ESTIMATION OF WOODY BIOMASS AVAILABILITY FOR ENERGY IN TEXAS

Prepared for
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EXECUTIVE SUMMARY

Texas House Bill (HB) 1090, passed in May 2007, mandates that "the commissioner of agriculture, in consultation with the Texas Forest Service, shall conduct a study to determine the volume of wood waste in the East Texas and Central Texas forest regions."

The primary goal of this study is to estimate forest wood waste in the East and Central Texas forest regions. In addition, conclusions were also made concerning the potential availability of biomass for energy production. Forest wood waste in this study includes logging residue from conventional thinning and final harvesting in East Texas, wood waste from pre-commercial thinning and timber stand improvement thinning in East Texas, as well as wood waste from brush control in Central Texas. Mill residue and urban wood waste are not included.

This study estimates the amount of biomass available for energy production by assuming all identified wood waste may be utilized as an energy feedstock. It is important to note that these estimates may be reduced due to economic, transportation and policy challenges, as well as current and potential demand by users outside the energy sector.

Forest Resources in East Texas

East Texas has abundant forest resources. Approximately 57 percent of the land area, or 12.1 million acres, is forested. Timberland accounts for 98 percent of total forestland. Major forest types in East Texas include southern yellow pine (42%), hardwood (43%), and oak-pine (13%).

Individual and family forest owners control 7.9 million acres, or 66 percent of the total timberland in East Texas. Corporate landowners and investors own 3.0 million acres of timberland, accounting for 25 percent of total timberland in East Texas. The remaining 8 percent is owned by federal, state or local governments. Southeast Texas has 6.5 million acres of timberland while Northeast Texas has 5.4 million acres of timberland.

Total inventory of live forest woody biomass in East Texas is estimated to be 472 million dry tons as of 2006. Merchantable biomass accounts for 73 percent, or 348 million dry tons while non-merchantable biomass accounts for 27 percent, or 124 million dry tons. The biomass of non-merchantable trees is the main potential biomass source for energy in East Texas.

The 2006 Forest Inventory and Analysis (FIA) data shows that the average net annual growth for live trees was 1.1 billion cubic feet, which is 38 percent higher than the average annual removal of live trees during the same period. The excess growth of forest resources in East Texas provides a potential woody biomass feedstock for energy production and other forest products.

Traditionally, mill residue is burned in boilers to produce steam to power various aspects of the forest products manufacturing processes. Larger-scale operations such as pulp and paper mills also commonly co-generate electricity using woody biomass-fired boilers coupled to steam

turbines. In recent years these facilities have expanded their acquisition of woody biomass to include logging residue, storm-damaged wood, urban waste wood, and even some non-woody sources of biomass.

Based on a recent survey of major woody biomass-using companies in East Texas[1], the 2006 consumption of logging residue and storm-damaged wood was found to be approximately 68,000 dry tons. In 2007 approximately 233,000 dry tons of wood materials were acquired from Texas lands and utilized by the major woody biomass-using companies located in Texas or adjacent to the Texas border in Louisiana, Arkansas and Oklahoma. Also, some smaller biomass using facilities both in Texas and located adjacent to the Texas border that are not included in this survey may consume nominal amounts of logging residue and storm damaged wood.

Forest Resources in Central Texas

All forest resource data in this study for Central Texas are based on three of a total of 10 panels of FIA data in the region. The 64-county Central Texas region has 18.3 million acres of forestland. The majority of forestland in the region (88%) is classified as unproductive.

The Central Texas forest region is divided into three sub-regions: Post Oak, Blacklands, and Hill Country. Oak, pinyon/juniper (cedar), and mesquite woodland are the main forest types in the region. Ninety-two percent of live trees are on private forestland, and eight percent are on public forestland.

Total biomass of live trees in Central Texas is 204 million dry tons. Ninety-four percent is from private forestland and six percent is from public forestland. The Hill Country sub-region has 42 percent of the total biomass in Central Texas. The Post Oak sub-region has 39 percent and the Blacklands sub-region has 19 percent. Desirable species compose 115 million dry tons of biomass, or 57 percent of the total in the region. Based on the landowner survey, 88 million dry tons of biomass, or 43 percent of the total woody biomass in the region, are from undesirable species.

Merchantable biomass is estimated to be 145 million dry tons, 71 percent of the total woody biomass in Central Texas. Non-merchantable biomass is 58 million dry tons. Ninety percent, or 130 million dry tons, of the merchantable biomass is classified as pulpwood, and only 10 percent is classified as sawlog. All non-merchantable and merchantable biomass from trees that are less than sawtimber size represents 57 percent of the total biomass in Central Texas. Non-merchantable biomass, merchantable biomass from undesirable species, and merchantable biomass from desirable species that are less than sawtimber size account for 76 percent of the total biomass in Central Texas.

Because there is not a well established forest products industry to utilize merchantable biomass for traditional forest products in Central Texas, most merchantable biomass, especially pulpwood

[1] Dr. Edward Dougal of Texas Forest Service conducted the woody biomass consumption survey.

size merchantable biomass, is potentially available for energy. Most biomass from brush control remains unused.

Biomass Supply Potential in East Texas

Biomass supply potential in East Texas includes wood waste from logging and biomass thinning operations in the region. Logging residue includes tops, limbs, and unutilized cull trees. Wood waste from biomass thinning in this study includes woody biomass from pre-commercial thinning and timber stand improvement thinning.

East Texas produces 1.5 million dry tons of wood waste from logging residue potentially available for energy annually, 63 percent from softwood and 37 percent from hardwood. Northeast Texas and Southeast Texas each account for roughly 50 percent. Polk, Tyler, Newton, Cass, and Nacogdoches are the top five producing counties of logging residue potentially for energy generation in East Texas.

Estimation of wood waste from biomass thinning is based on 2006 FIA data, a biomass thinning survey conducted by Texas Forest Service, and computer simulations of stand growth and management using the USDA Forest Service growth model Forest Vegetation Simulator (FVS).

Wood waste from biomass thinning is estimated to be 2.8 million dry tons annually in East Texas, 34 percent from softwood and 66 percent from hardwood. Of this, Northeast Texas accounts for 45 percent and Southeast Texas accounts for 55 percent. Polk, Tyler, Newton, Jasper, and Hardin are the top five counties having potential for producing wood waste from biomass thinning in East Texas.

Overall, about 4.3 million dry tons of wood waste is potentially available annually for energy generation in East Texas, 35 percent from logging residue and 65 percent from biomass thinning.

Note that not all of the 4.3 million dry tons of wood waste will be available for new power generation facilities in East Texas. A portion of the wood waste has already been consumed by existing biomass energy facilities in East Texas as described in Section 2.4. Other sources will be available at different prices due to different costs of extraction, collection, and transportation of the biomass. Logging residue presented in this study is a snapshot of 2006. However, annual availability of logging residue is highly related to mill production which may be affected by a variety of economic and market factors. Logging residue, biomass from pre-commercial thinning, biomass from timber stand improvement thinning, and biomass from hurricane-damaged wood are likely to have very different cost curves. This study is not intended for making financial decisions.

Biomass Supply Potential in Central Texas

With FIA data for the total woody biomass distribution in Central Texas, it is important to understand the constraints on availability of woody biomass in the region. Since ranchers are the main forestland owners in the region, a survey of ranchers in Central Texas was conducted to investigate brush control preferences and opinions on woody biomass for energy.

The survey found that Central Texas ranches have an average proportion of 40 percent with no brush to light brush, 27 percent with moderate brush, 20 percent with heavy brush, and 13 percent with extra heavy brush coverage. Sixty-nine percent of survey respondents conducted their last brush control operation within the last five years. Keeping current and future brush from encroaching on areas for livestock is the primary reason for brush control. The high cost of brush control is the main obstacle against conducting brush control on ranches.

The survey indicated that ranchers want to cut 62.9 percent of woody biomass of undesirable species and 7.1 percent of desirable species currently on their land given a financially feasible brush control operation. On average, respondents were very positive toward all statements about potential environmental and economic benefits of using woody biomass for energy.

Because of the lack of information on growth and removal of trees in Central Texas, this study estimated an empirical forest growth model for desirable and undesirable forest types by fitting a variant of a logistic function using FIA data for Central Texas. Average annual growth rates by age class can be estimated from the model for both desirable species and undesirable species.

By applying the annual growth rates to forestland acres in Central Texas by desirable and undesirable forest types, biomass supply potential in the region was estimated under three scenarios: optimal biological rotation ages for desirable and undesirable forest types, and rotation age five years shorter or longer than the optimal rotation ages. The average of the three scenarios was used as the best estimate of biomass supply potential in the region.

The average of the three scenarios shows that Central Texas can produce 1.6 million dry tons of woody biomass per year. Among the three sub-regions, Hill Country can produce 65 percent of the total biomass supply, Blacklands can produce 18 percent, and Post Oak can produce 17 percent. Fifteen percent of the biomass is from desirable species and 85 percent is from undesirable species.

The estimation of biomass supply potential in Central Texas excludes public forestland and accounts for the need to keep some of the trees for ranching and environmental benefits based on the rancher survey. Because there is only 30 percent of a full inventory of FIA data currently available for the region, biomass supply estimations were not detailed to county level in Central Texas and may change in the future as more data are collected and analyzed.

A Hot Spot analysis of woody biomass in Central Texas was performed to give a general indication about the concentration of woody biomass in the region.

CHAPTER 1. INTRODUCTION

1.1 House Bill 1090

As the nation's largest consumer and producer of energy (Texas Comptroller of Public Accounts 2008), Texas is looking at bioenergy as a renewable energy alternative as fossil fuel prices increase and more focus is placed on energy security. The abundance of woody biomass on forestland in Texas provides a potential resource for renewable energy production.

Texas House Bill (HB) 1090, passed in May 2007, is an act relating to the establishment of the Agricultural Biomass and Landfill Diversion Incentive Program by the Texas Department of Agriculture to make grants to encourage construction of facilities generating electric energy with certain types of agricultural residues, waste, debris, or crops.

The bill mandated in section 3 (a) that "the commissioner of agriculture, in consultation with the Texas Forest Service, shall conduct a study to determine the volume of wood waste in the East Texas and Central Texas forest regions." As defined in HB1090, "forest wood waste includes residual tops and limbs of trees, unused cull trees, pre-commercial thinnings, and wood or debris from noncommercial tree species, slash, or brush."

1.2 Goal, Scope, and Objectives of this Study

The primary goal of this study is to estimate forest wood waste in the East and Central Texas forest regions. In addition, conclusions were also made concerning the potential availability of biomass for energy production.

The East Texas and Central Texas forest regions were defined by the Texas Department of Agriculture for this report and are shown in Figure 2.1. The East Texas forest region includes the 43 counties of the Pineywoods, which coincide with the Northeast and Southeast Texas units of the cooperative Forest Inventory and Analysis (FIA) Program of the United States Department of Agriculture (USDA) Forest Service and Texas Forest Service. The Central Texas forest region includes 64 counties. It is further divided into three sub-regions: Hill Country, Blacklands, and Post Oak.

There are vast differences between East Texas and Central Texas forest regions in forest composition, land productivity, and wood utilization. Forests in East Texas are dominated by pine species such as loblolly, shortleaf, and longleaf, with hardwood species such as red oaks and white oaks. Forests in Central Texas are dominated by woodland species such as various juniper (cedar) and mesquite species, as well as oak and other hardwood species. Due to climatology and soil differences, East Texas is dominated mostly by highly-productive commercial timberlands,

while Central Texas is dominated mostly by non-commercial forestland with low productivity. East Texas has a highly developed forest products industry that utilizes wood for lumber, plywood, oriented strand board (OSB), pulp, posts and poles, and other forest products. Central Texas has very little commercial wood utilization, primarily fence post and fuel wood operations.

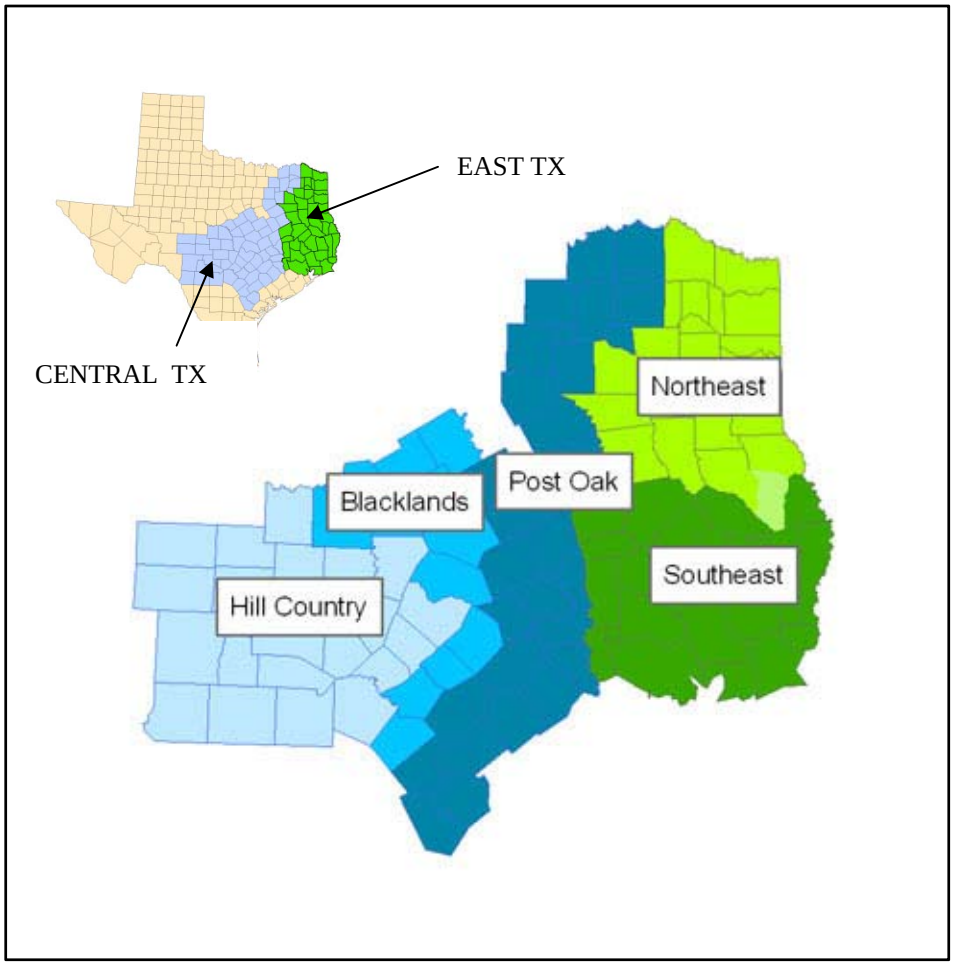

Figure 1.1 Texas forest regions

While the legislative directive was to estimate forest wood waste, this study also uses available data to estimate the amount of wood waste available for energy. Although various ecological, economic and policy constraints may affect availability, wood waste for energy in Texas ultimately depends on inventory of standing woody biomass on forestland in the two regions. The forest inventory establishes a maximum volume base from which sustainably-available woody biomass for energy can be estimated. Therefore, it is important to understand the inventory of the forest resource before investigating wood waste availability. Considering the differences in the forest resources of the two regions, forest resources in East Texas and Central Texas are described separately in this study.

Woody biomass for energy in East Texas can be separated into three types: 1) logging residue, including residual tops and limbs of trees, and unused cull trees; 2) small-diameter[2], non-merchantable biomass of commercial tree species from pre-commercial thinning and timber stand improvement thinning; and 3) mill residue, such as waste chips, sawdust, shavings and bark. Mill residue results from the production of primary wood products and is already used for pulping, fuel or landscaping. Mill residue is not a part of the wood waste definition in HB 1090 and is not covered in this study.

Because there is very limited commercial wood utilization in Central Texas, there is no logging residue or wood waste from thinning to be estimated. All wood waste in Central Texas would be from clearing of woody brush and trees in the region.

This study estimates the amount of biomass available for energy production by assuming all identified wood waste may be utilized as an energy feedstock. It is important to note that these estimates may be reduced due to economic, transportation and policy challenges, as well as current and potential demand by users outside the energy sector.

This study also does not cover urban waste that may contain woody biomass for energy.

All descriptions in this report about forest resources and biomass availability refer to their status in 2006, except when explicitly noted otherwise. In this report, the terms *wood waste*, *forest wood waste*, *biomass for energy*, and *woody biomass for energy* are used interchangeably.

1.3 Organization of this Study

This study is organized as follows. Chapter 2 describes forest resources in East Texas, Chapter 3 describes forest resources in Central Texas, Chapter 4 estimates available wood waste from East Texas, and Chapter 5 estimates available wood waste from Central Texas.

[2] Small trees are live trees that are 1.0 to 5.0 inches in diameter at breast height.

CHAPTER 2. FOREST RESOURCES IN EAST TEXAS[3]

2.1 Forestland Area in East Texas

East Texas has an abundance of forest resources. According to 2006 Forest Inventory and Analysis (FIA) data, 12.1 million acres (57%) of the 21.4 million acres in East Texas are forestland[4]. Provided by the USDA Forest Service, FIA data show reports on status and trends in forest area, location, tree size and species, tree growth, mortality, harvest, wood production and utilization rates by various product, biomass, and forestland ownership (FIA 2008). Timberland[5] accounts for 98 percent of the 12.1 million acres forestland (Table 2.1). The balance is reserved or unproductive forestland[6]. Sixty-eight percent of the total forestland has a site productivity index[7] higher than 85. Thirty-one percent has a productivity index of 20–84. Only 0.8 percent of forestland has a site productively index lower than 19 (Figure 2.1).

Individual and family forest owners control the largest share, 7.9 million acres, or 66 percent of the total timberland in East Texas. Corporate landowners and investors (Timberland Investment Management Organizations or TIMOs and Real Estate Investment Trusts or REITs) own 3.0 million acres of timberland, accounting for 25 percent of the total in East Texas. The remaining eight percent is owned by federal, state or local governments. Southeast Texas has 6.5 million acres of timberland while Northeast Texas has 5.4 million acres of timberland (Table 2.2).

[3] All forest resource data in East Texas are based on 2006 FIA data in East Texas, which was compiled based on the combination of data from cycle 7, subcycles 4 and 5, and cycle 8, subcycles 1, 2, and 3. Each complete FIA survey cycle in East Texas has 5 subcycles (panels) of data.

[4] As currently defined by FIA, forestland is land at least 10% stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated.

[5] According to FIA definition, timberland is forestland capable of producing a volume of industrial wood equal to or greater than 20.0 cubic feet/acre/year.

[6] Reserved land is land that is withdrawn by law(s) prohibiting management of the land for production of wood products. Unproductive land is land that grows less than 20 cubic feet volume per acre per year.

[7] Site productivity index is a classification of forest land in terms of inherent capacity to grow crops of industrial wood. It identifies the potential growth in cubic feet/acre/year and is based on the culmination of mean annual increment of fully stocked natural stands.

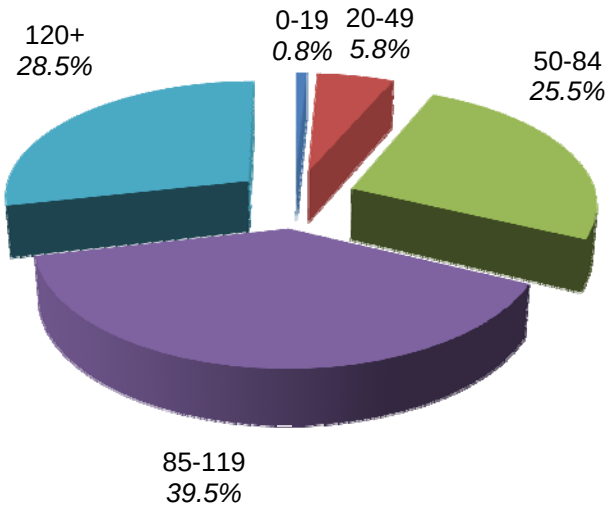

Figure 2.1 Percentage of forestland by site productivity, East Texas, 2006

Figure 2.2 shows timberland area by forest type group. Yellow pine[8] and hardwood are the two dominating forest type groups in East Texas, with yellow pine accounting for 41.6 percent of total timberland area, and hardwood accounting for 43.4 percent. Oak-pine has the third largest share of timberland area in East Texas with 13.3 percent. See Tables 2.3–2.5 for more details about timberland area characteristics in East Texas.

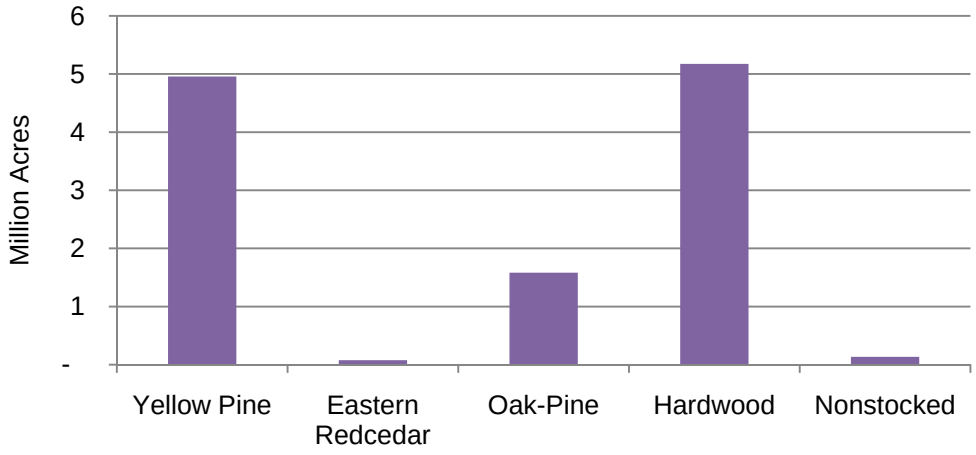

Figure 2.2 Timberland area by forest type group, East Texas, 2006

[8] Yellow pine refers to several closely related species of pine with yellow tinted wood, mainly loblolly pine, slash pine, and shortleaf pine.

2.2 Number and Volume of Live Trees in East Texas

There are 7.6 billion live trees on timberland in East Texas that are 1.0 inch or larger in diameter at breast height, or DBH (4.5 feet above the ground). Of these, 4.1 billion are growing stock trees[9]. Total volume of live trees 5.0 inches or larger DBH on timberland is 17.2 billion cubic feet, of which 15.9 billion cubic feet are growing stock trees. Total sawtimber volume on timberland is 62.4 billion board feet.

Of all the live tree volume in East Texas, 57 percent is in Southeast Texas, and 43 percent is in Northeast Texas. Southern yellow pine accounts for 52 percent of the total live tree volume, followed by 31 percent for hard hardwood, 15 percent for soft hardwood, and 2 percent for other softwood (Figure 2.3). See Tables 2.6–2.15 for more detail about the characteristics of number and volume of live trees in East Texas.

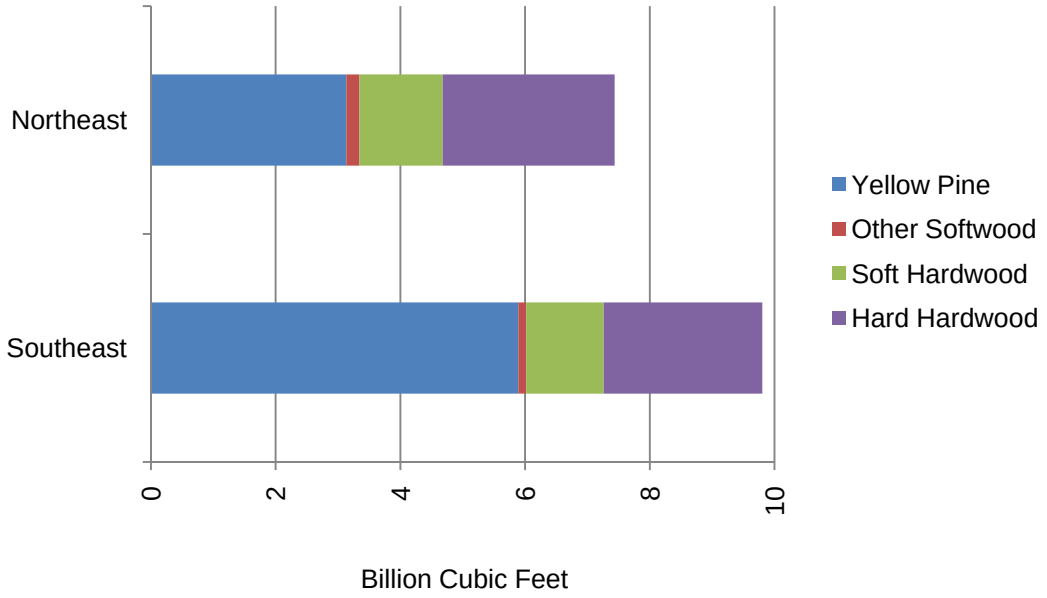

Figure 2.3 Volume of all live trees by region and species group, East Texas, 2006

2.3 Live Forest Biomass in East Texas

[9] Growing stock trees are those live trees that meet some merchantability standards. Non-growing stock trees are those trees that do not meet the standards of growing stock trees.

Standing forests in East Texas establish the basis for woody biomass potential for energy. According to FIA data, biomass of standing forests (all live forest biomass inventory) is defined as the oven dry weight of all wood and bark above a one-foot stump in all live trees that are 1.0 inch or greater in DBH and located on forestland, including all tops and limbs. It does not include stumps, foliage, seedlings, shrubs, vines, grasses, or other woody or non-woody plants. It consists of growing stock trees, cull trees[10], and small-diameter trees.

Total woody biomass of live trees in East Texas is estimated to be 472 million dry tons. Of this, 46 percent is pine, 37 percent is hard hardwood[11], 16 percent is soft hardwood, and the remaining is other softwood (Table 2.16). Figure 2.4 shows the distribution of the inventory by county.

A majority of the woody biomass, 348 million tons, is merchantable biomass, meaning biomass of the tree trunk or bole section that produces higher-valued sawlogs and pulpwood. In East Texas, 63 percent of the standing woody biomass is qualified for sawlogs, and 10 percent is pulpwood. The remaining 27 percent, or 125 million dry tons, is potential non-merchantable biomass, which includes tree tops and limbs from sawtimber and pulpwood, and small or cull trees.

Biomass of non-merchantable trees is the main potential biomass source for energy production. Biomass from tops and limbs is made available through normal timber harvesting for sawlogs and pulpwood. Biomass from whole cull and small trees is available through thinning for biomass. Since some areas of forestland are overstocked, biomass thinnings such as pre-commercial thinning and stand improvement thinning can be conducted to reduce fire hazard, reduce stand competition and improve growth of remaining trees. These biomass thinnings could be a significant source for woody biomass in East Texas (Figure 2.5). See Tables 2.16–2.18 for more details about the characteristics of biomass of live trees in East Texas.

Previous studies (e.g., Arano and Munn 2006) find ownership influences forest management practice intensity. Industrial landowners manage their lands more intensively than government and non-industrial private landowners. Sixty-one percent of the woody biomass is on land owned by individual/family, 23 percent is on land owned by TIMOs, REITs or other investors, and the remaining 15 percent is on public land.

[10] Cull trees are live trees that do not contain a sawlog due to rot, roughness, poor form, splits, or cracks. Cull trees include rough cull and rotten cull trees. Rough cull are trees that do not now, or prospectively, have at least one solid twelve-foot section, or two non-continuous eight-foot sections, reasonably free of form defect, on the merchantable bole or have 67% or more of the merchantable volume cull; and more than half of this cull is due to sound dead wood cubic-foot loss or severe form defect volume loss. Rough cull also contains trees of non-commercial species, western woodland softwoods and hardwoods, and eastern non-commercial hardwood. Rotten cull are trees with 67% or more of the merchantable volume cull, and more than 50% of this cull is due to rotten or missing cubic-foot volume loss.

[11] Please refer to Table 4.8 for a list of hard hardwood and soft hardwood species in Texas.

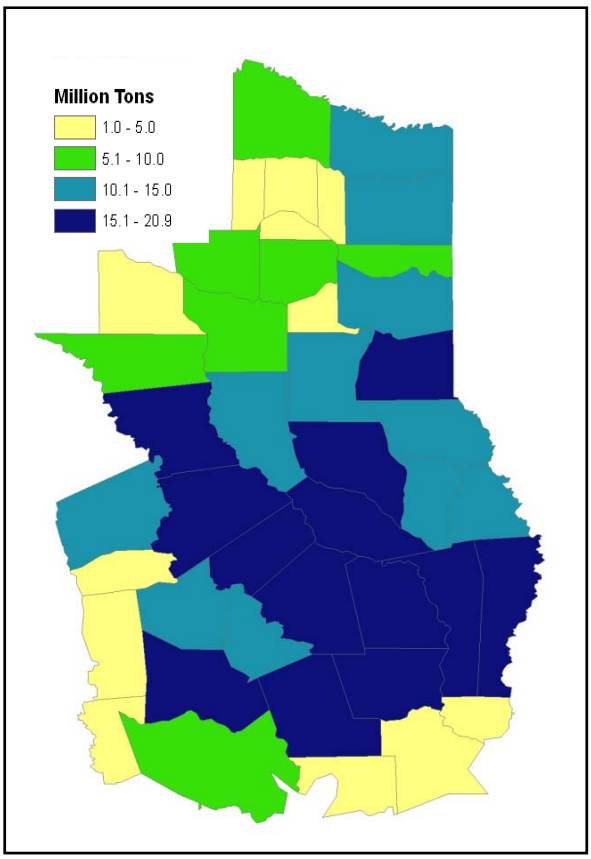

Figure 2.4 Total biomass of all live trees by county, East Texas, 2006

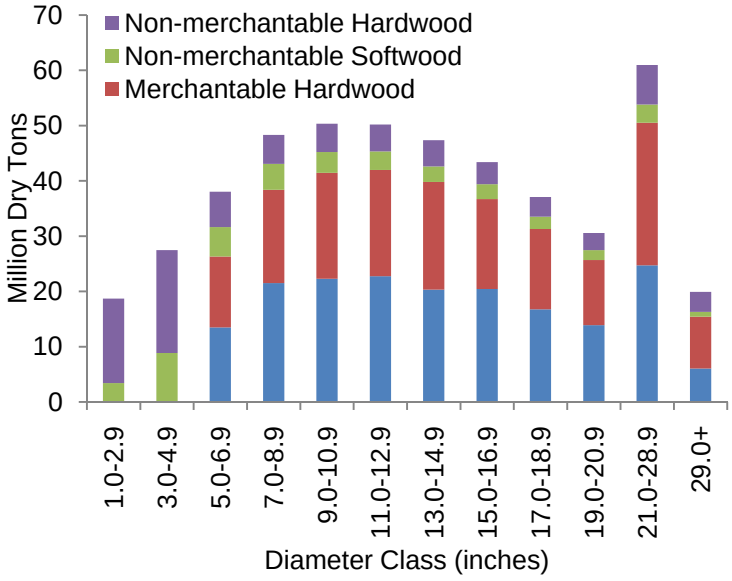

Figure 2.5 Total biomass of all live trees by diameter class, species group, and merchantability, East Texas, 2006

Forest type and stand origin are also important factors affecting forest management practices. Figure 2.6 shows percent of total biomass of live trees by forest type and stand origin in East Texas. The combination of planted pine and natural pine accounts for 48 percent of the total biomass in East Texas, mixed oak-pine forest 12 percent, and hardwood forest type 40 percent.

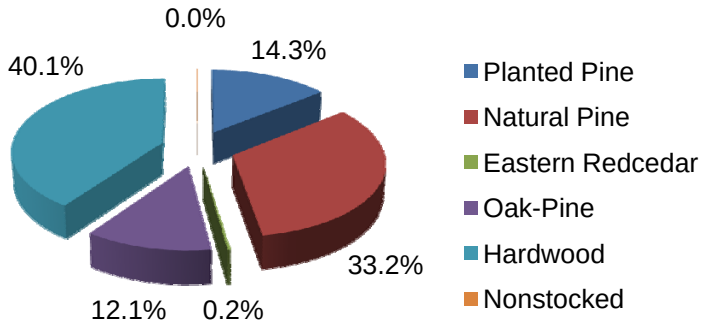

Figure 2.6 Total biomass of all live trees by forest type and stand origin, East Texas, 2006

2.4 Growth, Removal and Utilization of Forest Resources in East Texas

Forest resources are being used sustainably in East Texas. During the 2006 inventory cycle (from 2004 to 2006), substantially more growth occurred than removal of forest resources in East Texas. During the period, average net annual growth of live trees was 1.1 billion cubic feet, 38 percent higher than the average annual removal of live trees during the same period. Growth and removal comparisons for growing stock and sawtimber exhibit a similar pattern (Table 2.19). Compared to softwood, hardwood trees have a higher ratio of average net annual growth to removals (Table 2.20–2.21). The excess growth of forest resources in East Texas provides a potential woody biomass feedstock for energy production and other forest products.

The wood-based industry was one of the top 10 manufacturing sectors in the state in 2006. Forest products industry in East Texas manufactured 1.9 million board feet of lumber, 2.9 million square feet of plywood and OSB, and 2.8 million tons of paper and paperboard (Xu 2007). To make these products, the industry consumed 648.3 million cubic feet of industrial roundwood, of which 37 percent was used to make lumber, 28 percent was used to make plywood and OSB, and 34 percent was used to make paper and paperboard (Figure 2.7).

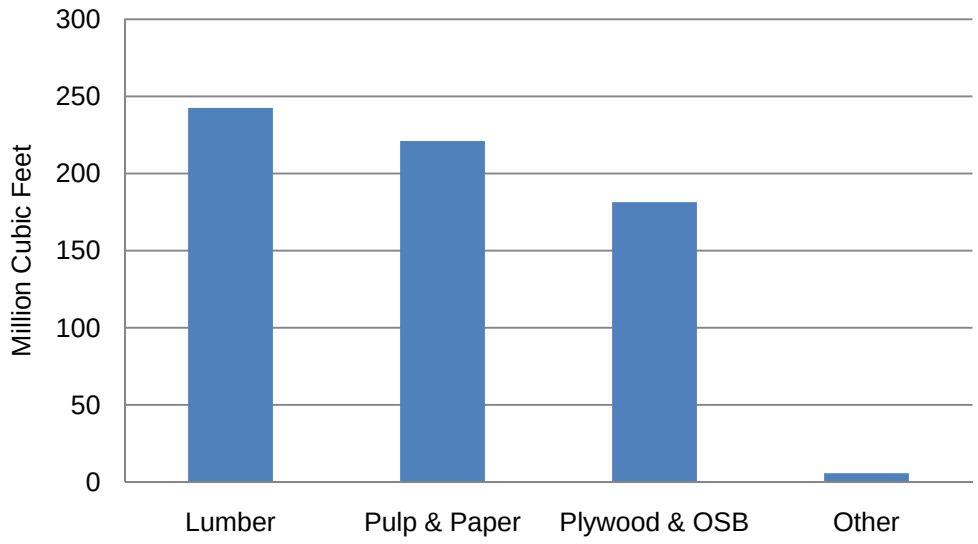

Figure 2.7 Industrial roundwood consumption by primary products, East Texas, 2006

For decades the forest products industry in East Texas has met a portion of its energy requirements by combusting woody biomass. This woody biomass consists primarily of mill residue in the form of chips, sawdust, shavings and bark. This practice continues today with lower value mill residue being burned in boilers to produce steam to power various aspects of the forest products manufacturing processes. Larger-scale operations such as pulp and paper mills also commonly co-generate electricity using woody biomass-fired boilers coupled to steam turbines.

In recent years these facilities have expanded their woody biomass acquisition activities to include additional sources of supply such as logging residue, storm-damaged wood, urban waste wood and even some non-woody sources of biomass. The expansion in utilization of woody biomass for energy has in part been accelerated by rising energy prices, especially for natural gas.

Based on a recent survey of major woody biomass-using companies in East Texas[12], the 2006 consumption of logging residue and storm-damaged wood was found to be approximately 68,000 dry tons. In 2007 approximately 233,000 dry tons of wood materials were acquired from Texas lands and utilized by the major woody biomass-using companies located in Texas or adjacent to the Texas border in Louisiana, Arkansas and Oklahoma. Also, some smaller biomass using facilities both in Texas and located adjacent to the Texas border that are not included in this survey may consume nominal amounts of logging residue and storm damaged wood.

[12] Dr. Edward Dougal of Texas Forest Service conducted the woody biomass consumption survey.

CHAPTER 3. FOREST RESOURCES IN CENTRAL TEXAS

3.1 Forestland Area in Central Texas

Texas Forest Service and USDA Forest Service began implementation of the Forest Inventory and Analysis (FIA) program on permanent forest plots in Central and West Texas in January 2004. Each 10-year inventory cycle has 10 panels of plots, with each annual panel containing 10 percent of the total plots. All forest resource data about Central Texas in this study are based on the first three panels of inventory data in the region. Estimates may change as more data are collected and analyzed.

According to these preliminary FIA data, using the current definition of forestland, the 64-county Central Texas region has 18.3 million acres of forestland. Compared to forestland in East Texas, the productivity of Central Texas forestland is substantially lower. Only 12.5 percent of forestland in Central Texas is classified as timberland. The majority of forestland in the region (88%) is classified as unproductive with low site productivity (Figure 3.1). Of the 18.3 million acres of forestland in Central Texas, 95 percent is held by private landowners and 5 percent belongs to federal, state or local governments (Table 3.1).

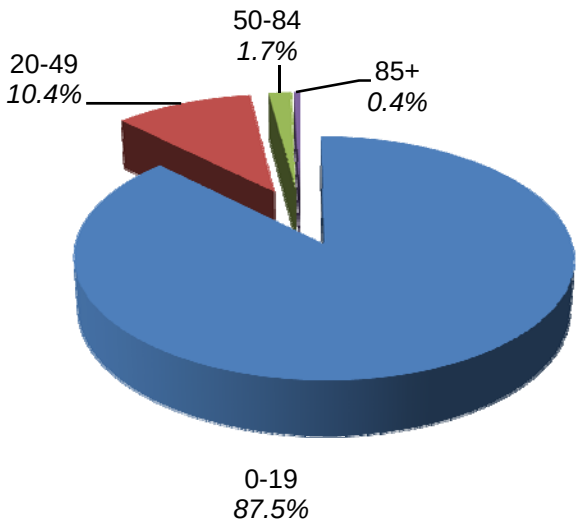

Figure 3.1 Forestland by site productivity index, Central Texas, 2006

Forest types and their distribution in Central Texas are distinctly different from those of East Texas. Oak forest types, including oak/pine, oak/hickory, and oak/gum/cypress cover 46 percent of the forestland in Central Texas. Pinyon/juniper forest type covers 24 percent of forestland in

the region, followed by 11 percent for mesquite woodland. Other hardwood forest represents eight percent. Southern yellow pine covers 0.3 percent of the forestland. The remaining around 10 percent is classified as non-stocked forest type[13] (Figure 3.2).

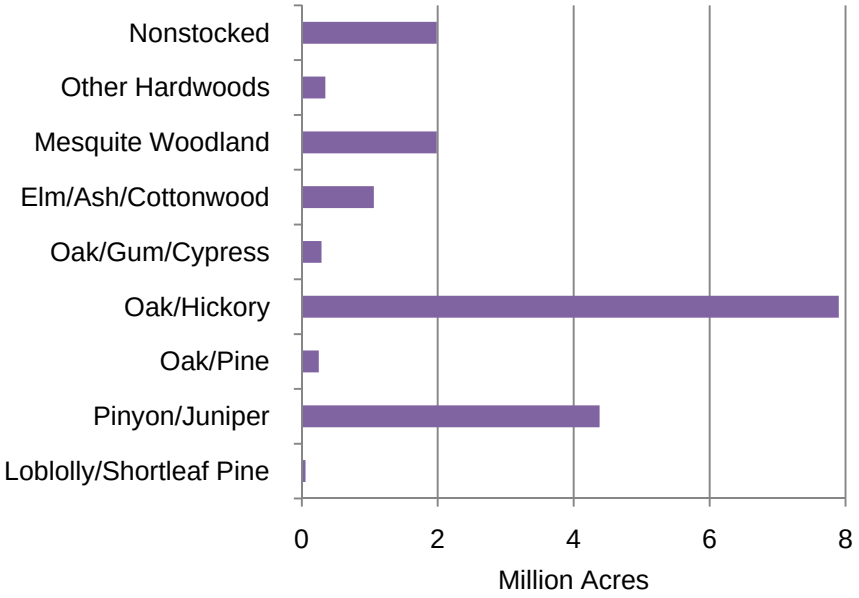

Figure 3.2 Forestland area by forest type group, Central Texas, 2006

The Central Texas forest region is divided into three sub-regions: Post Oak, Blacklands, and Hill Country. Distribution of forest type varies across sub-regions in Central Texas. Softwood (mainly juniper), oak/hickory, and mesquite are more concentrated in the Hill Country sub-region. Oak/pine, oak/gum/cypress, and elm/ash/cottonwood are concentrated in the Blacklands and Post Oak sub-regions. Forestland in the Hill Country sub-region and the Blacklands sub-region shares similar patterns of forest type distribution, with approximately 60 percent covered by hardwood and 30 percent by softwood. However, the Post Oak sub-region is mainly composed of hardwood. Table 3.2 shows area of forestland by forest type group, ownership and sub-region.

Forestland in Central Texas is roughly evenly distributed among large, medium, and small-diameter stand classes, each accounting for around 30 percent. Table 3.3 presents area of forestland by forest type group and stand size class. The pattern differs across forest type groups.

[13] Meeting the definition of accessible land and one of the following applied (1) less than 10% stocked by trees of any size, and not classified as cover trees, or (2) for several western woodland species where stocking standards are not available, less than 5% crown cover of trees of any size.

Forty percent of the softwood forestland is dominated by large-diameter[14] trees while 29 percent is dominated by small-diameter trees. On the other hand, 37 percent of the hardwood forestland is small-diameter tree dominated while only 29 percent is large-diameter tree dominated (Table 3.3).

3.2 Number and Volume of Live Trees in Central Texas

In Tables 3.4–3.11, hardwood species are listed in more detail than for East Texas. Since species like juniper (cedar) and mesquite do not usually grow into medium or large trees in Central Texas, categorizing hardwood species only as soft hardwood and hard hardwood is not sufficient to differentiate these hardwoods. In Chapter 5, a survey of ranchers classified Central Texas species into desirable and undesirable categories, based on willingness to keep those species on their lands. The classification of tree species group in Tables 3.4–3.11 is listed in Figure 3.3.

Desirable species group	Pine, Oak, Elm, Pecan, Ash, Cottonwood, Hickory, Black Cherry, Walnut
Undesirable species group	Juniper (cedar), Mesquite, Sugarberry, Sweet Acacia, Hackberry, Osage-Orange, Persimmon, Chinese Tallow, Chittamwood, Locust, Other Hardwood

Figure 3.3 Tree species group by desirability, Central Texas, 2006

There are 5.9 billion live trees on forestland in Central Texas (Table 3.4). Of these, 92 percent are on private land, and 8 percent are on public land. In the Hill Country and Blacklands sub-region, softwood (mainly juniper) and hardwood each account for about 50 percent of the total trees.

Small-diameter trees make up 72 percent of the 5.9 billion live trees. Of these, 70 percent have a diameter of less than 3.0 inches (Table 3.5).

Growing stock trees on timberland account for only four percent of total live trees on forestland in Central Texas. Table 3.6 shows the distribution by diameter class and species group. Juniper

[14] According to FIA, large-diameter trees are at least 11.0 inches diameter for hardwoods, and at least 9.0 inches diameter for softwoods. Small-diameter trees are less than 5.0 inches diameter. Medium-diameter trees are at least 5.0 inches diameter but not as large as large diameter trees.

(cedar), considered an undesirable species, accounts for 65 percent of total softwood trees, predominantly in the small-diameter class. This suggests a potential source of wood waste for energy.

Net volume of all live trees on forestland in Central Texas is estimated to be 8.0 billion cubic feet (Table 3.7). Eleven percent of the volume, or 905.2 million cubic feet, is from timberland (Table 3.8). Sawtimber trees on timberland are estimated to be able to produce 2.5 billion board feet of lumber (Table 3.9).

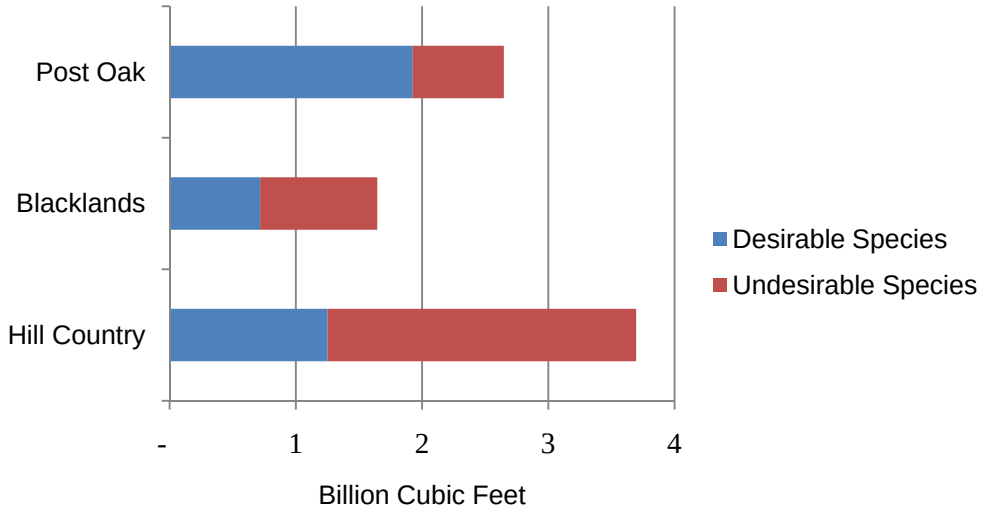

Figure 3.4 Volume of all live trees by region and species group, Central Texas, 2006

3.3 Live Forest Biomass in Central Texas

According to FIA, total biomass of all live trees in the Central Texas region is 204 million dry tons (Table 3.10). Ninety-four percent (191 million dry tons) is from private forestland and six percent is from public forestland. Desirable species compose 115 million dry tons of biomass, or 57 percent of the total in the region. Based on the landowner survey, 88 million dry tons of biomass, or 43 percent of the total woody biomass in the region, are from undesirable species (Figure 3.5).

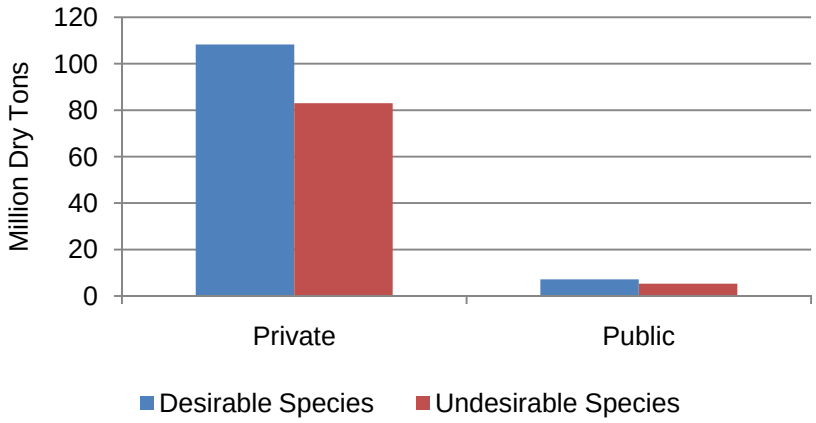

Figure 3.5 Total biomass of all live trees by ownership group and species group, Central Texas, 2006

Figure 3.6 describes total biomass of live trees by county. The Hill Country sub-region has 42 percent of the total biomass in Central Texas. The Post Oak sub-region has 39 percent and the Blacklands sub-region has 19 percent. Softwood (mainly juniper) accounts for 21 percent of the total private woody biomass while hardwood accounts for 79 percent (oaks 43%, mesquite 15%, other hardwood 21%). This pattern is roughly the same for the Hill Country sub-region and the Blacklands sub-region. The Post Oak sub-region has significantly higher percentage of hardwood (91%) and lower percentage of softwood (9%).

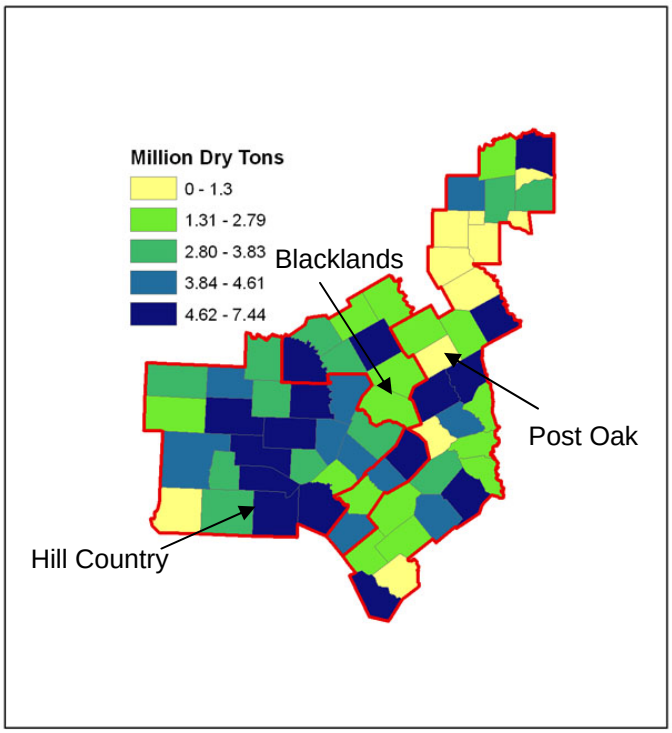

Figure 3.6 Total biomass of all live trees by county, Central Texas, 2006

Biomass from merchantable trees is estimated to be 145 million dry tons, or 71 percent of total woody biomass in Central Texas (Table 3.11). Non-merchantable trees produce 58 million dry tons of woody biomass. Ninety percent, or 130 million dry tons, of the biomass from merchantable trees is classified as pulpwood, and only ten percent is classified as sawlog. Ninety percent of the biomass from non-merchantable trees is hardwood, of which 45 percent is from oaks and 19 percent is from mesquite.

Figure 3.7 describes total biomass of all live trees by diameter class, species group, and merchantability in Central Texas. Among the four groups in the figure, non-merchantable undesirable species has the highest potential for energy. Second highest would be merchantable undesirable species, followed by non-merchantable desirable species. Biomass from trees in the three groups accounts for 60 percent of the total biomass in Central Texas. Merchantable desirable species is the least likely source of biomass among the four groups for energy, accounting for 40 percent of the total biomass in Central Texas. However, it is still possible to use at least a portion of the biomass of merchantable desirable species for energy since a developed wood-processing industry does not exist in Central Texas for other primary wood products, especially for pulpwood size trees. Biomass of all non-merchantable trees and merchantable trees that are less than sawtimber size is 57 percent of the total biomass in Central Texas. Biomass of the first three groups of trees plus merchantable desirable species trees that are less than sawtimber size is 76 percent of the total biomass in Central Texas.

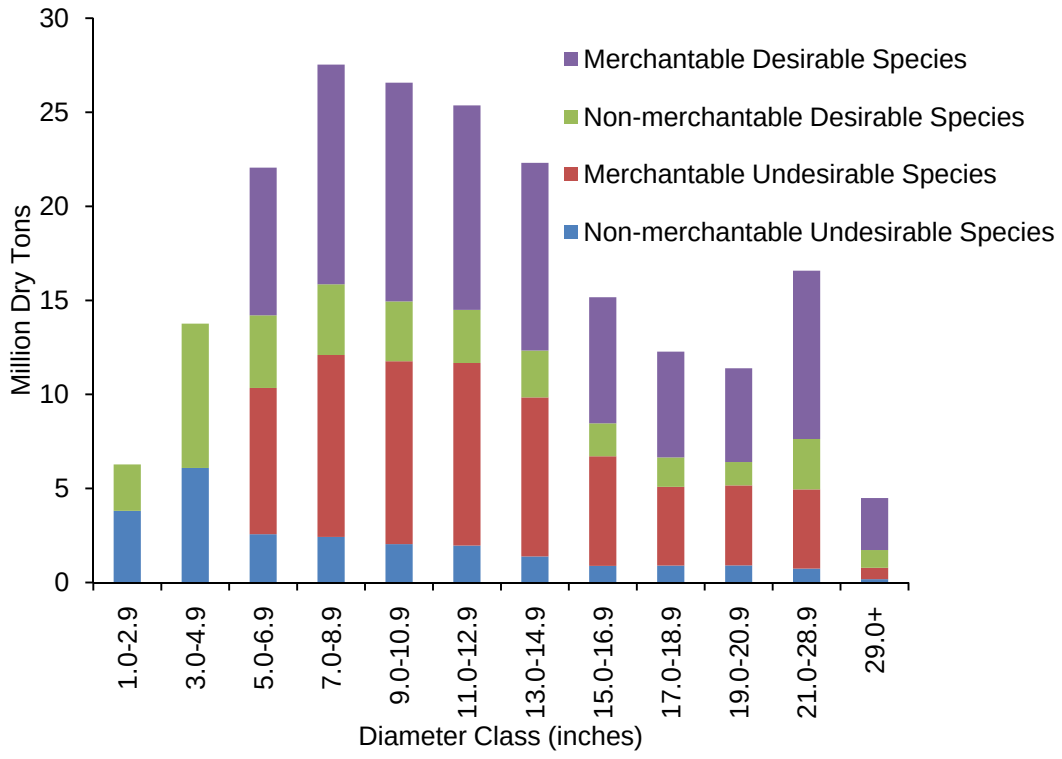

Figure 3.7 Total biomass of all live trees by diameter class, species group, and merchantability, Central Texas, 2006

3.4 Growth, Removal and Utilization of Forest Resources in Central Texas

The forest resource change information, such as growth and removal, in the FIA program is estimated by comparing the same field inventory plots at time 1 with time 2. Since this is the first inventory cycle that has ever been conducted in Central Texas, no forest resource change information is yet available from the FIA program in Central Texas. There is no systematic information about growth and removal of forest resources in the region from any other sources.

A well-developed primary wood-processing industry does not exist in Central Texas. Trees in the region exhibit relatively slow growth compared to East Texas due to soil type and low rainfall. Many trees in the region grow in poor form and smaller size. There is no sustainable quality timber supply in a concentrated area in the region to support a lumber, panel, or pulp and paper operation at an efficient scale. Most of the existing wood-processing facilities in the region are specialty mills for such products as aromatic wood or oil, fence posts, or mesquite firewood.

Although there is little commercial timber harvest, landowners do remove all or part of the trees on their land in Central Texas for several reasons. The primary reason for tree cutting is for ranchers to clear excess trees to open more space for raising livestock or producing hay. Species such as Ashe juniper, red-berry juniper and mesquite are very invasive in the area. Although ranches need some trees and shrubs for wildlife management and for livestock shading, periodic clearing of these excess invasive woody species is often necessary to maintain productive ranches. Studies (Griffin and McCarl 1989, Thurow and Hester 1997, Redeker 1998) have shown that clearing shrubs in Central Texas enhances water flow in local rivers. Both state and federal governments have incentive programs in the region to encourage landowners to clear shrubs for water conservation. Still another reason for removing trees in the region is converting lands to agriculture uses, real estate, or other purposes.

Regardless of the reasons for tree removal in Central Texas, most biomass harvested in the region remains unused. It usually incurs substantial cost to landowners to either burn it or dispose of it in other ways.

CHAPTER 4. WOODY BIOMASS POTENTIALLY AVAILABLE FOR ENERGY IN EAST TEXAS

4.1 Logging Residue

4.1.1 Definition of Logging Residue

Logging residue in this study includes tops, limbs, and unutilized cull trees. *Stumps*, the parts of trees that are lower than the cutting point and thus left after the harvesting operation, are not included in this study, since the cost of obtaining stump biomass is likely prohibitive. *Tops* refer to the tops of trees that are either broken during harvesting or are cut off the central stem of the tree due to a merchantability standard. *Limbs* refer to the branches of trees. *Cull trees* are trees that cannot be used to produce sawlogs due to defects, rot, or form. Some cull trees are used as pulpwood and others are left unutilized as a part of logging residue. Tops, limbs, and unutilized cull trees are the logging residue that is potentially available as biomass for energy or chemical extraction.

4.1.2 Estimation of Logging Residue

Estimation of logging residue is based on a wood utilization study by Bentley and Johnson (2004) and an annual mill survey conducted by Texas Forest Service (Xu 2006).

The forests of East Texas support a large and diverse forest products manufacturing sector. The primary manufacturing sector includes those manufacturing industries that utilize roundwood as raw material. Major primary wood products include lumber, structural panel products, and pulp and paper products.

East Texas sawmills produced 1.9 million board feet of lumber in 2006, 87 percent from softwood and 13 percent from hardwood. Production of structural panels, including plywood and OSB, was 2.9 million square feet (3/8 inch basis) in 2006. Paperboard production totaled 2.8 million tons in 2006. There was no paper or market pulp production in Texas in 2006.

Industrial roundwood harvest, the portion of total removed trees that was subsequently utilized in the manufacture of wood products, totaled 500 and 148 million cubic feet for pine and hardwood, respectively. Ninety-five percent of the industrial roundwood was from growing stock and five percent was from non-growing stock in 2006. Table 4.1 presents industrial timber harvest volume by county in East Texas, 2006.

Harvest of sawlogs for lumber production totaled 1.5 billion board feet, or 38 percent of the total timber harvest. Of these, softwood sawlogs accounted for 80 percent and hardwood sawlogs accounted for 20 percent. Harvest of timber for structural panel production was 181million cubic

feet in 2006, accounting for 28 percent of total timber harvest for the year. Harvest of timber for pulp and paper products was 2.5 million cords, accounting for 34 percent of the total timber harvest. Figure 4.1 illustrates timber harvest volume by species group and wood type group. Figure 4.2 shows intensity of timber harvest expressed in cubic feet of harvest per acre of timberland in East Texas.

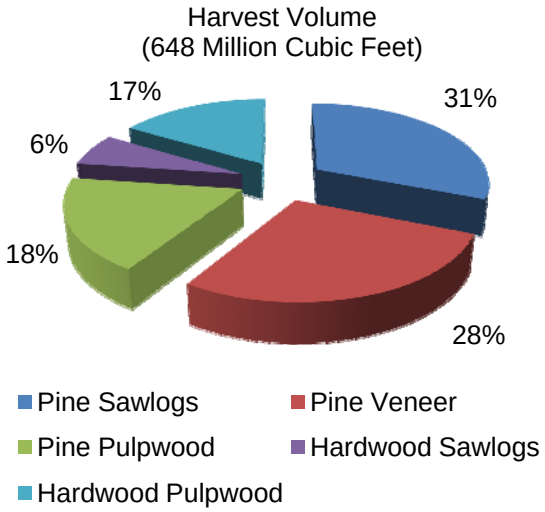

Figure 4.1 Volume of timber harvest by species group and wood type group, East Texas, 2006

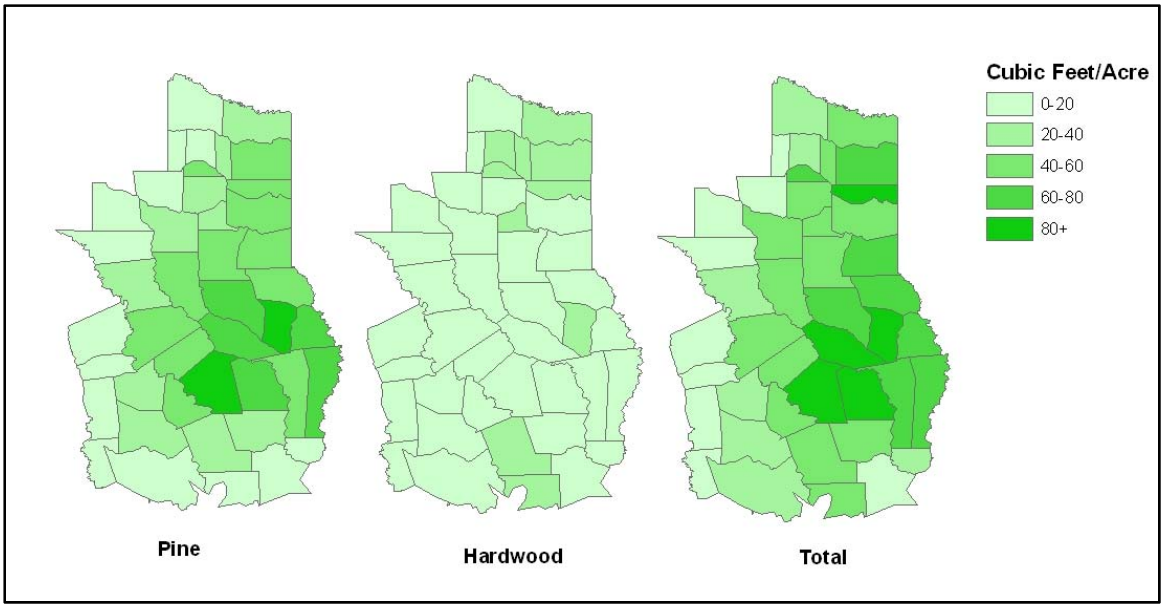

Figure 4.2 Intensity of timber harvest by county, East Texas, 2006

The wood utilization study by Bentley and Johnson (2004) characterizes harvest operations in East Texas and quantifies timber volume that is cut and utilized, as well as the portion that is left

in the forest after harvesting. The utilization rates are calculated by species group, logging residue source, and wood type. Table 4.2 presents the utilization rates used in the study.

Volume of industrial roundwood harvest in 2006 was queried from an annual mill survey conducted by Texas Forest Service. The industrial roundwood harvest is classified by county, species group, and major wood type. Based on the wood utilization rates above, volumes of tops/limbs and cull trees were estimated accordingly. The volumes were then converted to tons using conversion factors derived from FIA.

Table 4.3 estimates logging residue potentially available for energy. Total logging residue potentially available for energy in 2006 was 1.5 million dry tons, 63 percent from softwood and 37 percent from hardwood. Northeast and Southeast Texas each accounted for roughly 50 percent of the total logging residue available. Top/limbs were the largest source of logging residue, accounting for 58 percent of the total.

Table 4.4 estimates logging residue potentially available for energy by county, species group and source. Polk, Tyler, Newton, Cass, and Nacogdoches are the top five producing counties of logging residue for energy generation in East Texas. Figure 4.3 displays geographic distribution of logging residue potentially available for energy.

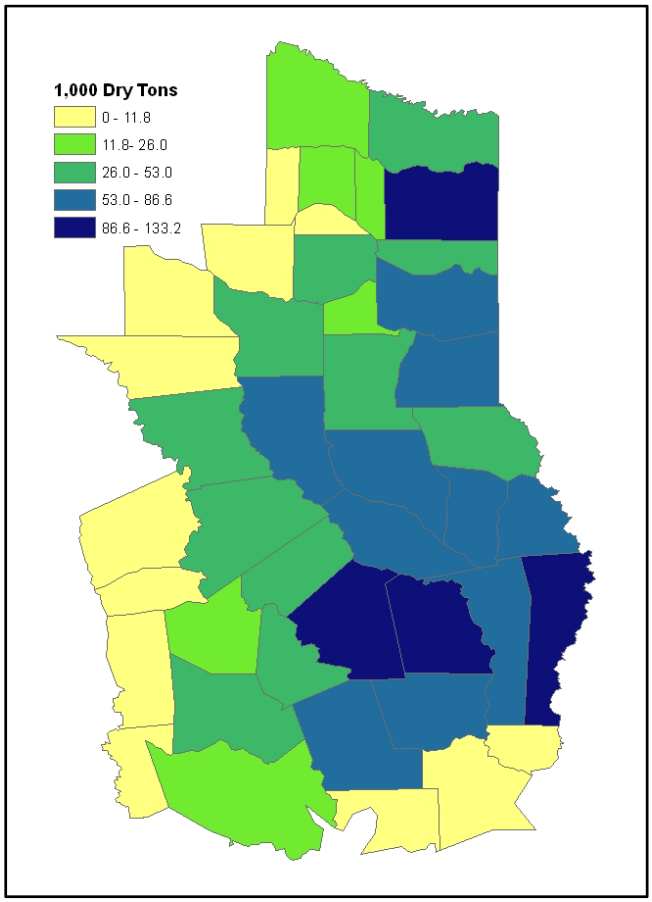

Figure 4.3 Geographic distribution of logging residue potentially available for energy, East Texas, 2006

4.2 Woody Biomass from Biomass Thinning

Intensive forest management practices such as pre-commercial thinning and timber stand improvement (TSI) thinning are other important potential sources of wood waste in East Texas. Pre-commercial thinning and TSI thinning are referred to as biomass thinning in this study. Forest wood waste from biomass thinning is estimated based on 2006 FIA data, a biomass thinning survey conducted by Texas Forest Service, and computer simulations of stand growth and management using the USDA Forest Service growth model Forest Vegetation Simulator (FVS) (Dixon 2007).

Initial forestland condition and biomass volume in East Texas were identified from FIA data. A biomass thinning survey of forestry consultants and loggers in East Texas was conducted to better understand current and potential biomass thinning practices in East Texas. Several thinning and management regimes were developed based on the returned surveys.

Finally, FVS was used to simulate stand growth and development and estimate volumes of potential biomass removal under various thinning and management regimes over the period of 2006–2015. FVS is a computer simulation model widely used in research on forest and ecosystem management (Dixon 2007). It is an individual-tree, distance-independent growth and yield model (Crookston 1997). The core of FVS is an individual tree model. Linked to the core are modules that simulate regeneration, mortality, and various management activities and produce reports on stand structure prediction and forest products estimation. Its regionally calibrated growth and yield models produce estimations based on localized biological and geographical conditions. The fire and fuel extension can be used to estimate biomass volume associated with various forest management regimes.

Potential woody biomass removals resulting from the simulation are summarized by forest type and county. The wood waste volumes are also partitioned into woody biomass from dead and cull trees, crowns and limbs of growing stock timber, and small-diameter trees. An annual estimate of wood waste from biomass thinning was also developed.

4.2.1 Definition of Pre-commercial and Timber Stand Improvement Thinning

Pre-commercial thinning of young stands removes excess sapling-sized trees to improve growing conditions for the remaining trees. Pre-commercial thinning is usually an expense for the landowner and does not provide income to cover the cost of thinning.

TSI thinning improves the composition, structure, condition, health and productivity of forest stands. TSI thinning usually removes poorly-formed, diseased, dying or cull trees on forest stands, and opens up the canopy to release trees of desirable species in the understory, allowing crop trees to grow more quickly in diameter and improving the quality of sawlogs on future crop trees. Pine bark beetle and wildlife hazard are also reduced after TSI thinnings. Other TSI activities such as prescribed burning, chemical release, and pruning are not included in this analysis.

Three major thinning methods exist: row thinning, thinning from below, and selective thinning. Row thinning removes trees in rows or strips at fixed spacing intervals throughout the stand. Row thinning is relatively efficient and commonly applied to young stands that are densely crowded and have a relatively uniform crown class. Most pre-commercial thinnings are accomplished by row thinning. Thinning from below removes small (intermediate and co-dominant crown position) trees to favor the larger, higher quality trees in the upper crown classes. Selective thinning removes certain trees based on their characteristics, spacing, and other considerations. It provides more flexibility than other thinning methods but could be more costly to implement depending on the conditions of the stands. TSI thinnings may adopt one or a combination of thinning methods.

4.2.2 Biomass Thinning Survey

To estimate potential woody biomass available from biomass thinnings, it is necessary to understand current pre-commercial thinning and TSI activities as well as potential changes if more mature woody biomass markets emerge in East Texas. To facilitate this, a biomass thinning survey was mailed to 348 forestry consultants and loggers in East Texas.

Consistent with Dillman (1978), a reminder postcard was mailed one week after the first mailing and a second questionnaire was mailed six weeks later. A total of 77 surveys were returned, yielding a 22 percent response rate. Ten cases were dropped due to missing data, resulting in a usable sample of 67.

The practice area reported by the 67 respondents covers all counties in East Texas, suggesting that the results are suitable to be applied to the entire region. Results showed that 91 percent of the wood waste from thinning and stand improvement is left on site to decompose. Seven percent is burned on site and the remaining 2 percent is sold for firewood or other uses. This indicated that biomass thinning could be a potential source of feedstock for woody bioenergy production.

Furthermore, the survey asked a series of questions about timing, intensity, and type of current biomass thinning and potential changes with an existing woody biomass market. In particular, the survey asked about current first thinning operations specifically to distinguish pre-commercial thinnings from commercial thinnings. The survey results indicated biomass thinning practices vary by forest type and stand origin.

There are three major forest types in East Texas: pine, hardwood, and mixed[15]. Pine forest type can be either naturally regenerated or planted. Hardwood and mixed forest types are largely naturally generated. Four categories of forest type are used for the purpose of this study: natural pine, pine plantation, hardwood, and mixed.

[15] Pine stands include all forest areas in which pine and other softwood make up more than two-thirds of the trees free to grow. Hardwood stands include all forest area where hardwoods are more than two-thirds of the trees free to grow. Mixed stands are forests where pine and other softwood and hardwood each make up more than one-third of the trees.

For natural pine stands, the survey showed that first thinning occurs around age 18 on average, with a minimum thinning age of 8. Besides stand age, another important criterion is stand basal area (BA). A measure of stand density, BA is the total cross-sectional area of trees in a stand at breast height (4.5 feet above the ground), measured in square feet per acre (ft^2/acre). The survey results indicated that first thinnings are usually conducted when BA of natural pine stands reaches 130 ft^2/acre. The BA is reduced to 75 ft^2/acre after first thinnings. Thinning from below is the most common practice for natural pine stands, accounting for 58 percent of the cases. Row thinning accounts for 22 percent and selective thinning 20 percent.

Compared to natural pine stands, first thinnings on pine plantations occur earlier, at age 15 on average, while the minimum thinning age is 8. Average starting BA (130 ft^2/acre) and target BA (75 ft^2/acre) are the same as first thinnings on natural pine. However, row thinning is the major method. The survey showed that around 80 percent of the cases are row thinning, 15 percent are thinning from below, and 5 percent are selective thinning. This is because pine plantation stands are normally densely stocked and have a relatively uniform crown class.

For hardwood stands, first thinning occurs when the stand age reaches 27 on average, while the minimum thinning age is 14. The survey results showed that average starting BA is 100 ft^2/acre and average target BA is 70 ft^2/acre. Thinning from below is shown to be the major thinning method for hardwood stands. Survey results showed that 64 percent of the cases are thinning from below, 30 percent are selective thinning, and 6 percent are row thinning.

For mixed stands, first thinning occurs when their age reaches 20, while the minimum thinning age is 8. Survey results showed starting BA of 115 ft^2/acre and target BA of 70 ft^2/acre on average. Thinning from below is the major thinning method for mixed stands, accounting for 74 percent of the cases while selective thinning accounts for 21 percent and row thinning accounts for 5 percent.

The interval between first thinning and second thinning differs by forest type category. The survey suggested an interval of seven years between first thinning and second thinning for natural pine stands. The intervals are 6 years for pine plantation stands, 10 years for hardwood stands, and 8 years for mixed stands on average.

The median final harvest age for natural pine was shown to be 40 years. Final harvest age was 35 years for pine plantation stands, 50 years for hardwood stands, and 45 years for mixed stands.

Table 4.5 summarizes some of the survey results on thinnings.

Regarding current TSI practices, the survey indicated that thinning and removal of cull trees, dead trees, and small-diameter trees account for 57 percent of the total TSI practices in the region. Prescribed burning accounts for 11 percent, chemical release accounts for 27 percent, and other TSI practices account for 5 percent. Meanwhile, when a hypothetical $10/green ton biomass market exists, the survey indicated a higher proportion of thinning practice (69%), and lower proportion of prescribed burning (8%), and chemical release (18%).

Survey respondents were asked to check undesirable species from a list of common tree species in East Texas (Table 4.6). Undesirable species are defined as species that would be removed or

are less likely to be kept in a TSI thinning operation. Chinese tallow, sweet gum, sugarberry, blackjack oak, cedar elm, black gum, American elm, river birch, red maple, and black hickory are among the undesirable species. Most oaks were noted as desirable species.

The survey provided an understanding of current and potential biomass thinning practices for wood waste production in East Texas. Several thinning and management regimes were developed based on the survey results.

4.2.3 Biomass Thinning Simulation

A total of 2,279 FVS-modeled stands representing all private timberland in East Texas were generated from 2006 FIA data for this analysis. Among these FVS stands, 604 stands were located within 50 feet of a water source, which would fall within a Streamside Management Zone (SMZ) based on industry-standard Forestry Best Management Practices (BMP) guidelines in Texas. These stands were excluded from this analysis because of the potential harvest restrictions. A total of 1,675 stands, representing 8.3 million acres, or 76 percent of all private timberland in East Texas, were included in this analysis (Table 4.7).

These FVS stands were imported into the Southern variant of the FVS to predict potential biomass harvested from thinnings in East Texas. The FVS stands include both stand and tree information. Stand information includes forest type, location, ownership, size, and site productivity. Tree information in the form of tree list data includes field measurements and estimates of diameter, height, crown ratio, and species.

4.2.3.1 Three thinning scenarios

Three thinning regime scenarios were developed incorporating the biomass thinning survey results. The analysis was accomplished by running these scenarios over a 10-year (2006–2015) projection period to capture the dynamic aspects of timber stands over time. An average annual biomass estimate was developed by dividing the 10-year total biomass by 10.

Base Scenario: The Base Scenario provides a moderate estimation of wood waste from biomass thinnings in East Texas. It has the following starting conditions for each of the four forest type categories:

- Thinning ages greater than or equal to the minimum starting ages in Table 4.5 and at least 5 years earlier than the final harvest ages in Table 4.5.
- Thinning BAs greater than the starting BAs in Table 4.5.

The thinning procedure in the base scenario for natural pine, mixed, and hardwood stands is:

- Remove all cull trees and dead trees. This procedure should cover wood waste available from wood damaged by storms and other natural disasters. In reality, some cull trees may be left in stands. However, considering small portion of these trees, the impact on estimation of woody biomass from thinnings is limited.

- Check BAs after the removal. If BAs are still greater than the target BAs in Table 4.5, remove all undesirable species. The list of desirable and undesirable species was derived from survey results. Table 4.8 shows the full list of desirable and undesirable species.
- Check BAs again after the subsequent removal. If BAs are still greater than the target BAs in Table 4.5, thin from below to target BAs.

Since row thinning is a common practice for pine plantations, a 20 percent row thinning (removal of every 5th row) was applied before thinning from below. The rest of the thinning procedure is the same as the other forest type categories. Figure 4.4 visually illustrates the effects of a thinning prescription on a sample pine plantation. Figure 4.4a shows the initial stand; Figure 4.4b shows the stand after removal of dead trees, cull trees, and undesirable species; Figure 4.4c shows the stand after 20 percent row thinning; and Figure 4.4d shows the stand after thinning from below to the target BA.

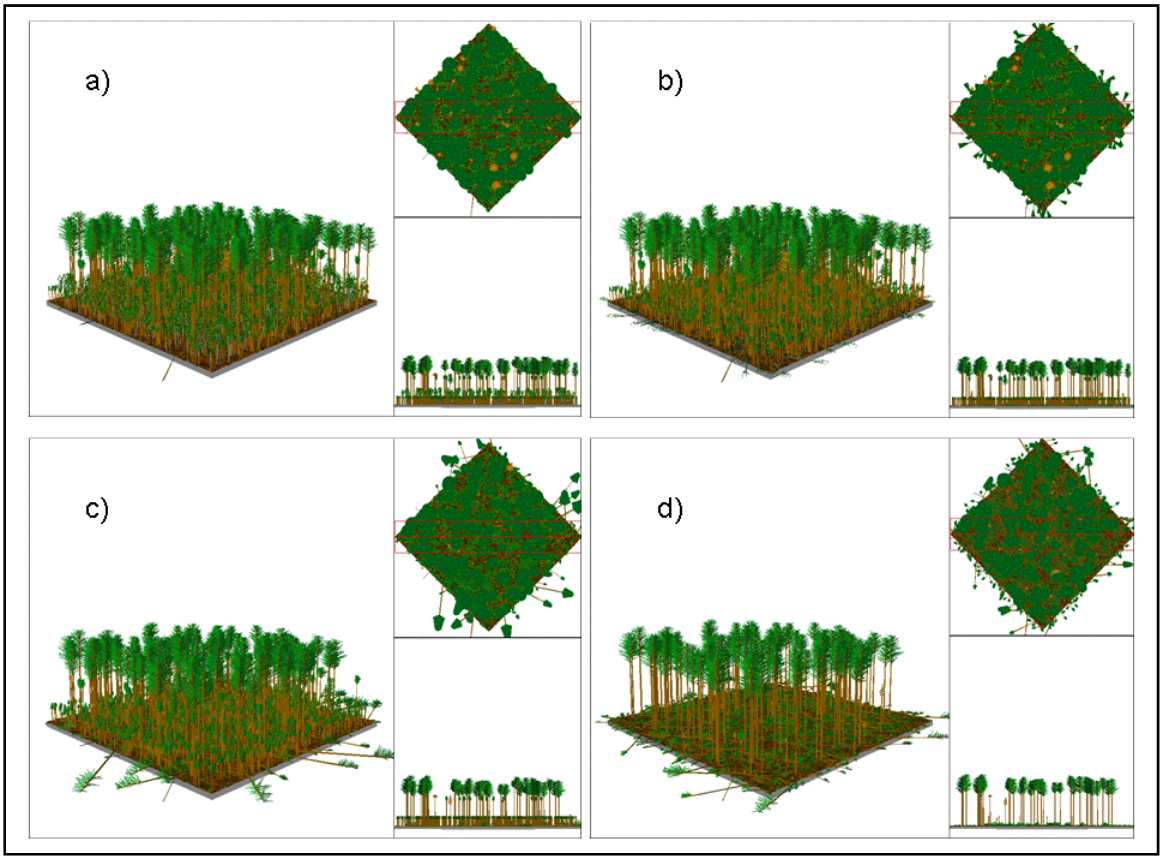

Figure 4.4 Visual display of thinning prescription on a sample pine plantation stand

After the first thinning, each stand was evaluated each year for the average year interval between the first and second thinning in Table 4.5. If a stand satisfied the interval condition, it was evaluated against the thinning age and basal area conditions above. Stands that satisfied all these conditions were thinned again as prescribed above. Since the simulation lasts for only 10 years, there were a maximum of two thinnings on each stand.

Alternative Scenario I: This scenario estimates the maximum potential for generating woody biomass from thinnings. It applies the same prescription as in the Base Scenario except that it allows a wider range of age classes for stands qualified for biomass thinning and thus generates higher estimates of wood waste than the Base Scenario.

Alternative Scenario II: This scenario is a conservative estimation of woody biomass availability. It applies the same prescription as in the Base Scenario except that the thinning starting age is changed to the average starting age in Table 4.5 in this scenario. This scenario narrows the age range of stands qualified for biomass thinning and thus generates more conservative estimates of wood waste than the Base Scenario.

In this study, all eligible trees were assumed to be thinned. All cut stems and branches were assumed to be removed from the stand (FVS YARDLOSS keyword). Note that this may not be realistic in the real world. Weights of tree bole and crown biomass for growing stock and non-growing stock trees removed from FIA plots by the prescribed thinnings were computed through a tree biomass function of the Fire and Fuels Extension (FFE) component of FVS (TREEBIO function). For this study, wood waste includes crown biomass of merchantable logs and above-ground tree bole and crown of non-growing stock trees and dead trees. Crown biomass estimates include material from foliage or needles and limbs.

The FFE uses an FVS routine to determine the volume of wood in each bole (Reinhardt and Crookston 2003). The resulting bole volumes are then converted to biomass using wood density values given by Brown *et al.* (1977). The FFE estimates the amount of crown material on each tree using the equations in Brown and Johnston (1976). Refer to Reinhardt and Crookston (2003) for technical specifics.

Annual wood waste estimates are summarized by sources (dead, growing stock, and non-growing stock trees) and major species group (softwood and hardwood). All weights are in dry tons.

4.2.3.2 Adjusting for biomass from existing thinnings

Annual wood waste estimates from the simulation include biomass potential from biomass thinnings as well as regular thinnings. To avoid double counting of logging residue that has already been analyzed in Section 4.1.2, it is necessary to subtract wood waste of regular thinnings from potential wood waste of biomass thinnings. This adjustment is done by applying the ratio of wood waste against industrial roundwood production from the analysis of logging residue in section 4.1.2 to industrial roundwood from simulated thinnings as in Equation 4.1

$$SE_{ij} = SM_{ij} - SC_{ij} = SM_{ij} - IM_{ij} \times r_j = SM_{ij} - IM_{ij} \times \frac{ST_j}{IT_j} \qquad (4.1)$$

In Equation 4.1, SE_{ij} denotes extra wood waste from a biomass thinning for stand i and species group j (j is either softwood or hardwood). SM_{ij} denotes total wood waste from a biomass thinning for stand i and species group j. SC_{ij} denotes wood waste from a regular thinning for stand i and species group j. IM_{ij} represents industrial roundwood production from a biomass thinning for stand i and species group j. r_j represents the ratio of total wood waste in regular

thinning and final harvest for species group *j* (ST_j) against corresponding roundwood production (IT_j).

In Equation 4.1, SM_{ij} and IM_{ij} waste are available from the thinning simulations, ST_j and IT_j are from the analysis for logging residue in section 4.1.2. This adjustment assumes the ratio of wood waste to industrial roundwood production is the same for thinning and final harvest.

4.2.3.3 Simulation summary

After the adjustment for wood waste from regular thinnings, under the Base Scenario, 2.8 million dry tons of wood waste from biomass thinnings is potentially available annually for energy. Of this, 34 percent is from softwood and 66 percent is from hardwood (Table 4.9). Biomass from removing non-growing stock trees accounts for 67 percent of total wood waste available while biomass from crowns of growing stock trees accounts for 29 percent and dead trees accounts for four percent (Figure 4.5).

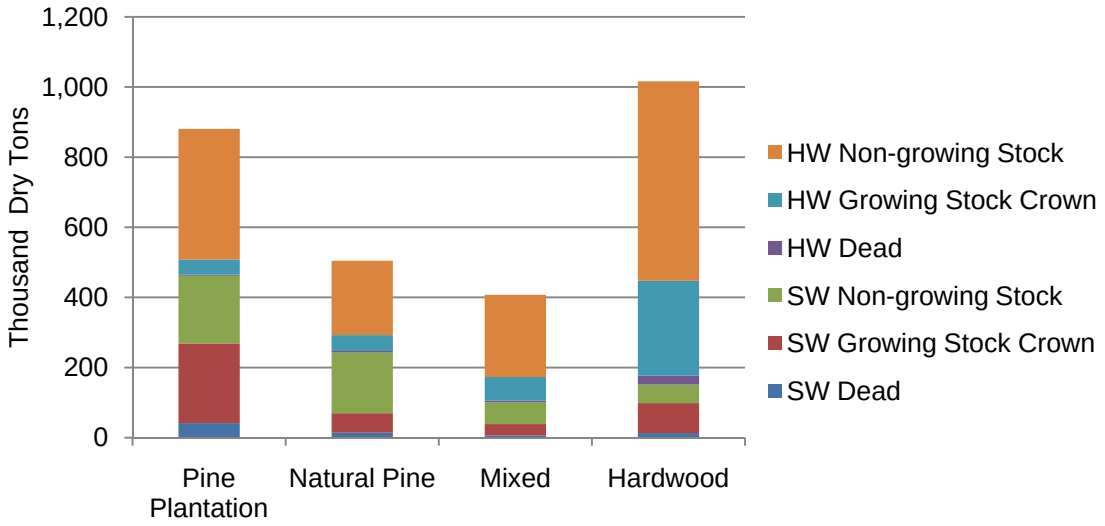

Figure 4.5 Wood waste from biomass thinning by source and forest type category, East Texas

Biomass thinnings on hardwood and pine plantation stands are the two largest sources for wood waste production, with 36 percent from hardwood stands and 31 percent from pine plantations. Biomass from thinnings on natural pine and mixed stands accounts for 18 percent and 15 percent of the total, respectively.

Annual wood waste from biomass thinnings by region and county is presented in Tables 4.10–4.11. Figure 4.6 displays the geographic distribution of wood waste from biomass thinnings potentially available on an annual basis. Under the Base Scenario, there is 1.3 million dry tons of wood waste available in Northeast Texas annually, 34 percent in softwood and 66 percent in hardwood. Sixty-seven percent of the wood waste in Northeast Texas is from non-growing stock trees, 29 percent is from crowns of growing stock trees, and four percent is from dead trees.

Southeast Texas has a relatively higher amount of wood waste available under the Base Scenario, roughly 1.5 million dry tons annually. Like the entire region, 66 percent is from hardwood and 34 percent is from softwood. Wood waste from non-growing stock trees accounts for 66 percent of total wood waste in Southeast Texas, crowns from growing stock trees account for 30 percent, and dead trees account for four percent.

Polk, Tyler, Newton, Jasper, and Hardin are the top five counties for producing wood waste from biomass thinnings in East Texas. All are in Southeast Texas.

Under Alternative Scenario I, 3.2 million dry tons of wood waste from biomass thinnings is available annually. Compared to the Base Scenario, Alternative Scenario I provides 0.4 million dry tons (or 14%) more wood waste from biomass thinnings annually. Thirty-nine percent of the wood waste is from softwood and 61 percent is from hardwood. Biomass from natural pine stands becomes the largest source of wood waste (33%) under this scenario, followed by biomass from hardwood stands (30%). Cass County exceeds Hardin County and becomes the fifth largest county for potential wood waste.

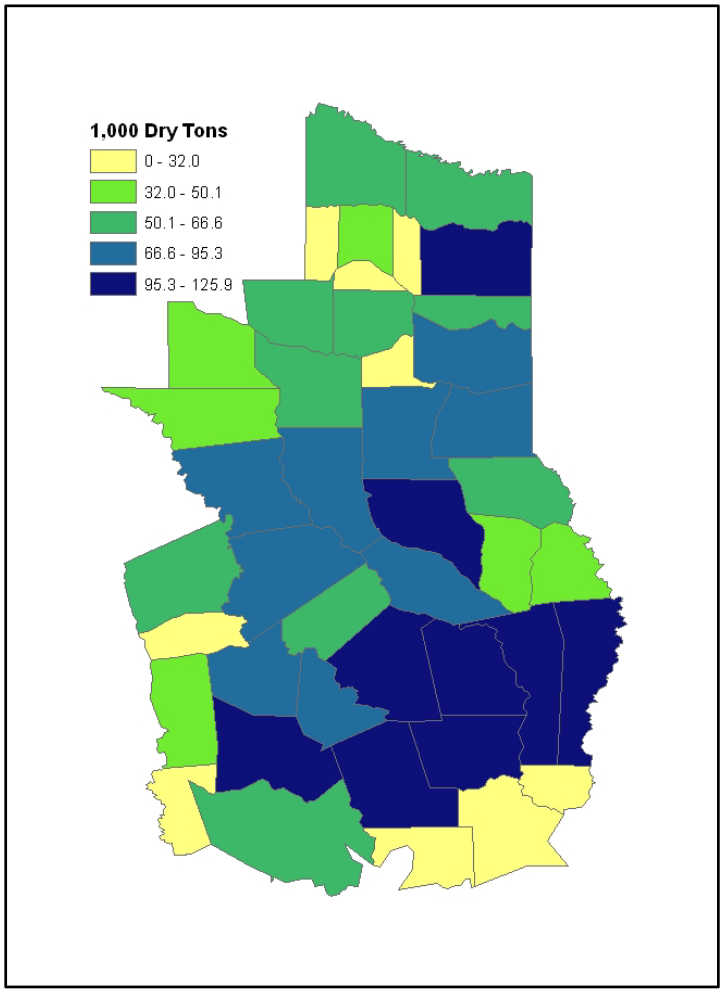

Figure 4.6 Geographic distribution of wood waste from biomass thinning in East Texas

On the other hand, Alternative Scenario II provides 2.3 million dry tons of wood waste from biomass thinning annually, 18 percent less than the Base Scenario. Compared to the Base Scenario, a higher proportion of wood waste is generated from natural pine stands under Alternative Scenario II although wood waste from biomass thinning on hardwood stands and pine plantations are still the largest two potential sources.

Although not recommended for use, wood waste availability was also estimated without excluding stands within Streamside Management Zones (Alternative Scenario III). After applying the same prescription as in the Base Scenario, 3.4 million dry tons of wood waste is estimated to be potentially available annually for energy in East Texas. In other words, it suggests that 0.6 million dry tons of wood waste is compromised for water quality protection each year. Refer to Table 4.12–4.20 for detailed data for these three alternative scenarios.

Figure 4.7 shows comparison of estimates of wood waste by species group from biomass thinning across various scenarios in the simulation.

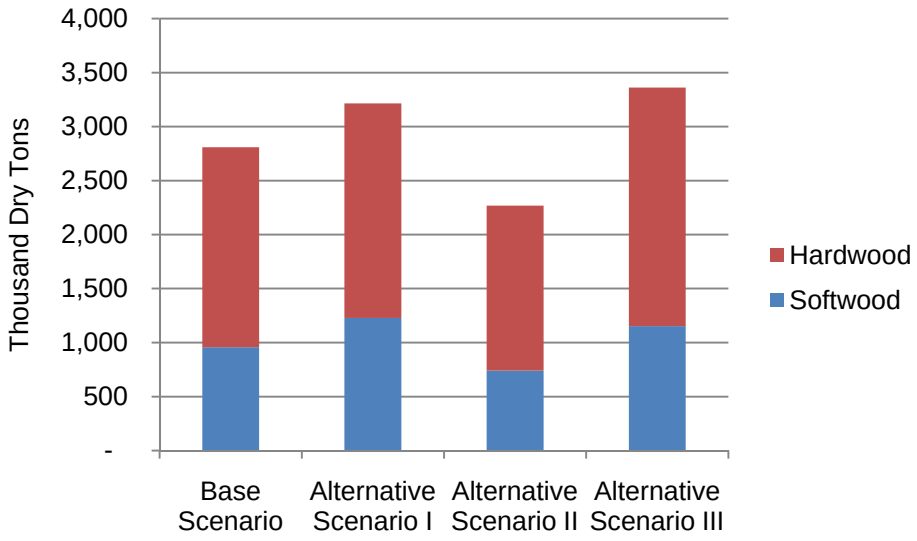

Figure 4.7 Comparison of wood waste from biomass thinning across various scenarios

4.3 Summary and Discussions

Biomass supply potential in East Texas includes wood waste potential from logging and biomass thinning operations in the region. Logging residue includes tops, limbs, and unutilized cull trees. Wood waste from biomass thinning in this study includes woody biomass from pre-commercial thinning and timber stand improvement thinning.

East Texas produces 1.5 million dry tons of wood waste from logging residue potentially available for energy annually, 63 percent from softwood and 37 percent from hardwood. Northeast Texas and Southeast Texas each account for roughly 50 percent. Polk, Tyler, Newton,

Cass, and Nacogdoches are the top five producing counties of logging residue for energy generation in East Texas.

Estimation of wood waste from biomass thinning is based on 2006 FIA data, a biomass thinning survey conducted by Texas Forest Service, and computer simulations of stand growth and management using the USDA Forest Service growth model Forest Vegetation Simulator (FVS).

Wood waste from biomass thinning is estimated to be 2.8 million dry tons annually in East Texas, 34 percent from softwood and 66 percent from hardwood. Of this, Northeast Texas accounts for 45 percent and Southeast Texas accounts for 55 percent. Polk, Tyler, Newton, Jasper, and Hardin are the top five counties having potential for producing wood waste from biomass thinning in East Texas.

Overall, about 4.3 million dry tons of wood waste is potentially available annually for energy generation in East Texas, 35 percent from logging residue and 65 percent from biomass thinning. Figure 4.8 displays the geographic distribution of total wood waste from logging residue and biomass thinning in East Texas.

Note that not all of the 4.3 million dry tons of wood waste will be available for new power generation facilities in East Texas. A portion of the wood waste has already been consumed by existing biomass energy facilities in East Texas as described in Section 2.4. Other sources will be available at different prices due to different costs of extraction, collection, and transportation of the biomass. Logging residue presented in this study is a snapshot of 2006. However, annual availability of logging residue is highly related to mill production which may be affected by a variety of economic and market factors. Logging residue, biomass from pre-commercial thinning, biomass from timber stand improvement thinning, and biomass from hurricane-damaged wood are likely to have very different cost curves. This study is not intended for making financial decisions.

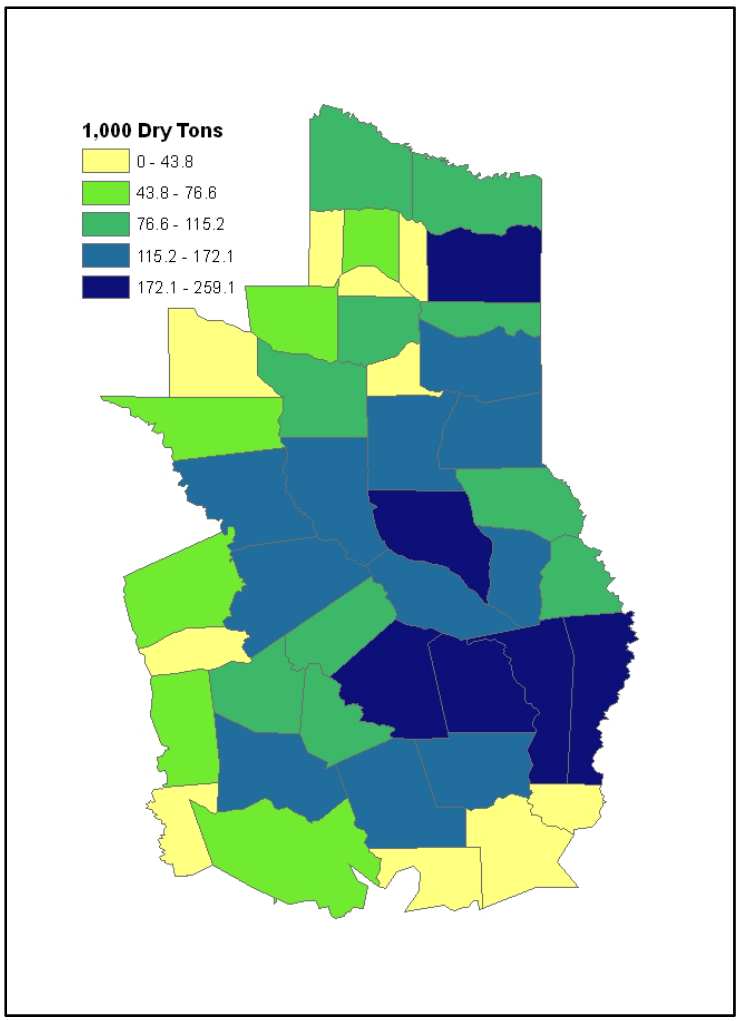

Figure 4.8 Geographic distribution of total wood waste potentially available for energy in East Texas

CHAPTER 5. WOODY BIOMASS POTENTIALLY AVAILABLE FOR ENERGY IN CENTRAL TEXAS

5.1 Rancher Survey in Central Texas

While there is 204 million dry tons of woody biomass in Central Texas, not all of it is available for energy. The need for some level of brush and tree coverage for livestock raising, wildlife management, and other environmental functions, plus the high cost of brush control practices, limit the available biomass supply in the region. Therefore, it is necessary to understand ranchers' and ranch managers' opinions and preferences on brush control on their lands. Texas Forest Service conducted a survey of ranchers in Central Texas to investigate ranchers' brush control preferences. With the combination of brush control preferences and FIA estimates of woody biomass, more realistic estimates of woody biomass potentially available for energy in Central Texas can be made.

5.1.1 Survey Design

There were four parts in the rancher survey questionnaire. The first part was about the current status of brush management. Questions in this part asked respondents to:

- describe the brush pattern on their lands
- check the year of their last brush control operation
- rate factors for and against brush control on their land
- identify desirable and undesirable brush species on their land
- estimate brush coverage on their land before and after a brush control operation
- state the maximum tolerable brush coverage on their land before conducting a brush control regardless of cost

The second part asked for ranchers' opinions on use of woody biomass as a source of energy and their brush control practices with the potential presence of a biomass market.

The third part of the survey contained general questions about the respondent and ranch, such as location and size of the ranch, and their reasons for owning ranches.

The last part of the survey provided opportunity for any additional comments the respondents might have.

5.1.2 Survey Administration

The respondents of the rancher survey were ranch owners and managers in counties with average biomass on forestland of at least 10 dry tons per acre. A total of 1,200 samples were selected

randomly from ranch owners and managers on the member list of Texas and Southwestern Cattle Raisers Association (TSCRA). Each survey instrument included a survey questionnaire, accompanied by a cover letter explaining the purpose of the survey, and a postage-paid self-addressed envelope. The surveys were mailed in May 2008. And a reminder postcard was sent one week later. A total of 451 completed questionnaires were returned for a response rate of 38 percent.

5.1.3 Major Survey Findings

In the survey, a ranch is classified as having no brush or light brush if less than 10 percent of it is covered by brush species. A ranch is classified as moderate if 11 percent to 30 percent is covered by brush. A ranch is classified as heavy if 31 percent to 50 percent is covered by brush. And it is classified as extra heavy if more than 50 percent of the ranch is covered by brush species.

According to respondents, ranches in Central Texas have an average proportion of 40 percent with no brush to light brush, 27 percent with moderate brush, 20 percent with heavy brush, and 13 percent with extra heavy brush coverage (Figure 5.1).

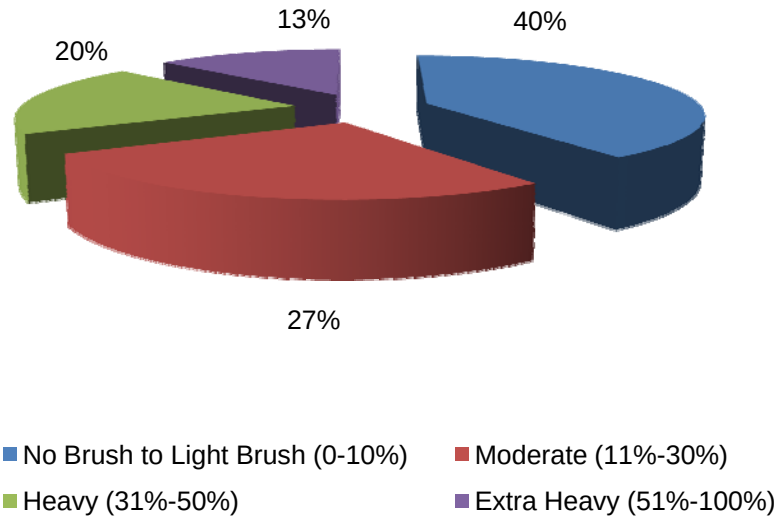

Figure 5.1 Brush pattern on ranches in Central Texas

Sixty-nine percent of respondents conducted their last brush control operation within the last 5 years, 77 percent within the last 10 years, 81 percent within the last 15 years, and 85 percent within the last 20 years. Five percent of them conducted their last brush control over 20 years ago. Ten percent said that they never conducted a brush control operation or did not know if they ever did (Figure 5.2).

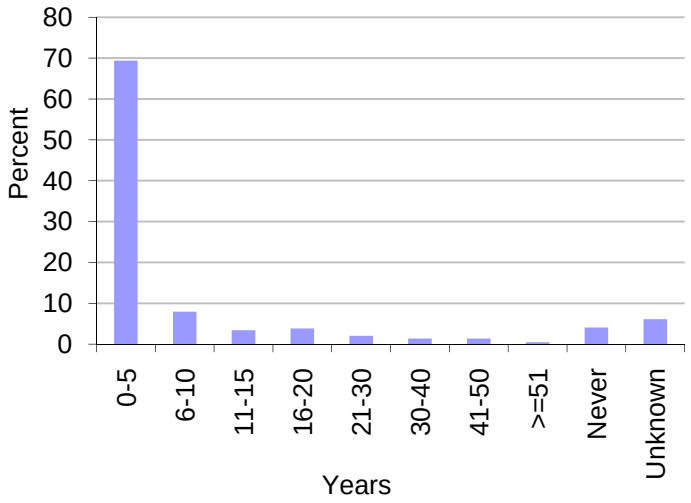

Figure 5.2 Percentage of ranches conducting their last brush control operation by year ago in Central Texas

Respondents were asked to rate the importance of seven factors on a 1 to 5 scale towards their decision to conduct brush control on their ranch, with 1 being Not Important and 5 being Very Important. The seven factors are:

- Better grass for livestock
- Controlling further brush expansion
- Land stewardship
- Water conservation
- Better land investment value
- Better hunting lease value
- Better aesthetics

Better Grass for Livestock and *Controlling Further Brush Expansion* were rated highest on average among the group of factors, at 4.6 and 4.4, respectively. This indicated that the main reason for ranchers to conduct brush control is to maintain quality land suitable for raising livestock presently and in the future, and be a good land steward. *Land Stewardship* and *Water Conservation* were rated at 4.2 and 4.1 on average, respectively. This indicated the level of concerns of the respondents about environmental quality in general and the scarcity of water in the region in particular. It also showed that they are aware of the negative impact of shrubs on water conservation in the area. *Better Aesthetics* and *Better Land Investment Value* were rated lower at 3.5 and 3.4 each. *Better Hunting Lease Value* was the least important, rated at 2.5 on average (Figure 5.3).

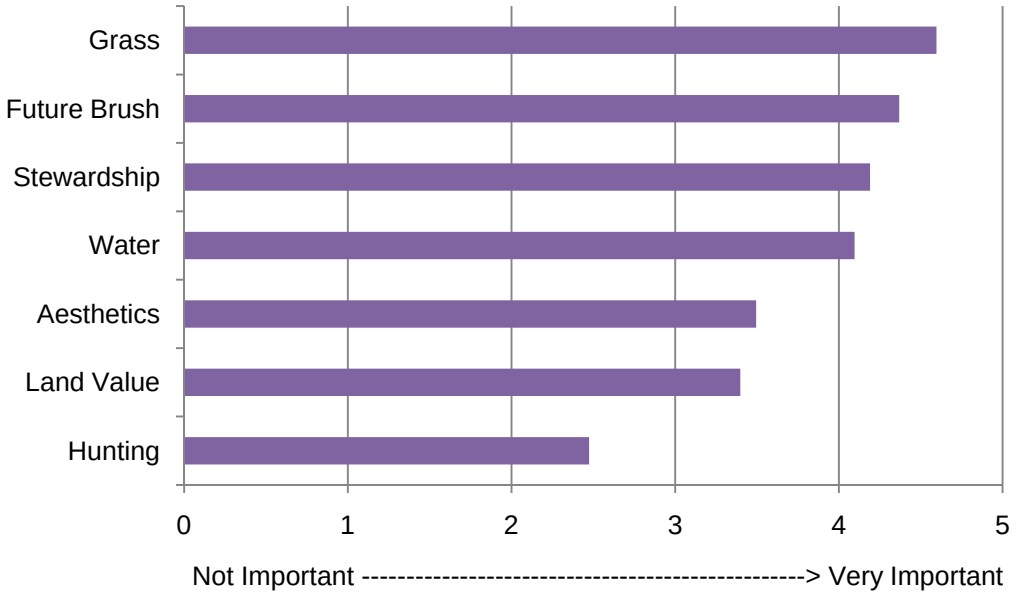

Figure 5.3 Importance of factors towards conducting brush control in Central Texas

The respondents were also asked to rate the importance of six factors on a 1 to 5 scale towards their decision NOT to conduct brush control, with 1 being Not Important and 5 being Very Important. The six factors are:

- total brush control cost too high
- per acre brush control cost too high
- concerns about disturbance to wildlife
- brush coverage not heavy enough
- concerns about potential damage to property (land, road, fences, aesthetics…)
- short lease term on ranch

Total Brush Control Cost Too High and *Per Acre Brush Control Cost Too High* were rated the highest at 3.8 and 3.7, respectively. The second group of factors, *Concerns about Disturbance to Wildlife* and *Brush Coverage Not Heavy Enough*, were rated substantially lower, at 3.0 and 2.8, respectively. Concerns about *Potential Damage to Property* (land, road, fences, aesthetics, etc.) and *Short Lease Term on Ranch* seemed to be the least of their concern, rated at 2.3 and 1.7, respectively (Figure 5.4).

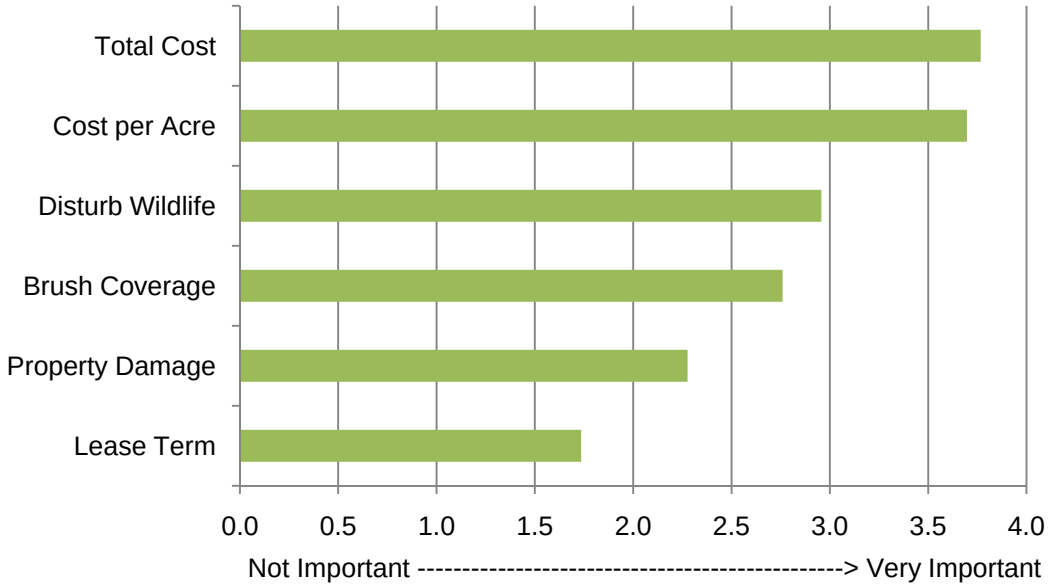

Figure 5.4 Importance of factors towards NOT conducting brush control in Central Texas

It is worth noting that the average rating of the factors for brush control (3.8) substantially outweighs the average ratings of the factors against brush control (2.9). This is not surprising because 69 percent of the respondents conducted brush control on their lands in the last 5 years.

In a brush control operation, ranchers may want to keep more of some species of trees and shrubs than others. In the survey, those species ranchers prefer to keep in a brush control operation were defined as desirable Species and species they prefer to keep less (or cut all) were defined as undesirable Species. Nineteen tree and shrub species that have the highest volume in the region are listed in the survey. The respondents were asked to first check whether each of these species is present on their land. If it is, then they were asked to check if it is a desirable Species or an undesirable Species. The results of the desirability of these species are presented in Figure 5.5, in which species are presented with the percent of the respondents who think they are desirable species. The species in Figure 5.5 can be clearly separated into two groups based on their desirability. Sixty-one percent or more respondents think that pecan, walnut, oak, hickory, pine, elm, black cherry, ash, and cottonwood are desirable species. Forty-two percent or fewer respondents think that chittamwood, persimmon, hackberry, Osage-orange, sweet acacia, sugarberry, mesquite, juniper (cedar), Chinese tallow, and locust are undesirable species. Mesquite, juniper (cedar), Chinese tallow, and locust are among the least desirable species in the region, with only 12 percent or fewer respondents rating them as desirable species.

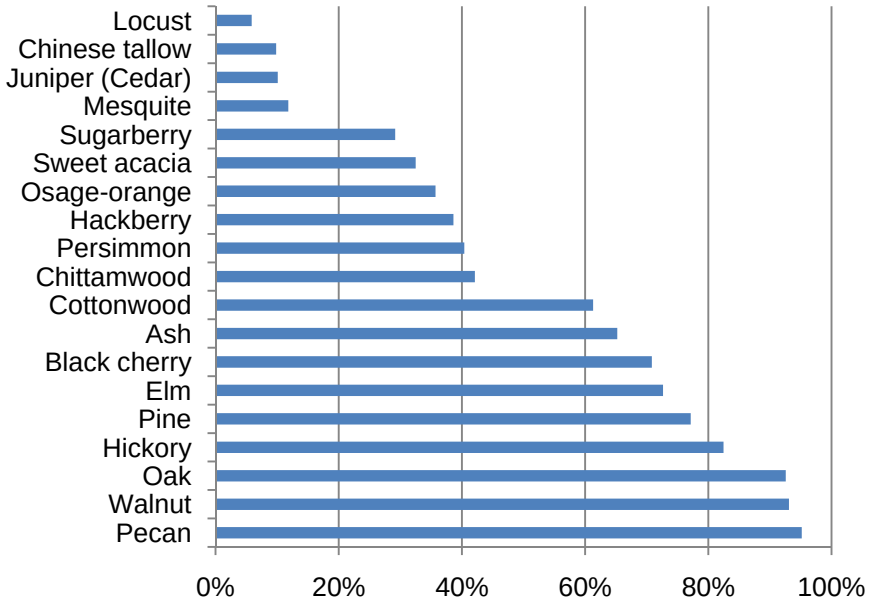

Figure 5.5 Percent of respondents reporting desirability of major tree species in Central Texas

Respondents were asked to estimate the percentage of their ranch that is currently grass or open land, or covered by different types of brush species (desirable or undesirable). Furthermore, they were asked to indicate the preferred brush coverage after a financially-feasible brush control operation. Results indicated that on average 54.8 percent of their land is grass or open land and they hope the coverage increases to 73.0 percent after a feasible brush control. Desirable species, on average, cover 18.5 percent of the land and they hope the coverage decreases to 17.2 percent after brush control. Undesirable species cover 26.7 percent of the land on average and ranchers hope coverage can be reduced to 9.9 percent after a feasible brush control. In other words, they would want to cut 62.9 percent of woody biomass of undesirable species and 7.1 percent of desirable species currently on their land given a financially-feasible brush control operation.

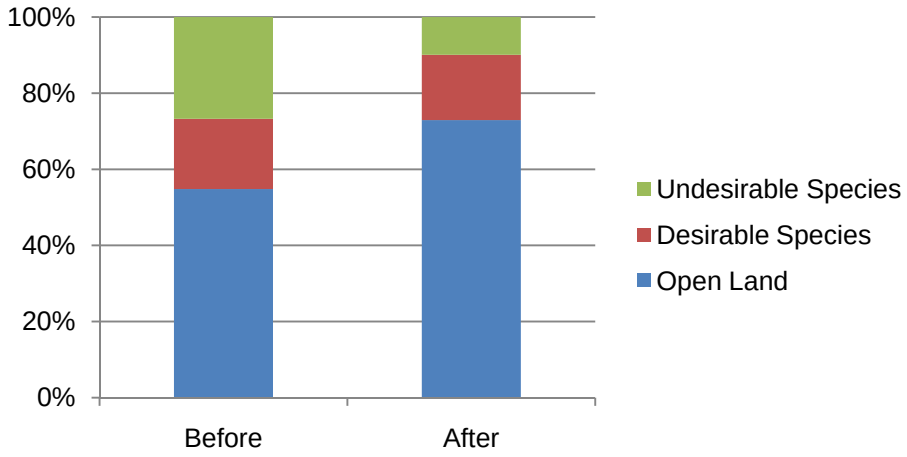

Figure 5.6 Percentage of open land and tree coverage on ranch before and after a brush control

After questions about the current status of brush and tree species on their land and their preference on brush control practices, respondents were introduced to the concept of woody biomass. They were told that woody biomass in this survey refers to stems, limbs, and leaves of harvested brush. Woody biomass can be used directly as fuel or as an input to produce biodiesel, ethanol, or generate electricity.

The respondents were then asked to rate six statements about using woody biomass as a source of energy by checking numbers 1 to 5. A 1 indicates strong disagreement with the statement and a 5 indicates strong agreement with the statement. Among the six questions, five were about potential benefits of using woody biomass for energy and one was about potential costs. The five statements about the potential benefits of using woody biomass for energy are:

- Environmentally friendly by being renewable and carbon neutral
- Reduce reliance on foreign oil
- Reduce brush control costs or increase landowner's income
- Enhance rural economies
- Utilize some previously under-utilized waste

The statement about potential costs of using woody biomass for energy was:

- Burning woody biomass may pollute air

Results of the questions are summarized in Figure 5.7. On average, respondents were positive toward all statements about potential benefits of using woody biomass for energy, giving a 4 or better rating on all five statements. On average, they do not share the opinion that burning woody biomass may pollute air, giving it a 2.9 rating.

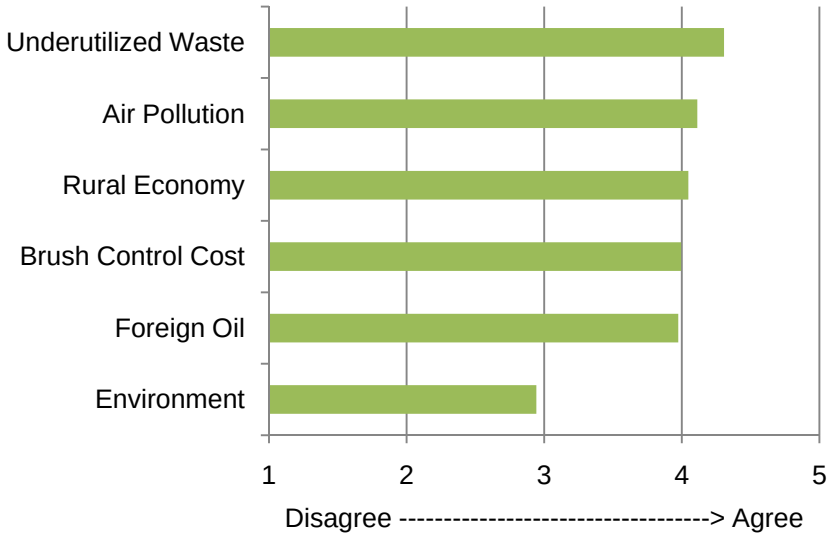

Figure 5.7 Opinion on statements about using woody biomass for energy

5.2 Sustainable Annual Biomass Supply in Central Texas

5.2.1 Available Forestland for Biomass Production in Central Texas

As described in Chapter 3, there are 18.3 million acres of forestland in Central Texas. However, not all of the forestland in the region is available for biomass production for energy. Publicly owned forestland is usually not actively managed and is an unlikely source for woody biomass for energy. Therefore, 846,700 acres of public forestland was excluded from this analysis.

As shown in Figure 5.6, ranchers on average would like to keep 17.2 percent of the 18.5 percent of desirable species on their land, which is to say that they would like to keep 92.9 percent of their desirable species and are only willing to cut 7.1 percent. On the other hand, ranchers on average would like to keep 9.9 percent of the 26.7 percent of their undesirable species on their land; in other words, they would like to keep 37.1 percent of their undesirable species and are willing to cut 62.9 percent. Applying these percentages to the private forestland in Table 5.1, the total available private forestland for potential biomass energy production in Central Texas is 5.9 million acres, of which 642,200 acres are forest types with dominant desirable species, and 5.3 million acres are forest types with dominant undesirable species.

5.2.2 Biomass Growth Models for Central Texas

Limited information is available about growth and removal of trees in Central Texas as described in Chapter 3. For analyzing the biomass supply potential in the region, Texas Forest Service developed an empirical growth model and fit it for both desirable and undesirable species in the region. Figure 5.8 describes biomass per acre by age class and forest type group in the region. Note that biomass per acre is by forest type group, not species group because most of the forests are in mixed species stands in the region. Desirable and undesirable forest types are classified by the dominant species. Casual observation of the curves for both desirable and undesirable forest types shows an initial acceleration of growth and then a tapering off of growth with increased age.

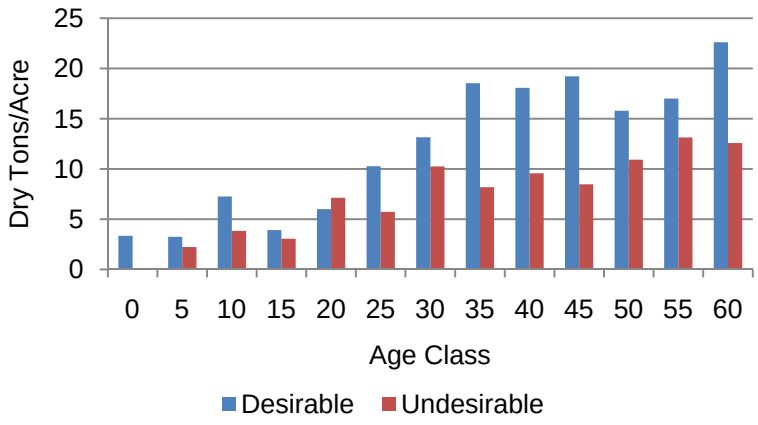

Figure 5.8 Biomass per acre by age class and forest type group in Central Texas

Several model specifications were tried and the best fit model takes the following form, which is a variant of a logistic function:

$$S_i = \frac{\beta_0}{1+e^{-\beta_1(T_i-\beta_2)}} + \varepsilon_i \qquad (5.1)$$

In Equation 5.1, S_i denotes biomass per acre, T_i represents age, β_0, β_1, and β_2 are parameters, and ε_i is the error term. Results are shown in Table 5.2. Figure 5.9 is a graphical representation of the estimated models.

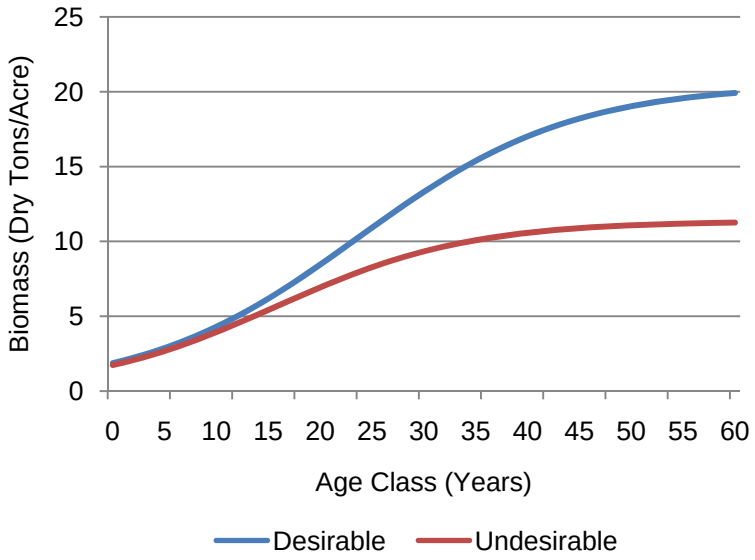

Figure 5.9 Estimated growth curves for desirable and undesirable forest types

5.2.3 Optimal Biological Rotation and Biomass Supply Potential in Central Texas

The optimal biological rotation age for both desirable and undesirable forest types can be estimated from the estimated biomass growth models. The estimated optimal biological rotation age for desirable forest types is 34, with an average annual biomass growth rate of 0.386 dry tons per acre per year. The estimated optimal biological rotation age for undesirable forest types is 23, with an average annual biomass growth rate of 0.262 dry tons per acre per year. Applying these optimal rotation ages and their corresponding biomass growth rates to private available forestland in Central Texas in Table 5.1, the estimate of sustainable annual yield of woody biomass in Central Texas is shown in Case I of Table 5.3.

Estimated annual biomass production potentially available for energy in Central Texas with optimal rotation is 1.63 million dry tons, of which 15 percent is desirable species and 85 percent is undesirable species. However, how sensitive is the estimated annual biomass supply to rotation ages? It is not practical to cut all trees at their optimal ages. To answer this question, two more scenarios were developed. In Case II, rotation ages are five years shorter than the optimal case,

and in Case III, rotation ages are five years longer than the optimal case. The estimated average annual biomass supply from these two cases is also displayed in Table 5.3.

The differences in biomass from these three cases are not substantial due to small differences in annual growth rates under these three cases. The estimated average annual biomass supply from Case II is 1.59 million dry tons, which is 2.4 percent lower than Case I. The estimated average annual biomass supply from Case III is 1.60 million dry tons, which is 1.6 percent lower than Case I. To account for the impact of variation in rotation ages, outputs of the three cases as best estimates of the average annual biomass supply potential from Central Texas were averaged.

The average of the three cases shows that Central Texas can potentially produce 1.6 million dry tons of woody biomass per year. Among the three sub-regions, the Hill Country region can produce 65 percent of the total biomass supply, the Blacklands region can produce 18 percent, and the Post Oak region can produce 17 percent. Fifteen percent of the biomass is from desirable species and 85 percent is from undesirable species.

5.3 Woody Biomass Hot Spots in Central Texas[16]

The 64-county Central Texas region is a large area. Forest resources are unevenly distributed in the region. In addition to understanding the total amount of biomass, the characteristics of forest resources in the region, and the estimated annual woody biomass supply potential, the geographic pattern of biomass distribution in Central Texas is also important. For a potential biomass using facility such as an electric power plant, it is important to understand the relative availability of wood waste in each location in Central Texas taking into account the biomass in surrounding areas within a certain distance of the facility. Does one area have more systematic concentration of woody biomass than others, or are they all randomly distributed in Central Texas?

The tool suitable for answering this question is the Hot Spot Analysis tool available in ArcMap (Mitchell 2005). The Hot Spot Analysis tool calculates the *Gi** statistic for woody biomass in each FIA plot, taking into account the woody biomass in its surrounding plots. Areas that have a higher *Gi** statistic are the hot spots of woody biomass supply.

$$Gi_i^*(r) = \frac{\sum_j w_{ij}(r) s_j}{\sum_j s_j} \qquad (5.2)$$

Where $Gi_i^*(r)$ is the Gi^* statistic for plot i with fixed radius r. $w_{ij}(r)$ is the weight of plot *j*, which is 1 if plot *j* is within radius *r* of plot *i*, 0 if not. S_j is the biomass dry weight on plot *j*. In this analysis, a 50-mile radius is used as the neighborhood of each FIA plot, consistent with the common practice of forest product industry using wood resources around a wood-processing facility.

[16] Jin Zhu of Texas Forest Service assisted the analysis and GIS mapping in this section.

A Hot Spot Analysis was conducted for Central Texas total private woody biomass based on woody biomass in each FIA plot in the region. This analysis also takes into account other West Texas forest plots outside of the Central Texas boundary that are within 50 miles of any Central Texas FIA plots. The resulted Gi^* statistics are displayed in Figure 5.10. The darker red areas in the figure are the biomass hot spots.

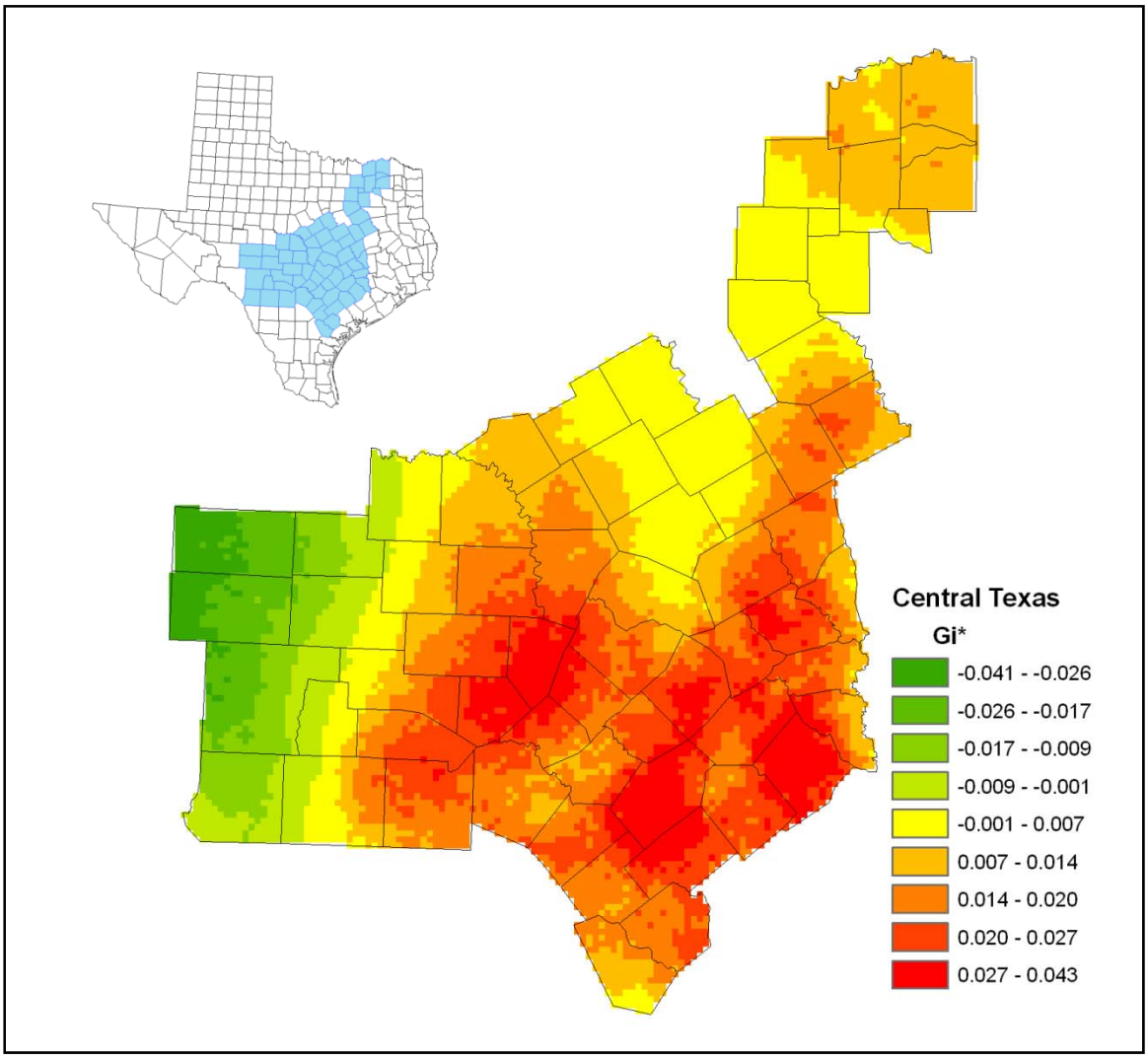

Figure 5.10 Hot Spot Analysis of woody biomass in Central Texas

5.4 Summary and Discussions

With FIA data for the total woody biomass distribution in Central Texas, it is important to understand the constraints on availability of woody biomass in the region. Since ranchers are the main forestland owners in the region, a survey of ranchers in Central Texas was conducted to investigate brush control preferences and opinions on woody biomass for energy.

The survey found that Central Texas ranches have an average proportion of 40 percent with no brush to light brush, 27 percent with moderate brush, 20 percent with heavy brush, and 13 percent with extra heavy brush coverage. Sixty-nine percent of survey respondents conducted their last brush control operation within the last five years. Keeping current and future brush from encroaching on areas for livestock is the primary reason for brush control. The high cost of brush control is the main obstacle against conducting brush control on ranches.

The survey indicated that ranchers want to cut 62.9 percent of woody biomass of undesirable species and 7.1 percent of desirable species currently on their land given a financially feasible brush control operation. On average, respondents were very positive toward all statements about potential environmental and economic benefits of using woody biomass for energy.

Because of the lack of information on growth and removal of trees in Central Texas, this study estimated an empirical forest growth model for desirable and undesirable forest types by fitting a variant of a logistic function using FIA data for Central Texas. Average annual growth rates by age class can be estimated from the model for both desirable species and undesirable species.

By applying the annual growth rates to forestland acres in Central Texas by desirable and undesirable forest types, biomass supply potential in the region was estimated under three scenarios: optimal biological rotation ages for desirable and undesirable forest types, and rotation age five years shorter or longer than the optimal rotation ages. The average of the three scenarios was used as the best estimate of biomass supply potential in the region.

The average of the three scenarios shows that Central Texas can produce 1.6 million dry tons of woody biomass per year. Among the three sub-regions, Hill Country can produce 65 percent of the total biomass supply, Blacklands can produce 18 percent, and Post Oak can produce 17 percent. Fifteen percent of the biomass is from desirable species and 85 percent is from undesirable species.

The estimation of biomass supply potential in Central Texas excludes public forestland and accounts for the need to keep some of the trees for ranching and environmental benefits based on the rancher survey. Because there is only 30 percent of a full inventory of FIA data currently available for the region, biomass supply estimations were not detailed to county level in Central Texas and may change in the future as more data are collected and analyzed. As with results in East Texas, it is important to note that not all biomass identified as potential feedstock for energy production may be a practical source because of economic, transportation and policy challenges, as well as potential demand by users outside the energy sector.

A Hot Spot Analysis of woody biomass in Central Texas was performed to give a general indication about the concentration of woody biomass in the region.

REFERENCES

Arano, K.G., and I.A. Munn. 2006. Evaluating forest management intensity: a comparison among forest landowner types. Forest Policy and Economics 9:237-248.

Bentley, J.W., and T.G. Johnson. 2004. Eastern Texas harvest and utilization study, 2003. Resource Bulletin SRS-97. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 28 p.

Brown, J.K., and C.M. Johnston. 1976. Debris Prediction System. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Fuel Science RWU 2104. 28 p.

Brown, J.K., J.A.K. Snell, and D.L. Bunnell. 1977. Handbook for predicting slash weight of western conifers. Gen. Tech. Rep. INT-37. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 37 p

Crookston, N.L. 1997. Suppose: An Interface to the Forest Vegetation Simulator. p7-14. In: Teck, R., M. Moeur, and J. Adams. 1997. Proceeding: Forest vegetation simulator conference. 1997 February 3-7, Fort Collins, Co. Gen. Tech. Rep. INT-GTR-373. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Dillman, D.A. 1978. Mail and telephone surveys: The total design method. John Wiley & Sons, New York, NY. 375 p.

Dixon, G.E. 2007. Essential FVS: A user's guide to the Forest Vegetation Simulator. U. S. Department of Agriculture, Forest Service, Forest Management Service Center, Fort Collins, CO. 210 p.

FIA. 2008. Forest Inventory and Analysis National Program. http://fia.fs.fed.us/. [Date accessed: May 19, 2008].

Griffin, R.C., and B.A. McCarl. 1989. Brushland management for increased water yield in Texas. Water Res. Bull. 25:175–186.

Mitchell, A. 2005. The ESRI Guide to GIS Analysis, Volume 2: Spatial Measurements & Statistics. ESRI Press. p175-180.

Redeker, E.J., 1998. The effects of vegetation on the water balance of an Edwards Plateau watershed: a GIS modeling approach. M.S. thesis, Texas A&M University.

Reinhardt, E., and N.L. Crookston. 2003. The Fire and Fuels Extension to the Forest Vegetation Simulator. Gen. Tech. Rep. RMRS-GTR-116. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 209 p.

Texas Comptroller of Public Accounts. 2008. Fiscal Notes. Special energy issue. Austin, TX. 15 p.

Thurow, T.L., and J.W. Hester. 1997. How an increase or reduction in juniper cover alters rangeland hydrology. p4:9-22. In: Taylor, C.A. Jr. (ed.). Juniper Symposium Proceedings. Texas A&M University Research Station, Technical Report 97-1, Sonora, TX.

Xu, W. 2006. Harvest Trends, 2005. College Station, TX: Texas Forest Service. 22 p.

Xu, W. 2007. Harvest Trends, 2006. College Station, TX: Texas Forest Service. 24 p.

Xu, W., and A.B. Carraway. 2007. Biomass from logging residue and mill residue in East Texas, 2005. College Station, TX: Texas Forest Service. 10 p.

Table 2.1 Total area by survey unit, land class, and census water, East Texas, 2006

Survey Unit	Total Area	Forestland				Other Land	Census Water
		Total	Timberland	Productive/ Reserved	Other		
		thousand acres					
Southeast	12,500.1	6,717.5	6,536.0	110.5	71.0	5,178.2	604.4
Northeast	9,918.1	5,412.2	5,391.7	—	20.5	4,229.9	276.0
All Units	22,418.2	12,129.7	11,927.7	110.5	91.5	9,408.1	880.4

Table 2.2 Area of timberland by survey unit and ownership class, East Texas, 2006

Survey Unit	All Classes	Ownership Class			
		National Forest	Other Public	Corporate/ Investor	Individual/ Family
		thousand acres			
Southeast	6,536.0	577.2	127.6	2,329.7	3,501.5
Northeast	5,391.7	96.3	174.7	701.6	4,419.0
All Units	11,927.7	673.6	302.3	3,031.3	7,920.6

Table 2.3 Area of timberland by survey unit and forest type group, East Texas, 2006

Survey Unit	All Groups	Forest Type Group										
		Longleaf-Slash	Loblolly-Shortleaf	Eastern Redcedar	Oak-Pine	Oak-Hickory	Oak-Gum-Cypress	Elm-ash-Cottonwood	Other Hardwood	Woodland Hardwood	Exotic Hardwood	Non-Stocked
		thousand acres										
Southeast	6,536.0	173.6	3,200.1	23.8	816.9	1,130.8	699.2	225.4	7.5	—	178.4	80.2
Northeast	5,391.7	27.9	1,555.0	54.4	765.2	1,915.4	613.3	386.2	11.7	4.1	3.1	55.3
All Units	11,927.7	201.5	4,755.2	78.3	1,582.2	3,046.2	1,312.6	611.5	19.3	4.1	181.5	135.5

Table 2.4 Area of timberland by survey unit and stand size class, East Texas, 2006

Survey Unit	All Classes	Stand Size Class			
		Sawtimber	Poletimber	Sapling-Seedling	Nonstocked
		thousand acres			
Southeast	6,536.0	3,427.9	1,504.8	1,522.8	80.5
Northeast	5,391.7	2,695.4	1,217.1	1,423.8	55.3
All Units	11,927.7	6,123.3	2,721.9	2,946.6	135.9

Table 2.5 Area of timberland by forest type group, stand origin, and ownership class, East Texas, 2006

Forest-type Group and Stand Origin	All Classes	Ownership Class			
		National Forest	Other Public	Forest Industry	Nonindustrial Private
			thousand acres		
Softwood Types					
Longleaf-Slash Pine					
Planted	131.2	—	—	109.2	22.0
Natural	70.3	11.2	—	35.5	23.6
Total	201.5	11.2	—	144.7	45.6
Loblolly-Shortleaf pine					
Planted	2,209.9	100.6	5.3	1,335.7	768.2
Natural	2,545.3	433.3	64.1	464.3	1,583.6
Total	4,755.2	533.9	69.4	1,800.0	2,351.8
Eastern Redcedar	78.3	—	10.2	—	68.0
Total Softwood	5,034.9	545.2	79.7	1,944.7	2,465.4
Hardwood Types					
Oak-Pine					
Planted	254.6	3.1	—	120.1	131.4
Natural	1,327.5	66.1	28.2	237.8	995.4
Total	1,582.2	69.3	28.2	357.9	1,126.8
Oak-Hickory	3,046.2	35.6	78.5	316.8	2,615.4
Oak-Gum-Cypress	1,312.6	12.4	68.7	327.5	904.0
Elm-Ash-Cottonwood	611.5	11.2	31.5	30.0	538.8
Other Hardwood	19.3	—	—	—	19.3
Woodland Hardwood	4.1	—	—	—	4.1
Exotic Hardwood	181.5	—	15.8	14.1	151.6
Total Hardwood	6,757.3	128.4	222.7	1,046.4	5,359.8
Nonstocked	135.5	—	—	40.2	95.3
All Groups	11,927.7	673.6	302.3	3,031.3	7,920.5

Table 2.6 Number of all live trees on timberland by species group and diameter class, East Texas, 2006

Species Group	All Classes	Diameter Class *(inches at breast height)*											
		1.0 – 2.9	3.0 – 4.9	5.0 – 6.9	7.0 – 8.9	9.0 – 10.9	11.0 – 12.9	13.0 – 14.9	15.0 – 16.9	17.0 – 18.9	19.0 – 20.9	21.0 – 28.9	29.0+
		thousand trees											
Softwood													
Yellow Pine	2,077,106	874,294	481,766	291,605	185,565	96,314	56,943	33,305	23,257	14,107	8,778	10,114	1,058
Other Softwoods	138,073	88,044	26,144	8,827	5,322	3,373	2,331	1,210	803	712	527	523	257
All Softwoods	2,215,179	962,338	507,910	300,432	190,887	99,687	59,274	34,515	24,060	14,819	9,305	10,637	1,315
Hardwood													
Soft Hardwoods	2,157,588	1,521,627	351,505	126,071	67,874	39,255	21,007	13,966	6,898	4,054	2,419	2,696	216
Hard Hardwoods	3,231,072	2,296,937	482,748	189,076	100,175	61,233	38,102	26,615	16,302	—	7,189	10,645	2,050
All Hardwoods	5,388,660	3,818,564	834,253	315,147	168,049	100,488	59,109	40,581	23,200	4,054	9,608	13,341	2,266
All Species	7,603,839	4,780,902	1,342,163	615,579	358,936	200,175	118,383	75,096	47,260	18,873	18,913	23,978	3,581

Table 2.7 Number of growing stock trees on timberland by species group and diameter class, East Texas, 2006

Species Group	All Classes	Diameter Class *(inches at breast height)*									
		5.0 – 6.9	7.0 – 8.9	9.0 – 10.9	11.0 – 12.9	13.0 – 14.9	15.0 – 16.9	17.0 – 18.9	19.0 – 20.9	21.0 – 28.9	29.0+
		thousand trees									
Softwood											
Yellow Pine	1,928,141	284,510	182,625	94,994	56,312	33,101	23,146	13,884	8,669	9,871	983
Other Softwoods	92,669	7,082	4,753	2,732	2,118	883	630	538	456	490	257
All Softwoods	2,020,810	291,592	187,378	97,726	58,430	33,984	23,776	14,422	9,125	10,361	1,240
Hardwood											
Soft Hardwoods	222,043	91,867	53,541	33,148	17,626	12,027	5,954	3,666	1,968	2,101	145
Hard Hardwoods	330,051	124,708	73,315	48,517	31,044	22,295	13,737	—	6,146	8,988	1,301
All Hardwoods	552,094	216,575	126,856	81,665	48,670	34,322	19,691	3,666	8,114	11,089	1,446
All Species	1,280,128	508,167	314,234	179,391	107,100	68,306	43,467	18,088	17,239	21,450	2,686

Table 2.8 Volume of all live trees on timberland by species group and diameter class, East Texas, 2006

Species Group	All Classes	Diameter Class *(inches at breast height)*									
		5.0 – 6.9	7.0 – 8.9	9.0 – 10.9	11.0 – 12.9	13.0 – 14.9	15.0 – 16.9	17.0 – 18.9	19.0 – 20.9	21.0 – 28.9	29.0+
		million cubic feet									
Softwood											
Yellow Pine	9,025.3	675.6	1,087.3	1,127.9	1,134.7	1,019.1	1,035.1	832.9	678.2	1,195.5	239.0
Other Softwoods	336.7	21.8	31.7	33.4	38.0	27.4	23.7	30.8	29.2	52.2	48.4
All Softwoods	9,362.0	697.4	1,119.0	1,161.4	1,172.7	1,046.5	1,058.8	863.7	707.4	1,247.6	287.5
Hardwood											
Soft Hardwoods	2,577.5	285.7	370.5	397.8	356.8	333.2	238.5	186.1	139.2	224.3	45.5
Hard Hardwoods	5,302.3	436.0	519.6	579.8	586.3	599.1	510.1	481.7	387.5	867.0	335.2
All Hardwoods	7,879.8	721.7	890.1	977.6	943.2	932.3	748.6	667.8	526.6	1,091.3	380.7
All Species	17,241.8	1,419.1	2,009.1	2,139.0	2,115.9	1,978.8	1,807.3	1,531.5	1,234.0	2,338.9	668.2

Table 2.9 Volume of growing stock trees on timberland by species group and diameter class, East Texas, 2006

Species Group	All Classes	Diameter Class *(inches at breast height)*									
		5.0 – 6.9	7.0 – 8.9	9.0 – 10.9	11.0 – 12.9	13.0 – 14.9	15.0 – 16.9	17.0 – 18.9	19.0 – 20.9	21.0 – 28.9	29.0 and larger
		million cubic feet									
Softwood											
Yellow Pine	8,917.6	662.2	1,074.1	1,114.5	1,124.7	1,014.0	1,031.3	823.5	671.7	1,175.7	225.9
Other Softwoods	301.2	18.6	28.7	28.2	35.5	21.7	19.3	24.6	26.1	49.9	48.4
All Softwoods	9,218.8	680.8	1,102.8	1,142.8	1,160.2	1,035.7	1,050.6	848.1	697.8	1,225.6	274.3
Hardwood											
Soft Hardwoods	2,224.9	221.1	307.4	352.1	312.6	298.7	212.1	174.2	121.0	190.1	35.6
Hard Hardwoods	4,454.9	314.1	406.8	483.5	499.5	520.6	453.0	425.9	349.2	773.0	229.5
All Hardwoods	6,679.8	535.2	714.1	835.6	812.1	819.3	665.1	600.1	470.2	963.1	265.1
All Species	15,898.6	1,216.0	1,816.9	1,978.4	1,972.3	1,855.0	1,715.8	1,448.2	1,168.0	2,188.7	539.4

Table 2.10 Volume of sawtimber on timberland by species group and diameter class, East Texas, 2006

Species Group	All Classes	Diameter Class *(inches at breast height)*							
		9.0 – 10.9	11.0 – 12.9	13.0 – 14.9	15.0 – 16.9	17.0 – 18.9	19.0 – 20.9	21.0 – 28.9	29.0 and larger
		million board feet							
Softwood									
Yellow Pine	39,081.0	4,039.7	5,107.6	5,252.2	5,834.7	4,962.5	4,257.4	7,965.9	1,661.0
Other Softwoods	1,316.2	96.9	148.5	102.4	97.4	128.3	140.8	294.5	307.4
All Softwoods	40,397.2	4,136.6	5,256.1	5,354.7	5,932.1	5,090.9	4,398.2	8,260.3	1,968.4
Hardwood									
Soft Hardwoods	6,137.8	—	1,092.3	1,225.3	979.1	865.4	646.5	1,102.5	226.7
Hard Hardwoods	15,816.6	—	1,797.3	2,172.1	2,095.4	2,106.7	1,821.4	4,375.4	1,448.2
All Hardwoods	21,954.4	—	2,889.7	3,397.4	3,074.5	2,972.1	2,467.9	5,477.9	1,675.0
All Species	62,351.6	4,136.6	8,145.7	8,752.1	9,006.6	8,062.9	6,866.0	13,738.3	3,643.4

Table 2.11 Volume of live trees on timberland by survey unit and species group, East Texas, 2006

Survey Unit	All Species	Softwoods			Hardwoods		
		All Softwood	Yellow Pine	Other Softwood	All Hardwood	Soft Hardwood	Hard Hardwood
		million cubic feet					
Southeast	9,804.5	6,017.6	5,892.3	125.2	3,786.9	1,244.0	2,542.8
Northeast	7,437.4	3,344.4	3,133.0	211.4	4,092.9	1,333.5	2,759.5
All Units	17,241.8	9,362.0	9,025.3	336.7	7,879.8	2,577.5	5,302.3

Table 2.12 Volume of growing stock on timberland by survey unit and species group, East Texas, 2006

Survey Unit	All Species	Softwoods			Hardwoods		
		All Softwood	Yellow Pine	Other Softwood	All Hardwood	Soft Hardwood	Hard Hardwood
		million cubic feet					
Southeast	9,117.9	5,960.7	5,845.4	115.3	3,157.2	1,060.1	2,097.1
Northeast	6,780.7	3,258.1	3,072.1	185.9	3,522.6	1,164.8	2,357.8
All Units	15,898.6	9,218.8	8,917.6	301.2	6,679.8	2,224.9	4,454.9

Numbers in rows and columns may not sum to totals due to rounding.

Table 2.13 Volume of sawtimber on timberland by survey unit and species group, East Texas, 2006

Survey Unit	All Species	Softwoods			Hardwoods		
		All Softwood	Yellow Pine	Other Softwood	All Hardwood	Soft Hardwood	Hard Hardwood
		million board feet					
Southeast	36,477.0	25,996.6	25,480.8	515.9	10,480.4	2,965.4	7,515.0
Northeast	25,874.6	14,400.5	13,600.2	800.3	11,474.0	3,172.4	8,301.6
All Units	62,351.6	40,397.2	39,081.0	1,316.2	21,954.4	6,137.8	15,816.6

Table 2.14 Volume of live trees and growing stock on timberland by ownership class and species group, East Texas, 2006

Ownership Class	All Species	Softwoods			Hardwoods		
		All Softwood	Yellow Pine	Other Softwood	All Hardwood	Soft Hardwood	Hard Hardwood
				Live trees (million cubic feet)			
National Forest	2,145.5	1,783.2	1,783.1	0.1	362.3	115.3	247.0
Other Public	566.0	254.8	177.8	77.0	311.2	115.7	195.5
Forest Industry	4,010.7	2,597.7	2,475.9	121.8	1,413.0	481.4	931.6
Nonindustrial Private	10,519.6	4,726.4	4,588.6	137.8	5,793.3	1,865.2	3,928.1
All Classes	17,241.8	9,362.0	9,025.3	336.7	7,879.8	2,577.5	5,302.3
				Growing stock trees (million cubic feet)			
National Forest	2,110.8	1,780.0	1,780.0	0.1	330.7	107.1	223.6
Other Public	516.6	252.5	177.4	75.2	264.1	101.6	162.5
Forest Industry	3,818.3	2,584.2	2,464.4	119.8	1,234.1	416.6	817.5
Nonindustrial Private	9,452.8	4,602.0	4,495.8	106.2	4,850.8	1,599.5	3,251.4
All Classes	15,898.6	9,218.8	8,917.6	301.2	6,679.8	2,224.9	4,454.9

Table 2.15 Volume of sawtimber on timberland by ownership class and species group, East Texas, 2006

Ownership Class	All Species	Softwoods			Hardwoods		
		All Softwood	Yellow Pine	Other Softwood	All Hardwood	Soft Hardwood	Hard Hardwood
				All size classes (million board feet)			
National Forest	10,519.2	9,542.2	9,542.2	—	977.0	286.2	690.9
Other Public	2,214.8	1,322.6	996.6	326.0	892.2	316.0	576.2
Forest Industry	13,419.9	9,137.8	8,515.9	621.8	4,282.1	1,133.0	3,149.1
Nonindustrial Private	36,197.6	20,394.6	20,026.3	368.3	15,803.1	4,402.6	11,400.4
All Classes	62,351.6	40,397.2	39,081.0	1,316.2	21,954.4	6,137.8	15,816.6
				Trees ≥ 15.0 d.b.h. (million board feet)			
National Forest	8,313.3	7,666.3	7,666.3	—	647.0	151.9	495.1
Other Public	1,683.7	1,074.5	837.3	237.2	609.3	188.0	421.3
Forest Industry	7,558.5	4,367.6	3,818.3	549.3	3,190.9	713.9	2,477.0
Nonindustrial Private	23,761.6	12,541.4	12,359.6	181.8	11,220.2	2,766.5	8,453.7
All Classes	41,317.2	25,649.8	24,681.5	968.4	15,667.3	3,820.2	11,847.1

Table 2.16 Total biomass on forestland by forest type group, stand origin, and species group, East Texas, 2006

Forest-type Group and Stand Origin	All Classes	Softwoods			Hardwoods		
		All Softwood	Yellow Pine	Other Softwood	All Hardwood	Soft Hardwood	Hard Hardwood
				million dry tons			
Planted Pine	67.4	58.8	58.8	0.0	8.6	3.5	5.1
Natural Pine	157.0	124.3	123.9	0.4	32.7	11.3	21.4
Eastern Redcedar	1.2	0.9	0.1	0.8	0.2	0.0	0.2
Oak-Pine	57.3	24.6	23.6	0.9	32.7	9.4	23.3
Hardwood	189.3	16.6	9.4	7.3	172.7	50.0	122.7
Nonstocked	0.2	0.0	0.0	0.0	0.1	0.1	0.1
All Groups	472.3	225.3	215.85	9.41	247.0	74.25	172.80

Table 2.17 Total biomass of live trees on forestland by species group, region, ownership group, and merchantability, East Texas, 2006

Species	Total	Southeast			Northeast		
		All	Public	Private	All	Public	Private
		Total biomass (million dry tons)					
Pine	215.9	142.0	41.3	100.7	73.9	5.5	68.4
Other Softwood	9.4	3.8	0.7	3.1	5.6	1.7	3.9
All Softwood	225.3	145.8	42.0	103.8	79.5	7.2	72.3
Soft Hardwood	74.3	36.9	5.8	31.1	37.4	2.1	35.3
Hard Hardwood	172.8	86.5	10.3	76.2	86.3	6.1	80.2
All Hardwood	247.1	123.3	16.1	107.3	123.7	8.2	115.5
Total	472.3	269.1	58.0	211.1	203.2	15.4	187.9
		Merchantable biomass (million dry tons)					
Pine	175.0	115.3	35.2	80.0	59.8	4.6	55.2
Other Softwood	7.2	3.0	0.5	2.5	4.1	1.3	2.8
All Softwood	182.2	118.3	35.8	82.5	63.9	5.9	58.0
Soft Hardwood	49.2	24.3	3.9	20.3	24.9	1.4	23.5
Hard Hardwood	116.2	56.7	6.8	49.9	59.5	4.5	54.9
All Hardwood	165.4	81.0	10.7	70.3	84.4	5.9	78.5
Total	347.6	199.3	46.5	152.8	148.3	11.9	136.4
		Non-merchantable biomass (million dry tons)					
Pine	40.8	26.7	6.1	20.6	14.1	0.9	13.2
Other Softwood	2.3	0.8	0.1	0.6	1.5	0.4	1.1
All Softwood	43.1	27.5	6.2	21.3	15.6	1.2	14.3
Soft Hardwood	25.1	12.6	1.8	10.7	12.5	0.7	11.8
Hard Hardwood	56.6	29.8	3.5	26.2	26.8	1.6	25.3
All Hardwood	81.7	42.3	5.4	37.0	39.3	2.3	37.1
Total	124.7	69.8	11.6	58.3	54.9	3.5	51.4

Table 2.18 Total biomass of all live trees on forestland by species group, diameter class, and merchantability, East Texas, 2006

Species	Total	1.0-2.9	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-28.9	29.0+
						Total biomass (million dry tons)							
Pine	215.9	3.1	8.4	18.3	25.5	25.3	25.3	22.4	22.6	18.2	14.9	26.6	5.3
Other Softwood	9.4	0.3	0.4	0.6	0.7	0.7	0.9	0.7	0.5	0.8	0.8	1.4	1.6
All Softwood	225.3	3.4	8.9	18.8	26.2	26.0	26.1	23.1	23.1	19.0	15.7	28.0	6.9
Soft Hardwood	74.3	5.7	7.5	7.2	8.4	8.9	8.2	7.6	5.7	4.4	3.4	6.0	1.2
Hard Hardwood	172.8	9.6	11.1	12.0	13.7	15.4	15.9	16.6	14.6	13.7	11.5	27.0	11.8
All Hardwood	247.1	15.3	18.6	19.2	22.1	24.3	24.1	24.2	20.3	18.1	14.9	33.0	13.0
Total	472.3	18.7	27.5	38.0	48.3	50.3	50.2	47.4	43.4	37.1	30.6	61.0	19.9
						Merchantable biomass (million dry tons)							
Pine	175.0	0.0	0.0	13.1	20.9	21.7	22.0	19.7	20.0	16.1	13.2	23.5	4.7
Other Softwood	7.2	0.0	0.0	0.4	0.6	0.6	0.7	0.6	0.4	0.7	0.6	1.2	1.3
All Softwood	182.2	0.0	0.0	13.5	21.5	22.3	22.8	20.3	20.4	16.8	13.9	24.7	6.0
Soft Hardwood	49.2	0.0	0.0	4.9	6.6	7.3	6.8	6.4	4.8	3.7	2.9	4.9	1.0
Hard Hardwood	116.2	0.0	0.0	7.9	10.3	11.9	12.5	13.1	11.5	10.8	8.9	20.9	8.4
All Hardwood	165.4	0.0	0.0	12.8	16.9	19.2	19.2	19.5	16.3	14.5	11.8	25.8	9.4
Total	347.6	0.0	0.0	26.3	38.4	41.5	42.0	39.8	36.7	31.3	25.7	50.5	15.4
						Non-merchantable biomass (million dry tons)							
Pine	40.8	3.1	8.4	5.2	4.6	3.6	3.2	2.7	2.6	2.1	1.7	3.0	0.6
Other Softwood	2.3	0.3	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3
All Softwood	43.1	3.4	8.9	5.3	4.7	3.8	3.4	2.8	2.7	2.2	1.8	3.3	0.8
Soft Hardwood	25.1	5.7	7.5	2.3	1.8	1.6	1.4	1.3	0.9	0.7	0.6	1.1	0.3
Hard Hardwood	56.6	9.6	11.1	4.1	3.4	3.5	3.4	3.5	3.1	2.8	2.5	6.1	3.4
All Hardwood	81.7	15.3	18.6	6.4	5.2	5.1	4.9	4.7	4.0	3.6	3.1	7.2	3.6
Total	124.7	18.7	27.5	11.7	9.9	8.9	8.2	7.6	6.7	5.8	4.9	10.4	4.5

Table 2.19 Average net annual growth and annual removals of live trees, growing stock, and sawtimber on timberland by species group, East Texas, 2004-2006

Species Group	Live Trees		Growing Stock		Sawtimber	
	Net Annual Growth	Annual Removal	Net Annual	Annual Removal	Net Annual	Annual Removals
			million cubic feet			
Softwood						
Yellow Pine	672.6	567.0	664.3	558.3	2,555.3	2,087.9
Other Softwood	15.8	1.6	10.8	0.4	42.5	1.7
All softwoods	688.4	568.6	675.1	558.7	2,597.8	2,089.6
Hardwood						
Soft Hardwood	127.4	64.0	115.4	56.4	345.1	144.2
Hard Hardwood	248.2	137.4	233.0	118.2	932.4	407.6
All Hardwoods	375.5	201.3	348.5	174.7	1,277.5	551.9
All Species	1,063.9	769.9	1,023.6	733.4	3,875.3	2,641.5

Table 2.20 Average net annual growth and annual removals of live trees on timberland by ownership class and species group, East Texas, 2004-2006

Ownership Class	All Species	Softwoods			Hardwoods		
		All Softwood	Yellow Pine	Other Softwood	All Hardwood	Soft Hardwood	Hard Hardwood
		Average net annual growth (million cubic feet)					
National Forest	69.4	63.1	63.1	0	6.3	1.7	4.6
Other Public	21.7	12.7	12.0	0.7	9.0	2.5	6.5
Forest Industry	284.2	241.4	239.8	1.6	42.8	13.8	29.0
Nonindustrial Private	688.8	371.2	357.7	13.5	317.6	109.4	208.2
All Classes	1,063.9	688.4	672.6	15.8	375.5	127.4	248.2
		Average annual removals (million cubic feet)					
National Forest	0.7	0.7	0.7	0	0	0	0
Other Public	0.6	0.6	0.6	0	0	0	0
Forest Industry	242.7	220.9	220.6	0.3	21.8	8.8	12.9
Nonindustrial Private	526.0	346.4	345.1	1.3	179.6	55.1	124.4
All Classes	769.9	568.6	567.0	1.6	201.3	64.0	137.4

Table 2.21 Average net annual growth and annual removals of growing stock on timberland by ownership class and species group, East Texas, 2004-2006

Ownership Class	All Species	Softwoods			Hardwoods		
		All Softwood	Yellow Pine	Other Softwood	All Hardwood	Soft Hardwood	Hard Hardwood
		Average net annual growth (million cubic feet)					
National Forest	68.2	62.7	62.6	0	5.5	1.4	4.1
Other Public	20.1	12.7	12.0	0.8	7.4	1.4	6.0
Forest Industry	280.9	239	237.6	1.4	41.9	14.3	27.6
Nonindustrial Private	654.4	360.7	352.1	8.6	293.7	98.3	195.3
All Classes	1,023.6	675.1	664.3	10.8	348.5	115.4	233.0
		Average annual removals (million cubic feet)					
National Forest	0.7	0.7	0.7	0	0	0	0
Other Public	0.6	0.6	0.6	0	0	0	0
Forest Industry	236.4	218.1	218.0	0.1	18.3	8.3	10.0
Nonindustrial Private	495.7	339.4	339.0	0.4	156.4	48.1	108.2
All Classes	733.4	558.7	558.3	0.4	174.7	56.4	118.2

Table 3.1 Area of forestland by forest type group, ownership group, and site class, Central Texas, 2006

Forest Type Group	Private			Public			All		
	Timberland	Unproductive	Total	Timberland	Unproductive	Total	Timberland	Unproductive	Total
	thousand acres								
Softwood									
Loblolly/Shortleaf pine	35.1	-	35.1	20.2	-	20.2	55.3	-	55.3
Pinyon/Juniper	138.7	3,993.3	4,132.1	25.5	223.4	248.9	164.2	4,216.7	4,380.9
Total Softwood	173.8	3,993.3	4,167.1	45.7	223.4	269.1	219.5	4,216.7	4,436.3
Hardwood									
Oak/Pine	87.7	139.6	227.3	-	21.9	21.9	87.7	161.5	249.2
Oak/Hickory	1,188.0	6,345.3	7,533.3	67.1	301.5	368.6	1,255.1	6,646.8	7,901.9
Oak/Gum/Cypress	81.9	201.2	283.1	6.4	-	6.4	88.3	201.2	289.4
Elm/Ash/Cottonwood	438.7	528.2	966.8	57.6	34.6	92.3	496.3	562.8	1,059.1
Mesquite Woodland	21.3	1,941.2	1,962.6	-	22.9	22.9	21.3	1,964.2	1,985.5
Other Hardwoods	10.3	335.0	345.3	-	-	-	10.3	335.0	345.3
Total Hardwood	1,827.8	9,490.5	11,318.3	131.1	381.0	512.1	1,959.0	9,871.4	11,830.4
Nonstocked	91.3	1,828.4	1,919.7	5.4	60.1	65.5	96.6	1,888.6	1,985.2
All Groups	2,093.0	15,312.2	17,405.2	182.2	664.5	846.7	2,275.1	15,976.7	18,251.9

Table 3.2 Area of forestland by forest type group, ownership group, and sub-region, Central Texas, 2006

Forest Type Group	Private				Public				Total
	Hill Country	Blacklands	Post Oak	Total	Hill Country	Blacklands	Post Oak	Total	
	thousand acres								
Softwood									
Loblolly/Shortleaf pine	-	27.7	7.4	35.1	-	20.2	-	20.2	55.3
Pinyon/Juniper	3,148.5	728.0	255.6	4,132.1	165.9	77.6	5.4	248.9	4,380.9
Total Softwood	3,148.5	755.8	262.9	4,167.1	165.9	97.9	5.4	269.1	4,436.3
Hardwood									
Oak/Pine	-	69.7	157.6	227.3	-	-	21.9	21.9	249.2
Oak/Hickory	4,545.6	1,006.3	1,981.4	7,533.3	117.5	153.2	97.9	368.6	7,901.9
Oak/Gum/Cypress	69.8	72.4	140.9	283.1	-	6.4	-	6.4	289.4
Elm/Ash/Cottonwood	201.7	224.8	540.4	966.8	-	-	92.3	92.3	1,059.1
Mesquite Woodland	1,083.9	391.5	487.2	1,962.6	-	-	22.9	22.9	1,985.5
Other Hardwoods	50.7	28.6	265.9	345.3	-	-	-	-	345.3
Total Hardwood	5,951.7	1,793.3	3,573.3	11,318.3	117.5	159.5	235.0	512.1	11,830.4
Nonstocked	1,285.4	403.6	230.7	1,919.7	60.1	-	5.4	65.5	1,985.2
All groups	10,385.6	2,952.7	4,066.9	17,405.2	343.6	257.4	245.8	846.7	18,251.9

Table 3.3 Area of forestland by forest type group and stand size class, Central Texas, 2006

Forest Type Group	Stand Size Class				
	All size classes	Sawtimber	Poletimber	Sapling-Seedling	Nonstocked
	thousand acres				
Softwood					
Loblolly/Shortleaf pine	55.3	47.9	-	7.4	-
Pinyon/Juniper	4,380.9	1,723.4	1,392.9	1,264.6	-
Total Softwood	4,436.3	1,771.4	1,392.9	1,272.0	-
Hardwood					
Oak/Pine	249.2	65.3	89.7	94.2	-
Oak/Hickory	7,901.9	2,140.7	3,210.0	2,551.2	-
Oak/Gum/Cypress	289.4	81.6	47.1	160.7	-
Elm/Ash/Cottonwood	1,059.1	308.6	323.9	426.6	-
Mesquite Woodland	1,985.5	842.9	194.7	947.9	-
Other Hardwoods	345.3	21.3	78.4	245.6	-
Total Hardwood	11,830.4	3,460.4	3,943.7	4,426.3	-
Nonstocked	1,985.2	-	-	-	1,985.2
All groups	18,251.9	5,231.8	5,336.6	5,698.2	1,985.2

Table 3.4 Number of all live trees on forestland by species group, ownership group, and sub-region, Central Texas, 2006

Species group	Priavate				Public				Total
	Hill Country	Blacklands	Post Oak	Total	Hill Country	Central	Post Oak	Total	
	million trees								
Softwood									
Pine	12.3	11.0	10.5	33.8	-	11.9	-	11.9	45.7
Juniper	1,640.3	409.3	151.6	2,201.2	145.0	83.2	27.1	255.3	2,456.6
Total Softwoods	1,652.6	420.3	162.1	2,235.0	145.0	95.1	27.1	267.2	2,502.2
Hardwood									
Mesquite	232.0	89.7	136.5	458.1	0.3	0.3	4.5	5.2	463.3
Oak	660.2	121.1	289.7	1,071.1	20.8	46.2	9.6	76.7	1,147.7
Elm	48.8	95.2	302.2	446.2	0.5	0.8	28.1	29.4	475.6
Pecon	1.0	2.3	7.7	11.0	-	-	0.6	0.6	11.6
Sugarberry	19.8	19.7	74.7	114.2	-	2.0	0.8	2.8	117.0
Ash	1.9	9.0	49.6	60.5	-	6.4	25.1	31.5	92.0
Cottonwood	-	-	-	-	-	-	6.1	6.1	6.1
Sweet Acacia	2.3	0.4	68.5	71.3	-	-	-	-	71.3
Hackberry	29.9	3.9	35.0	68.8	-	-	4.1	4.1	72.9
Osage-Orange	-	-	17.6	17.6	-	-	6.3	6.3	23.9
Persimmon	404.2	48.7	38.8	491.7	4.1	-	-	4.1	495.8
Hickory	0.2	1.3	21.1	22.6	-	-	4.0	4.0	26.5
Chinese Tallow	-	-	1.9	1.9	-	-	-	-	1.9
Black cherry	8.2	-	1.7	9.9	-	-	-	-	9.9
Chittamwood	10.1	15.9	20.8	46.8	-	5.7	0.6	6.3	53.1
Walnut	3.5	12.1	0.1	15.7	-	-	-	-	15.7
Locust	-	-	40.0	40.0	-	-	5.9	5.9	45.9
Other hardwood	97.1	46.3	76.7	220.0	0.3	2.1	8.7	11.1	231.2
Total hardwood	1,519.2	465.6	1,182.7	3,167.5	26.1	63.5	104.4	194.0	3,361.5
All Species	3,171.8	886.0	1,344.8	5,402.6	171.1	158.6	131.5	461.2	5,863.8

Table 3.5 Number of all live trees on forestland by species group and diameter class, Central Texas, 2006

Species group	Diameter Class												
	All classes	1.0–2.9	3.0–4.9	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–24.9	25.0+
	million trees												
Softwood													
Pine	45.7	30.5	4.0	3.9	2.2	2.3	1.3	0.3	0.6	-	0.5	0.1	-
Juniper	2,456.6	1,322.8	490.7	256.4	155.2	93.5	58.5	40.3	19.4	9.0	5.5	4.2	1.1
Total Softwoods	2,502.2	1,353.3	494.7	260.3	157.4	95.7	59.8	40.5	20.0	9.0	6.0	4.3	1.1
Hardwood													
Mesquite	463.3	195.9	101.4	64.7	43.0	22.6	17.0	7.4	3.5	3.0	2.8	1.4	0.6
Oak	1,147.7	304.6	316.6	220.9	137.8	71.0	39.2	25.7	11.5	7.2	4.8	6.0	2.4
Elm	475.6	264.8	109.9	49.9	24.7	10.7	6.2	3.9	1.9	1.8	1.1	0.7	0.1
Pecon	11.6	-	1.6	1.9	2.0	1.4	1.6	1.0	0.6	0.5	0.3	0.4	0.3
Sugarberry	117.0	77.2	17.7	12.5	5.1	1.6	1.4	0.5	0.4	0.3	0.1	0.1	-
Ash	92.0	70.8	1.6	7.7	5.8	3.3	1.0	0.9	0.4	0.3	-	0.3	-
Cottonwood	6.1	5.8	-	0.2	0.2	-	-	-	-	-	-	-	-
Sweet Acacia	71.3	30.8	30.1	6.5	1.9	0.8	0.3	0.4	0.2	-	0.2	-	-
Hackberry	72.9	46.3	12.9	6.9	3.7	1.8	0.4	0.5	0.4	-	-	-	-
Osage-Orange	23.9	12.9	1.6	4.5	2.3	0.8	0.7	0.4	0.3	0.3	-	-	-
Persimmon	495.8	480.1	11.8	2.5	0.9	0.3	0.1	-	-	-	-	-	-
Hickory	26.5	12.6	5.8	3.1	1.8	1.2	1.5	0.3	0.2	-	0.2	-	-
Chinese Tallow	1.9	1.6	-	-	0.3	-	-	-	-	-	-	-	-
Black Cherry	9.9	1.6	2.0	1.1	1.2	1.5	1.3	0.8	0.1	0.3	-	-	-
Chittamwood	53.1	45.7	3.3	2.0	1.2	0.4	0.4	0.2	-	-	-	-	-
Walnut	15.7	7.8	-	3.9	2.2	1.4	0.1	0.3	-	-	-	-	-
Locust	45.9	43.3	-	1.5	1.0	-	-	0.1	-	-	-	-	-
Other Hardwood	231.2	97.3	68.4	34.0	17.1	8.6	4.4	0.8	0.2	0.1	0.1	0.1	-
Total Hardwood	3,361.5	1,699.1	684.7	423.8	252.0	127.2	75.7	43.1	19.8	13.8	9.6	9.1	3.5
All Species	5,863.8	3,052.4	1,179.4	684.2	409.3	222.9	135.6	83.6	39.8	22.8	15.7	13.4	4.6

Table 3.6 Number of growing stock trees on timberland by species group and diameter class, Central Texas, 2006

Species group	All classes	Diameter Class 1.0–2.9	3.0–4.9	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–24.9	25.0+
						million trees							
Softwood													
Pine	23.4	14.2	1.9	2.2	1.6	1.8	1.1	0.1	-	-	0.4	0.1	-
Juniper	43.1	18.4	10.7	6.0	4.1	2.5	0.7	0.7	-	-	-	-	-
Total Softwoods	66.5	32.6	12.6	8.1	5.6	4.4	1.8	0.8	-	-	0.4	0.1	-
Hardwood													
Mesquite	-	-	-	-	-	-	-	-	-	-	-	-	-
Oak	56.9	8.8	3.6	12.2	11.5	8.1	5.0	3.9	2.3	0.4	0.8	0.3	-
Elm	33.7	9.6	8.8	7.3	3.2	2.7	0.6	0.4	0.3	0.3	-	0.4	0.1
Pecon	2.4	-	-	-	0.4	0.7	0.6	0.3	-	0.4	-	-	-
Sugarberry	14.5	8.6	1.6	2.8	1.4	-	0.1	-	-	-	-	-	-
Ash	27.9	18.6	-	3.2	2.8	2.0	0.3	0.6	0.2	0.3	-	-	-
Cottonwood	0.3	-	-	0.2	0.2	-	-	-	-	-	-	-	-
Sweet Acacia	-	-	-	-	-	-	-	-	-	-	-	-	-
Hackberry	8.3	1.6	1.9	2.2	1.7	0.6	-	0.2	0.1	-	-	-	-
Osage-Orange	0.3	-	-	-	-	-	-	0.3	-	-	-	-	-
Persimmon	0.5	-	-	0.3	-	0.2	-	-	-	-	-	-	-
Hickory	6.2	3.6	-	0.5	0.6	0.5	0.8	0.1	0.2	-	-	-	-
Chinese Tallow	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Cherry	1.6	1.6	-	-	-	-	-	-	-	-	-	-	-
Chittamwood	-	-	-	-	-	-	-	-	-	-	-	-	-
Walnut	0.3	-	-	0.3	-	-	-	-	-	-	-	-	-
Locust	3.5	3.2	-	0.2	-	-	-	0.1	-	-	-	-	-
Other Hardwood	4.8	1.6	1.9	0.8	0.2	0.1	0.1	-	-	-	-	-	-
Total Hardwood	161.3	57.2	17.9	29.9	21.9	14.9	7.5	5.9	3.1	1.4	0.8	0.7	0.1
All Species	227.7	89.8	30.5	38.0	27.5	19.3	9.2	6.7	3.1	1.4	1.2	0.9	0.1

Table 3.7 Net volume of live trees on forestland by species group, ownership group, and sub-region, Central Texas, 2006

Species group	Priavate				Public				Total
	Hill Country	Blacklands	Post Oak	Total	Hill Country	Blacklands	Post Oak	Total	
	million cubic feet								
Softwood									
Pine	10.0	58.3	2.0	70.3	-	46.1	-	46.1	116.4
Juniper	1,763.9	543.7	235.4	2,543.1	147.0	100.0	4.1	251.1	2,794.1
Total Softwoods	1,774.0	602.0	237.4	2,613.4	147.0	146.0	4.1	297.1	2,910.5
Hardwood									
Mesquite	389.2	223.6	225.1	837.9	1.8	2.0	11.4	15.2	853.1
Oak	1,051.1	352.5	1,256.3	2,659.9	35.0	51.7	45.2	131.9	2,791.9
Elm	76.7	136.6	307.7	521.0	1.6	3.0	34.9	39.4	560.5
Pecon	10.7	40.4	96.8	147.8	-	-	12.9	12.9	160.7
Sugarberry	5.5	17.9	65.4	88.8	-	-	4.2	4.2	93.0
Ash	6.7	4.1	101.4	112.2	-	1.3	20.8	22.1	134.4
Cottonwood	-	-	-	-	-	-	1.1	1.1	1.1
Sweet Acacia	0.6	13.9	27.4	41.8	-	-	-	-	41.8
Hackberry	10.5	4.1	32.0	46.6	-	-	14.1	14.1	60.7
Osage-Orange	-	-	41.5	41.5	-	-	2.8	2.8	44.3
Persimmon	2.8	-	6.4	9.2	-	-	-	-	9.2
Hickory	0.6	5.4	40.4	46.4	-	-	5.1	5.1	51.5
Chinese Tallow	-	-	1.4	1.4	-	-	-	-	1.4
Black Cherry	50.3	-	0.7	51.0	-	-	-	-	51.0
Chittamwood	0.8	0.5	11.8	13.0	-	-	1.4	1.4	14.5
Walnut	8.3	17.6	1.8	27.7	-	-	-	-	27.7
Locust	-	-	7.3	7.3	-	-	0.2	0.2	7.5
Other Hardwood	122.1	18.3	22.0	162.4	0.4	4.1	6.5	11.0	173.4
Total Hardwood	9.1	18.0	20.9	48.0	-	-	1.6	1.6	5,077.6
All Species	1,783.1	620.1	258.2	2,661.4	147.0	146.0	5.7	298.7	7,988.1

Table 3.8 Net Volume of growing stock trees on timberland by species group and diameter class, Central Texas, 2006

Species group	Diameter Class												
	All classes	1.0–2.9	3.0–4.9	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–24.9	25.0+
	million cubic feet												
Softwood													
Pine	82.2	-	-	4.1	8.1	16.1	17.2	3.0	-	-	26.7	7.0	-
Juniper	78.1	-	-	12.9	19.1	21.9	9.9	14.5	-	-	-	-	-
Total Softwoods	160.3	-	-	17.0	27.2	37.9	27.1	17.5	-	-	26.7	7.0	-
Hardwood													
Mesquite	-	-	-	-	-	-	-	-	-	-	-	-	-
Oak	416.9	-	-	28.7	57.9	69.3	63.7	74.8	63.3	11.3	33.2	14.8	-
Elm	124.4	-	-	17.3	14.8	22.3	9.0	8.1	9.8	11.0	-	22.1	10.0
Pecon	40.2	-	-	-	2.3	6.8	7.8	7.5	-	15.7	-	-	-
Sugarberry	14.0	-	-	5.9	6.5	-	1.6	-	-	-	-	-	-
Ash	83.0	-	-	10.1	16.5	20.5	5.2	15.6	4.5	10.6	-	-	-
Cottonwood	1.1	-	-	0.3	0.8	-	-	-	-	-	-	-	-
Sweet Acacia	-	-	-	-	-	-	-	-	-	-	-	-	-
Hackberry	26.5	-	-	5.7	7.7	5.9	-	3.2	3.9	-	-	-	-
Osage-Orange	5.2	-	-	-	-	-	-	5.2	-	-	-	-	-
Persimmon	2.4	-	-	0.9	-	1.5	-	-	-	-	-	-	-
Hickory	22.8	-	-	0.7	2.4	3.2	9.7	2.2	4.5	-	-	-	-
Chinese Tallow	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Cherry	-	-	-	-	-	-	-	-	-	-	-	-	-
Chittamwood	-	-	-	-	-	-	-	-	-	-	-	-	-
Walnut	0.5	-	-	0.5	-	-	-	-	-	-	-	-	-
Locust	2.6	-	-	0.3	-	-	-	2.3	-	-	-	-	-
Other Hardwood	5.3	-	-	1.4	0.5	1.4	2.0	-	-	-	-	-	-
Total Hardwood	744.8	-	-	71.7	109.5	130.9	99.2	118.9	86.1	48.6	33.2	36.9	10.0
All Species	905.2	-	-	88.7	136.7	168.8	126.2	136.4	86.1	48.6	59.9	43.9	10.0

Table 3.9 Net Volume of sawtimber trees on timberland by species group and diameter class, Central Texas, 2006

Species group	Diameter Class												
	All classes	1.0–2.9	3.0–4.9	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–24.9	25.0+
	million board feet												
Softwood													
Pine	367.2	-	-	-	-	54.5	79.1	15.7	-	-	171.9	46.0	-
Juniper	213.8	-	-	-	-	89.8	47.1	77.0	-	-	-	-	-
Total Softwoods	581.0	-	-	-	-	144.3	126.2	92.7	-	-	171.9	46.0	-
Hardwood													
Mesquite	-	-	-	-	-	-	-	-	-	-	-	-	-
Oak	1,159.0	-	-	-	-	-	229.3	314.9	299.9	55.3	176.6	83.0	-
Elm	317.2	-	-	-	-	-	31.7	31.0	43.2	49.9	-	109.1	52.3
Pecon	136.1	-	-	-	-	-	27.3	31.6	-	77.2	-	-	-
Sugarberry	5.8	-	-	-	-	-	5.8	-	-	-	-	-	-
Ash	148.1	-	-	-	-	-	17.0	62.9	19.1	49.1	-	-	-
Cottonwood	-	-	-	-	-	-	-	-	-	-	-	-	-
Sweet Acacia	-	-	-	-	-	-	-	-	-	-	-	-	-
Hackberry	31.8	-	-	-	-	-	-	13.0	18.8	-	-	-	-
Osage-Orange	20.9	-	-	-	-	-	-	20.9	-	-	-	-	-
Persimmon	-	-	-	-	-	-	-	-	-	-	-	-	-
Hickory	61.8	-	-	-	-	-	32.9	8.7	20.2	-	-	-	-
Chinese Tallow	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Cherry	-	-	-	-	-	-	-	-	-	-	-	-	-
Chittamwood	-	-	-	-	-	-	-	-	-	-	-	-	-
Walnut	-	-	-	-	-	-	-	-	-	-	-	-	-
Locust	8.9	-	-	-	-	-	-	8.9	-	-	-	-	-
Other Hardwood	7.6	-	-	-	-	-	7.6	-	-	-	-	-	-
Total Hardwood	1,897.0	-	-	-	-	-	351.5	491.8	401.2	231.6	176.6	192.1	52.3
All Species	2,478.1	-	-	-	-	144.3	477.7	584.5	401.2	231.6	348.5	238.1	52.3

Table 3.10 Total biomass on forestland by species group, ownership group, and sub-region, Central Texas, 2006

Species group	Priavate				Public				Total
	Hill Country	Blacklands	Post Oak	Total	Hill Country	Blacklands	Post Oak	Total	
	million dry tons								
Softwood									
Pine	0.1	1.3	0.1	1.6	-	1.0	-	1.0	2.6
Juniper	24.7	8.0	6.3	39.1	2.0	1.7	0.2	3.9	43.0
Total Softwoods	24.9	9.4	6.4	40.6	2.0	2.7	0.2	4.9	45.6
Hardwood									
Mesquite	13.9	7.2	7.7	28.8	0.1	0.1	0.4	0.5	29.3
Oak	34.2	11.1	38.0	83.2	1.0	1.6	1.3	4.0	87.2
Elm	1.9	3.3	8.5	13.7	0.0	0.1	0.8	0.9	14.7
Pecon	0.3	1.1	2.7	4.0	-	-	0.3	0.3	4.4
Sugarberry	0.2	0.4	2.1	2.7	-	0.0	0.1	0.1	2.8
Ash	0.2	0.1	2.2	2.5	-	0.1	0.6	0.7	3.2
Cottonwood	-	-	-	-	-	-	0.0	0.0	0.0
Sweet Acacia	0.0	0.4	1.3	1.7	-	-	-	-	1.7
Hackberry	0.4	0.1	0.9	1.3	-	-	0.3	0.3	1.7
Osage-Orange	-	-	1.1	1.1	-	-	0.1	0.1	1.1
Persimmon	0.9	0.2	0.3	1.4	0.0	-	-	0.0	1.4
Hickory	0.0	0.1	1.2	1.4	-	-	0.2	0.2	1.5
Chinese Tallow	-	-	0.0	0.0	-	-	-	-	0.0
Black Cherry	1.1	-	0.0	1.1	-	-	-	-	1.1
Chittamwood	0.1	0.0	0.4	0.5	-	0.0	0.0	0.1	0.5
Walnut	0.2	0.4	0.1	0.7	-	-	-	-	0.7
Locust	-	-	0.4	0.4	-	-	0.0	0.0	0.4
Other Hardwood	4.0	0.9	1.2	6.0	0.0	0.1	0.2	0.3	6.4
Total Hardwood	57.4	25.4	67.8	150.6	1.2	1.9	4.5	7.5	158.2
All Species	82.3	34.8	74.2	191.3	3.2	4.6	4.7	12.5	203.8

Table 3.11 Total biomass of all live trees on forestland by species group and merchantability, Central Texas, 2006

Species group	Merchantable			Non-Merchantable	Total
	Pulpwood	Sawlog	Total		
	million dry tons				
Softwood					
Pine	0.8	1.3	2.2	0.4	2.6
Juniper	36.4	1.3	37.7	5.3	43.0
Total Softwoods	37.2	2.7	39.8	5.8	45.6
Hardwood					
Mesquite	18.4	-	18.4	10.9	29.3
Oak	53.1	7.8	61.0	26.2	87.2
Elm	7.6	2.0	9.6	5.0	14.7
Pecon	2.3	1.2	3.5	0.8	4.4
Sugarberry	1.6	0.0	1.6	1.1	2.8
Ash	1.7	0.6	2.3	1.0	3.2
Cottonwood	0.0	-	0.0	0.0	0.0
Sweet Acacia	0.9	-	0.9	0.8	1.7
Hackberry	0.9	0.1	1.1	0.6	1.7
Osage-Orange	0.7	0.1	0.8	0.4	1.1
Persimmon	0.2	-	0.2	1.2	1.4
Hickory	0.7	0.4	1.1	0.5	1.5
Chinese Tallow	0.0	-	0.0	0.0	0.0
Black Cherry	0.9	-	0.9	0.3	1.1
Chittamwood	0.3	-	0.3	0.3	0.5
Walnut	0.5	-	0.5	0.2	0.7
Locust	0.1	0.1	0.2	0.2	0.4
Other Hardwood	3.3	0.1	3.4	3.0	6.4
Total Hardwood	93.2	12.4	105.6	52.6	158.2
All Species	130.4	15.1	145.4	58.3	203.8

Table 4.1 Total industrial timber harvest volume and value by county, East Texas, 2006

County	Volume Harvested			Value of Harvest	
	Pine	Hardwood	Total	Stumpage	Delivered
	– – – – – thousand cubic feet – – – – –			*– – – – – thousand dollars – – – – –*	
Anderson	9,456.8	2,158.0	11,614.7	9,526.7	16,455.6
Angelina	23,756.1	5,127.4	28,883.5	21,194.4	38,095.7
Bowie	8,221.2	6,703.8	14,924.9	7,982.5	17,154.8
Camp	1,250.7	821.7	2,072.4	1,001.3	2,282.0
Cass	18,574.1	12,518.3	31,092.4	17,192.8	36,146.7
Chambers	400.6	1,136.5	1,537.1	769.7	1,769.5
Cherokee	17,500.8	5,751.2	23,252.0	15,958.2	30,034.1
Franklin	167.3	238.0	405.3	252.7	527.0
Gregg	2,225.2	2,178.6	4,403.8	3,074.2	5,968.9
Grimes	2,293.4	11.2	2,304.7	2,493.0	3,770.2
Hardin	15,995.4	7,357.1	23,352.5	13,748.5	27,798.4
Harris	4,221.9	802.3	5,024.3	4,662.9	7,561.3
Harrison	15,069.2	5,865.2	20,934.4	12,991.6	25,547.7
Henderson	1,472.0	1,234.6	2,706.6	2,008.4	3,756.8
Houston	15,259.1	2,373.2	17,632.3	12,537.7	22,828.3
Jasper	27,476.8	5,531.2	33,008.0	18,489.8	37,926.4
Jefferson	690.9	295.7	986.5	739.6	1,329.8
Leon	1,731.9	417.7	2,149.5	2,009.9	3,283.5
Liberty	10,901.3	8,568.4	19,469.7	12,218.8	24,300.6
Madison	22.5	86.8	109.3	34.6	104.6
Marion	12,888.9	4,835.5	17,724.4	11,210.9	21,885.2
Montgomery	9,095.7	2,403.3	11,499.0	9,243.3	15,967.2
Morris	2,549.1	1,798.8	4,347.9	2,975.3	5,606.9
Nacogdoches	26,499.5	5,392.7	31,892.2	21,807.6	40,616.4
Newton	34,146.0	4,688.7	38,834.7	23,924.1	46,502.6
Orange	2,084.3	1,683.6	3,768.0	2,002.4	4,328.9
Panola	16,825.8	4,918.5	21,744.3	13,005.2	25,937.4
Polk	47,805.0	5,165.0	52,970.0	41,463.5	71,893.7
Red River	4,069.3	3,809.5	7,878.8	3,295.6	8,286.6
Rusk	12,390.5	3,142.5	15,533.0	11,097.8	20,384.5
Sabine	18,119.1	3,363.7	21,482.8	13,689.6	26,293.6
San Augustine	24,062.2	6,153.9	30,216.1	18,918.1	36,763.6
San Jacinto	13,058.8	2,518.5	15,577.3	10,562.2	19,632.3
Shelby	18,017.0	3,180.9	21,198.0	12,182.7	24,639.6
Smith	6,239.9	4,371.5	10,611.4	6,773.4	13,325.9
Titus	1,064.8	3,215.8	4,280.7	1,788.9	4,601.3
Trinity	18,270.1	1,041.2	19,311.3	17,143.2	28,120.4
Tyler	36,223.8	8,792.4	45,016.2	26,229.0	52,762.1
Upshur	7,857.2	3,420.7	11,277.9	8,862.9	15,696.3
Van Zandt	311.8	259.6	571.4	402.8	777.3
Walker	8,531.2	1,259.8	9,791.0	8,815.1	14,394.9
Waller	488.3	2.1	490.4	572.4	843.1
Wood	1,580.3	1,446.5	3,026.8	1,691.4	3,558.9
Other Counties	1,183.8	2,264.1	3,447.9	1,161.0	3,394.6
Total	500,049.4	148,305.8	648,355.2	427,705.3	812,855.3

Table 4.2 Wood utilization rates in East Texas

Species Group	Wood Type	Total Volume	Industrial Roundwood	Logging Residue	
				Top/limb	Cull
Softwood					
	Sawtimber	100.0%	87.9%	7.9%	4.2%
	Poletimber	100.0%	91.7%	7.5%	0.8%
	Total	100.0%	88.3%	7.9%	3.8%
Hardwood					
	Sawtimber	100.0%	76.9%	13.3%	9.9%
	Poletimber	100.0%	83.8%	12.6%	3.6%
	Total	100.0%	78.6%	13.1%	8.3%

Source: Bentley and Johnson (2004)

Table 4.3 Logging residue potentially available for energy generation by species group, source, and region, East Texas, 2006

Region	Species Group	Top/Limb	Unused Cull	Total Available Residue
			thousand dry tons	
Northeast				
	Softwood	250.3	88.8	339.1
	Hardwood	201.3	96.7	298.0
	All	451.6	185.5	637.1
Southeast				
	Softwood	429.6	157.5	587.1
	Hardwood	172.0	74.0	245.9
	All	601.6	231.4	833.0
East Texas				
	Softwood	679.9	246.2	926.2
	Hardwood	373.2	170.7	543.9
	All	1,053.2	416.9	1,470.1

Table 4.4 Logging residue potentially available for energy generation by county, source, and species group, East Texas, 2006

County	Softwood			Hardwood			All Species		
	Top/ Limb	Cull	Total	Top/ Limb	Cull	Total	Top/ Limb	Cull	Total
Northeast Texas	*thousand dry tons*								
Anderson	13.1	5.3	22.3	6.8	4.7	13.4	19.9	10.0	35.8
Bowie	11.2	4.1	18.8	16.0	6.0	27.2	27.2	10.0	46.1
Camp	1.7	0.5	2.7	2.1	0.9	3.6	3.7	1.4	6.3
Cass	25.3	9.0	42.4	29.9	11.1	50.8	55.2	20.2	93.2
Cherokee	23.8	8.4	39.8	16.6	9.9	31.3	40.3	18.3	71.1
Franklin	0.2	0.1	0.4	0.7	0.5	1.5	1.0	0.6	1.8
Gregg	3.1	1.2	5.2	6.9	4.8	13.5	9.9	5.9	18.7
Harrison	20.5	7.2	34.2	14.6	6.2	25.5	35.1	13.4	59.7
Henderson	2.0	0.8	3.5	3.8	2.6	7.5	5.9	3.5	11.0
Marion	17.5	6.1	29.2	12.6	6.1	22.6	30.1	12.2	51.8
Morris	3.6	1.6	6.3	4.3	1.6	7.4	7.9	3.3	13.6
Nacogdoches	35.9	12.6	60.1	14.5	7.6	26.5	50.5	20.2	86.6
Panola	22.6	7.4	37.5	12.1	5.0	21.0	34.7	12.4	58.5
Red River	5.3	1.3	8.5	9.8	4.6	17.4	15.1	5.9	26.0
Rusk	16.9	6.1	28.4	9.1	5.5	17.3	26.0	11.7	45.7
Shelby	24.0	7.3	39.4	7.8	3.2	13.6	31.8	10.5	53.0
Smith	8.6	3.4	14.7	11.4	5.5	20.4	20.0	8.9	35.0
Titus	1.5	0.6	2.5	8.1	3.5	14.1	9.5	4.1	16.6
Upshur	11.0	4.7	19.0	9.6	5.4	17.9	20.6	10.2	36.9
Van Zandt	0.4	0.2	0.7	0.8	0.6	1.7	1.3	0.8	2.4
Wood	2.2	0.9	3.7	3.5	1.3	6.0	5.7	2.2	9.7
Northeast Total	250.3	88.8	419.2	201.3	96.7	360.4	451.6	185.5	779.6
Southeast Texas									
Angelina	32.7	12.6	55.4	13.2	6.2	23.5	45.9	18.8	79.0
Chambers	0.6	0.3	1.0	2.8	1.2	4.9	3.4	1.5	6.0
Grimes	3.3	1.6	5.8	0.0	0.0	0.0	3.3	1.6	5.8
Hardin	21.7	7.7	36.4	17.8	7.0	30.6	39.6	14.6	67.0
Harris	6.0	2.8	10.5	2.0	0.9	3.6	8.1	3.7	14.1
Houston	20.8	7.5	34.8	6.2	3.0	11.2	27.0	10.5	46.0
Jasper	36.7	11.4	60.4	13.8	5.9	24.2	50.5	17.3	84.5
Jefferson	1.0	0.4	1.7	0.8	0.3	1.3	1.7	0.8	3.0
Leon	2.5	1.1	4.3	1.3	0.9	2.6	3.8	2.0	6.9
Liberty	15.1	6.1	25.8	22.1	10.3	39.2	37.2	16.4	65.0
Madison	0.0	0.0	0.1	0.2	0.1	0.3	0.2	0.1	0.4
Montgomery	12.7	5.5	22.0	5.9	2.4	10.2	18.6	7.8	32.1
Newton	46.0	15.4	76.5	12.0	5.5	21.2	58.0	20.9	97.7
Orange	2.8	1.0	4.7	4.1	1.6	7.1	6.9	2.6	11.8
Polk	65.8	25.6	111.7	12.5	4.9	21.4	78.4	30.4	133.2
Sabine	24.6	8.7	41.2	9.1	4.7	16.6	33.7	13.5	57.8
San Augustine	32.6	11.3	54.4	15.4	6.7	27.0	48.0	18.0	81.4
San Jacinto	17.8	6.4	29.8	5.8	1.9	9.6	23.6	8.3	39.4
Trinity	25.5	10.6	43.7	3.0	1.7	5.5	28.4	12.4	49.3
Tyler	48.6	15.8	80.5	21.0	7.9	35.8	69.7	23.6	116.3
Walker	12.1	5.4	21.0	2.9	0.9	4.7	14.9	6.3	25.6
Waller	0.7	0.4	1.3	0.0	0.0	0.0	0.7	0.4	1.3
Southeast Total	429.6	157.5	722.9	172.0	74.0	300.7	601.6	231.4	1,023.5
Total	679.9	246.2	1,142.1	373.2	170.7	661.0	1,053.2	416.9	1,803.1

Table 4.5 Survey results of thinnings by forest type

Item		Natural Pine	Pine Plantation	Mixed	Hardwood
First Thinning	Age	18	15	20	27
	Minimum Starting Age	8	8	8	14
	Starting BA	130	130	115	100
	Target BA	75	75	70	70
	Thinning Methods				
	Thinning from Below	58%	15%	74%	64%
	Row Thinning	22%	80%	5%	6%
	Selective Thinning	20%	5%	21%	30%
	Total	100%	100%	100%	100%
Interval between First thinning and Second Thinning (in years)		7	6	8	10
Final Harvest Age		40	35	45	50

Table 4.6 Percentage of survey respondents rating certain tree species as undesirable

Species	Percentage
Chinese Tallow	68%
Sweet Gum	63%
Sugarberry	61%
Blackjack Oak	59%
Cedar Elm	58%
Black Gum	56%
American Elm	53%
River Birch	51%
Red Maple	42%
Black Hickory	41%
Eastern Redcedar	37%
Post Oak	37%
Mockernut Hickory	31%
Water Tupelo	29%
Water Hickory	27%
American Beech	25%
Overcup Oak	20%
Laurel Oak	19%
Willow Oak	15%
Green Ash	12%
Pecan	10%
White Ash	10%
Swamp Chestnut Oak	8%
White Oak	7%
Bald Cypress	5%
Water Oak	5%
Cherry Cark Oak	3%

Table 4.7 Number and area of FVS stands in the study by forest type

Forest Type	Number of Stands	Area (million acres)
Natural Pine	329	1.7
Pine Plantation	413	1.9
Mixed	228	1.1
Hardwood	705	3.6
Total	1,675	8.3

Table 4.8 Desirability of tree species by group

Species Groups	Desirable	Undesirable	Broad Species
All Western Species		x	
Ash	x		Hard Hardwood
Bald Cypress	x		Other Softwood
Basswood		x	Soft Hardwood
Beech	x		Hard Hardwood
Black Walnut	x		Hard Hardwood
Cottonwood and Aspen	x		Soft Hardwood
Eastern Noncommercial Hardwoods		x	Soft Hardwood
Eastern Red Cedar		x	Other Softwood
Hard Maple	x		Hard Hardwood
Hickory	x		Hard Hardwood
Loblolly Pine	x		Pine
Longleaf Pine	x		Pine
Other Eastern Hard Hardwoods	x		Hard Hardwood
Other Eastern Soft Hardwoods		x	Soft Hardwood
Other Red Oaks	x		Hard Hardwood
Other White Oaks	x		Hard Hardwood
Select Red Oaks	x		Hard Hardwood
Select White Oaks	x		Hard Hardwood
Shortleaf Pine	x		Pine
Slash Pine	x		Pine
Soft Maple		x	Soft Hardwood
Sweet Gum		x	Soft Hardwood
Tupelo And Black Gum		x	Soft Hardwood
Yellow Birch	x		Hard Hardwood
Yellow-Poplar		x	Soft Hardwood

Table 4.9 Annual wood waste available from biomass thinnings by forest type, species group, and source, East Texas, Base Scenario

Forest Type	Softwood				Hardwood				All Species			
	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total
	thousand dry tons											
Pine Plantation	41.5	227.4	192.8	461.7	3.1	42.9	372.9	418.9	44.5	270.3	565.8	880.6
Natural Pine	14.1	55.8	172.9	242.8	4.7	45.0	212.0	261.7	18.8	100.8	384.9	504.5
Mixed	6.5	32.3	61.5	100.3	5.2	67.3	234.8	307.2	11.6	99.6	296.3	407.5
Hardwood	13.2	85.5	52.9	151.6	25.3	270.6	568.5	864.4	38.5	356.2	621.4	1,016.0
Total	75.2	401.0	480.2	956.5	38.2	425.8	1,388.2	1,852.2	113.4	826.8	1,868.4	2,808.6

Table 4.10 Annual wood waste available from biomass thinnings by county, species group, and source, Northeast Texas, Base Scenario

County	Softwood				Hardwood				All Species			
	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total
	thousand dry tons											
Anderson	2.2	12.9	17.3	32.4	1.3	14.1	47.6	62.9	3.5	27.0	64.9	95.3
Bowie	1.3	8.3	11.9	21.5	0.8	9.0	31.6	41.4	2.2	17.3	43.4	62.9
Camp	0.6	2.2	2.2	5.0	0.1	1.8	6.6	8.5	0.7	4.0	8.8	13.5
Cass	2.4	14.2	19.0	35.6	1.4	15.5	52.3	69.2	3.8	29.7	71.3	104.8
Cherokee	2.5	13.1	14.4	30.0	1.3	14.4	43.9	59.7	3.8	27.6	58.3	89.7
Franklin	0.5	3.0	3.9	7.4	0.3	3.2	10.9	14.4	0.8	6.2	14.8	21.8
Gregg	0.7	3.7	4.0	8.4	0.4	4.1	12.2	16.7	1.1	7.8	16.2	25.0
Harrison	1.9	10.4	12.0	24.3	1.0	11.4	35.6	47.9	2.9	21.7	47.6	72.2
Henderson	1.0	6.3	9.4	16.7	0.6	6.9	24.5	32.0	1.6	13.2	33.9	48.7
Marion	1.5	8.0	9.1	18.6	0.8	8.8	27.2	36.9	2.3	16.9	36.3	55.5
Morris	0.5	3.1	4.4	8.0	0.3	3.4	11.7	15.4	0.8	6.5	16.2	23.4
Nacogdoches	2.9	14.9	15.6	33.4	1.5	16.4	48.8	66.6	4.4	31.3	64.3	100.0
Panola	3.0	13.9	13.3	30.1	1.3	14.4	43.1	58.8	4.2	28.2	56.4	88.9
Red River	1.7	9.1	12.3	23.1	0.8	9.3	33.3	43.5	2.5	18.5	45.6	66.6
Rusk	1.8	10.8	14.5	27.1	1.1	11.7	39.8	52.6	2.9	22.5	54.3	79.7
Shelby	2.1	9.7	9.5	21.3	0.9	9.9	30.3	41.0	2.9	19.5	39.8	62.2
Smith	1.2	7.5	10.5	19.2	0.7	8.2	28.3	37.2	2.0	15.7	38.8	56.4
Titus	0.8	5.0	7.3	13.1	0.5	5.5	19.2	25.2	1.3	10.5	26.5	38.3
Upshur	1.4	7.9	10.4	19.6	0.8	8.6	28.7	38.1	2.1	16.5	39.1	57.7
Van Zandt	0.8	5.0	7.3	13.1	0.5	5.5	19.2	25.1	1.3	10.5	26.5	38.2
Wood	1.4	8.3	11.8	21.4	0.8	9.0	31.4	41.2	2.2	17.3	43.2	62.6
Northeast Total	32.1	177.2	219.9	429.2	17.2	190.9	626.2	834.3	49.3	368.1	846.1	1,263.5

Table 4.11 Annual wood waste available from biomass thinnings by county, species group, and source, Southeast Texas, Base Scenario

County	Softwood				Hardwood				All Species			
	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total
	thousand dry tons											
Angelina	2.3	11.6	11.8	25.7	1.1	12.8	37.6	51.5	3.4	24.4	49.4	77.3
Chambers	0.3	1.5	2.2	4.0	0.2	1.7	5.9	7.7	0.4	3.2	8.0	11.7
Grimes	1.1	6.6	9.5	17.1	0.6	7.1	25.2	32.9	1.7	13.7	34.7	50.1
Hardin	3.0	15.4	17.5	35.9	1.4	16.0	51.8	69.2	4.4	31.4	69.3	105.1
Harris	1.4	8.4	11.4	21.3	0.8	9.2	31.2	41.2	2.3	17.6	42.6	62.5
Houston	1.9	11.5	15.7	29.1	1.1	12.6	42.7	56.4	3.1	24.1	58.4	85.5
Jasper	3.1	16.8	19.4	39.4	1.7	18.5	57.7	77.8	4.8	35.3	77.1	117.2
Jefferson	0.9	3.8	3.5	8.3	0.3	3.4	11.3	14.9	1.2	7.2	14.7	23.2
Leon	1.2	7.6	11.2	20.0	0.7	8.2	29.3	38.3	2.0	15.8	40.5	58.3
Liberty	3.8	16.1	16.0	35.8	1.2	14.4	49.2	64.8	5.0	30.4	65.1	100.6
Madison	0.6	3.7	5.4	9.7	0.4	4.0	14.3	18.7	1.0	7.7	19.8	28.5
Montgomery	2.6	14.4	17.8	34.7	1.4	15.7	50.9	68.0	4.0	30.1	68.7	102.8
Newton	3.5	17.6	19.5	40.6	1.6	18.0	58.2	77.7	5.1	35.5	77.7	118.3
Orange	0.9	4.7	5.0	10.7	0.5	5.2	15.6	21.3	1.4	9.9	20.7	32.0
Polk	3.4	18.2	20.7	42.3	1.8	20.0	61.9	83.6	5.2	38.2	82.5	125.9
Sabine	1.7	7.6	7.1	16.4	0.7	7.5	23.1	31.3	2.3	15.1	30.2	47.7
San Augustine	1.4	7.0	7.0	15.3	0.7	7.7	22.3	30.7	2.1	14.6	29.3	46.0
San Jacinto	1.9	10.5	12.3	24.7	1.0	11.5	36.1	48.6	3.0	22.0	48.4	73.3
Trinity	1.8	8.6	8.9	19.3	0.8	8.6	27.4	36.8	2.6	17.2	36.4	56.1
Tyler	3.7	17.8	19.5	41.0	1.6	17.9	58.4	77.9	5.3	35.7	77.9	118.9
Walker	2.2	11.5	14.7	28.4	1.1	11.8	40.9	53.7	3.2	23.3	55.5	82.1
Waller	0.5	3.0	4.1	7.6	0.3	3.3	11.1	14.7	0.8	6.3	15.2	22.3
Southeast Total	43.1	223.8	260.2	527.2	21.0	234.9	762.0	1,017.9	64.1	458.7	1,022.2	1,545.1

Table 4.12 Annual wood waste available from biomass thinnings by forest type, species group, and source, East Texas, Alternative Scenario I

Forest Type	Softwood				Hardwood				All Species			
	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total
	thousand dry tons											
Pine Plantation	42.7	201.5	172.0	416.1	2.6	38.2	352.7	393.5	45.2	239.7	524.7	809.6
Natural Pine	24.6	224.5	313.6	562.7	4.6	65.2	414.0	483.7	29.1	289.6	727.6	1,046.4
Mixed	6.4	28.7	61.9	97.0	5.0	66.9	223.2	295.2	11.5	95.6	285.2	392.2
Hardwood	9.7	80.6	61.3	151.7	24.5	243.9	546.3	814.7	34.2	324.6	607.7	966.4
Total	83.4	535.2	608.9	1,227.5	36.6	414.2	1,536.3	1,987.1	120.0	949.4	2,145.1	3,214.6

Table 4.13 Annual wood waste available from biomass thinnings by county, species group, and source,Northeast Texas, Alternative Scenario I

County	Softwood				Hardwood				All Species			
	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total
	thousand dry tons											
Anderson	2.4	15.3	20.6	38.3	1.2	13.8	50.4	65.5	3.6	29.2	71.0	103.8
Bowie	1.4	8.8	13.4	23.6	0.8	8.9	32.3	41.9	2.2	17.6	45.6	65.5
Camp	0.5	2.6	2.5	5.5	0.1	1.6	6.8	8.5	0.7	4.2	9.2	14.1
Cass	2.7	17.1	22.7	42.4	1.3	15.3	55.6	72.2	4.0	32.3	78.3	114.6
Cherokee	3.0	20.2	20.2	43.4	1.3	14.0	51.8	67.1	4.2	34.3	72.1	110.6
Franklin	0.6	3.6	4.7	8.8	0.3	3.2	11.6	15.0	0.8	6.7	16.3	23.8
Gregg	0.8	5.8	5.7	12.4	0.4	3.9	14.6	18.9	1.2	9.8	20.3	31.3
Harrison	2.2	15.0	16.1	33.3	1.0	11.1	40.7	52.8	3.2	26.1	56.8	86.1
Henderson	1.0	6.2	10.3	17.5	0.6	6.8	24.6	31.9	1.6	13.0	34.9	49.5
Marion	1.8	12.1	12.5	26.3	0.8	8.6	31.7	41.1	2.5	20.7	44.2	67.4
Morris	0.5	3.3	5.0	8.8	0.3	3.3	12.1	15.7	0.8	6.6	17.0	24.5
Nacogdoches	3.5	24.0	22.8	50.3	1.4	15.9	58.9	76.2	4.9	39.9	81.6	126.4
Panola	3.4	22.3	19.7	45.4	1.2	13.8	52.2	67.2	4.6	36.1	71.9	112.6
Red River	1.7	9.7	13.8	25.1	0.8	9.1	33.9	43.8	2.5	18.8	47.7	68.9
Rusk	2.0	12.8	17.2	32.0	1.0	11.6	42.1	54.7	3.0	24.3	59.3	86.7
Shelby	2.3	15.0	13.6	30.9	0.8	9.4	35.9	46.2	3.2	24.4	49.5	77.1
Smith	1.3	8.3	12.1	21.8	0.7	8.1	29.3	38.1	2.0	16.4	41.4	59.8
Titus	0.9	5.2	8.1	14.2	0.5	5.4	19.5	25.4	1.3	10.6	27.7	39.6
Upshur	1.5	9.6	12.5	23.7	0.7	8.4	30.8	40.0	2.2	18.1	43.3	63.6
Van Zandt	0.9	5.2	8.1	14.2	0.5	5.4	19.5	25.4	1.3	10.6	27.7	39.6
Wood	1.4	8.9	13.4	23.7	0.8	8.9	32.3	41.9	2.2	17.8	45.6	65.6
Northeast Total	35.8	231.0	274.7	541.6	16.5	186.4	686.7	889.5	52.3	417.5	961.4	1,431.1

Table 4.14 Annual wood waste available from biomass thinnings by county, species group, and source, Southeast Texas, Alternative Scenario I

County	Softwood				Hardwood				All Species			
	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total
	thousand dry tons											
Anderson	2.8	19.1	17.7	39.6	1.1	12.4	45.9	59.4	3.9	31.5	63.6	99.0
Bowie	0.3	1.7	2.5	4.5	0.1	1.7	6.0	7.9	0.4	3.4	8.5	12.3
Camp	1.1	6.8	10.6	18.6	0.6	7.0	25.6	33.2	1.7	13.9	36.2	51.8
Cass	3.3	21.1	22.7	47.1	1.4	15.5	58.0	74.9	4.7	36.6	80.7	122.0
Cherokee	1.6	9.9	13.5	24.9	0.8	9.0	33.0	42.8	2.4	18.9	46.4	67.7
Franklin	2.1	13.4	18.4	34.0	1.1	12.4	45.0	58.4	3.2	25.8	63.4	92.4
Gregg	3.6	24.6	26.2	54.4	1.6	18.0	66.3	85.9	5.3	42.6	92.5	140.3
Harrison	0.9	5.4	4.6	10.9	0.3	3.2	12.7	16.2	1.2	8.5	17.3	27.1
Henderson	1.3	7.6	12.3	21.1	0.7	8.1	29.5	38.3	2.0	15.7	41.8	59.5
Marion	3.7	20.9	20.0	44.5	1.2	13.5	53.7	68.3	4.9	34.3	73.6	112.8
Morris	0.6	3.8	6.0	10.4	0.3	4.0	14.5	18.8	1.0	7.8	20.5	29.2
Nacogdoches	2.9	19.2	22.6	44.7	1.4	15.4	56.4	73.1	4.3	34.6	79.0	117.9
Panola	3.8	24.2	25.3	53.4	1.5	17.3	65.3	84.1	5.4	41.5	90.6	137.5
Red River	1.1	7.5	7.2	15.8	0.5	5.0	18.7	24.2	1.5	12.5	25.9	40.0
Rusk	4.0	27.0	28.2	59.2	1.7	19.4	71.7	92.9	5.7	46.5	99.9	152.1
Shelby	1.9	11.8	10.3	24.0	0.6	7.2	27.6	35.4	2.5	19.0	37.9	59.3
Smith	1.7	11.6	10.6	23.9	0.7	7.4	27.5	35.6	2.3	19.0	38.1	59.4
Titus	2.2	15.1	16.3	33.6	1.0	11.2	41.3	53.5	3.2	26.3	57.6	87.1
Upshur	2.0	12.3	12.0	26.3	0.7	8.2	31.4	40.3	2.7	20.5	43.4	66.6
Van Zandt	3.9	24.3	25.2	53.5	1.5	17.2	65.3	84.0	5.5	41.5	90.4	137.4
Wood	2.2	13.4	17.1	32.7	1.0	11.5	42.8	55.2	3.2	24.8	59.9	88.0
Southeast Total	0.6	3.5	4.8	8.9	0.3	3.2	11.7	15.2	0.8	6.7	16.5	24.1

Table 4.15 Annual wood waste available from biomass thinnings by forest type, species group, and source, East Texas, Alternative Scenario II

Forest Type	Softwood				Hardwood				All Species			
	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total
	thousand dry tons											
Pine Plantation	37.0	167.2	129.6	333.8	1.7	24.7	285.8	312.2	38.8	191.9	415.4	646.1
Natural Pine	11.7	49.9	162.5	224.1	3.8	45.3	202.0	251.0	15.5	95.2	364.5	475.2
Mixed	5.0	10.6	45.1	60.7	5.1	55.1	179.8	239.9	10.0	65.7	224.9	300.6
Hardwood	8.5	74.1	39.7	122.3	25.5	245.2	453.4	724.0	34.0	319.4	493.1	846.4
Total	62.3	301.9	376.9	741.0	36.1	370.2	1,121.0	1,527.2	98.3	672.1	1,497.8	2,268.2

Table 4.16 Annual wood waste available from biomass thinnings by county, species group, and source, Northeast Texas, Alternative Scenario II

County	Softwood				Hardwood				All Species			
	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total
	thousand dry tons											
Anderson	1.9	9.5	13.5	24.9	1.2	12.2	36.9	50.3	3.1	21.7	50.4	75.2
Bowie	1.2	6.0	9.2	16.4	0.8	7.8	23.8	32.4	2.0	13.8	33.1	48.8
Camp	0.5	1.7	1.8	3.9	0.1	1.6	5.5	7.2	0.6	3.2	7.3	11.1
Cass	2.1	10.5	14.8	27.4	1.3	13.4	40.6	55.4	3.4	23.9	55.5	82.8
Cherokee	2.0	10.1	11.3	23.4	1.2	12.6	36.9	50.7	3.2	22.7	48.2	74.1
Franklin	0.4	2.2	3.1	5.7	0.3	2.8	8.4	11.5	0.7	5.0	11.5	17.2
Gregg	0.6	2.9	3.1	6.5	0.3	3.6	10.4	14.2	0.9	6.4	13.5	20.8
Harrison	1.6	7.9	9.4	18.9	1.0	9.9	29.2	40.0	2.5	17.8	38.6	58.9
Henderson	0.9	4.5	7.3	12.7	0.6	5.9	18.2	24.7	1.5	10.4	25.5	37.5
Marion	1.2	6.2	7.1	14.5	0.7	7.7	22.6	31.1	2.0	13.9	29.8	45.6
Morris	0.4	2.2	3.4	6.1	0.3	2.9	8.9	12.1	0.7	5.1	12.3	18.2
Nacogdoches	2.3	11.6	12.3	26.1	1.4	14.3	41.6	57.3	3.7	25.9	53.9	83.5
Panola	2.3	10.8	10.6	23.7	1.2	12.6	37.6	51.4	3.5	23.4	48.2	75.1
Red River	1.4	6.7	9.6	17.7	0.8	8.1	25.5	34.4	2.2	14.7	35.2	52.1
Rusk	1.6	7.9	11.3	20.8	1.0	10.2	30.8	42.0	2.6	18.1	42.1	62.8
Shelby	1.7	7.5	7.5	16.7	0.8	8.6	26.1	35.6	2.5	16.2	33.7	52.3
Smith	1.1	5.5	8.2	14.7	0.7	7.1	21.6	29.3	1.8	12.5	29.7	44.1
Titus	0.7	3.6	5.7	10.0	0.5	4.7	14.5	19.6	1.2	8.3	20.1	29.6
Upshur	1.1	5.8	8.1	15.1	0.7	7.4	22.5	30.6	1.9	13.3	30.6	45.7
Van Zandt	0.7	3.6	5.6	10.0	0.5	4.7	14.4	19.6	1.2	8.3	20.1	29.6
Wood	1.2	6.0	9.2	16.4	0.8	7.8	23.8	32.3	2.0	13.8	33.0	48.7
Northeast Total	26.8	132.7	172.2	331.7	16.2	165.7	500.0	681.9	43.0	298.4	672.2	1,013.6

Table 4.17 Annual wood waste available from biomass thinnings by county, species group, and source, Southeast Texas, Alternative Scenario II

County	Softwood				Hardwood				All Species			
	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total
	thousand dry tons											
Angelina	1.8	9.0	9.3	20.2	1.1	11.2	32.4	44.6	2.9	20.2	41.7	64.8
Chambers	0.2	1.1	1.7	3.1	0.1	1.5	4.5	6.1	0.4	2.6	6.2	9.1
Grimes	0.9	4.7	7.4	13.1	0.6	6.1	18.9	25.7	1.5	10.9	26.3	38.7
Hardin	2.5	11.6	13.8	27.9	1.3	14.0	42.4	57.7	3.8	25.6	56.3	85.7
Harris	1.2	6.2	8.9	16.3	0.8	7.9	24.1	32.9	2.0	14.1	33.0	49.2
Houston	1.7	8.5	12.2	22.3	1.1	10.8	33.0	44.9	2.7	19.3	45.2	67.2
Jasper	2.5	12.8	15.2	30.6	1.6	16.1	47.5	65.1	4.1	28.9	62.7	95.7
Jefferson	0.7	3.0	2.8	6.5	0.3	3.0	9.8	13.0	1.0	5.9	12.6	19.6
Leon	1.1	5.4	8.7	15.2	0.7	7.1	21.9	29.7	1.8	12.5	30.6	44.9
Liberty	3.0	12.2	12.8	28.1	1.2	12.6	41.4	55.2	4.2	24.8	54.2	83.3
Madison	0.5	2.7	4.2	7.4	0.4	3.5	10.7	14.5	0.9	6.2	14.9	22.0
Montgomery	2.1	10.8	13.9	26.8	1.3	13.6	40.8	55.8	3.5	24.4	54.7	82.6
Newton	2.9	13.3	15.4	31.6	1.5	15.7	48.0	65.2	4.4	29.0	63.4	96.8
Orange	0.7	3.7	4.0	8.4	0.4	4.5	13.2	18.2	1.2	8.2	17.2	26.6
Polk	2.8	13.9	16.2	32.9	1.7	17.4	51.2	70.3	4.4	31.3	67.5	103.2
Sabine	1.3	5.9	5.7	12.9	0.6	6.6	20.2	27.4	2.0	12.5	25.9	40.3
San Augustine	1.1	5.4	5.5	12.0	0.6	6.7	19.4	26.7	1.7	12.1	24.9	38.7
San Jacinto	1.6	8.0	9.6	19.2	1.0	10.0	29.6	40.6	2.6	18.0	39.2	59.7
Trinity	1.5	6.6	7.1	15.1	0.7	7.5	23.1	31.4	2.2	14.1	30.2	46.5
Tyler	3.0	13.5	15.4	32.0	1.5	15.6	48.3	65.4	4.5	29.2	63.8	97.4
Walker	1.8	8.5	11.5	21.9	1.0	10.2	32.0	43.2	2.8	18.8	43.5	65.1
Waller	0.4	2.2	3.2	5.8	0.3	2.8	8.6	11.7	0.7	5.0	11.8	17.5
Southeast Total	35.5	169.2	204.7	409.3	19.8	204.5	621.0	845.3	55.3	373.7	825.7	1,254.7

Table 4.18 Annual woody waste available from biomass thinnings by forest type, species group, and source, East Texas, Alternative Scenario III

Forest Type	Softwood				Hardwood				All Species			
	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total
	thousand dry tons											
Pine Plantation	52.0	258.2	216.7	526.9	3.5	47.3	426.4	477.2	55.5	305.5	643.1	1,004.0
Natural Pine	20.8	80.7	232.3	333.9	6.0	66.3	255.4	327.6	26.7	147.0	487.7	661.4
Mixed	8.0	35.5	76.5	120.1	7.1	78.7	264.8	350.6	15.2	114.2	341.4	470.7
Hardwood	14.2	90.0	67.0	171.1	36.4	344.4	672.8	1,053.6	50.6	434.3	739.8	1,224.7
Total	95.0	464.4	592.6	1,152.0	53.0	536.6	1,619.4	2,208.9	147.9	1,001.0	2,212.0	3,360.9

Table 4.19 Annual wood waste available from biomass thinnings by county, species group, and source, Northeast Texas, Alternative Scenario III

County	Softwood				Hardwood				All Species			
	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total
	thousand dry tons											
Anderson	2.7	14.9	21.7	39.3	1.8	17.9	55.7	75.4	4.5	32.8	77.4	114.7
Bowie	1.6	9.5	14.9	26.1	1.2	11.5	37.0	49.7	2.8	21.0	52.0	75.8
Camp	0.7	2.5	2.6	5.7	0.2	2.2	7.7	10.0	0.9	4.7	10.2	15.8
Cass	3.0	16.5	23.7	43.2	2.0	19.7	61.2	82.9	5.0	36.2	84.9	126.1
Cherokee	3.3	15.4	17.6	36.3	1.8	18.1	51.1	71.0	5.1	33.5	68.7	107.3
Franklin	0.6	3.4	4.9	9.0	0.4	4.1	12.7	17.2	1.0	7.5	17.6	26.2
Gregg	0.9	4.3	4.8	10.1	0.5	5.1	14.2	19.8	1.4	9.4	19.1	29.9
Harrison	2.5	12.1	14.8	29.4	1.4	14.3	41.5	57.2	3.9	26.4	56.3	86.5
Henderson	1.2	7.3	11.9	20.3	0.9	8.8	28.8	38.5	2.1	16.0	40.7	58.8
Marion	2.0	9.4	11.1	22.5	1.1	11.1	31.7	43.9	3.1	20.5	42.8	66.4
Morris	0.6	3.6	5.5	9.7	0.4	4.3	13.8	18.5	1.0	7.9	19.3	28.2
Nacogdoches	3.9	17.5	18.9	40.2	2.0	20.5	56.7	79.2	5.8	38.0	75.6	119.4
Panola	3.8	16.1	15.9	35.9	1.7	17.9	50.0	69.5	5.5	34.0	65.9	105.4
Red River	2.0	10.5	15.4	27.8	1.2	11.9	39.0	52.1	3.2	22.3	54.4	79.8
Rusk	2.3	12.5	18.1	32.9	1.5	14.9	46.5	63.0	3.8	27.4	64.7	95.9
Shelby	2.7	11.2	11.4	25.3	1.2	12.3	35.1	48.5	3.8	23.5	46.5	73.8
Smith	1.5	8.7	13.2	23.4	1.1	10.4	33.1	44.6	2.6	19.1	46.3	68.0
Titus	1.0	5.8	9.2	15.9	0.7	7.0	22.6	30.2	1.7	12.7	31.7	46.2
Upshur	1.7	9.1	12.9	23.8	1.1	10.9	33.6	45.6	2.8	20.0	46.6	69.4
Van Zandt	1.0	5.8	9.1	15.9	0.7	7.0	22.5	30.2	1.7	12.7	31.7	46.1
Wood	1.6	9.6	14.8	26.0	1.2	11.5	36.8	49.5	2.8	21.0	51.7	75.5
Northeast Total	40.5	205.5	272.6	518.6	24.0	241.2	731.3	996.4	64.5	446.7	1,003.9	1,515.0

Table 4.20 Annual wood waste available from biomass thinnings by county, species group, and source, Southeast Texas, Alternative Scenario III

County	Softwood				Hardwood				All Species			
	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total	Dead	Growing-stock Crown	Nongrowing-stock Whole	Total
	thousand dry tons											
Angelina	3.1	13.6	14.3	31.0	1.5	16.0	43.7	61.2	4.6	29.6	58.0	92.2
Chambers	0.3	1.8	2.7	4.8	0.2	2.1	6.9	9.2	0.5	3.9	9.6	14.1
Grimes	1.3	7.6	12.0	20.8	0.9	9.1	29.5	39.5	2.2	16.7	41.5	60.4
Hardin	3.8	17.8	21.5	43.1	2.0	20.1	60.3	82.4	5.8	37.9	81.8	125.5
Harris	1.8	9.8	14.3	25.8	1.2	11.7	36.5	49.4	2.9	21.4	50.8	75.2
Houston	2.4	13.3	19.6	35.3	1.6	16.0	50.0	67.6	4.0	29.3	69.7	103.0
Jasper	4.1	19.7	23.9	47.6	2.3	23.3	67.2	92.7	6.3	42.9	91.1	140.3
Jefferson	1.1	4.3	4.1	9.6	0.4	4.2	13.0	17.6	1.5	8.5	17.1	27.2
Leon	1.4	8.7	14.1	24.3	1.1	10.5	34.4	46.0	2.5	19.2	48.6	70.3
Liberty	4.5	18.1	19.2	41.8	1.7	17.8	57.0	76.5	6.2	35.9	76.2	118.3
Madison	0.7	4.3	6.9	11.9	0.5	5.2	16.8	22.5	1.2	9.4	23.7	34.3
Montgomery	3.3	16.7	22.1	42.1	2.0	19.9	59.4	81.3	5.2	36.6	81.5	123.3
Newton	4.4	20.2	23.8	48.5	2.2	22.5	67.7	92.4	6.6	42.7	91.5	140.9
Orange	1.2	5.5	6.1	12.9	0.6	6.5	18.2	25.3	1.8	12.0	24.3	38.2
Polk	4.4	21.2	25.4	51.1	2.5	25.1	72.1	99.6	6.9	46.4	97.4	150.7
Sabine	2.2	8.7	8.5	19.4	0.9	9.3	26.7	37.0	3.0	18.1	35.2	56.3
San Augustine	1.8	8.2	8.4	18.4	0.9	9.6	25.9	36.4	2.8	17.7	34.3	54.8
San Jacinto	2.5	12.2	15.1	29.8	1.4	14.5	42.1	58.0	3.9	26.7	57.2	87.8
Trinity	2.3	9.9	10.8	23.0	1.0	10.7	31.9	43.6	3.3	20.6	42.7	66.6
Tyler	4.6	20.5	23.8	48.9	2.2	22.4	67.9	92.5	6.8	42.9	91.7	141.4
Walker	2.6	13.2	18.2	34.1	1.5	14.9	47.7	64.1	4.1	28.1	66.0	98.2
Waller	0.6	3.5	5.1	9.2	0.4	4.2	13.0	17.6	1.0	7.6	18.2	26.8
Southeast Total	54.4	258.9	320.0	633.3	29.0	295.4	888.1	1,212.5	83.5	554.3	1,208.1	1,845.9

Table 5.1 Private forestland potentially available for biomass energy production in Central Texas

Forest type	Hill Country	Central	Post Oak	Total
		thousand acres		
Desirable	342.0	99.5	200.8	642.2
Undesirable	3,502.6	976.0	779.6	5,258.2
Total	3,844.6	1,075.5	980.3	5,900.4

Table 5.2 Estimated parameters for desirable and undesirable forest types

	β_0	β_1	β_2	F	Adj. R^2
Desirable	20.51	0.097	23.66	137.30	0.97
	(2.11)	(0.028)	(3.65)		
Undesirable	11.36	0.108	15.84	121.47	0.97
	(0.99)	(0.037)	(3.32)		

Note: standard errors of the estimated parameters are in parentheses.

Table 5.3 Estimated annual yield of woody biomass by case in Central Texas

Case	Forest type	Rotation Age	Annual Growth Rate	Hill Country	Central	Post Oak	Total
					thousand dry tons		
Case I: Optimal Ration Age							
	Desirable	34	0.386	132.0	38.4	77.5	247.9
	Undesirable	23	0.262	917.7	255.7	204.2	1,377.6
	Total			1,049.7	294.1	281.7	1,625.5
Case II: Shorter Rotation Age							
	Desirable	29	0.378	129.4	37.6	75.9	243.0
	Undesirable	18	0.256	895.2	249.5	199.3	1,343.9
	Total			1,024.6	287.1	275.2	1,586.9
Case III: Longer Rotation Age							
	Desirable	39	0.381	130.2	37.9	76.4	244.5
	Undesirable	28	0.258	902.3	251.5	200.8	1,354.6
	Total			1,032.5	289.3	277.3	1,599.1
Average of the Three Cases							
	Desirable			130.5	38.0	76.6	245.1
	Undesirable			905.1	252.2	201.4	1,358.7
	Total			1,035.6	290.2	278.1	1,603.9