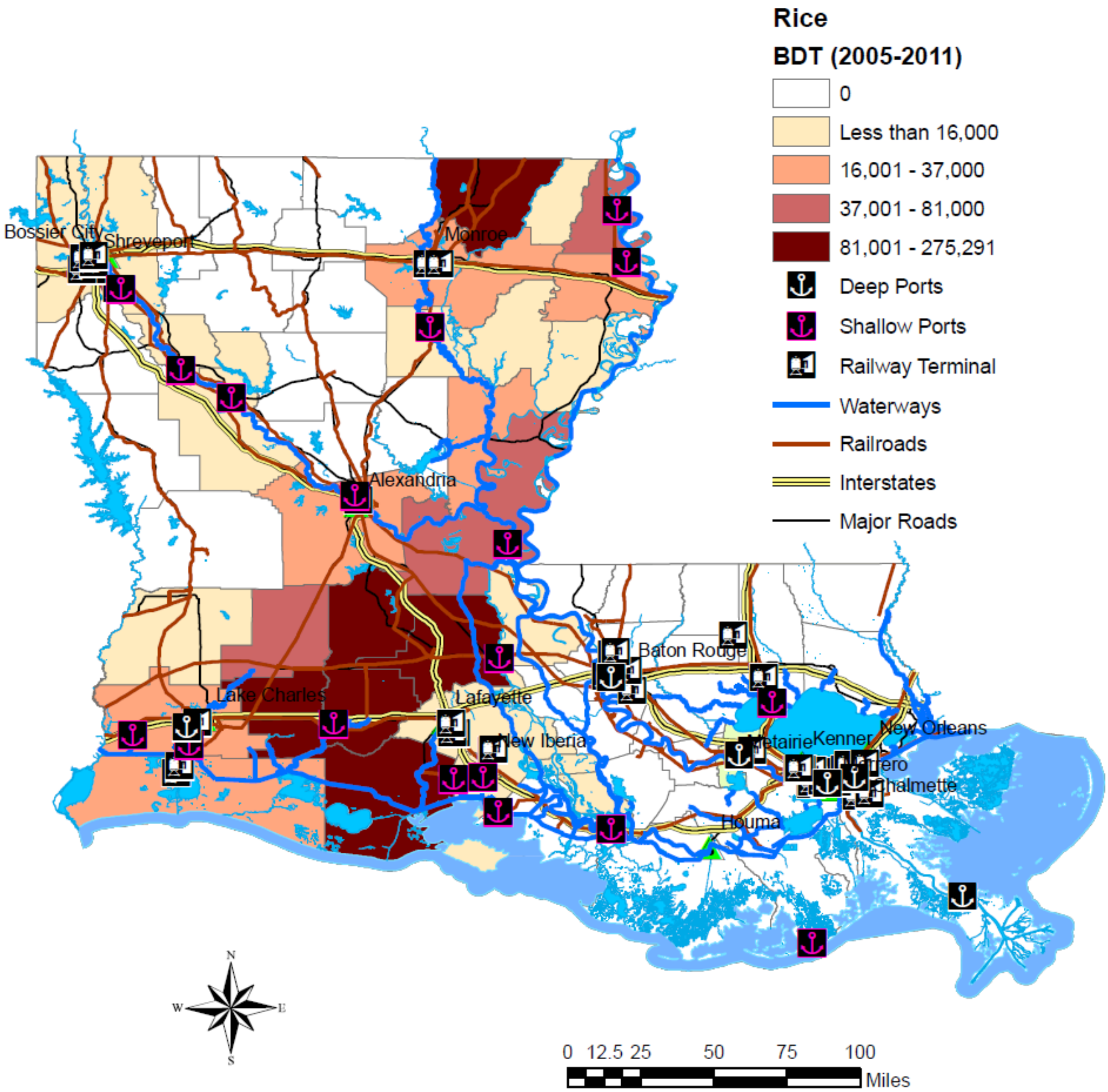

Figure 19. Transportation options for rice residues being produced in Louisiana

When the transportation options were considered for rice, water and road had a significant role to play. Since rice production, in general, was concentrated near the river system, the Mississippi being the chief, water transportation was seen as a viable option. Water transportation was chiefly done through barges. But there were no major railway terminals in the rice producing belts.

7.2.2. Sugarcane

In the case of sugarcane, the average total production for residue from 2005 to 2011 was 738,982 Bone Dry tonnes. The parishes that topped production were Iberia, Assumption, Iberville, St. Mary, Point Coupee and St. Martin (Fig. 20). There were 24 parishes that cultivated sugarcane in the state. Most of them were in the south central region of the state. The average sugarcane produced per acre was 6946 lbs. and about 421,000 acres of land was used for sugarcane cultivation in the state.

Unlike rice, rail transportation was also suitable for sugarcane. The intermodal terminals in Lafayette, Baton Rouge and New Iberia could be utilized for railway transportation and I-10 was running right through the sugarcane belt in Louisiana. Sugarcane producing parishes also had access to major deep-water ports like Port of Baton rouge and a large number of shallow ports.

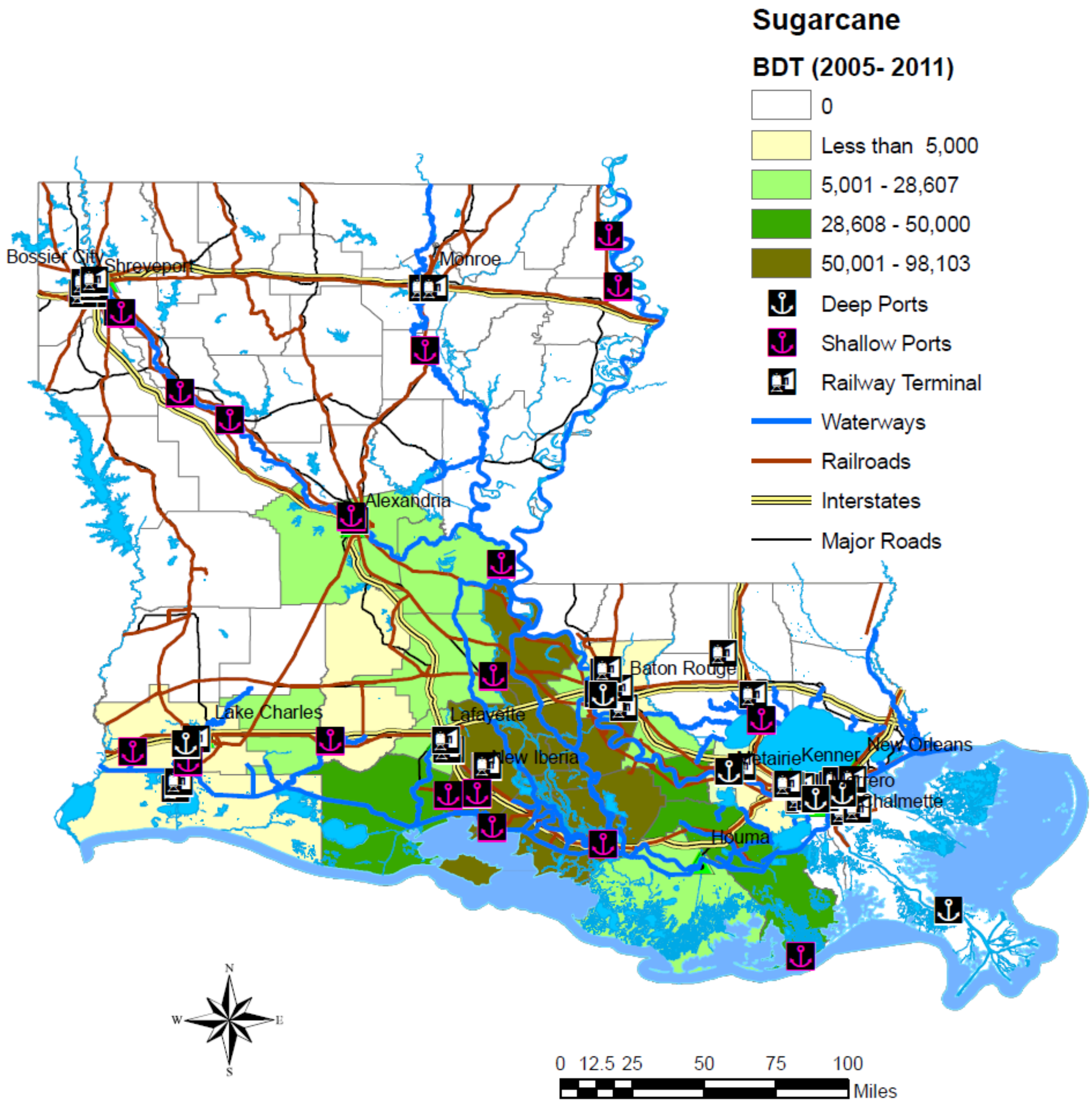

Figure 20. Transportation options for sugarcane residues being produced in Louisiana.

7.2.3. Corn

Corn was the most widely used ethanol feedstock in the U.S. The average corn production in the state for the past 6 years was 1,502,670 BDT. Corn plantations were primarily concentrated in the Northeastern tip of the state and gradually reduced as it went further south. Franklin, Morehouse, Madison, Richland, East Carroll and Tensas produced the highest amount

of corn (Fig. 21). There were again 41 parishes that produced corn. The average corn production per acre was 140 bu. and the average area was 508,911 acres. The main type of residues from corn cultivation was fodder, stalks, leaves, roots and husks.

When it came to residue transportation, corn had all the three options. In the road network, interstate I-20 was in this region. Coming to the railways, the intermodal terminal at Monroe was the closest. There were 2 shallow water ports in East Carroll and Madison parishes, which provided water transportation for the Corn Belt.

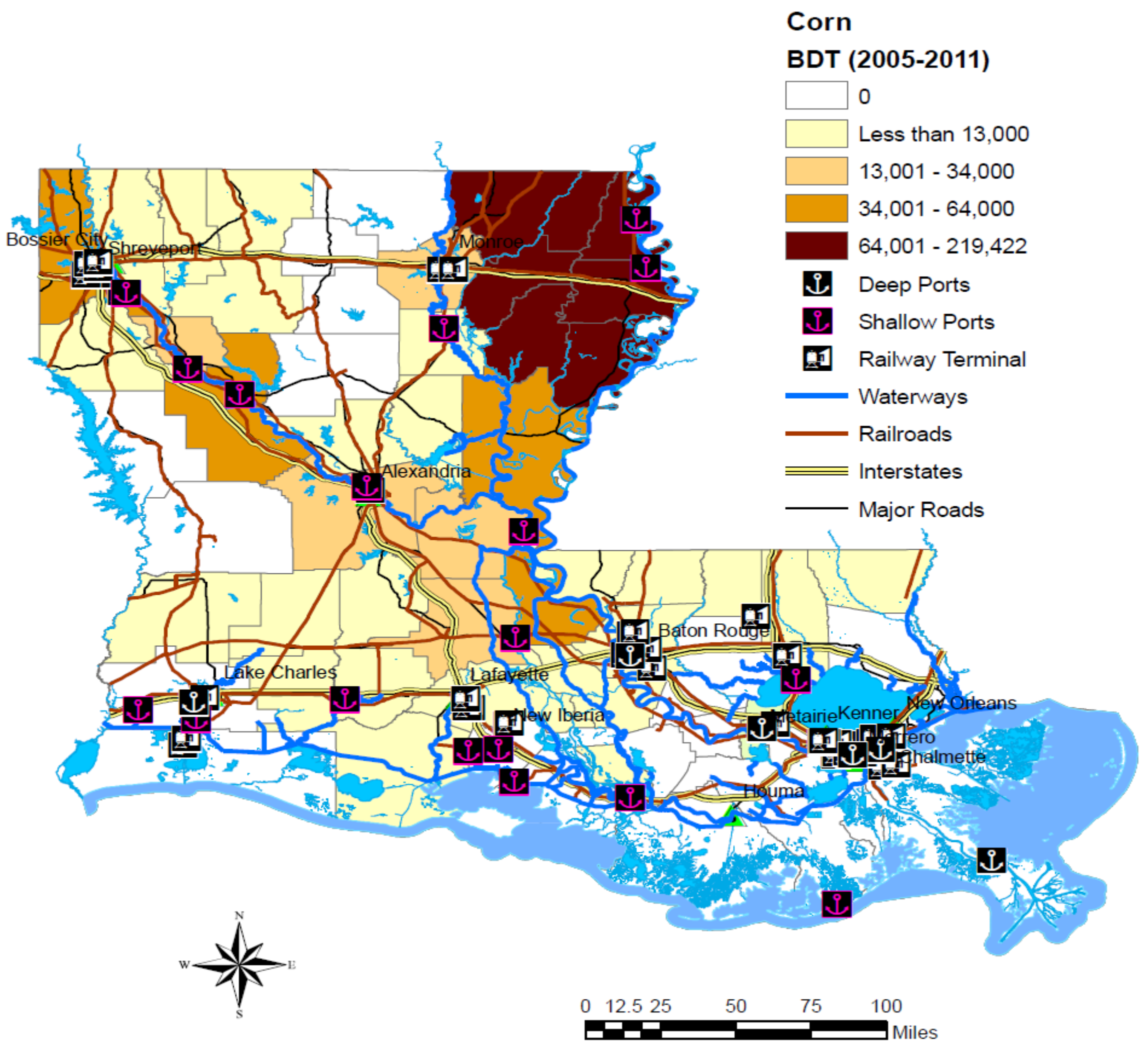

Figure 21. Transportation options for corn residues being produced in Louisiana.

7.2.4. Soybean

Soybean was the most widely cultivated crop in the state. Around 50 parishes out of the 64 parishes cultivated soybean. The total average residue from 2005-2011 was 1,656,814 BDT. It accounted approximately 25 percent of the agricultural residue considered for the study. Soybean cultivation in the state was found in the North eastern and central region of the state along the Mississippi. East Carroll, Pointe Coupee, St. Landry, Madison, Morehouse, Avoyelles and Concordia were the major producers of Soybean in the state (Fig. 22). The average soybean produced per acre was around 37 bu. and around 914,055acres was under soybean cultivation. Straw obtained from soybean was the major residue.

As far as the transportation was concerned, road and water transportation were most suitable for this crop. The interstate, I-49 and I-10 ran through the soybean belt. Monroe, Baton Rouge and Lafayette were the closest railway terminals. Furthermore, there were 4 shallow water ports in the region and the Baton Rouge deep-water port in close proximity to the highest soybean producing parishes.

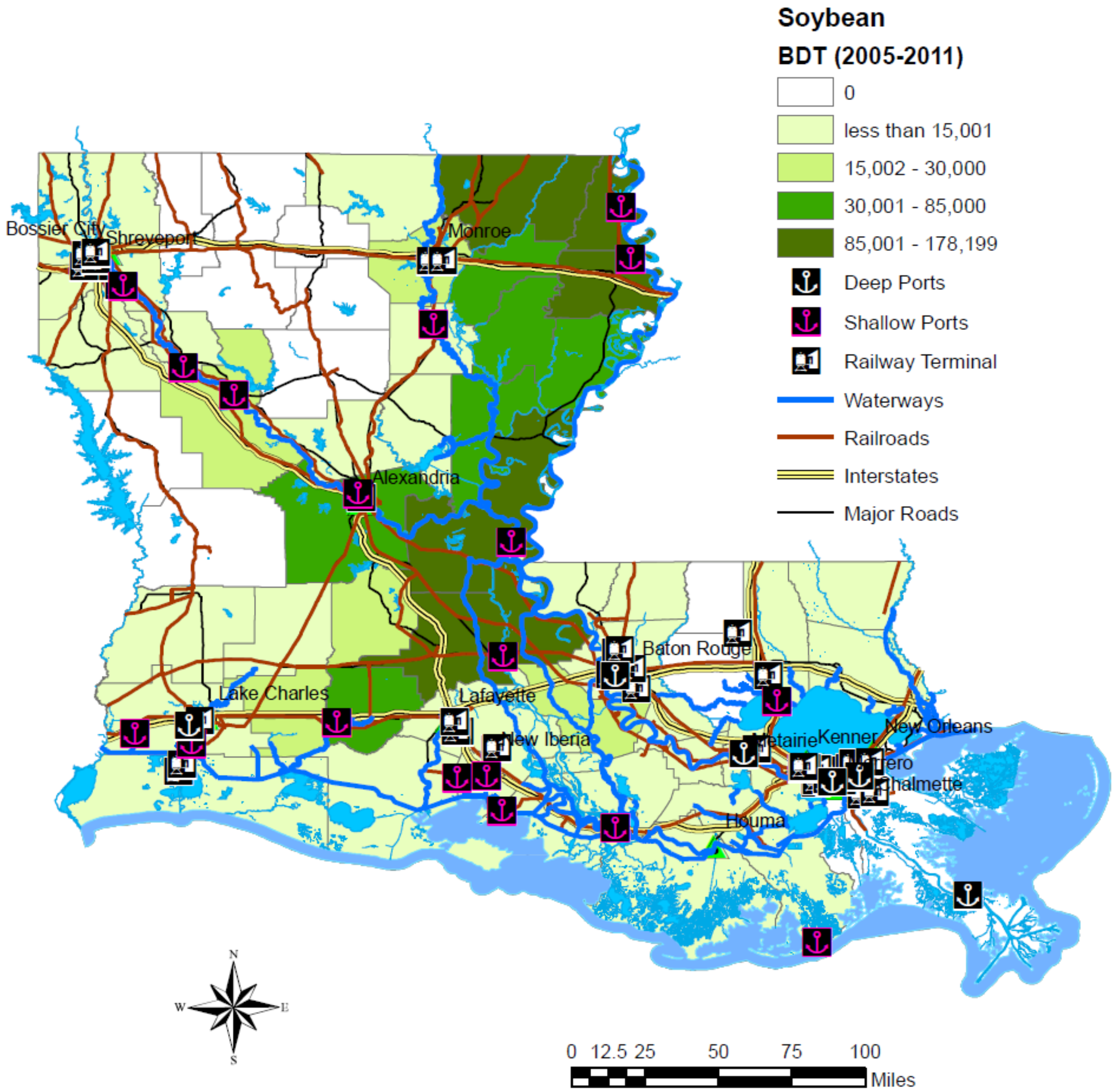

Figure 22. Transportation options for soybean residues being produced in Louisiana

7.2.5. Wheat

The total wheat residue production for the state was 337,025 BDT. Pointe Coupee, Franklin, Richland, West Carroll and Morehouse were the major producers. The state featured on an average 189,381 acres of wheat fields and produced around 58bu. per acre. There were 37 parishes in which wheat was cultivated. Similar to soybean, wheat production was also concentrated in the North eastern parishes and the central region of the state. Hence the

transportation option for the crop was comparable to that of Soybeans, with I-20, I-49 and I-10 running through the wheat belt and Monroe, Baton Rouge and Lafayette as the closest railway intermodal terminals. The water transportation was also similar with 5 shallow water ports in the region and the Baton Rouge deep water port in close proximity. In wheat, straw was the major form of residue.

7.2.6. Cotton

Cotton was a major crop being produced in Louisiana. On an average, for the last 6 years (2005-2011), there was 564,332 BDT of cotton residue being produced. All the cotton growing regions in the state were in close proximity to river systems. The States' highest cotton growing regions were in the northeastern parts with Tensas, Madison, Catahoula, Franklin, Concordia and Morehouse having the maximum production in the state (Fig. 23). 371,520acres of land was dedicated for cotton. The main residues for cotton were gin trash, seed and lint.

Coming to transportation, the highest cotton producing regions had little access to rails with only one railway intermodal terminal in Monroe. All the 4 northeastern ports could be utilized for water transportation. Again, the I-20 was the only interstate passing through the region.

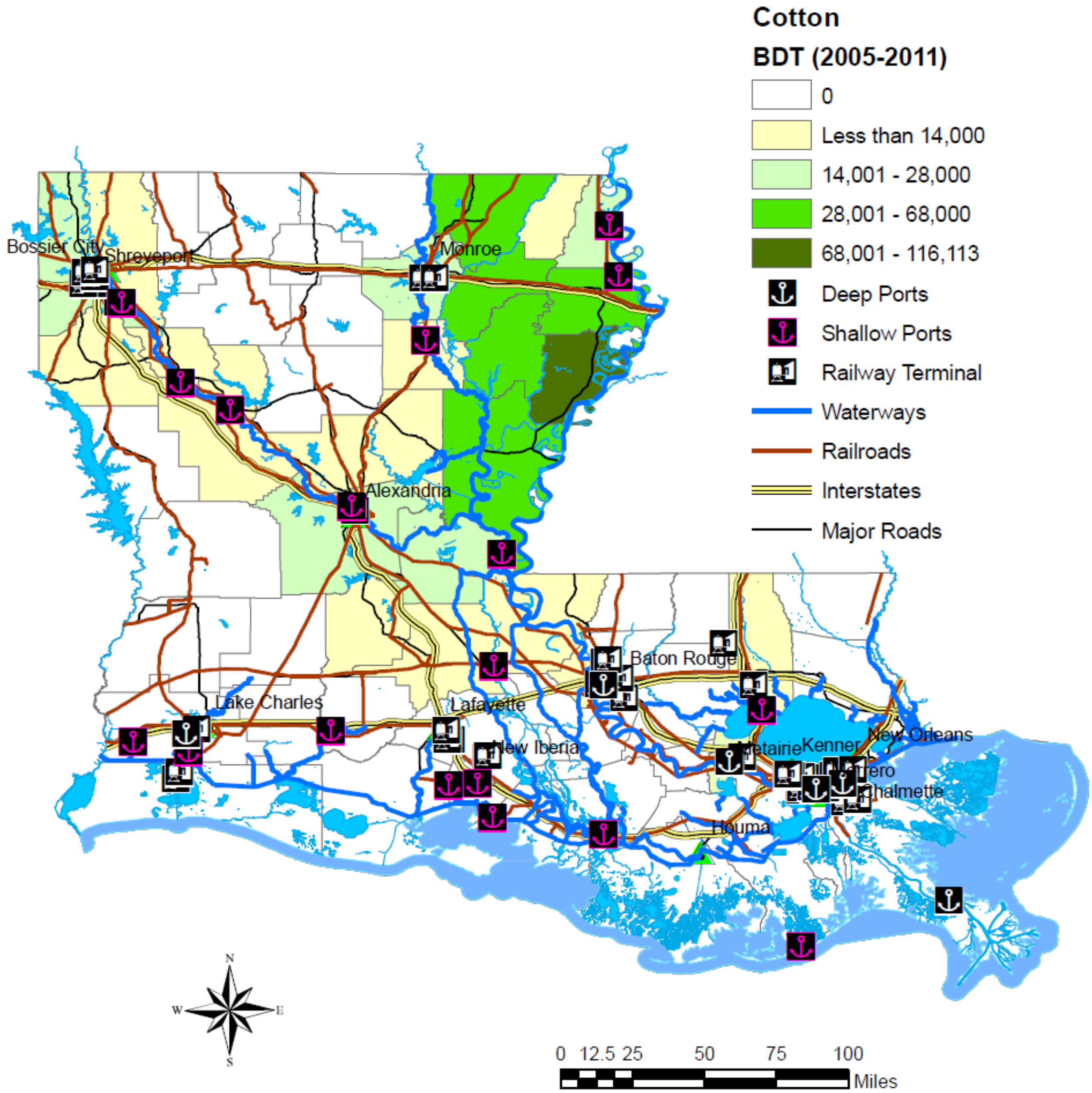

Figure 23. Transportation options for cotton residues being produced in Louisiana

7.2.7. Grain sorghum

The total average grain sorghum residue produced was around 446,398 BDT. Sorghum was grown in 32 parishes, which were around the central region of the state, with Avoyelles, Catahoula, Concordia, St. Landry, Pointe Coupee and Rapides being the major producers. On an average 116,413 acres of sorghum was cultivated and the average yield per acre was 63 cwt.

As far as water transportation was concerned, the sorghum growing belt could utilize the port in Alexandria, Avoyelles and St. Landry. For deep water ports Baton Rouge was the closest one. The nearest railway terminals were in Alexandria, Lafayette and Baton Rouge. I-49 and I-10 were the interstates running through the region.

7.2.8. Oats

The chief residue from oats production was oats straw. They were primary used for bedding and ethanol production. The average total residue production was 6830 BDT. Around 23 parishes produced oats in 5,294 acres of land, in which, Concordia, West Carroll, Franklin, Richland and Pointe Coupee were the major producers.

7.2.9. Peanut

The chief residues for peanut were hulls, vines, nuts. Morehouse and Richland were the only 2 parishes which produced peanuts and the average residue produced was 309 BDT. Very little is known about their potential for energy production. But around 2.5 T of vines are produced per acre.

7.2.10. Potato

Around 5828 BDT of residues were produced in potato. Potato was grown in 25 parishes, which were, with Livingston, West Feliciana, Pointe Coupee and Caddo being the major producers. On an average 199 acres of potato was cultivated and the average yield per acre was 186 cwt.

7.3. Reference

LSU AgCenter. 2012**.** 2011 Parish Totals. Available online at http://www.lsuagcenter.com/mcms/webtools/viewExternal.aspx?url=http://www.lsuagcenter.com/agsummary/index.aspx ; last assessed on 12/2/2011.

CHAPTER 8: DISCUSSION

Rapid increment in volume and types of agricultural residues, due to current intensive agriculture in the wake of population growth and improved living standard has resulted in a severe crisis as these degenerating agricultural residues emits methane and leachate. In addition to these, open burning by the farmers in the developing world to clear the lands generates CO_2 and other local pollutants. Consequently, improper management of agricultural residue has been contributing towards climate change, water and soil contamination, and local air pollution. However, this waste has a value of energy content which could be extracted economically.

Globally, around 140 billion metric tons of biomass is generated annually from agriculture. This volume of biomass can be converted to approximately 50 billion tons of oil, and agricultural biomass waste converted to energy can substantially displace fossil fuel, reduce emissions of greenhouse gases and provide renewable energy to some 1.6 billion people in developing countries. As raw materials, biomass wastes have attractive potentials for large-scale industries and community-level enterprises (UNEP 2009).

In Louisiana there are several sources of residues of major crops that could be used to produce ethanol and electricity. For instance, rice hulls have been used in southwest Louisiana to produce electricity, and sugarcane bagasse is used by sugar factories as burning fuel (LSU AgCenter 2012). In general, biomass energy has the potential to provide a significant portion of nation's energy needs, while revitalizing rural economies, increasing energy independence, and reducing pollution. Besides this, farmers would gain a new valuable income for their products. Furthermore, rural communities could become entirely self-sufficient when it comes to energy, using locally grown crops and residues to fuel cars and tractors and to heat and power homes and buildings. Biomass currently provides about two percent of nation's electricity, one percent of the fuel used in cars and trucks, and some of the heat and steam used by homes and businesses.

With more energy crops and better conversion technology, it could gain a much larger portion of the market. The eight leading U.S. crops produce more than 500 million tons of residues each year (Nelson 2002). Some amount of this residue may be available for harvest and use as feedstock for biomass energy (Andrews 2006).

A key determinant for biomass supply is an infrastructure that ensures economically viable feedstock logistics and handling from farm to plant. Other determining factors include regional demand, local resources (water), and enabling infrastructure (e.g., storage facilities, roads, rails, and barges for transporting the feedstocks).

Looking into the total agricultural residue production in Louisiana, the cultivation was concentrated near the banks of the major river system. It was also noted that most of the fertile lands in the banks of Mississippi was utilized for agricultural cultivation, whereas, the prominent timber producing parishes had no major rivers running through them. Interestingly the highest logging residue producing parishes such as Union, Sabine, Vernon, Bienville, Jackson, Winn etc., had almost no agriculture residue (except for Beauregard). Moreover, most of the crops were not evenly distributed. Each crop had its own region within the state. For instance, the sugar cane production was concentrated towards the southern region in the state.

One of the fundamental challenges to enhance production and distribution of agricultural residue is managing the increased demands on the feedstock transportation and storage infrastructure, and developing more efficient modes of distribution for biofuels. If logistical improvements make biomass feedstocks cost effective to deliver and store, this would eventually lead to increased availability of feedstocks and lower prices. This is particularly relevant for feedstocks of nascent biomass such as agricultural residues, which have not yet established a harvest, transportation, and storage infrastructure for biofuels use. If these issues are resolved,

improved marketability would allow feedstock producers to achieve higher returns (BDRB 2008).

In general all the major modes of transportation could be used for agricultural residue transportation. Unlike the major logging residue producing parishes, all the major agricultural parishes were in close proximity to ports in the state. This opened them to the waterway system, which could play a major role, since it was the cheapest mode of transportation (Fig. 24). The interstates like I-20, I-10 and I-49 also connected the various agricultural producing parishes. The railway intermodal terminals in Monroe and Alexandria could also supplement for state wide and intra state distribution. In fact, farm products (20.9 percent) was one of the nine commodity types that dominated tonnage terminating by rail in Louisiana and originating by rail outside the state. In the aggregate (all movement types), farm products (grains including wheat, corn, and soybeans) constitute 8 percent of Louisiana's rail traffic.

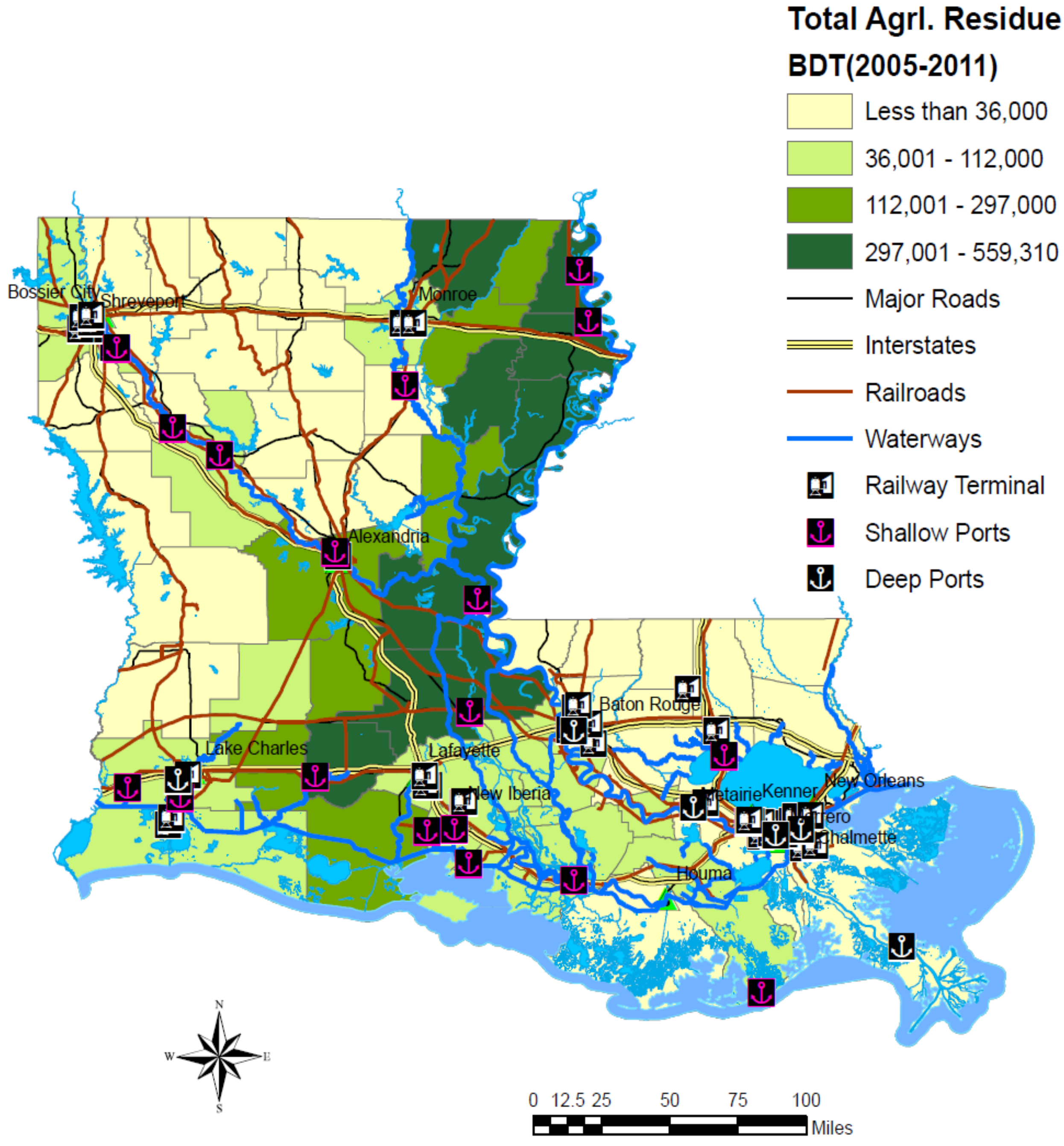

Figure 24. Transportation options for agricultural residues in Louisiana.

Agricultural biomass can be converted in to products with desired features depending on the material (Table 7).

Table 7. Cellulosic waste biomass conversion to energy (UNEP 2009)

Technology	Conversion Process Type	Biomass Waste	Energy or Fuel Produced
Biodiesel Production	Chemical	Soy Beans and Waste Vegetable Oil	Biodiesel
Direct Combustion	Thermochemical	Agricultural Waste and Mixed Waste	Heat, Steam and Electricity
Ethanol Production	Biochemical (aerobic)	Rice And Corn Straw, Sugar or Starch Crops	Ethanol
Gasification	Thermochemical	Agricultural Waste Mixed Waste	Low Or Medium-Btu Producer Gas
Methanol Production	Thermochemical	Agricultural Waste Mixed Waste	Methanol
Pyrolysis	Thermochemical	Agricultural Waste Municipal Solid Waste	Synthetic Fuel Oil (Biocrude) Charcoal

8.1. Crop residue production

8.1.1. Rice

Coming to rice, roughly 1.08 kg residue was produced per kg of the commodity and around 85 percent of the residues produced were collectable. Again around 80 gal of ethanol was produced per ton of rice. However this was the most expensive fuel alcohol feedstock among the major crops grown in Louisiana. Hence it was not utilized as the primary source of ethanol produced in the state.

Rice residues had a number of uses. Hulls were used for purposes which included: burning for energy – steam production, fuel, mill feed, compost, livestock feed, fine abrasive for certain polishing operations, for production of hand soap and furfural, product used in making synthetic rubber, rayon and many other synthetic materials, conditioners for commercial fertilizers (CES 1983).

The bran was primarily used to feed livestock, where as the straw were regarded as energy resource in burning, production of methanol and ethanol and was also grazed by crawfish.

The straws again found use in livestock bedding and feed, usually left in the field, plowed into field for nutrients.

8.1.2. Sugarcane

Crops high in sugar content (like sugarcane and sugarbeets) are easier to process into ethanol than starch crops since the sugar required by fermentation is already present. Fermenting and distilling ethanol from these crops was not much different than rum or brandy production. Even though ethanol production was not competitive with sugar production at current prices (due to human consumption), production of ethanol from industrial-use sugarcane is being pursued in Louisiana, Hawaii, and Florida (Christiansen 2008 and BDRB 2008). One ton of sugarcane produced about 19.3 gallons of ethanol, a greater ethanol output per acre than for corn. Yet in 2007, around 880,000 acres of U.S. sugarcane were only cultivated (USDA/NASS, 2008), which was less than 1 percent of total acres devoted to corn.

Coming to residue, the major one was bagasse. It was used for making compost, ceiling tiles, paper fuel. Approximately 75 percent of bagasse generated was used for fuel. About 130-140 Kg dry weight of bagasse was obtained from 1 Metric Ton (MT) of fresh stalks. Again 1 MT of bagasse had the same Btu content as 0.23 T of bituminous coal, 0.18 T of fuel oil, 0.15 T natural gas. The major barriers for associated with the bagasse utilization were its high moisture content (about 50 percent) and subsequently low density which resulted in high transportation cost.

The other forms of sugarcane residues were cane, molasses and field residue. These were either, burned: steam, or used for production of ethanol, methane or left in the field to decompose for soil erosion protection (CES 1983). Molasses from sugarcane had been the predominant feedstock in Louisiana for fuel alcohol. Furthermore the green leaves for sugarcane contain nutrients and could be used as a feed for livestock, but there were problems with the

collection, so in most cases it was left in the field. But in reality the actual amounts of field residues produced were very small.

8.1.3. Corn

Corn (*Zea mays* L.) (and to a lesser extent, wheat) is receiving the most attention due to its concentrated production area and because it produces 1.7 times more residue (or stover) than other leading cereals, based on current production levels (Wilhelm *et al.* 2004), sufficient quantity to support commercial scale production (DiPardo 2000 and Andrews 2006).

The main type of residues from corn cultivation were fodder, stalks, leaves, roots and husks. The uses of corn residues varied from soil erosion protection and as fertilizer when left in the field to ethanol production (CES 1983). About 60 lb of residue is produced from 1 Bu (TVA Biomass Fuels Program 1982). Again, with the proximity of the ports, it is difficult to compete with the export prices, hence, approximately 95percent of the corn produced in Louisiana was being exported.

8.1.4. Soybean

Straw obtained from soybean was the major residues. About 1.75 kg residue was produced per kg of commodity, which was around 85 lb of residue /Bu (TVA Biomass Fuels Program 1982). Again 80 percent of the residues were collectable. However most of the residues were left in the field for erosion protection. Some were used for bedding and the rest were burned for fuel. But in general the fuels had low energy value (CES 1983).

8.1.5. Cotton

The main residues for cotton were gin trash, seed and lint. The cotton residues had greatest value when it is brought back to the field for protecting the soil; It was also used for compost, fertilizer, steam, methane, ethanol production. But some of the barriers concerned with the use of the residues were related to space and labor, and the fact that it does not burn well,

since it contained too much dirt which creates a risk of pollution. Furthermore the heating value of the residues were not very high.

Again around 60-65 Mt of residues were produced for every 100 MT of cotton lint (CES 1983). Cotton residues were considered as one of the most compostable natural material.

8.1.6. Grain sorghum

The residue from the grain sorghum were usually returned to the soil or grazed by cattle. The grain was potential for energy production in Louisiana too, as this could be used as feedstock for alcohol production. But only 0.9 percent of the residue being produced was. Around 60 lb of residue was produced per Bu and the residue yield was approximately 0.57 T/ac.; 1.27 MT/ha. Again around 1.57 kg of residue was produced per kg of commodity (CES 1983).

Eight U.S. ethanol plants used grain sorghum (milo) as a feedstock (RFA 2008). Grain sorghum was grown primarily in the Central Plains (Kansas, Nebraska, Missouri) and Southern Plains (Texas, Oklahoma, Arkansas). Approximately 15 percent of U.S. grain sorghum is being used for ethanol (NSP 2008). Grain sorghum produces roughly the same amount of ethanol per bushel as corn, but the sorghum yield (bushels per acre) is lower than for corn (BDRB 2008).

8.1.7. Potato

For other crops like vegetables, the number of home gardens in any given year fluctuates greatly with people’s interest and the economy. When economic conditions were weak, the number of households using home gardens increased. Vegetable gardening extended the family food budget by freeing up limited funds for other food purchases. A survey of Louisiana home gardeners in 2008 showed the average age of gardeners was 62 years old with a median age of 67 years. The median Louisiana garden size was 800 square feet and calculations indicated each garden generated produce valued at an average of $512. This value was used to calculate the

gross farm value of home gardens in Louisiana. The 2011 gross farm value of home vegetable gardens in Louisiana was estimated to be $246.2 million (LSU AgCenter 2011).

In addition to major residue producing crops like corn and soybean, other crops such as rice and sugarcane, which face residue disposal issues, might also contribute biomass for fuel in the future (DiPardo 2000, and Wilhelm *et al.* 2004). Crop residues can be found throughout the United States, but are primarily in the Midwest because of corn stover's preeminence. Despite all these, crop residues were also generally regarded in enhancing and protecting soil quality. Some common properties of crop residues left on the soil surface on soil functions include (Andrews 2006):

- Protection from erosive forces
- Increased or maintained soil organic matter
- Additions to the available pool of soil nutrients
- Increased biological activity and improved soil structure
- Improved crop yields (Hargrove, 1991)

Hence while harvesting the residue several criteria should be kept in mind. Some of the recommendations are (Wortmann et.al. 2008 and Andrews 2006):

- Residue Removal Rates: Sustainable crop residue removal has to be considered when harvesting the residues. The rates for biofuel production usually vary by factors such as management, yield, and soil type.
- Availability of manure to replace carbon and nutrients removed with crop residue with special emphasis on the value of nutrients removed in crop residue and impact on fertilizer and lime requirement.

- Removal rates vary with soil cover: appropriate conversion is necessary and will vary by crop and region. While areas with low slopes and high yields may support residue harvest, in many areas the residue amounts required for maintaining soil quality will be higher than current soil cover practices. Again certain amount of crop residue is required to maintain soil organic matter
- Impact on wind and water erosion, runoff, and residue cover needed to comply with conservation programs and the need for using cover crops to provide ground cover and control erosion and runoff plus provide additional carbon to the soil system
- Additional Conservation Practices: Conservation practices such as contour cropping or conservation tillage must be used to compensate for the loss of erosion protection seen with residue removal. In many regions, cover crops are another viable alternative.
- Periodic Monitoring and Assessment: Regardless of the residue removal practice chosen, fields should be carefully monitored for visual signs of erosion or crusting
- Availability of equipment to effectively harvest residue

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CHAPTER 9: CONCLUSION

A study was done to determine the total production for the logging residue and major agricultural residue in the state of Louisiana. The average total production for logging residue in the state from 2000 to 2010 was estimated around 3,073,978 Bone dry tons (BDT) and for agricultural crop residue it was approximately 6,773,985 BDT (2005- 2011). While the western and northern parishes such as Winn, Vernon, Bienville, Union, Beauregard and Sabine topped the logging residue production, for the agricultural residue the north-eastern, and central parishes like Morehouse, Madison, Franklin, East Carroll and Pointe Coupee were the major producers. Although pine contributed to around 60 percent of timber harvested in the state, but when it came to logging residues the hardwood species had the major share.

Subsequently, for the tree distribution in the state, the North eastern parishes had a good density of pine trees whereas the western region was dominated by hardwood species. Looking into the production during the period from 2000 to 2010, there was an overall decrease in the timber harvest. However, there was a slight increase in 2003 and 2006.

For agriculture, the 9 major crops cultivated in the state (production basis) were rice, sugar cane, cotton, oats, soybean, sorghum, wheat, potato and peanut. Soybean, rice, corn and sugarcane constituted majority of the production. Similar to the timber production, most of the crops were not evenly distributed. Each crop had its own unique region within the state. Furthermore, the cultivation was concentrated near the banks of major river system. It was also noted that most of the fertile lands in the banks of Mississippi were utilized for agricultural cultivation, whereas, the prominent timber producing parishes had no major rivers running through them. Interestingly the highest logging residue producing parishes such as Union, Sabine, Vernon, Bienville, Jackson, Winn etc., had almost no agriculture residue (except for Beauregard).

In general transportation was regarded as a critical factor which determined the economic feasibility of any biomass energy programs. In the state among the three primary mode of transportation, the roads, rail and waterways system, the road system was the most effective form of transportation for logging residue and the timber industry in general. Since, most of the logging residue producing belts in the state had little access to rail and waterway system, these option were not widely utilized. However, the Red River was the principal waterway which ran through the high timber producing belt in the state. The waterway system could be utilized for international and long distance freights.

Unlike the major logging residue producing parishes, all the major agricultural parishes were in close proximity to ports in the state. This opened them to the waterway system, which could play a major role, since it was the cheapest mode of transportation. The interstates highways like I-20, I-10 and I-49 also connected the various agricultural producing parishes. The railway intermodal terminals in Monroe and Alexandria could also supplement for state wide and intra state distribution.

As new markets are being opened for biomass in Europe, more sophisticated logistic supply chains are coming into place, which employ different combinations of transportation modes. These would not only serve long distance freight but also reduce cost for the entire operation. Furthermore, these permutations of freight, which employ more than one mode of freight have also been proved to be environmentally friendly and can be employed for long distance shipment.

GLOSSARY

Biomass: An energy resource derived from organic matter, including the by-products from the timber industry, agricultural crops, raw material from the forest, major parts of household waste and wood.

Board foot: Unit of measure applied to roundwood. It relates to lumber that is 1-foot long, 1-foot wide, and 1-inch thick (or its equivalent).

Bone Dry Ton (BDT): Wood pulp or residue that weighs 2,000 lb (907 kg) at 0 percent moisture content.

British Thermal Unit (BTU): The amount of heat energy needed to raise the temperature of one pound of water by one degree Fahrenheit.

Commercial species: Tree species currently or potentially suitable for industrial wood products.

Dedicated energy crops: Include short rotation woody crops, such as hybrid poplar, hybrid willow, and herbaceous crops such as switchgrass, grown specifically for use as an energy source.

Ethanol: An alcohol fuel made from the sugars found in grains, such as corn, sorghum, and wheat, as well as potato skins, rice, sugar cane, sugar beets, and yard clippings.

Feedstock: A raw material that can be converted to one or more useful products.

Fiber products: Byproducts used in the manufacture of pulp, paper, paperboard, and composite products, such as waferboard or chipboard.

Fuelwood production: The volume of roundwood harvested to produce some form of energy, e.g., heat, steam, in residential, industrial, or institutional settings.

Gasification: Biomass gasification is conversion of solid biomass (wood, agriculture residues etc.) in to a combustible gas mixture normally called “producer gas” (or low Btu gas).

Growing-stock removals: The growing-stock volume removed from poletimber and sawtimber trees in the timberland inventory. (Note: Includes volume removed for roundwood products, logging residues, and other removals.)

Hardwoods: Dicotyledonous trees, usually broadleaf and deciduous.

Log: A primary forest product harvested in long, primarily 8-, 12-, and 16-foot lengths.

Logging residues: The unused merchantable portion of growing-stock trees cut or destroyed during logging operations.

Merchantable volume: Solid-wood volume in the merchantable portion of live trees.

Metric Ton: a unit of weight, equal to 1000 kilograms (2204.623 pounds or 1.1023 short *ton* or 0.9842 *long* ton)

Noncommercial species: Tree species of typically small size, poor form, or inferior quality that normally do not develop into trees suitable for industrial wood products.

Other removals: The growing-stock volume of trees removed from the inventory by cultural operations such as timber stand improvement, land clearing, and other changes in land use, resulting in the removal of the trees from timberland.

Production: The total volume of roundwood harvested from land within a State, regardless of where it is consumed. Production is the sum of timber harvested and used within a State, and all roundwood exported to other States.

Pulpwood: A roundwood product that will be reduced to individual wood fibers by chemical or mechanical means. The fibers are used to make a broad generic group of pulp products that includes paper products, as well as chipboard, fiberboard, insulating board, and paperboard.

Roundwood chipped: Any timber cut primarily for industrial manufacture, delivered to non pulpmills, chipped, and then sold to pulpmills for use as fiber. Includes tops, jump sections, whole trees, and pulpwood sticks.

Roundwood products: Any primary product, such as lumber, poles, pilings, pulp, or fuelwood that is produced from roundwood.

Saw log: A roundwood product, usually 8 feet in length or longer, processed into a variety of sawn products such as lumber, cants, pallets, railroad ties, and timbers

Sawtimber volume: Growing-stock volume in the saw-log portion of sawtimber-sized trees in board feet (International ¼-inch rule).

Softwoods: Coniferous trees, usually evergreen, having leaves that are needles or scale-like.

Standard cord: A unit of measure applied to roundwood, usually bolts or split wood. It is a stack of wood 4 feet high, 4 feet wide, and 8 feet long encompassing 128 cubic feet of wood, bark, and air space. This usually translates to approximately 75.0 to 81.0 cubic feet of solid wood for pulpwood, because pulpwood is more uniform.

Standard unit: A unit measure applied to roundwood timber products. Board feet (International ¼ rule) is the standard unit used for saw logs and veneer; cords are used for pulpwood, composite panel, and fuelwood; hundred pieces for poles; thousand pieces for posts; and thousand cubic feet for all other miscellaneous forest products

Stumpage revenue: Timber in standing trees; the price charged by a land owner to companies or operators for the right to harvest timber on that land

Timber removals: The total volume of trees removed from the timberland inventory by harvesting, cultural operations such as stand improvement, land clearing, or changes in land use. (Note: Includes roundwood products, logging residues, and other removals.)

APPENDIX A - PARISH WISE LOGGING RESIDUE PRODUCTION

Average total logging residue production (BDT) in Louisiana (2000-2010)

PARISH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Acadia	23594	11544	29948	12472	7456	4781	10223	11544	5150	5278	2656	11331
Allen	152846	101588	116222	142282	129604	116993	108074	101588	93475	77294	102936	112991
Ascension	14096	6130	4799	14197	17986	6582	21622	6130	5192	7788	5060	9962
Assumption	152	1186	4298	1452	1080	421	1920	1186	1525	1909	4604	1794
Avoyelles	11054	52358	32613	53351	34689	58448	29378	52358	30580	52114	32533	39952
Beauregard	142632	129517	140088	143643	117561	125691	168391	129517	130373	106521	132613	133322
Bienville	126782	138653	133641	168400	164883	170344	163556	138653	124270	112370	123287	142258
Bossier	126962	63098	68065	88069	75459	99222	77236	63098	52017	49269	68469	75542
Caddo	78048	50990	69691	63544	53490	62620	48114	50990	57177	45669	40921	56478
Calcasieu	50500	16807	23567	32953	34131	46804	59820	16807	29182	15290	19463	31393
Caldwell	84216	103038	67755	62448	53533	66658	67479	103038	63487	89367	69376	75490
Cameron	65	477	3703	11429	12020	23080	269	477	89	187	0	4709
Catahoula	32853	60556	23233	34686	40756	35753	23781	60556	21159	42206	12254	35254
Claiborne	94801	100077	130079	145685	113204	132824	102283	100077	103313	87759	106820	110629
Concordia	25118	27910	38594	56987	46655	39767	31632	27910	18581	17729	12973	31260
De Soto	136867	111972	98384	100641	100080	112831	108261	111972	95857	98579	104594	107276
East Baton Rouge	22119	37808	27195	32031	29390	36872	28845	37808	23450	28314	14322	28923
East Carroll	19823	20679	16601	31828	14570	10526	10527	20679	4469	15025	1746	15134
East Feliciana	53960	58017	40811	82947	55244	49533	38282	58017	66165	50943	47346	54660
Evangeline	78444	36940	48093	43129	55819	42899	50591	36940	60509	44099	52196	49969
Franklin	22895	17754	8482	13135	8283	18716	14192	17754	5853	10724	12968	13705
Grant	40715	42784	29104	43808	56175	48352	59308	42784	63507	38359	49204	46736
Iberia	1637	6769	241	1139	1419	1393	526	6769	101	6032	0	2366
Iberville	117117	34094	23713	50909	37824	58394	40120	34094	12327	39249	19551	42490
Jackson	112872	91252	98849	156750	151765	141052	160110	91252	118803	85036	74303	116549
Jefferson	919	2019	714	7197	10418	12732	12882	2019	396	850	101	4568
Jefferson Davis	14948	4387	5309	9481	6354	7566	5263	4387	6464	2625	7469	6750
Lafayette	5199	650	386	2679	1084	2248	1424	650	356	577	252	1410

Table continued

PARISH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Lafourche	1315	1422	1936	255	723	2928	3585	1422	9151	1555	8076	2943
La Salle	107392	91404	80038	68195	79901	81380	81717	91404	66282	81476	83038	82930
Lincoln	61104	60537	69677	63481	92953	76519	80216	60537	67134	53078	58902	67649
Livingston	116199	92515	68019	110450	58697	48059	83636	92515	65526	94278	51514	80128
Madison	54493	53014	44805	28455	9598	13660	31397	53014	43595	39001	29480	36410
Morehouse	41476	42298	49216	54944	45657	48533	53225	42298	53264	33412	26840	44651
Natchitoches	110019	86584	111459	102281	103190	113289	128941	86584	116562	74161	91211	102207
Orleans	0	1481	497	301	1968	3612	2332	1481	550	1455	1090	1342
Ouachita	63418	41844	48121	50571	46270	68263	63730	41844	28023	39729	45095	48810
Plaquemines	180	186	1274	141	250	166	126	186	326	14	18	261
Pointe Coupee	27308	50266	60372	69173	47234	63596	37847	50266	29642	52553	29205	47042
Rapides	104733	99567	72719	89952	84277	79072	85539	99567	78501	80946	104259	89012
Red River	18346	16326	37772	34857	28860	40317	44935	16326	37818	15979	32169	29428
Richland	24400	14042	17129	22590	12728	15792	10117	14042	7290	10694	9289	14374
Sabine	108828	116424	135709	142632	152489	147151	152658	116424	126294	107812	126302	130248
St. Bernard	14	371	2150	30	417	81	124	371	0	230	0	344
St. Charles	2276	253	997	7237	8357	7352	2617	253	297	151	27	2711
St. Helena	59783	67370	64400	49293	57214	29894	41802	67370	55660	68829	63185	56800
St. James	4012	7901	10815	4708	5513	6454	8703	7901	4719	7537	3631	6536
St. John the Baptist	18	278	32	965	2242	802	142	278	32	269	5889	995
St. Landry	26675	54042	54309	42804	30938	41829	39016	54042	59527	58978	84462	49693
St. Martin	2710	6923	1253	7648	6573	13545	29182	6923	17814	9070	13457	10464
St. Mary	1576	12	106	41	1911	9	671	12	143	61	256	436
St. Tammany	37139	20534	17227	39949	35709	40441	79492	20534	33653	15772	11388	31985
Tangipahoa	63947	56488	54057	61771	51668	51061	86278	56488	41148	43184	36828	54811
Tensas	26653	56732	15431	37743	23026	36566	39177	56732	18876	47657	38142	36067
Terrebonne	62	370	263	1295	1312	6226	1475	370	3439	444	1560	1529
Union	151554	165572	141943	144229	128253	146553	149236	165572	117233	136803	112550	141772
Vermilion	2391	1246	159	1873	1371	9102	1200	1246	743	218	9801	2668

Table continued

PARISH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Washington	76958	70127	89837	86562	72542	54454	146545	70127	30358	66263	37770	72868
West Baton Rouge	12280	10916	9698	8599	8123	31807	29338	10916	22695	9755	7636	14706
West Carroll	9836	9593	16250	12093	11110	11202	6663	9593	4504	8450	2417	9246
West Feliciana	53663	46055	39459	45321	46303	41377	35803	46055	49231	40875	24258	42582
Winn	114850	143793	129052	167544	187782	175712	222615	143793	195476	130685	131146	158404
Total	3335445	3060489	2988921	3456919	3088433	3262881	3459393	3060489	2800849	2665385	2634553	3073978

Pine logging residue production (BDT) in Louisiana (2000-2010)

PARISH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Acadia	12743	2403	6559	2967	2666	2639	4591	2403	3637	1918	1226	3977
Allen	82670	65125	67688	79094	75455	68028	56823	65125	62370	50094	67920	67308
Ascension	2074	288	250	298	6177	1107	2218	288	363	178	836	1280
Assumption	0	0	0	0	0	80	0	0	0	0	0	7
Avoyelles	1650	1476	4273	4369	2026	11704	2607	1476	1418	2327	1659	3180
Beauregard	97729	95021	94017	105754	92557	91437	120711	95021	104805	72544	101613	97383
Bienville	68675	81418	79661	96761	101279	95101	96866	81418	75921	58116	81611	83348
Bossier	38617	20517	24056	33715	30967	47633	31354	20517	26705	14407	35451	29449
Caddo	28741	18769	25820	19612	19082	27453	21280	18769	23129	15281	19478	21583
Calcasieu	28347	11551	17067	26431	27898	32104	45536	11551	25760	10648	13799	22790
Caldwell	39394	43720	29806	31261	31590	34913	36724	43720	36906	42388	44632	37732
Cameron	0	0	0	0	0	1760	0	0	0	0	0	160
Catahoula	19303	25685	12211	17497	19301	16811	9951	25685	8993	18331	7245	16456
Claiborne	42442	41423	51754	57917	53964	61871	41754	41423	44027	30172	44619	46488
Concordia	0	0	0	0	0	5834	0	0	0	0	0	530
De Soto	59415	42589	42896	50350	53607	60035	59309	42589	52514	33206	55212	50156
East Baton Rouge	2506	5695	2179	3104	2058	5804	2815	5695	3290	2820	1962	3448
East Carroll	0	0	0	0	0	1491	0	0	0	0	0	136
East Feliciana	17039	16274	13970	17711	18745	19558	14196	16274	23063	12465	14511	16710
Evangeline	29182	16059	22209	19838	22194	22841	27248	16059	35651	24012	26201	23772
Franklin	2779	2242	355	1548	129	4585	2056	2242	1251	2072	2706	1997
Grant	22790	24131	17689	23990	30550	30429	33151	24131	38802	19600	31970	27021
Iberia	0	0	0	0	0	38	0	0	0	0	0	3
Iberville	0	0	0	0	0	7885	0	0	0	0	0	717
Jackson	56416	53590	55174	92183	90814	84063	95275	53590	78138	48980	47623	68713
Jefferson	0	0	0	0	0	298	0	0	0	0	0	27
Jefferson Davis	6129	1261	1663	2925	2927	3920	3248	1261	4067	1270	3219	2899
Lafayette	0	0	0	0	0	253	0	0	0	0	0	23

Table continued

PARISH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
La Salle	64270	52957	53198	41293	44194	45656	54628	52957	42065	50749	60733	51155
Lincoln	21577	14927	24965	22372	43123	35602	31651	14927	23992	12841	25268	24659
Livingston	61361	56675	41866	66532	37454	22907	44604	56675	30670	58272	26254	45752
Madison	0	0	0	0	0	1640	0	0	0	0	0	149
Morehouse	13503	17269	25649	25303	25181	20796	23223	17269	21242	10137	13163	19339
Natchitoches	63300	48603	61727	61264	67615	71540	83224	48603	74022	37873	54778	61141
Orleans	0	0	0	0	0	420	0	0	0	0	0	38
Ouachita	22704	16772	16242	15225	19358	25806	24106	16772	13771	16425	22403	19053
Plaquemines	0	0	0	0	0	10	0	0	0	0	0	1
Pointe Coupee	0	0	0	0	0	7912	0	0	0	0	0	719
Rapides	56845	61153	48787	57638	52559	49774	55575	61153	58393	40945	67287	55464
Red River	8580	8537	20317	17415	16026	21897	23971	8537	22677	8008	16193	15651
Richland	145	109	632	387	845	2910	309	109	699	171	214	594
Sabine	76591	84782	95757	106795	111011	99266	108976	84782	88154	77301	86871	92753
St. Bernard	0	0	0	0	0	13	0	0	0	0	0	1
St. Charles	0	0	0	0	0	1324	0	0	0	0	0	120
St. Helena	33885	37746	37189	22585	34377	13354	21259	37746	30708	42846	40158	31987
St. James	0	0	0	0	0	1072	0	0	0	0	0	97
St. John the Baptist	0	0	0	0	0	109	0	0	0	0	0	10
St. Landry	216	528	136	154	143	4855	147	528	484	416	1443	823
St. Martin	0	0	0	0	0	1565	0	0	0	0	0	142
St. Mary	0	0	0	0	0	0	0	0	0	0	0	0
St. Tammany	24469	15538	13703	28560	21737	31790	51238	15538	30042	13721	10195	23321
Tangipahoa	38210	28254	27864	38346	27613	26489	38881	28254	24327	22633	16624	28863
Tensas	0	0	0	0	0	5444	0	0	0	0	0	495
Terrebonne	0	0	0	0	0	677	0	0	0	0	0	62
Union	74302	71699	69104	66592	65659	74659	78979	71699	62663	57248	64064	68788
Vermilion	0	0	0	0	0	1543	0	0	0	0	0	140
Vernon	103902	124691	118288	118811	97246	104669	104019	124691	112286	103596	135386	113417

Table continued

PARISH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Webster	44411	29008	34121	37575	28999	34740	35198	29008	27699	15969	23586	30938
West Baton Rouge	0	0	0	0	0	5254	0	0	0	0	0	478
West Carroll	0	0	0	0	0	1955	0	0	0	0	0	178
West Feliciana	5915	1728	2904	4953	2833	7466	3596	1728	5824	1340	4167	3859
Winn	55902	89155	74432	92984	118899	96889	141567	89155	131798	86744	89367	96990
Total	1479956	1382963	1396987	1575706	1548303	1590722	1723904	1382963	1468460	1170606	1392573	1464831

Hardwood logging residue production (BDT) in Louisiana (2000-2010)

PARISH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Acadia	10852	9141	23389	9505	4791	2142	5631	9141	1513	3360	1431	7354
Allen	70176	36463	48534	63188	54149	48965	51251	36463	31105	27199	35016	45683
Ascension	12022	5843	4549	13899	11809	5475	19404	5843	4829	7610	4224	8682
Assumption	152	1186	4298	1452	1080	341	1920	1186	1525	1909	4604	1787
Avoyelles	9404	50882	28340	48982	32662	46744	26772	50882	29163	49787	30874	36772
Beauregard	44903	34495	46071	37889	25004	34255	47680	34495	25567	33977	31000	35940
Bienville	58108	57235	53980	71639	63604	75242	66690	57235	48349	54254	41676	58910
Bossier	88344	42581	44009	54354	44492	51588	45882	42581	25312	34861	33018	46093
Caddo	49306	32222	43871	43932	34408	35167	26834	32222	34048	30389	21442	34895
Calcasieu	22153	5256	6500	6522	6234	14699	14284	5256	3423	4642	5664	8603
Caldwell	44821	59318	37949	31187	21943	31745	30755	59318	26581	46979	24744	37758
Cameron	65	477	3703	11429	12020	21320	269	477	89	187	0	4549
Catahoula	13550	34871	11022	17190	21455	18942	13830	34871	12166	23875	5009	18798
Claiborne	52359	58654	78325	87768	59240	70953	60529	58654	59287	57587	62201	64141
Concordia	25118	27910	38594	56987	46655	33933	31632	27910	18581	17729	12973	30729
De Soto	77452	69383	55488	50291	46472	52796	48952	69383	43343	65373	49383	57120
East Baton Rouge	19613	32113	25016	28927	27332	31069	26030	32113	20160	25494	12359	25475
East Carroll	19823	20679	16601	31828	14570	9035	10527	20679	4469	15025	1746	14998
East Feliciana	36921	41742	26841	65236	36499	29974	24086	41742	43101	38478	32835	37951
Evangeline	49262	20882	25883	23291	33625	20058	23343	20882	24858	20087	25995	26197
Franklin	20116	15512	8127	11586	8155	14131	12135	15512	4602	8652	10263	11708
Grant	17925	18653	11415	19818	25625	17923	26158	18653	24706	18759	17234	19715
Iberia	1637	6769	241	1139	1419	1355	526	6769	101	6032	0	2362
Iberville	117117	34094	23713	50909	37824	50509	40120	34094	12327	39249	19551	41773
Jackson	56457	37662	43676	64568	60950	56990	64835	37662	40665	36056	26680	47836
Jefferson	919	2019	714	7197	10418	12434	12882	2019	396	850	101	4541
Jefferson Davis	8819	3125	3646	6556	3427	3646	2014	3125	2396	1354	4250	3851
Lafayette	5199	650	386	2679	1084	1995	1424	650	356	577	252	1387

Table continued

PARISH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Lafourche	1315	1422	1936	255	723	2496	3585	1422	9151	1555	8076	2903
La Salle	43122	38447	26840	26902	35707	35723	27089	38447	24218	30726	22305	31775
Lincoln	39527	45610	44712	41108	49830	40917	48565	45610	43143	40236	33634	42990
Livingston	54838	35840	26153	43918	21244	25152	39032	35840	34856	36006	25260	34376
Madison	54493	53014	44805	28455	9598	12020	31397	53014	43595	39001	29480	36261
Morehouse	27973	25030	23567	29641	20476	27737	30003	25030	32022	23274	13678	25312
Natchitoches	46718	37981	49732	41017	35574	41749	45717	37981	42540	36289	36433	41066
Orleans	0	1481	497	301	1968	3192	2332	1481	550	1455	1090	1304
Ouachita	40714	25072	31879	35345	26911	42457	39624	25072	14253	23305	22692	29757
Plaquemines	180	186	1274	141	250	157	126	186	326	14	18	260
Pointe Coupee	27308	50266	60372	69173	47234	55684	37847	50266	29642	52553	29205	46323
Rapides	47888	38414	23931	32315	31718	29298	29964	38414	20108	40001	36972	33548
Red River	9766	7789	17455	17442	12834	18420	20964	7789	15141	7971	15976	13777
Richland	24255	13933	16497	22203	11883	12882	9808	13933	6590	10523	9074	13780
Sabine	32237	31642	39953	35837	41479	47884	43682	31642	38140	30512	39430	37494
St. Bernard	14	371	2150	30	417	67	124	371	0	230	0	343
St. Charles	2276	253	997	7237	8357	6028	2617	253	297	151	27	2590
St. Helena	25898	29624	27210	26708	22838	16540	20543	29624	24953	25983	23027	24814
St. James	4012	7901	10815	4708	5513	5382	8703	7901	4719	7537	3631	6438
St. John the Baptist	18	278	32	965	2242	693	142	278	32	269	5889	985
St. Landry	26459	53514	54173	42651	30795	36974	38869	53514	59043	58562	83019	48870
St. Martin	2710	6923	1253	7648	6573	11980	29182	6923	17814	9070	13457	10321
St. Mary	1576	12	106	41	1911	9	671	12	143	61	256	436
St. Tammany	12670	4996	3524	11389	13973	8651	28254	4996	3611	2051	1193	8664
Tangipahoa	25737	28234	26193	23425	24055	24572	47396	28234	16820	20552	20204	25947
Tensas	26653	56732	15431	37743	23026	31122	39177	56732	18876	47657	38142	35572
Terrebonne	62	370	263	1295	1312	5549	1475	370	3439	444	1560	1467
Union	77252	93873	72839	77637	62593	71894	70257	93873	54570	79555	48486	72984
Vermilion	2391	1246	159	1873	1371	7559	1200	1246	743	218	9801	2528

Table continued

PARISH	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Vernon	38520	48232	43421	46465	36051	39575	34316	48232	38000	43222	40886	41538
Washington	25730	16530	29030	22963	23097	23846	55508	16530	14222	13720	6845	22547
Webster	71772	43017	62732	88813	50042	43992	61672	43017	43530	40063	35785	53130
West Baton Rouge	12280	10916	9698	8599	8123	26553	29338	10916	22695	9755	7636	14228
West Carroll	9836	9593	16250	12093	11110	9246	6663	9593	4504	8450	2417	9069
West Feliciana	47749	44327	36555	40367	43471	33911	32206	44327	43407	39535	20092	38722
Winn	58948	54638	54620	74560	68883	78824	81048	54638	63678	43940	41780	61414
Total	1855489	1677526	1591935	1881213	1540130	1672159	1735489	1677526	1332389	1494779	1241980	1609147

APPENDIX B - PARISH WISE AGRICULTURAL RESIDUE PRODUCTION

Rice residue production (BDT) in Louisiana (2005-2011)

PARISH	2005	2006	2007	2008	2009	2010	2011	Average
Acadia	294082	216282	222781	293744	287220	311937	300992	275291
Allen	53176	30741	38320	38382	41511	52365	53201	43957
Avoyelles	50484	46410	47734	11472	60623	51260	47305	45041
Beauregard	8207	3290	4176	5194	6962	7378	4602	5687
Bossier	267	510	510	0	38	157	157	234
Caddo	0	0	0	0	0	540	0	77
Calcasieu	50565	23037	32739	27682	27948	44807	30241	33860
Caldwell	4022	3370	8882	8172	5315	4913	0	4954
Cameron	37289	10026	31656	31730	44090	49614	45658	35724
Catahoula	17448	7509	8596	12641	32268	28963	9197	16660
Concordia	50068	27864	35718	47161	58810	59963	48111	46814
East Carroll	59823	43698	22998	26328	34267	64624	10445	37455
Evangeline	164427	110839	121180	158890	152072	170590	153682	147383
Franklin	3481	0	0	0	12567	9459	483	3713
Iberia	3035	708	695	1425	1711	1878	3482	1848
Jefferson Davis	254419	175548	229689	264818	255810	294688	287462	251776
Lafayette	21497	14609	10440	10999	14141	14958	24109	15822
Madison	21689	21518	20049	19133	26083	39529	24844	24692
Morehouse	170721	87141	83651	106597	178910	235542	102121	137812
Natchitoches	14488	15270	30457	0	9973	13389	8630	13172
Ouachita	33638	29682	25751	32926	25438	34869	18433	28677
Pointe Coupee	4979	6575	7440	7857	9471	14522	5963	8115
Rapides	28581	31250	28447	3617	36150	36796	30886	27961
Red River	0	0	0	0	0	1298	1392	384
Richland	20850	16591	17830	20247	23904	31901	21157	21783
St. Landry	81270	61251	68496	79915	92894	101593	81753	81024
St. Martin	15435	12257	14934	19921	14628	15671	15214	15437
Tensas	6554	3085	5046	4976	11968	13173	4434	7034
Vermilion	230368	86512	170307	195007	149220	176679	161907	167143
West Carroll	24661	12179	12782	8645	13458	20757	14397	15268
Total	1725525	1097754	1301304	1437479	1627450	1903812	1510257	1514797

Soybean residue production (BDT) in Louisiana (2005-2011)

PARISH	2005	2006	2007	2008	2009	2010	2011	Average
Acadia	25618	54883	66970	92142	56567	59334	54199	58530
Allen	996	1324	1247	3853	4238	4161	3845	2809
Ascension	966	485	0	2576	2641	2588	1641	1557
Assumption	0	89	104	87	5620	3514	3264	1811
Avoyelles	86646	107653	106506	103261	116330	161921	134960	116754
Beauregard	2402	4077	7578	4502	3729	3737	1981	4001
Bossier	11465	13050	13522	11192	8685	7575	2237	9675
Caddo	7745	8203	6562	5966	7457	12179	6711	7832
Calcasieu	4686	0	6174	9243	6128	3922	8564	5531
Caldwell	6928	6464	2880	5313	3256	7552	5441	5405
Cameron	0	0	1241	2660	0	0	2983	983
Catahoula	75442	72985	33978	64806	66556	95457	60562	67112
Concordia	152137	93914	89499	97493	84419	146191	147860	115930
De Soto	1630	1572	2364	1119	794	491	556	1218
East Baton Rouge	604	0	0	0	0	0	1591	314
East Carroll	179185	175660	133857	133029	164818	262227	198619	178199
East Feliciana	739	1259	0	1141	1038	1210	1943	1047
Evangeline	12455	21575	29966	30265	35372	31326	43881	29263
Franklin	105193	72262	32763	68769	81275	99572	74168	76286
Grant	8356	12370	10753	8111	15798	10554	7699	10520
Iberia	5318	6214	8434	19262	17980	6790	11662	10809
Iberville	22263	16235	19753	15438	23053	25510	24559	20973
Jefferson Davis	8577	13681	27581	34907	22819	29428	27741	23534
Lafayette	6666	6808	7350	13453	14348	10143	12081	10121
Lafourche	616	0	0	199	1670	0	348	405
La Salle	222	194	131	172	373	637	748	354
Madison	133004	153788	92761	120418	106014	136636	139896	126074
Morehouse	106067	80766	59281	132882	78544	187105	184166	118402
Natchitoches	44931	34583	22127	23100	22861	25977	21904	27926
Ouachita	21593	18273	16723	27392	25223	31203	34766	25025
Pointe Coupee	175578	142481	135466	104681	169585	181669	124399	147694
Rapides	38187	57083	41375	33543	75957	72080	53964	53170
Red River	9132	7174	6728	8746	8962	7064	5444	7607
Richland	67945	40732	32174	43638	52835	73644	73084	54865
St. Charles	186	0	0	0	0	0	0	27
St. James	67	96	0	415	1763	2237	1491	867
St. John	1527	1488	1585	1161	2554	1288	1288	1556
St. Landry	105302	124185	128952	126758	159871	191473	166377	143274
St. Martin	8176	8949	10713	11597	16523	20145	18779	13554
St. Mary	4213	3579	4985	4773	8592	1451	4474	4581

Table continued

PARISH	2005	2006	2007	2008	2009	2010	2011	Average
St. Tammany	626	336	268	268	0	0	0	214
Tangipahoa	336	0	0	0	0	0	1514	264
Tensas	42332	44630	59657	34800	81986	89291	51807	57786
Terrebonne	671	0	0	0	0	0	0	96
Union	0	0	0	298	0	0	0	43
Vermilion	7353	1772	4205	11235	13338	8991	22122	9859
Washington	0	0	0	0	0	0	3600	514
West Baton Rouge	22371	7107	7305	12043	18694	16279	20493	14899
West Carroll	88255	71996	63493	75634	87903	105440	104570	85327
West Feliciana	2133	3212	1807	2625	2507	1670	1566	2217
Total	1606841	1493189	1298821	1504965	1678671	2139666	1875548	1656814

Sugarcane residue production (BDT) in Louisiana (2005-2011)

PARISH	2005	2006	2007	2008	2009	2010	2011	Average
Acadia	2516	2904	2148	2233	2496	2259	2186	2392
Ascension	21483	25173	28073	27408	26686	33745	32368	27848
Assumption	61513	69835	77499	75060	82492	64921	72489	71973
Avoyelles	24064	19435	20673	14722	13781	17013	13511	17600
Calcasieu	3983	2915	5061	2799	2389	3224	1489	3123
Cameron	408	0	544	0	0	43	0	142
East Baton Rouge	707	422	0	0	0	0	0	161
Evangeline	1020	1041	1431	173	90	89	292	591
Iberia	83548	88264	96179	98546	107423	106193	106570	98103
Iberville	55147	68060	71558	70081	78606	77026	76702	71026
Jefferson Davis	3899	3591	4527	4911	9863	8442	5253	5784
Lafayette	18715	20736	25017	22742	21515	22334	22204	21895
Lafourche	45828	52571	49006	46600	52649	41649	47030	47905
Pointe Coupee	47045	57226	70123	64827	73346	79153	79971	67385
Rapides	15585	18935	22542	21263	18403	16881	19091	18957
St. Charles	3456	3188	3111	2982	2478	2277	2140	2804
St. James	32193	39061	49254	43357	42963	48602	46147	43083
St. John	14034	13173	16179	13303	14593	12653	11576	13644
St. Landry	13525	17536	14612	9299	10214	13808	11735	12961
St. Martin	39575	51240	55768	52142	56864	50632	49049	50753
St. Mary	56686	51970	85398	71281	84265	67227	74222	70150
Terrebonne	13068	16225	19375	18304	18034	14256	15839	16443
Vermilion	31175	33281	47471	46293	48846	57047	55459	45653
West Baton Rouge	22984	28022	32201	26725	29786	29618	30913	28607
Total	612154	684802	797751	735053	797784	769091	776236	738982

Corn residue production (BDT) in Louisiana (2005-2011)

PARISH	2005	2006	2007	2008	2009	2010	2011	Average
Acadia	0	0	561	0	508	0	0	153
Allen	0	415	590	502	511	541	579	448
Avoyelles	19695	8860	32240	13673	28810	22781	26469	21790
Beauregard	1051	2704	1813	1495	1472	1821	1373	1676
Bienville	0	0	2186	2186	1674	1502	754	1186
Bossier	10945	8370	5987	8778	4718	7903	6867	7653
Caddo	27813	32706	75055	40744	44423	69102	40131	47139
Caldwell	2760	2183	12468	7382	8078	9958	5172	6857
Catahoula	43548	36762	105048	57756	71313	39213	57057	58671
Claiborne	0	193	948	0	0	0	0	163
Concordia	30849	23000	132694	69840	55811	50706	70931	61976
De Soto	808	394	1036	579	904	577	165	638
East Baton Rouge	386	0	0	0	0	0	0	55
East Carroll	115944	112885	273185	0	109618	144160	198841	136376
East Feliciana	4101	3137	1916	1725	1312	1715	563	2067
Evangeline	1610	1153	3932	3496	2260	2533	1427	2344
Franklin	93306	87729	305920	229606	272131	251102	296160	219422
Grant	4815	3080	8409	2660	4155	3870	3183	4310
Iberville	1550	422	1522	892	1064	0	1648	1014
Jefferson Davis	0	6	0	0	0	0	0	1
Lafayette	1943	550	2148	1647	1546	1406	1650	1556
La Salle	0	1803	977	646	682	1223	826	880
Madison	133936	123510	406084	186209	196681	169885	191083	201055
Morehouse	102728	111552	392715	241650	236551	209407	208089	214670
Natchitoches	23189	9200	71185	42537	35718	28055	31295	34454
Ouachita	7336	10608	56142	31634	34050	27040	28401	27887
Pointe Coupee	39440	36283	53290	44981	46948	41556	42063	43509
Rapides	18352	15580	47956	22213	35935	30755	30421	28744
Red River	7469	4249	27055	26366	9895	11906	5301	13177
Richland	62417	72049	203934	143046	169695	141117	164052	136616
St. Helena	0	2146	0	0	0	0	0	307
St. Landry	27162	16744	36204	23539	16396	15236	29771	23579
St. Martin	30	9	0	0	91	70	62	37
Tangipahoa	0	1502	0	0	0	0	0	215
Tensas	121781	67655	229155	124061	165187	117786	103626	132750
Vermilion	0	0	0	0	0	0	10	1
Washington	0	429	0	0	0	0	0	61
Webster	603	400	768	284	0	858	569	498
West Baton Rouge	991	1126	971	791	937	1726	937	1068

Table Continued

PARISH	2005	2006	2007	2008	2009	2010	2011	Average
West Carroll	40984	36755	118787	57042	65680	68140	63053	64349
West Feliciana	1972	2232	3906	2574	2822	7243	2479	3318
Total	949514	838385	2616785	1390535	1627574	1480892	1615004	1502670

Sorghum residue production (BDT) in Louisiana (2005-2011)

PARISH	2005	2006	2007	2008	2009	2010	2011	Average
Acadia	14686	4690	10616	12190	3685	2794	2816	7354
Allen	469	0	0	0	0	33	35	77
Avoyelles	109326	126233	191887	125451	53638	59449	88258	107749
Beauregard	1175	2794	2313	559	525	416	1623	1344
Bossier	11342	447	0	793	696	696	514	2070
Calcasieu	0	0	978	1772	0	0	387	448
Caldwell	909	0	8820	4404	0	0	0	2019
Catahoula	37273	40165	273627	46709	39223	64099	52742	79120
Concordia	26042	27930	148385	19966	129330	17952	37056	58095
East Carroll	8045	7695	17125	0	132	0	4568	5366
Evangeline	1964	3890	13180	11595	3792	1155	7153	6104
Franklin	4093	1235	40958	6933	154	6996	3704	9153
Grant	1408	1411	4151	2988	2597	1574	1979	2301
Iberville	693	2021	5640	1156	1876	919	577	1840
Jefferson Davis	603	0	548	69	629	0	698	364
Lafayette	1672	846	512	118	254	440	241	583
La Salle	425	646	0	670	30	0	25	257
Madison	3828	6896	24362	5954	1383	0	5867	6899
Morehouse	7234	3192	77212	18266	4631	7071	11807	18488
Natchitoches	2171	1369	19387	8169	1726	1546	7560	5990
Ouachita	482	566	18246	11550	1435	1296	5968	5649
Pointe Coupee	17350	38019	70762	13344	3891	5008	5332	21958
Rapides	18878	22352	46946	16786	7503	12722	26786	21711
Richland	6860	10166	62384	8844	4975	3524	5427	14597
St. Landry	46595	71191	68051	45867	45601	20112	41468	48412
St. Martin	4602	3694	3369	3134	3000	1732	2183	3102
Tensas	6730	7375	18295	5654	1927	5008	17130	8874
Vermilion	2187	0	0	0	0	0	0	312
West Baton Rouge	729	1555	8352	349	478	0	0	1638
West Carroll	2302	2866	15120	2263	107	4348	2621	4233
West Feliciana	1091	82	681	82	0	117	0	293
Total	341165	389328	1151910	375637	313218	219007	334525	446398

Oats residue production (BDT) in Louisiana (2005-2011)

PARISH	2005	2006	2007	2008	2009	2010	2011	Average
Avoyelles	42	102	70	53	61	26	136	70
Beauregard	0	0	0	0	0	221	293	73
Bossier	86	86	86	204	18	23	19	75
Caddo	0	0	0	0	130	0	0	19
Caldwell	92	0	67	81	0	146	0	55
Catahoula	121	809	292	0	38	47	32	191
Concordia	1160	175	11661	3797	1950	7382	2553	4097
De Soto	0	0	80	0	0	0	0	11
East Carroll	41	28	36	0	12	0	0	17
East Feliciana	0	0	0	31	28	29	24	16
Franklin	598	413	247	318	350	501	551	425
Grant	330	498	0	242	225	0	0	185
Jefferson Davis	7	0	13	29	16	0	0	9
Lafayette	0	0	0	0	0	0	148	21
Madison	54	0	12	0	150	120	501	120
Morehouse	82	13	63	361	623	120	148	202
Natchitoches	0	0	0	0	113	93	56	37
Pointe Coupee	240	191	202	201	186	383	186	227
Rapides	0	0	0	0	0	317	0	45
Red River	0	10	45	19	16	0	0	13
Richland	1240	1010	100	63	0	170	166	393
West Carroll	958	300	362	541	590	281	608	520
West Feliciana	0	58	0	0	0	0	0	8
Total	5053	3692	13335	5939	4506	9860	5423	6830

Cotton residue production (BDT) in Louisiana (2005-2011)

PARISH	2005	2006	2007	2008	2009	2010	2011	Average
Avoyelles	25684	37300	23276	9457	8325	9956	13161	18165
Bossier	1886	1921	1874	1060	985	844	2275	1549
Caddo	31608	43102	33569	14951	13694	25816	30737	27640
Caldwell	12315	12775	11919	4675	4289	5934	4567	8068
Catahoula	90240	106021	72872	30295	50288	40158	50976	62979
Concordia	64150	78216	57351	26217	32302	14964	34424	43946
De Soto	1335	1251	1394	778	681	794	329	937
East Carroll	62623	61058	29155	0	5829	6454	14987	25729
Evangeline	2061	2305	1633	803	264	1235	1170	1353
Franklin	88861	88803	51021	21662	19081	21219	39650	47185
Grant	3462	3438	1005	55	484	781	1170	1485
La Salle	454	75	395	0	289	359	1270	406
Madison	151818	120277	52403	26700	24663	49005	49907	67825
Morehouse	101113	97678	31793	16588	8602	13792	13404	40424
Natchitoches	12753	17780	9448	2469	3043	3529	6084	7872
Ouachita	23339	26853	14530	7374	4285	11476	11789	14235
Pointe Coupee	16602	22505	14761	4176	3633	5494	6881	10579
Rapides	27832	36815	22978	9427	12110	16901	19460	20789
Red River	9728	10844	4561	1923	1556	274	482	4195
Richland	63313	59502	17967	9073	7227	17544	23165	28256
St. Landry	3586	4684	2350	1225	1496	1208	1949	2357
Tangipahoa	0	0	0	0	0	0	643	92
Tensas	149039	172847	133771	65669	87527	89489	114450	116113
West Baton Rouge	0	0	0	228	0	0	0	33
West Carroll	28000	38095	8944	1274	875	1861	4799	11978
West Feliciana	330	517	0	80	62	0	0	141
Total	972134	1044662	598971	256158	291587	339085	447729	564332

Potato residue production (BDT) in Louisiana (2005-2011)

PARISH	2005	2006	2007	2008	2009	2010	2011	Average
Ascension	3	3	5	5	5	325	5	50
Avoyelles	0	0	0	0	0	280	4	41
Caddo	47	61	47	47	47	3000	47	471
East Baton Rouge	0	0	0	0	0	0	1	0
Franklin	0	0	80	0	110	0	0	27
Iberia	8	11	16	24	19	2000	38	302
Iberville	5	0	0	0	0	0	0	1
Lafourche	17	22	21	19	21	1410	23	219
Livingston	82	51	61	53	53	14000	220	2074
Madison	0	0	0	118	0	0	0	17
Ouachita	2	3	6	0	0	0	0	2
Pointe Coupee	32	33	33	76	69	3960	64	610
Rapides	4	0	0	0	0	0	0	1
Red River	19	15	14	14	35	1875	31	286
Richland	0	9	5	5	5	0	0	3
St. Charles	19	17	15	10	14	1100	18	170
St. James	13	11	11	3	0	0	0	5
St. John	0	9	4	2	7	240	4	38
St. Landry	7	9	17	13	13	0	13	10
St. Tammany	7	7	6	6	3	350	8	55
Tangipahoa	13	18	18	184	30	1920	30	316
Terrebonne	25	22	18	19	24	920	15	149
Washington	12	19	17	17	3	1845	31	278
West Carroll	6	6	3	3	3	125	4	21
West Feliciana	5	6	8	1	7	4375	96	643
Winn	5	3	6	6	5	240	3	38
Total	331	336	412	625	477	37965	654	5828

Wheat residue production (BDT) in Louisiana (2005-2011)

PARISH	2005	2006	2007	2008	2009	2010	2011	Average
Acadia	179	1206	4437	10380	376	533	2096	2744
Allen	0	0	0	289	505	0	979	253
Avoyelles	7723	7547	19769	29149	10131	9793	18870	14712
Beauregard	714	598	1864	1009	1028	1495	2509	1317
Bossier	6046	5890	5355	5822	3547	316	2570	4221
Caddo	2693	2840	0	5508	4819	482	0	2334
Calcasieu	0	0	1011	923	0	0	0	276
Caldwell	102	0	1262	3614	1550	206	3652	1484
Catahoula	4619	8012	17883	17967	13529	3454	19443	12130
Concordia	3477	3267	19404	20521	15153	3641	17287	11821
De Soto	0	0	78	304	868	0	0	179
East Baton Rouge	41	0	0	0	0	0	0	6
East Carroll	4012	1922	8699	18673	8847	957	13653	8109
East Feliciana	620	1059	0	1380	1147	0	1311	788
Evangeline	251	2582	4845	16301	1753	734	1728	4028
Franklin	22086	17644	38788	90985	32195	18677	61928	40329
Grant	2938	318	4933	1970	245	612	3264	2040
Iberia	252	184	1759	2428	1583	0	188	914
Iberville	5820	6641	8744	117	3365	792	4307	4255
Jefferson Davis	3534	4131	6885	3263	151	0	1178	2735
Lafayette	549	2076	0	4854	3435	661	3827	2200
Madison	2703	1269	2439	12533	5080	3955	14320	6043
Morehouse	10534	14293	28398	63058	30605	15335	41770	29142
Natchitoches	1978	1910	8513	13072	13922	1377	2808	6226
Ouachita	2294	2185	4900	9204	4322	2295	2393	3942
Pointe Coupee	45333	49106	75551	76492	40706	43802	56676	55381
Rapides	1599	1443	4047	6711	4471	4133	8080	4355
Red River	666	1915	3513	2611	2341	3128	6400	2939
Richland	14671	17065	37313	78797	34217	17543	41028	34376
St. Landry	11741	12754	34236	48606	21656	12080	25404	23782
St. Martin	2011	1808	4844	3768	691	951	1904	2282
St. Mary	0	0	513	1944	1133	0	0	513
Tensas	2230	2215	30599	44767	17211	20256	132	16773
Vermilion	0	0	0	2186	884	0	951	574
West Baton Rouge	3381	0	4302	6112	3532	1824	3545	3242
West Carroll	16596	19855	25780	49438	36731	12691	43771	29266
West Feliciana	1799	1280	1343	1411	1539	1005	829	1315
Total	183192	193017	412006	656165	323267	182726	408801	337025

Peanut residue production (BDT) in Louisiana (2005-2011)

PARISH	2005	2006	2007	2008	2009	2010	2011	Average
Morehouse	458	59	54	28	57	384	155	171
Richland	51	61	363	126	18	184	154	137
Washington	2	2	3	2	0	0	0	1
Total	512	122	420	157	75	568	310	309

Average agricultural residue production (BDT) in Louisiana (2005-2011)

PARISH	Rice	Soybean	Sugarcane	Corn	Sorghum	Oats	Cotton	Potato	Wheat	Peanut	Total
Acadia	275291	58530	2392	153	7354	0	0	0	2744	0	346464
Allen	43957	2809	0	448	77	0	0	0	253	0	47544
Ascension	0	1557	27848	0	0	0	0	50	0	0	29455
Assumption	0	1811	71973	0	0	0	0	0	0	0	73784
Avoyelles	45041	116754	17600	21790	107749	70	18165	41	14712	0	341921
Beauregard	5687	4001	0	1676	1344	73	0	0	1317	0	14097
Bienville	0	0	0	1186	0	0	0	0	0	0	1186
Bossier	234	9675	0	7653	2070	75	1549	0	4221	0	25476
Caddo	77	7832	0	47139	0	19	27640	471	2334	0	85512
Calcasieu	33860	5531	3123	0	448	0	0	0	276	0	43238
Caldwell	4954	5405	0	6857	2019	55	8068	0	1484	0	28841
Cameron	35724	983	142	0	0	0	0	0	0	0	36849
Catahoula	16660	67112	0	58671	79120	191	62979	0	12130	0	296863
Claiborne	0	0	0	163	0	0	0	0	0	0	163
Concordia	46814	115930	0	61976	58095	4097	43946	0	11821	0	342679
De Soto	0	1218	0	638	0	11	937	0	179	0	2983
East Baton Rouge	0	314	161	55	0	0	0	0	6	0	536
East Carroll	37455	178199	0	136376	5366	17	25729	0	8109	0	391252
East Feliciana	0	1047	0	2067	0	16	0	0	788	0	3918
Evangeline	147383	29263	591	2344	6104	0	1353	0	4028	0	191066
Franklin	3713	76286	0	219422	9153	425	47185	27	40329	0	396541
Grant	0	10520	0	4310	2301	185	1485	0	2040	0	20841
Iberia	1848	10809	98103	0	0	0	0	302	914	0	111975
Iberville	0	20973	71026	1014	1840	0	0	1	4255	0	99109
Jackson	0	0	0	0	0	0	0	0	0	0	0
Jefferson	0	0	0	0	0	0	0	0	0	0	0
Jefferson Davis	251776	23534	5784	1	364	9	0	0	2735	0	284202
Lafayette	15822	10121	21895	1556	583	21	0	0	2200	0	52198

Table continued

PARISH	Rice	Soybean	Sugarcane	Corn	Sorghum	Oats	Cotton	Potato	Wheat	Peanut	Total
Lafourche	0	405	47905	0	0	0	0	219	0	0	48529
La Salle	0	354	0	880	257	0	406	0	0	0	1896
Lincoln	0	0	0	0	0	0	0	0	0	0	0
Livingston	0	0	0	0	0	0	0	2074	0	0	2074
Madison	24692	126074	0	201055	6899	120	67825	17	6043	0	432724
Morehouse	137812	118402	0	214670	18488	202	40424	0	29142	171	559310
Natchitoches	13172	27926	0	34454	5990	37	7872	0	6226	0	95678
Orleans	0	0	0	0	0	0	0	0	0	0	0
Ouachita	28677	25025	0	27887	5649	0	14235	2	3942	0	105416
Plaquemines	0	0	0	0	0	0	0	0	0	0	0
Pointe Coupee	8115	147694	67385	43509	21958	227	10579	610	55381	0	355457
Rapides	27961	53170	18957	28744	21711	45	20789	1	4355	0	175733
Red River	384	7607	0	13177	0	13	4195	286	2939	0	28602
Richland	21783	54865	0	136616	14597	393	28256	3	34376	137	291026
Sabine	0	0	0	0	0	0	0	0	0	0	0
St. Bernard	0	0	0	0	0	0	0	0	0	0	0
St. Charles	0	27	2804	0	0	0	0	170	0	0	3002
St. Helena	0	0	0	307	0	0	0	0	0	0	307
St. James	0	867	43083	0	0	0	0	5	0	0	43955
St. John	0	1556	13644	0	0	0	0	38	0	0	15238
St. Landry	81024	143274	12961	23579	48412	0	2357	10	23782	0	335401
St. Martin	15437	13554	50753	37	3102	0	0	0	2282	0	85166
St. Mary	0	4581	70150	0	0	0	0	0	513	0	75244
St. Tammany	0	214	0	0	0	0	0	55	0	0	269
Tangipahoa	0	264	0	215	0	0	92	316	0	0	887
Tensas	7034	57786	0	132750	8874	0	116113	0	16773	0	339330
Terrebonne	0	96	16443	0	0	0	0	149	0	0	16688
Union	0	43	0	0	0	0	0	0	0	0	43
Vermilion	167143	9859	45653	1	312	0	0	0	574	0	223544

Table continued

PARISH	Rice	Soybean	Sugarcane	Corn	Sorghum	Oats	Cotton	Potato	Wheat	Peanut	Total
Vernon	0	0	0	0	0	0	0	0	0	0	0
Washington	0	514	0	61	0	0	0	278	0	1	855
Webster	0	0	0	498	0	0	0	0	0	0	498
West Baton Rouge	0	14899	28607	1068	1638	0	33	0	3242	0	49487
West Carroll	15268	85327	0	64349	4233	520	11978	21	29266	0	210963
West Feliciana	0	2217	0	3318	293	8	141	643	1315	0	7936
Winn	0	0	0	0	0	0	0	38	0	0	38
Total	1514797	1656814	738982	1502670	446398	6830	564332	5828	337025	309	6773986

VITA

Anil Raj Kizhakkepurakkal was born in December, 1981, in Manjeri, Kerala, India. He graduated his secondary and higher secondary schools in 1997 and 1999, respectively. He was admitted to the College of Forestry, Kerala Agricultural University (KAU), India, in 2000. His undergrad thesis was "Wood properties changes due to gamma irradiation in certain selected tropical timber species." After graduation in 2004, Anil served in the Kerala Forest Department, the Kerala Forest Research Institute and the College of Forestry, KAU. In 2006, he came to the US to pursue his higher education. In Aug 2008, he graduated with his Masters of Science in forestry at Louisiana State University. His Master's thesis was entitled, "Opportunities and challenges associated with development of wood biomass energy production in Louisiana". He is currently completing his requirements for his Doctor of Philosophy in forestry and Masters of Science in Environmental Sciences at Louisiana State University.