Using Forest Inventory and Analysis Data to Support Resinous Stump Harvesting in the Coastal Southeast

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Donald G. Hodges, Major Professor

We have read this thesis and recommend its acceptance:

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(Original signatures are on file with official student records.)
Using Forest Inventory and Analysis Data to Support Resinous Stump Harvesting in the Coastal Southeast

A Thesis Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Christopher Ryan King
May 2017
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I hereby wish to express my appreciation to Mr. Pat Grozier, former Vice President of Supply Chain at Pinova Holdings, Inc. who initiated this project. His desire to explore new ideas led to a challenging project with FIA, and ultimately a career for me in a proud and fascinating industry. His replacement Carla Toth has been extremely supportive and deserves many thanks as well. Mr. Richard Stager, Forest Resources Supervisor at Pinova, was also instrumental throughout this project. I also wish to thank Mr. Ronnie Kirkland, a respected forester and Wood-Quality Supervisor at Pinova. Mr. Kirkland gave me a guided tour and “showed me the ropes” of the resinous stump industry. These individuals (along with the rest of Pinova) took me in and gave me a career I am quite proud of. For this I am eternally grateful.

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Strange, Dr. Jason Henning, and others. I also had the pleasure of working with some fantastic policy professors like Dr. Mike Fitzgerald and Dr. David Houston. Finally, I would like to thank Dr. John Zobel, who came to the rescue and served on my graduate committee as the department’s new professor of Forestry / Natural Resource Biometrics.

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ABSTRACT

The objective of the research was to investigate the feasibility and potential opportunities for using broad-scale forest inventory data for identifying high-probability sites containing longleaf and slash pine stumps. The purpose was to assist in locating resinous stumps for today’s remaining naval stores industry. USDA Forest Service, Forest Inventory & Analysis (FIA) Phase 2 plots where longleaf and slash pine were present were observed. Plots were also limited to those which had been re-measured at least once. Variables observed include basal area, diameter, recent cutting, and past cutting. FIA’s Timber Products Output data regarding mill sourcing were assessed as well. Once selected, these variables were displayed using Inverse Distance Weighted (IDW) interpolated mapping. An index of suitability was developed, and the values were then combined to create a composite map of “hot-spots”. To obtain the most beneficial view, nine scenarios were developed with different weights distributed across the variables. The data were too broad-scale to identify specific tracts of land for resinous stump resources. However, interpolated mapping provided some broader insights into resource availability and potential. This information, as well as relationships between resources and ownership, are useful to the wood-based rosin industry. Comparing interpolated maps of FIA phase 2 data with county-level procurement records allowed for the identification of areas where potential for the resource was high (basal area, diameter, cutting, etc.), yet no stump utilization was currently taking place. Many of these areas were selected and field-checked. The findings did prove fairly accurate upon field testing and suggested an approximate 85% success rate. Several ideas for future developments and methods were also shared. These included the need for spatial procurement data, more spatial analysis, and the incorporation of newer tools for prospecting.
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CHAPTER 1  
INTRODUCTION OF THE PROJECT AND ORGANIZATIONS  

Resinous Stump Harvesting

Naval stores production goes back to at least biblical times, and is even older than the lumber industry. Asian natives used gum and resins from trees along the Mediterranean Sea. In the Bible, Noah is commanded to use pitch heavily when building his Ark (Gerrell, 1997). Harvesting rosin from pine trees in some form has been a practice in North America for centuries, and possibly longer. Native Americans used pine rosin for a variety of purposes, as did European settlers. The extraction of naval stores (i.e., tar, pitch, rosin, and turpentine derived from pine resin) began in 1608 with the first European settlements in Virginia. This was most often done by cutting wound faces in the bark of longleaf pine trees and collecting the resin once it had accumulated (Frost 2006). This method produced turpentine, which is the name used for rosin collected from live trees.

Through the early 1800s to early 1900s, rosin was in especially high demand due to its waterproofing and adhesive properties. Tar and pitch, since ancient times, had been the only known materials that would impregnate wood, water-proofing the hulls of wooden ships. The world’s sailing fleets were supplied with tar, pitch, and timber for more than 200 years by North Carolina’s pine resources (Wrench 2014). Early on, substantial production occurred in New England. By the mid-nineteenth century, nearly all American-made naval stores (both domestic consumption and exported products) came from the Carolinas.

North and South Carolina both contained large acreages and healthy stands of longleaf pine (Pinus palustris). However, these resources proved finite as unsustainable practices went unrestricted for 100 years. As this occurred, the heart of naval stores production drifted south,
where longleaf pine resources were also quite vast. This continued along the one hundred-mile-wide pine belt into Georgia and Florida. Production then moved westward through southern Alabama, Mississippi, Louisiana, and Texas until reaching the end of the longleaf pine’s range (Dyer & Sicilia 1990). These areas south of the Carolinas held untapped resources, and Georgia had become the national leader in naval stores production by 1890 (Sullivan, 2016). This industry as a whole was once North Carolina’s largest, and certainly one of the most important industries in the South.

Extracting raw turpentine and tar from southern pines and manufacturing derivative products (i.e., spirits of turpentine and rosin) created a culture and history unique to the region (Outland 2004). In the early to mid-1900s, less harmful and improved production methods were developed and adopted. In 1901, Gifford Pinchot and the Division of Forestry began laboratory research across several universities. Investigations into turpentine production techniques, along with many other forestry issues, were helpful towards improving the industries. Testing also proved that longleaf pine produced excellent timber for building purposes (Rutkow, 2012).

Forestry was being developed as a science and the United States was becoming aware of the vast loss of southern pine forests. Federal cooperation and new mechanical processes improved the industry, as did groups like the American Turpentine-Farmers Association. The product market also grew increasingly more specific (Outland 2004). Since 1930, innovation and competition from large chemical companies have largely reduced turpentine (rosin collected from live trees) efforts in the American South. Only the tar industry remains today, in which wood-based (pine stumpwood) rosins are used to produce products for markets worldwide. These markets include adhesives, agriculture, beverages, construction, foundry, fruit coating, gum base, inks, personal care, tires, and rubber.
Longleaf and Slash Pine

Longleaf pine (*Pinus palustris*) and slash pine (*Pinus elliottii*) are both native pine species in the southeastern United States. While both species produce resinous stumps, this report will focus mostly on longleaf pine. Although slash pine stumps are still desirable for rosin and the range is similar, longleaf pine is the primary species in resin production (historically and today). The longleaf pine range today is spread across eight southern states, though largely fragmented. This range is quite limited when compared to the historical extent, especially in volume (Oswalt 2012).

When the Spanish arrived in the 1500s, longleaf pine dominated 60 million acres in the Southeast. It occupied another 30 million acres that contained stands mixed with hardwoods and other pine species. These forests covered nearly 150,000 square miles. Less than 3 million acres remained in 1960 (98% decline). This decline of an ecosystem is one of the largest known in history worldwide (Earley, 2004). Today, longleaf pine forests are beginning to re-establish across their former range. This is due to the efforts of land-owners, land managers, state and federal forests, and many conservationists across the region. Table 1.1 provides estimated acreages of longleaf pine forests in 2010 based on U.S. Forest Service Forest Inventory & Analysis (USFS FIA) data. The total across all ownerships indicates 4.28 million acres of longleaf forests. This is still a long way from historical acreages, but shows a positive, gradual increase overall.

Table 1.2 shows surveyed mill draws of longleaf and slash pine by USFS FIA’s Timber Products Output (TPO) unit in 2009. More than 940 million cubic feet were collected annually in the region, with a total of 32 million green tons. This demonstrates the importance of this species, even today, to the forest industry and the region as well.
Table 1.1: Area of longleaf pine forest by region and ownership class, 2010 (Oswalt 2012)

<table>
<thead>
<tr>
<th>Forest type and region</th>
<th>Ownership Class</th>
<th>U.S. Forest Service</th>
<th>U.S. Fish &amp; Wildlife Service</th>
<th>Department of Defense</th>
<th>Other Federal</th>
<th>State</th>
<th>County and municipal</th>
<th>Private</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All ownership</td>
<td>thousand acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longleaf</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal plain (east)</td>
<td>2,938,157</td>
<td>453,374</td>
<td>53,395</td>
<td>254,127</td>
<td>53,695</td>
<td>329,051</td>
<td>28,542,17</td>
<td>1,765,972</td>
</tr>
<tr>
<td>Coastal plain (west)</td>
<td>258,872</td>
<td>116,928</td>
<td>0</td>
<td>10,662</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>125,190</td>
</tr>
<tr>
<td>Piedmont</td>
<td>103,688</td>
<td>23,689</td>
<td>0</td>
<td>0</td>
<td>6,091</td>
<td>0</td>
<td>0</td>
<td>73,908</td>
</tr>
<tr>
<td>Total</td>
<td>3,300,717</td>
<td>593,991</td>
<td>53,395</td>
<td>264,789</td>
<td>53,695</td>
<td>335,142</td>
<td>34,635</td>
<td>1,965,070</td>
</tr>
<tr>
<td>Longleaf - oak</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal plain (east)</td>
<td>857,401</td>
<td>61,906</td>
<td>6,523</td>
<td>45,484</td>
<td>19,106</td>
<td>109,092</td>
<td>4,691</td>
<td>610,599</td>
</tr>
<tr>
<td>Coastal plain (west)</td>
<td>39,357</td>
<td>17,483</td>
<td>0</td>
<td>6,093</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15,782</td>
</tr>
<tr>
<td>Piedmont</td>
<td>87,879</td>
<td>13,167</td>
<td>0</td>
<td>0</td>
<td>11,313</td>
<td>0</td>
<td>0</td>
<td>63,398</td>
</tr>
<tr>
<td>Total</td>
<td>984,637</td>
<td>92,556</td>
<td>6,523</td>
<td>51,577</td>
<td>19,106</td>
<td>120,405</td>
<td>4,691</td>
<td>689,779</td>
</tr>
<tr>
<td>Combined Longleaf</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal plain (east)</td>
<td>3,795,559</td>
<td>515,280</td>
<td>59,918</td>
<td>299,611</td>
<td>72,801</td>
<td>438,143</td>
<td>33,234</td>
<td>2,376,572</td>
</tr>
<tr>
<td>Coastal plain (west)</td>
<td>298,229</td>
<td>134,410</td>
<td>0</td>
<td>16,755</td>
<td>0</td>
<td>0</td>
<td>6,093</td>
<td>140,972</td>
</tr>
<tr>
<td>Piedmont</td>
<td>191,566</td>
<td>36,856</td>
<td>0</td>
<td>0</td>
<td>17,404</td>
<td>0</td>
<td>0</td>
<td>137,306</td>
</tr>
<tr>
<td>Total</td>
<td>4,285,354</td>
<td>686,547</td>
<td>59,918</td>
<td>316,366</td>
<td>72,801</td>
<td>455,547</td>
<td>39,326</td>
<td>2,654,849</td>
</tr>
</tbody>
</table>

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

0 = no sample for the cell or a value of >0.0 but <0.05.
Table 1.2: Longleaf and Slash Pine Annual Mill Draw (Southern Research Station, FIA, 2009)

<table>
<thead>
<tr>
<th></th>
<th>Thousand Cubic Feet</th>
<th>Green Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>62,386</td>
<td>2,182,395</td>
</tr>
<tr>
<td>Florida</td>
<td>361,658</td>
<td>12,582,616</td>
</tr>
<tr>
<td>Georgia</td>
<td>311,392</td>
<td>10,862,135</td>
</tr>
<tr>
<td>Louisiana</td>
<td>77,574</td>
<td>2,683,037</td>
</tr>
<tr>
<td>Mississippi</td>
<td>58,716</td>
<td>2,047,152</td>
</tr>
<tr>
<td>North Carolina</td>
<td>12,997</td>
<td>445,756</td>
</tr>
<tr>
<td>South Carolina</td>
<td>36,479</td>
<td>1,266,972</td>
</tr>
<tr>
<td>Texas East</td>
<td>19,183</td>
<td>661,834</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>940,385</strong></td>
<td><strong>32,731,897</strong></td>
</tr>
</tbody>
</table>

With a gradual increase in acreage throughout its original range and a sustainable level of resource harvesting, longleaf and slash pine forests likely have a positive future. FIA data give some positive indications for the species as a whole. An increase has been seen in longleaf saplings, and young longleaf stands are filling acreages once lost to the species (Oswalt, 2012). However, increasing development may slow this trend or even reverse it. With continued conservation and promoted replanting and management efforts, the South may once again flourish with longleaf pine forests and ecosystems.

**Pinova Inc. (formerly Hercules)**

Pinova Inc. was founded in 1911 when Homer Yaryan built the Brunswick, Georgia plant. Mr. Yaryan can be credited with introducing the modern Naval Stores era as well as unprecedented green chemistry methods. His patented pine rosin extraction process was the foundation for more than 100 years of chemical industry innovation. Hercules Inc. purchased the business in 1920. This Delaware company originally manufactured gunpowder, and was
acquired by Du Pont in the 1880s (Ingram & Stansell 1995). Hercules purchased the Yaryan Rosin & Turpentine Co. plants in Brunswick, Georgia and Gulfport, Mississippi with the hopes of diversifying from explosives (Streich 2012). This line of business was completely new for Hercules, yet they continued to innovate and improve processes. The company started processing rosin derivatives from longleaf and slash pine tree stumps (Dyer & Sicilia 1990). Throughout the 20th century the company made great strides in innovation for the rosin industry, using primarily longleaf and slash pine stumps as a raw material (and occasional supplementing with imported gum-rosin). The company officially became Pinova, Inc. in 2010.

Today, Pinova, Inc.’s Forest Resources section employs 16 foresters and more than 30 contractors working from Louisiana to North Carolina, covering nearly the entire range of longleaf pine. Foresters procure the desired pine stumpwood from landowners (private, company, and government) following timber harvest operations. Stumps are extracted using large excavators, outfitted with custom shearing heads to both dig and cut to length if needed. Trucks carry stumps to the plant in Brunswick, GA, where they are either sent to inventory or to the mill. When milled, the stumps are ground finely and sent through the rosin-extraction process. Extracted rosin is refined to specific products for current markets.

Currently, Pinova is the only company in the world producing wood-based rosin products. They produce performance specialty rosin, polyterpene resins, and sensory ingredients for many of the world’s industries and best-known brands. Pinova’s performance rosin, resins, and polyterpene resins reach customers in more than 100 countries. In 2016, Pinova was purchased by DRT, which stands for Dérivés Résiniques et Terpéniques (Resinic and Terpenic Derivatives). The France-based company operates in many of the same markets, and will keep Pinova operating just as it has been in recent years.
USFS Forest Inventory & Analysis

The United States Department of Agriculture (USDA) Forest Service – Forest Inventory & Analysis program is responsible for assessing the condition of U.S. Forests on a periodic basis. It is managed by the USFS Research and Development Department in cooperation with National, State, and private forest systems. The program assesses forest ownership and condition and analyzes trends in forest conditions and use. FIA as an organization reports on past, current, and predicted trends in forests. Specific variables include species, area, location, size, growth, mortality, harvesting, wood production, ownership, and even wood usage. The program and its regional units cover all forested lands within the United States (USFS FIA, 2008).

The Southern Research Station (SRS) is a regional section of the FIA program covering 13 southeastern states (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, eastern Oklahoma, South Carolina, Tennessee, eastern Texas, and Virginia). Figure 1.1 shows the Southern Research Station’s inventoried states. One of the research priorities for SRS FIA is to monitor longleaf pine. Longleaf pine is a high-priority conservation species and forest ecosystem receiving continuous monitoring and analysis. The FIA program (and likely none other) has the resources, data, and analytical ability to provide continuous and unbiased monitoring. With such resources, this important southern forest system can benefit from large-scale monitoring across the entirety of its range (Oswalt 2012). This allows us to see progress in restoration and any changes that occur in the dynamics of the species population. It also gives us a set of analysis tools which can be applied to almost any industry relating to these specific resources.
The Forest Inventory system contains three “phases” for analysis of forested land. Phase 1 is largely focused on remote sensing (aerial photography and satellite imagery). The goal is classifying land uses and status, while observing phenomena such as urbanization. Phase 2 uses FIA field plots as sample locations to collect standard forest inventory data (species, height, distribution, volume, etc.). Figure 1.2 shows the Phase 2 plot layout, designed to cover a one acre sample area, with directions and measurement specifications. Field crews visit plots (typically every 5 years depending on the state) to obtain measurements and even visit non-forest plots to quantify changes in land usage. FIA plots are distributed at a rate of approximately 1 plot every 6,000 acres of total land. Phase 3 uses a much smaller sample of Phase 2 plots to collect more detailed ecological data during summer months. This includes vegetation inventory, crown condition, soil data, lichens, woody debris, etc. These intensive samples are distributed approximately 1 every 96,000 acres (USFS FIA, 2008). All FIA plot data used in this study was taken from Phase 2 sampling. This data contained all variables necessary for the intended analysis.
*The macroplot is used for an increased sample of larger diameter trees and is not used by the Southern Research Station*

Figure 1.2: USFS FIA Phase 2 Mapped Plot Design (Woudenberg, 2010)
Research Objectives and Potential Benefits

The primary research objectives of the project include:

1. Assess the entire resource of resinous longleaf and slash pine stumps in the southeastern United States, based on Forest Inventory & Analysis Phase 2 plot data;
2. Assess Pinova’s current sourcing of longleaf and slash pine stumps and determine the quantity of uncaptured, yet available resources;
3. Determine what methods could be used to identify untouched resources and assist Pinova in locating them throughout their operations area; and
4. Evaluate mapped information and mapping tools to better observe resources and create actionable methods for Pinova’s foresters.

Specific benefits of the project include:

1. **Resource Assessment:** Provide Pinova, Inc. with information about the current availability of their primary source for producing wood-based rosin products.
2. **Mapping Tools and Models:** Develop a set of tools through FIA data, GIS, and Pinova’s data that can be used continuously to locate resources and potential work-sites.
3. **Methods Testing:** Employ field testing regionally to evaluate both current methods and usefulness of the mapping approach.
4. **Future Planning:** Increase knowledge of current resource coverage and potential future resource coverage, as well as tools to increase efficiency and progress.
CHAPTER 2
LONGLEAF PINE: SOURCING FOR WOOD-BASED ROSIN

Introduction

Pinova’s unique method of using resinous pine stumps as a resource for rosin creates an equally unique set of challenges. With an increasing variety of markets and continual product demand, sourcing is currently an important focus for the company. And with quantity increasing, quality must be maintained as well. Although Pinova pays landowners for their stumps, the greatest costs involve getting the stumps pulled and hauled to the plant. These costs must be justified by the rosin received after processing the stumps.

In recent years, Pinova has developed a testing method to estimate the amount (pounds) of rosin per ton of wood (averaged across a truck load). These tests are used to sample the three types of wood currently being harvested: Old lightered stumps (highest rosin yield), Seconds (in-between, refers to “second generation stumps”), and Fresh-cut stumps (lowest rosin yield). The old stumps have shed their sapwood, bark, and much of the original water content. What remains is a solid waterproof stump that contains, on average, 300-500 lbs. of rosin per ton of wood. As “old original” stumps become harder to find, Pinova now settles for “seconds” and fresh-cut stumps. “Seconds” are stumps that have started to shed outer layers and less material is attached to the rosin-rich heartwood. Fresh-cut longleaf stumps can deliver a rosin yield of 150-250 lbs. per ton, depending on the size of the heart. The company is working on new methods to make fresh-cut stumps more viable as a source, since this sustainable resource is likely the future for the company as older stumps become too rare.
Regional Differences

Many region-specific standards and challenges must be considered across the range of Pinova’s operations. In North Carolina, a sufficient supply of old “lightered” stumps still remains and is the sole resource obtained. “Lightered” is a term used for rosin-rich longleaf pine heartwood when the sapwood and bark have rotted away. The higher rosin content (about 500 lbs. per ton) justifies the higher delivery costs to the plant in Brunswick, GA. Methods in this region focus on finding clearcuts that contain older longleaf pine stumps that have not been harvested by Hercules in the past. Without any spatial data of past harvesting, this requires a “boots on the ground” approach to locate such tracts of land for procurement.

In Georgia, Florida, South Carolina, and Alabama, historically intensive harvesting due to proximity to the plant has made older longleaf stumps quite rare. Foresters in this region must focus primarily on the second-growth stumps (typically from trees cut in the previous harvest, 8-30 years ago). In Georgia and northern Florida, the focus has largely become fresh-cut longleaf stumps. These stumps produce between 100 and 250 lbs. of rosin per ton of wood, depending on the ratio of the heartwood to the rest of the stump. Foresters and contractors use the ratio of heartwood to sapwood to select tracts and stumps for harvesting. A process of shearing is used to only keep the most rosin-rich part of the stump. This changes methods considerably since the same tract of land could potentially be harvested multiple times.

Mississippi and Louisiana produce “seconds” almost exclusively, since older stumps are rare but distance prohibits the lower rosin yielding fresh-cut stumps. This region is important for maintaining sheer volume, however quality (rosin lbs/ton) remains an issue. Methods in this region consist of looking for tracts where trees have been cut for a longer period of time (preferably eight years or more), shedding some of the sapwood and bark.
Pinova’s Currently Available Data

Pinova has undergone many changes in methods for the sourcing of wood-rosin. In the early years, old longleaf pine heartwood stumps could be found in abundance. Once the desired stumps closest to the plant in Brunswick, GA became scarce, they simply moved further out. The company had large crews that would move from place to place harvesting stumps across vast acreages. For many years, the company had crews working on paper company land (e.g., Weyerhauser, Rayonier, International Paper, etc.). Foresters could simply obtain harvest maps from paper companies and keep their crews running year-around.

As resources became less abundant, company foresters changed focus partially to smaller tracts and long-neglected private landowners to find older stumps. The company also began experimenting with harvesting fresh-cut longleaf stumps closer to the plant. These stumps contained a lower rosin yield (lbs. per ton of wood), but still justified their sourcing costs. Sourcing costs can be very significant since Pinova receives wood from distances of up to nearly 500 miles (Figure 2.1). No consistent records were kept as to harvested areas on company or state lands. This means that newly timbered areas must still be checked for stumps, while they may have already been harvested. If the land has been previously bedded before planting, it is also unlikely to contain resinous stumps.

Leasing records were available from historical company databases for the past several years. The leasing data contains landowner addresses but not property locations, except for the county in which the harvested property is located. This allowed spatial analysis at the county level only. Symbolizing total volumes received by the county recorded was possible and gave a much-needed picture of the company’s activity over the past five years. This information also provides a picture of ownership types procured from (Table 2.1). As of 2014, Pinova had 15
foresters covering designated counties (Figure 2.2) and running over 30 contractors. Their locations and assigned counties were among the many variables that were discussed and analyzed throughout this project.

Over their history of working behind loggers and finding resinous stumps anywhere they could, Pinova collected very little data and kept few records. Generally, the extent of information on where they had been was isolated within in the leasing data. The lease forms (between Pinova and landowners to purchase stumps) contain the county and state from which the wood came. Lacking any further spatial detail, tons pulled at the county level were observed for each of the past five years (Figures 2.3 and 2.4).

In order to determine which counties had supported the most harvesting (or none at all) in recent years, the county-level tonnage was combined for the five years of data. Figure 2.5 shows the combined tons leased for 2010-2014. This map clearly identifies “gaps” within the current harvesting range where no wood had been harvested in the previous five years. It also identifies the most heavily worked counties throughout the current range. Some of the gaps may be explained by mostly developed areas, particular large ownerships, or simply by forester placement (out of range). Regardless of the reason, this information was useful internally for analysis of current operations.

Though greater detail would have been preferable, a county-level visual analysis of where the company was working the most (and the least) proved useful. This new informative layer could be combined with FIA suitability mapping, allowing visual determinations to be made. Heavily worked areas could be “checked” against high-potential areas. Prospectively, resource-rich areas would be identified that were not currently being worked.
Figure 2.1: Freight Distances from Brunswick, GA Plant (up to 500 Miles)

Table 2.1: Pinova Sourced Tons by Ownership Type in 2011 and 2012

<table>
<thead>
<tr>
<th>Year</th>
<th>Company</th>
<th>Government</th>
<th>Private</th>
<th>Total Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>53,922</td>
<td>3,601</td>
<td>106,158</td>
<td>163,681</td>
</tr>
<tr>
<td>2012</td>
<td>30,152</td>
<td>18,533</td>
<td>82,214</td>
<td>130,899</td>
</tr>
<tr>
<td>Average</td>
<td>42,037</td>
<td>11,067</td>
<td>94,186</td>
<td>147,290</td>
</tr>
<tr>
<td>Percentage</td>
<td>28.5%</td>
<td>7.5%</td>
<td>63.9%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
Figure 2.2: Pinova’s 15 forester units as of November 2014
Figure 2.3: Tons Pulled at County Level for 2010, 2011, 2012, and 2013
Figure 2.4: 2014 Tons Pulled from Counties based on Pinova Lease Data
Figure 2.5: Tons Pulled from Counties over the Five Year Period
CHAPTER 3

USING FIA DATA TO LOCATE RESINOUS STUMP “HOTSPOTS”

Introduction

FIA’s longleaf pine forest type is defined as forests where pine species account for a minimum of 50 percent of all-live trees, with longleaf pine being the most common pine. (Oswalt 2012). The mixed longleaf pine/oak forest type is identified by plots where pine species account for 25 to 50 percent of trees measured. Again, longleaf pine must be the most dominant pine species (Oswalt 2012). From an initial sample of all Phase 2 plots in the relevant states, plots were identified where any of these conditions occurred. Plots which had not been re-measured were also removed from the list. An SQL query script was developed (Appendix A) to pull the plots and chosen attributes from FIA’s database. The public database was used, where plots are slightly offset to protect sampling locations, to ensure future repeatability. Query results were placed in a table with selected attributes to be formatted and used in GIS applications.

Although the project as a whole was required to be completed in a relatively short time frame, FIA and Pinova personnel discussed progress and methodology frequently. The discussions began with each organization educating one-another on methods, resources, goals, etc., which led to the exploring of opportunities for collaboration and ways to proceed. Understanding Pinova’s operations aided in the selection of variables from plot data. For example, they prefer longleaf stumps with a large heart (more rosin) so a minimum DBH variable was useful. These decisions along with weighting preferences and scenarios were discussed to yield the most useful result in a short time.
Methods and Procedures

The starting sample contained 49,861 Phase 2 FIA plots in the southeastern states (Figure 3.1). This consisted of all Phase 2 plots currently recorded that fell within the states monitored by FIA’s Southern Research Station. Some of these plots had not been re-measured (preventing change-related analysis). Many of these plots also contained no sampling of longleaf pine forest types, and were therefore not relevant to the project.

Keeping only plots that had been remeasured, the sample was reduced to 40,205. From there, plots were selected which had a presence of longleaf pine (1,675) and slash pine (3,202). This left a final sample of 4,877 plots (9.78% of the original total). Figure 3.2 shows the distribution of selected FIA Phase 2 plots. This final collection of plots were queried for the chosen variables, which could be analyzed and symbolized spatially.

Six variables were selected to be observed across these plots:

- Basal Area (BA) – The percent of plot basal area comprised of longleaf or slash pine
- Forest Type (FT) – where LLP or SLSH = 1, Mixed = 0.5, and None = 0
- Greater than 15” DBH (GT15) – The percent of stems ≥ 15 inches in diameter at breast height (DBH) comprised of longleaf or slash pine
- Cut Recently (Cut) – The percent of recently (1-5 years) cut trees (statuscd=3) comprised of longleaf or slash pine
- Cut in the past (Cutp) – The percent of historically (6-10 years) cut trees (statuscd=3) comprised of longleaf or slash pine
- Draw from mills (Milldraw) – The percent of total county-level mill draw (reported biomass) comprised of longleaf and slash pine
Figure 3.1: Map Showing Coverage of FIA Phase 2 Plots in Target Area (49,861)

Figure 3.2: Selected FIA Phase 2 Plot Coverage with Longleaf and Slash Pine
Due to redundancy, the Forest Type (FT) variable was removed. Basal area (stocking) is used in an algorithm to determine the assigned forest type. Any contributing value was adequately represented by the Basal Area (BA) layer. Another layer using mill data was added to improve representation of harvesting activity at the county level.

This resulted in the following (final) list of variables:

- Basal Area (BA) – The percent of plot basal area comprised of longleaf or slash pine
- Greater than 15” DBH (GT15) – The percent of stems ≥ 15 inches in diameter at breast height (DBH) comprised of longleaf or slash pine
- Cut Recently (Cut) – The percent of recently (1-5 years) cut trees (statuscd=3) comprised of longleaf or slash pine
- Cut in the past (Cutp) – The percent of historically (6-10 years) cut trees (statuscd=3) comprised of longleaf or slash pine
- Draw from mills (Mill Draw) – The percent of total county-level mill draw (reported biomass) comprised of longleaf and slash pine
- Relative mill draw (Mill Relative) – The county level mill draw relative to the highest county value.

Basal area was chosen to represent the presence of longleaf or slash pine on the plot, as well as the relative percentage. The intention was to focus only on areas where the desired species were prevalent. The GT15 variable was selected to identify larger (≥ 15 inches DBH) longleaf/slash trees, rendering larger stumps. This was to indicate where recently cut trees would have larger heartwood diameters, and also where timber was older. Pinova’s foresters indicated that older timber was more likely to contain older, more desirable stumps. The Cut and Cutp variables were both used to identify timber harvesting in certain time frames to indicate potential access to stumps. Timber harvested in the past (6-10 years) would theoretically have shed some
bark and sapwood, leaving the desired rosin-filled heartwood. The Mill Draw and Mill Relative variables were both added to further indicate both presence of desired forest-type and active harvesting in the particular county. These data come from the mill surveys performed by FIA’s Timber Product Outputs (TPO) section. The draw indicates a total harvesting volume, while the relative draw shows volume compared to other counties. The relative draw layer relates surveyed county volumes to the county with the highest recorded volumes, and was used to provide a better indication of relative suitability when mapped.

An SQL script was developed to pull values from the FIA Database for each variable (Appendix A). Data pulled for the desired variables included: Vol Lbs 10, Vol Lbs, Slash BA per Acre, Longleaf BA per Acre, BA per Acre, Trees Cut, Longleaf Cut, Slash Cut, Past Cut, Past Longleaf Cut, and Past Slash Cut. For this dataset, each variable was calculated (using equations shown in Appendix B) to provide values between 0 and 1. Data were retrieved through FIA’s EVALidator system, which is publicly available and uses slightly offset coordinates to protect plot locations. This was used to ensure future repeatability for Pinova. With this index containing uniform values, plots could be interpolated within ArcGIS based on a particular variable. This allowed the spreading of available data across the focus area based on higher/lower values. Figures 3.3, 3.4, 3.5, 3.6, 3.7, and 3.8 show the interpolated maps produced for Basal Area, GT15, Cut, Past Cut, Mill Draw, and Relative Mill Draw, respectively. Figure 3.9 shows a combination of both mill layers to give an even representation of that county-level data. Viewing these variables interpolated individually helped to assess what each value contributed visually. Index values (0-1) were symbolized at even intervals from blue (lowest suitability) to red (highest suitability).
Figure 3.3: Interpolated Map of Relative Basal Area for Longleaf and Slash Pine

Values Represent (Slash Basal Area per Acre + Longleaf Basal Area per Acre) / Basal Area per Acre

Figure 3.4: Target Species – Large Diameter (>15”dbh) Interpolated Map

Values Represent (Slash ≥ 15” DBH + Longleaf ≥ 15” DBH) / Total ≥ 15” DBH
Figure 3.5: Target Species – Recent Cutting Detected (1-5 years) Interpolated Map

Figure 3.6: Target Species – Past Cutting Detected (6-10 years) Interpolated Map
Figure 3.7: Longleaf and Slash Pine Mill Draw at County Level

Figure 3.8: County Level Mill Draw (Longleaf & Slash Pine) Relative to Highest in Region
Figure 3.9: Combined Mill Variables (Equally Weighted Percent Draw plus Relative Draw)
Results

Section 1: Weighting Variables

All percentages were coded as decimals to ensure that variable values were between 0 and 1. The six stacked layers were combined to develop a composite score or “Suitability Index”. In this scenario, a perfect score would equal 1. The first scores were developed with variables weighted equally at 16.666% each. The following equation was used to give a composite score for each plot in the sample:

\[
\frac{\Sigma (BA + GT15 + CUT + CUT_p + Milldraw + Mill Relative)}{6}
\]

The next question was whether each variable should be weighted differently based on relativity to the overall goals. For example, if GT15 and CUT provide a better indication of large longleaf pine being harvested, the variables could be weighted more heavily in the Suitability Index. Discussions about weighting preferences were held with Pinova’s Forest Resources team as well. A blank table (similar to Table 3.1) was sent to Pinova with seven scenario options. Based on their internal discussions, they provided the seven scenarios they preferred and returned the completed table. Overall, they were most interested in the Large Stems, Cut, and Past Cut layers. The Large Stems layer (based on a minimum 15” diameter) indicated the presence of larger longleaf pines needed for the desired stumps. The Cut and Past Cut layers (based on harvesting in the past five years and five to ten years, respectively) indicated access to the stumps. Two additional scenarios were added later (Scenarios 8 and 9) to include weight from the Relative Draw layer. This variable was added later to better display the mill data...
overall. It was given only a 10% weight because it is broader (county level) data and too high of a weight would have blurred plot level data. County-level data provides a useful addition across plot values, but can create a false indication of suitability across areas with no indication otherwise. Nine different scenarios were outlined with different weight distributions across the variables (Table 3.1). While there was a greater focus on layers involving cutting data and large diameter, the other layers were included as well in some scenarios. Overall, they seemed to provide a fairly comprehensive variety across the available layers.

For these weighted scenarios, the following equation was used for composite scoring:

\[
= BA(S_n) + GT15(S_n) + CUT(S_n) + CUT_p(S_n) \\
+ Milldraw(S_n) + Mill Relative(S_n)
\]

Where \( S_n \) = Weight for \( n \) Scenario

<table>
<thead>
<tr>
<th>Layers</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
<th>Scenario 5</th>
<th>Scenario 6</th>
<th>Scenario 7</th>
<th>Scenario 8</th>
<th>Scenario 9</th>
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</thead>
<tbody>
<tr>
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<td>0</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Large Stems</td>
<td>0</td>
<td>50</td>
<td>50</td>
<td>25</td>
<td>33</td>
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<td>45</td>
<td>30</td>
</tr>
<tr>
<td>Cut</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>33</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Past Cut</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>25</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td>County Draw</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Relative Draw</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>99</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
Section 2: Displaying Results

These composite scores were calculated across the sample plots for each weighted scenario. The resulting values were used to create interpolated maps, where higher values would indicate “hot spots”. Interpolation is a process of estimating surface values at unsampled points. This is usually a raster operation where the known surface values of nearby points are used to get a good estimation (Wade 2006). Inverse Distance Weighted (IDW) interpolation assumes spatial autocorrelation in the data. It assigns higher weights to points closer to known locations (shorter ranges of spatial autocorrelation) and that weight diminishes with distance. This technique was ideal for FIA plot data symbology since plot coverage is relatively broad. Spatial pattern recognition is derived computationally from pixel proximity (Lillesand, 2008). Autocorrelation can be assumed for these purposes when data patterns extend to surrounding plots. IDW interpolation was completed for all weighted variable scenarios.

These “hot spots” would indicate a higher probability of that location having the desired characteristics (Figures 3.10-3.19). Many conversations were held about the weightings and which scenario(s) would be preferable. Scenarios including mill-survey data (Figures 3.16-3.19) provided good overall coverage since there were values for each entire county. However, this reduced accuracy once interpolated as it gives some false indication across counties. This is because higher values raised suitability across entire counties, and those values may not be consistent through particular areas. Scenario 2 (Figure 3.11) is a useful display of the overall resource potential as it indicates large trees with higher relative basal area. However, there is no indication of access (harvesting). Scenarios 4 and 5 (Figures 3.13 and 3.14) provided indication of both cutting to provide access and size to provide useable longleaf stumps. It was determined that these would be the primary choices for further analysis.
Figure 3.10: Interpolated Map of Suitability Index – Scenario 1

Figure 3.11: Interpolated Map of Suitability Index – Scenario 2
Figure 3.12: Interpolated Map of Suitability Index – Scenario 3

Figure 3.13: Interpolated Map of Suitability Index – Scenario 4
Figure 3.14: Interpolated Map of Suitability Index – Scenario 5

Figure 3.15: Interpolated Map of Suitability Index – Scenario 6
Figure 3.16: Interpolated Map of Suitability Index – Scenario 7

Figure 3.17: Interpolated Map of Suitability Index – Scenario 8
Figure 3.18: Interpolated Map of Suitability Index – Scenario 9

Legend
scenario9_idw
0 - 0.025761051
0.025761051 - 0.086943546
0.086943546 - 0.151346174
0.151346174 - 0.218968932
0.218968932 - 0.28659169
0.28659169 - 0.344554055
0.344554055 - 0.413596944
0.413596944 - 0.518441147
0.518441147 - 0.821133484

Values Represent (Percent Basal Area * .30) + (Percent ≥ 15" DBH * .30) + (Percent PAST_CUT * .30) + (Percent Relative Mill Draw * .10)

Figure 3.19: Interpolated Map of Suitability Index – Composite (All Variables Equally Weighted)

Legend
composite_idw
0 - 0.024093243
0.024093243 - 0.091168652
0.091168652 - 0.15586886
0.15586886 - 0.229451168
0.229451168 - 0.29703335
0.29703335 - 0.367615533
0.367615533 - 0.432315866
0.432315866 - 0.499057124
0.499057124 - 0.740935687

Values Represent (Percent Basal Area + Percent ≥ 15" DBH + Percent CUT + Percent Past Cut + Percent Mill Draw + Percent Relative Mill Draw) / 6
Based on the mapping results and conversations with Pinova managers and foresters, it was decided that Scenario 5 (GT15, Cut, and Past Cut weighted in thirds) displayed the plot data well for the intended purposes. This was because these variables gave the most direct indication of both presence and access. The GT15 variable indicated the presence of mature longleaf and slash pines, while the Cut variables indicated access to stumps. Scenario 6 gave a good display as well, with only GT15 (large stems) and recent cut data. The resulting suitability maps would then be compared with a variety of other layers such as ownership, Pinova’s data, and aerial imagery for interpretation. Discussions of future objectives also included soils data, elevation, and topography. The overall composite map was also included periodically since it represented the largest variety of data. The Scenario 5, Scenario 6, and Composite maps were used most heavily in combining Pinova’s data and testing.

With fairly recent imagery, whether flown photography or satellite imagery, one could use the suitability mapping as a filter. Within high suitability areas, imagery could be interpreted and possible harvest sights might be identified. Image interpretation requires systematic examination and often includes field reports and other maps as well. Interpretations can then be made for phenomena and the nature of physical objects. This method requires experience, patience, and ideally a substantial knowledge of the particular region (Lillesand, 2008). Though time and resources have not yet permitted these efforts, they are likely to be made in the future. Other future efforts will include the comparison of quality testing (rosin levels) to current spatial information. A very basic study of imagery, along with high suitability readings and lack of recent tonnage, was suitable for some initial field testing.
Section 3: Field Testing

Management in Forest Resources at Pinova had decided to focus initially on North Carolina, South Carolina, and Florida. These were the areas where they wanted to increase sourcing and where they believed there to be greater resources than were being captured. After mapping both the FIA data and Pinova’s data and comparing layers, many areas with no overlap became evident. This indicated a lack of sourcing where the plot data indicated resource potential. This was likely due to untraveled areas, forester placement, inaccessible ownerships, or simply uncontacted ownerships.

By overlaying the interpolated maps of scenarios and Pinova’s sourcing at the county level, it was possible to observe potentially overlooked areas for sourcing. This included counties where potential was indicated but no stumps had been procured. It also included “hot spots” within those counties where potential was higher and targeting could be suggested. Figure 3.20 shows examples of locations in the Carolinas where FIA plot data indicating cutting of longleaf/slash pine, yet no stumps had been procured. These areas are circled in red. In this particular example, Scenario 1 is used to observe only cut and past-cut data over the previous three years of Pinova’s procurement activity. This was primarily to test the ability to find previously overlooked timber harvests using FIA’s data.

For many efforts, Scenario 6 (suitability index including only recent cutting and large diameter longleaf and slash pine) was used because the recent cutting data were likely more helpful when searching for potential tracts. The Past Cut variable used in Scenario 5 indicates older cutting (5-10 years). These areas still have potential, but require certain circumstances to be accessible. This can mean prescribed burning, heavily thinned plantations, land clearing, or other
Figure 3.20: Cutting Indicated vs. Pinova’s County Procurement in the Carolinas
management which reduces ground cover. While prospecting in the field, it was decided that this variable should be omitted and Scenario 6 used more often.

The next effort was to field-test these unworked “hotspots”, to both assess the mapping and analyze potential usage. This was done with no added costs, since foresters already spend the majority of their time prospecting for potential tracts to harvest. Areas in the Carolinas were examined in coordination with Pinova’s area foresters. Testing FIA data-driven “high potential areas” in central Florida was completed using Pinova’s area forester, as well as assistance from others. Figure 3.21 depicts the composite suitability interpolation of FIA data with major roads. This provided “hot spots” for field testing in both the “panhandle” and central Florida regions. Figure 3.22 shows the areas with the highest suitability, with those over unworked counties circled in red. These maps were used to limit selected test areas to those within counties not worked in the past five years.

Because conservation areas, state forests, and federal lands are highly dependent on access (Pinova only has access to some), they were not included in the focus areas. These areas were displayed with a solid layer placed over other layers to prevent selection. However, these ownerships were observed separately to determine which lands justify efforts to gain access. Figures 3.23 and 3.24 show two sets of “hotspots” in central Florida with conservation, state, and federal ownerships marked. Figure 3.25 shows a similar set of areas within the Florida Panhandle and southern Georgia. These areas were numbered and mapped to a smaller scale to be checked by area foresters. Area maps with satellite imagery under a transparent “hotspot” layer were provided to help navigate areas and make decisions on suitability.
Figure 3.21: Florida Composite Suitability Interpolation with Major Roads

Figure 3.22: Cutting Indicated vs. Pinova’s County Procurement in Florida
Figure 3.23: Central-West Florida “Hotspots” with Conservation, State, and Federal Ownership
Figure 3.24: Central Florida “Hotspots” with Scenario 6 Suitability Mapping
Figure 3.25: Scenario 6 “Hotspots” in Florida Panhandle and Southern Georgia
After selecting highly suitable locations in each region, a set of maps was developed to be used in checking the sites. Methods included simple road maps as well as satellite imagery to locate these areas and check them. Physical checks of the locations depended on experienced methods of the area foresters. Once in the area, a forester could search for logging operations and/or recent cutting. Tracts could then be checked for desired stumps and potentially procured. Figure 3.26 shows the imagery surrounding five areas to be checked in central Florida.

Several of the areas (or locations near-by) were already being harvested by contractors. This was a positive sign for data accuracy, but unexpected due to the lease data over previous years. Many areas fell mostly on paper or timber company land (a total of 34%). These forests are longleaf pine but are unlikely to contain the desired stumps, since they are often replanted in loblolly pine or are not grown to sufficient age to develop a good heartwood ratio. It is likely that the FIA data showed higher suitability in these areas because of the “cut” and “past-cut” variables, since harvesting is prevalent.

Remaining areas were labelled either “positive” or “negative” by area foresters. Positive areas were those likely to contain desired stumpwood, provided the right tracts were clear-cut to allow access. Negative areas were those unlikely to be productive due to land use, previous stumping, incorrect species, or other factors. Table 3.2 shows the distribution of area findings across the three observed regions. Average percentages for each category give an idea of the success-rate. “Working” indicates foresters already had a crew in the area. “Company” indicates the area was located on plantations or paper company land (high longleaf basal area and frequent cutting). While these areas may be of interest closer to the plant, they were not of interest in these areas. This is because they contain only fresh-cut stumps, usually with smaller heartwood ratios. The areas indicated by foresters to be “negative” averaged only 15%. This indicates, if
Figure 3.26: Imagery for Five Areas to be checked in Central Florida

<table>
<thead>
<tr>
<th>Region</th>
<th>Areas</th>
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<th>Company</th>
<th>Positive</th>
<th>Negative</th>
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</thead>
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<td>2</td>
</tr>
<tr>
<td>Central Florida</td>
<td>20</td>
<td>2</td>
<td>8</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Panhandle</td>
<td>7</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Average %</strong></td>
<td><strong>100%</strong></td>
<td><strong>10%</strong></td>
<td><strong>34%</strong></td>
<td><strong>41%</strong></td>
<td><strong>15%</strong></td>
</tr>
</tbody>
</table>

**Total Positive (Working & Positive)** 51%

**Total Negative (Company Excluded)** 15%
company lands were excluded from the search and selection process, that the remaining areas would likely yield an 85% positive success ratio. This is by no means a guaranteed rate of success, but rather indicates the potential for success based on the limited number of field-checked areas.

This process was highly subjective by nature. Being called positive meant that the area consisted of tracts of land with the correct species, age class, and recent timber harvesting. Being called negative indicated a lack of these qualities. The final call was mostly dependent on the forester’s long working knowledge of the area and experience. This process did not indicate good potential for locating specific tracts to harvest. It did, however, provide a strong starting point for prospecting such tracts. As tools become available (remote sensing and recent imagery) for locating timber harvests, these “hotspots” could provide specific areas to look at more closely. Scanning over large regions for certain conditions can be a daunting task and such a filter could make the process much more efficient.

Multiple issues were identified in using this process to prospect stumping locations. One of these issues was simply logistics. The mapping effort requires someone to locate such areas and provide foresters with resources to check them. Checking the locations is also time consuming, and sometimes requires more travel than usual methods. Timing is also an issue, since recent imagery is difficult and/or expensive to obtain. Once tracts are located with imagery, they may already be re-planted, re-purposed, or overgrown. Scale is nearly always a problem as well when using FIA data – based maps. Although the information is accurate, it is limited to a larger scale. This creates challenges when trying to pinpoint areas to observe.
Conclusions

Despite the limitations of FIA plot data at smaller scales, this application certainly provided value. From a management and future planning view, a solid assessment of the raw material resources for a business is always beneficial. Pinova was able to evaluate the percentage of the entire resource that they were obtaining (estimated 15% of fresh-cut longleaf stumps). This indicates a positive and likely sustainable outlook for the company’s future. This certainly depends on continued efforts to increase acreage of longleaf pine forests, restoring the prevalence of the historically and ecologically significant species. As for old “lightered” stumps, an estimation cannot be made. These stumps accumulated over hundreds of years, and Pinova has little to no record of what and where they have harvested. There were also other companies in the past 50 years which harvested stumps but went out of business. However, the information is still useful for tracking down remaining areas to procure. Older timber holds a greater likelihood of hiding old stumps (since access has been prevented). Pinova also does have a general idea of historically worked regional areas.

Field testing indicated accuracy for the “hot spot” suitability mapping with FIA data. Although no guarantees can be made regarding access, ownership, or ability to purchase, the maps accurately represented areas of higher suitability. The limited field-checking done suggested a 51% chance of the area being good for prospecting, which rose to 85% if company lands were excluded. In some areas (such as South Georgia) Pinova does harvest fresh-cut stumps on large company lands. For these places company lands would not be “negative” and perhaps the process would be of even greater value.

This process allows the company and its foresters to target certain areas when prospecting. It may be especially useful when pinpointing particular ownerships (e.g., DOD...
lands, state and national forests, large plantations) with which to develop contracts. Ownership was clearly an aspect needing further attention. For example, if the data consistently shows high probability across a particular military base, it may become a priority to develop a working contract there. For plantations and paper company lands near Brunswick where fresh-cut stumps can be harvested, there is opportunity for better planning. Particular plantations and areas could be targeted while others are put “on hold” until age increases. With current efforts to record worked tracts spatially and connect them with quality testing, there is potential for using those results to target regions with consistently higher rosin levels.

It also became apparent that using this mapped information requires some experience and knowledge of the source. Figure 3.27 shows some “hot spots” in Pasco County, Florida that may seem to indicate high potential at first glance. However, understanding plot spacing and the values required to indicate a high potential may refute that assumption. These two areas are likely highlighted due to higher values on individual plots. Viewing the imagery will also show that these areas are relatively developed and not likely to contain much acreage of high potential forested areas. A better indication of suitability is shown in Figures 3.28 and 3.29. This area shows a much higher suitability over a larger area, and would require multiple high-value plots to produce such “heat”. Upon viewing imagery and field checking, this was in fact decided to be a high-potential area. This demonstrates how interpolated maps can be take “too literally” and some limits are required before consistent values are assumed. Being careful of details and mindful of scale can prevent mistakes in this method, improving overall success.
Figure 3.27: False Suitability Indicators in Unworked Pasco Co., Florida

Figure 3.28: Good Indicator for Sourcing Potential in Clay Co., Florida
Figure 3.29: Good Indicator over Satellite Imagery in Clay Co., Florida
CHAPTER 4

FUTURE POSSIBILITIES FOR METHODS AND PROCEDURES

Data Potential within Pinova

As management in Forest Resources at Pinova agreed, there was a definite need to start collecting data spatially on all stumps procured and their respective parcels. Although it is unfortunate that past data were not collected, there is still great value in doing so now. Foresters could save an enormous amount of time checking tracts if they knew whether or not Hercules had harvested them previously. A lack of data not only represents a loss of that particular knowledge, but also knowledge that could have been gained from it. For example, volume/acre and lbs./ton rosin testing could have been mapped with such data. However, the simple addition of GPS coordinates to the leasing process will make spatial data analysis entirely possible in the future. With detailed data such as soil, elevation, and rosin yield, customized models could actually be created for prospecting quality wood.

Possibilities exist for data acquisition and usage in both old “lightered” stump and fresh-cut stump prospecting. In areas where old stumps are targeted, tracts could be recorded where no stumps were found to save from re-checking in the future. Expected land-use following timber harvest could also be recorded. Examples of this would be: replanted, natural regeneration, cleared/developed, converted to agriculture, etc. This would provide potential future tracts in case fresh-cut stumps become viable in that area. For harvesting fresh-cut stumps, data could be collected to show higher quality areas (larger hearts) in longleaf stands. It could also help to predict future resources when longleaf stands are on a scheduled harvest rotation.
GIS Tools, Layers, and Analysis Methods

The next step is likely to be simple image interpretation assisted by all available data, regional knowledge, and maps. Scanning imagery in this way requires up-to-date imagery, time, and experienced manpower to be completed properly. Resulting potentials range from locating clearcuts to be checked to a sophisticated modeling based on quality testing, soil data, and elevation data. In creating models, the idea is to gain understanding through simplification. This means simplification is the initial goal, but models can be built from largely different media, data types, and knowledge (Longley, 2003). The advantage to “starting fresh” is the ability to evaluate all options and consider further analysis techniques with the best available methods. This will certainly be the goal moving forward.

Interpolation is a useful tool when sample points are limited. Due to the nature of resinous stumps and how they are distributed, this tool has some definite potential for sampling this resource. Stumps are originally dispersed only within historic and current ranges of longleaf pine. The available stumps are further reduced by actions such as historical extraction by Hercules Inc., cleared land, and sedimentation. Each of these phenomena tend to follow spatial patterns and have higher values in particular areas. If Pinova’s data were recorded spatially, be it stumped tracts, quality (lbs. rosin per ton of wood), or even lack of stumps, this data could also be interpolated. Potentially, important variables like wood quality and volume (tons/acre) could be interpolated and mapped to find areas to focus on more intensely.

Satellite imagery and remote sensing tools are now more practical and accessible than ever. These tools are being used with great success in a variety of fields, including wildfire, agriculture, insect damage, disaster impacts, and even frost. They can detect phenomena like drought, defoliation, development, and deforestation. With web-based access systems that can
produce data as frequently as once a week, there is great potential in clear-cut detection. Timber harvesting is the most important factor in resinous stump procurement, since it provides access. If harvests can be detected using these change-detecting tools, it would significantly improve prospecting for potential stump harvesting sights.

NASA has developed and is continually improving the Moderate Resolution Imaging Spectroradiometer (MODIS) system. MODIS is a remote sensing tool that can provide 1,000-m, 500-m, and 250-m resolution spectral bands. The system can produce a broad global coverage every one to two days. MODIS has already been used to evaluate rangeland production for 15 years using the Normalized Difference Vegetation Index (NDVI) at 250 square meter resolution (Reeves, 2017). MODIS provides global maps that include these vegetation indices to help scientists determine vegetation density and change. It is easily conceivable that this tool could help to detect clear-cutting and locate potential stump harvesting sites.

Perhaps the best tool currently available is the USDA Forest Service developed ForWarn system. This satellite-based forest change recognition system uses remote sensing primarily to track disturbances, but has many potential applications. The system is web-based and continuously updated (near-daily), and is in a useable format for foresters and land managers. It specifically detects change in the NDVI data derived from MODIS. Even seasonal leaf phenology expectations are accounted for to define “abnormal” changes (Norman, 2013). Potential prospecting with this tool for Pinova is not limited to identifying harvest locations. ForWarn detects forest change from large storms, fires, flooding, and other disturbances. These events can be (and have been in the past) large volume drivers for Pinova, as they allow access across large acreages to resources previously unavailable. Figure 4.1 shows vegetation loss from
a tornado in Springfield, MA in June, 2011. The potential is certainly high for this tool and it should certainly be pursued over the coming years.

![Figure 4.1: ForWarn NDVI Change Detected from MA 2011 Tornado (Norman, 2013)](image)

**Updates and New Developments**

Pinova recently developed a customized GIS-based tool which is web-based and user-friendly. The tool was developed in collaboration with Thomas & Hutton, a Georgia and South Carolina based company that provides solutions in engineering, surveying, planning, and GIS. It is a custom version of their geothinQ℠ tool which allows foresters to collect and use spatial data without having GIS experience. Cartographic mapping tools, landowner tax parcel layers, and geolocation are just a few of the features in geothinQ℠. Figure 4.2 gives a basic picture of the geothinQ℠ layout. This tool has been developed and customized over several months with the hopes of covering spatial technology needs and more.

Tablets, geothinQ℠ access, and training were officially introduced to Pinova’s foresters in January 2017. With this toolset foresters can collect data on previous, current, and future tracts for stump harvesting. Leasing data, plus detailing attributes can also be recorded to allow for
future analysis. A current objective is to connect quality testing data to the sourced locations. Details such as wood type, ownership type, acreages, volume, topography, and even soils, suggest vast potential for analysis in just a few months.

Changes are occurring in the wood-rosin industry, Pinova’s processing, and in the resource itself. The rosin products market for Pinova is much more specialized than it once was. Plant processing of stumps is being updated and made more efficient. Methods are currently being testing to core stumps, only harvesting the resinous heart section of the stump. Old, original “lightered” stumps are becoming increasingly rare. Today’s longleaf pine management does not produce the large heartwood needed to re-create them. However, the company’s current efforts suggest that it is poised to make fresh-cut stumps more and more viable. This sourcing method is much more sustainable and is likely to only improve. Although the pine rosin industry is not nearly what it once was, there seems to be a strong future for its remaining business.

Figure 4.2: Layout of geothinQ℠ Web-Based Mapping Tool by Thomas and Hutton


Eberhardt, Thomas L.; Sheridan, Philip M.; Mahfouz, Jolie M.; So, Chi-Leung. 2006. Old resinous turpentine stumps as an indicator of the range of longleaf pine in Southeastern Virginia. In: Longleaf Pine: seeing the forest through the trees, Proceedings of the Sixth Longleaf Alliance Regional Conference. 6 p.


APPENDIX
Appendix A: SQL Query Script for FIA Downloaded Data

```sql
-- &eval_grp = 012013, 052013, 122013, 212012, 222012, 282013, 372013, 402013, 452013, 472012, 48201, 512012
select Combo.*, cut.Trees_cut, cut.longleaf_cut, cut.slash_cut, prev_cut.past_trees_cut, prev_cut.past_longleaf_cut, prev_cut.past_slash_cut
from (select ba.*, gt.gt15, gt.longleaf_sample, gt.slash_sample
      from (select p.cn plt_cn,
              p.prev_plt_cn,
              p.statecd,
              p.countycd,
              p.lat,
              p.lon,
              count(t.cn) ALL_TREES,
              sum(t.tpa_unadj * t.dia * t.dia * 0.005454) ba_per_acre,
              sum(t.tpa_unadj * t.dia * t.dia * 0.005454 * decode(t.spcd, 121, 1, 0)) longleaf_ba_per_acre,
              sum(t.tpa_unadj * t.dia * t.dia * 0.005454 * decode(t.spcd, 111, 1, 0)) slash_ba_per_acre
              from FS_FIADB.PLOTSNAP p, FS_FIADB.COND C, FS_FIADB.tree t
              where P.eval_grp in (&eval_grp)
              and p.cn = c.plt_cn
              and c.plt_cn = t.plt_cn
              and c.condid = t.condid
              and c.cond_status_cd = 1
              and t.statuscd = 1
              and t.dia >= 1.0
              and t.tpa_unadj is not null
              and t.dia is not null
              group by p.statecd,
              p.countycd,
              p.cn,
              p.prev_plt_cn,
              p.lat,
              p.lon
              order by p.statecd,
              p.countycd,
              p.cn,
              p.prev_plt_cn,
              p.lat,
              p.lon) ba,
      (select p.cn plt_cn,
           count(t.cn) GT15,
           sum(decode(t.spcd, 121, 1, 0)) longleaf_sample,
           sum(decode(t.spcd, 111, 1, 0)) slash_sample
           from FS_FIADB.PLOTSNAP p, FS_FIADB.COND C, FS_FIADB.tree t
           where P.eval_grp in (&eval_grp)
           and p.cn = c.plt_cn
           and c.plt_cn = t.plt_cn
           and c.condid = t.condid
           and c.cond_status_cd = 1
           and t.statuscd = 1)
where P.eval_grp in (&eval_grp)
and p.cn in (&eval_grp)
and p.cn = 139994277010854
and p.cn = 139994277010854
and p.cn = 139994277010854
and p.cn = 139994277010854
and p.cn = 139994277010854
and p.cn = 139994277010854
and p.cn = 139994277010854
and p.cn = 139994277010854
and p.cn = 139994277010854
```

61
and t.dia >= 15.0
and t.tpa_unadj is not null
and t.dia is not null
group by p.cn
order by p.cn) gt
where ba.plt_cn = gt.plt_cn(+)) Combo,

(select p.cn plt_cn,
  --p.lat,
  -- p.lon,
  count(t.cn) Trees_cut,
  sum(decode(t.spcd, 121, 1, 0)) longleaf_cut,
  sum(decode(t.spcd, 111, 1, 0)) slash_cut
from FS_FIADB.PLOTSNAP p, FS_FIADB.COND C, FS_FIADB.tree t
where P.eval_grp in (&eval_grp)
  --and p.cn=236497051010854
  /* and ((c.statecd = 05 and c.unitcd in (1, 2)) or
  (c.statecd = 22 and c.unitcd in (1, 2)) or
  (c.statecd = 28 and c.unitcd = 1))*/
and p.cn = c.plt_cn
and c.plt_cn = t.plt_cn
and c.condid = t.condid
and c.cond_status_cd = 1
and t.statuscd = 3
group by p.cn, p.lat, p.lon
order by p.cn, p.lat, p.lon)

) cut,

(select p.prev_plt_cn prev_plt_cn,
  -- t.?,
  --p.lat,
  --p.lon,
  count(t.cn) past_Trees_cut,
  sum(decode(t.spcd, 121, 1, 0)) past_longleaf_cut,
  sum(decode(t.spcd, 111, 1, 0)) past_slash_cut
from FS_FIADB.PLOTSNAP p, FS_FIADB.COND C, FS_FIADB.tree t
where P.eval_grp in (&eval_grp)
  --and p.cn=236497051010854
  /* and ((c.statecd = 05 and c.unitcd in (1, 2)) or
  (c.statecd = 22 and c.unitcd in (1, 2)) or
  (c.statecd = 28 and c.unitcd = 1))*/
and p.prev_plt_cn = c.plt_cn
and c.plt_cn = t.plt_cn
and c.condid = t.condid
and c.cond_status_cd = 1
and t.statuscd = 3
group by p.prev_plt_cn
order by p.prev_plt_cn) prev_cut
where Combo.plt_cn = cut.plt_cn(+)
and combo.prev_plt_cn = prev_cut.prev_plt_cn(+)
--and combo.plt_cn=139994277010854
Appendix B: Calculations for Variables and Scenarios

- PCT_Draw = VOL_LBS_10 / VOL_LBS
- PCT_Relative = VOL_LBS_10 / Highest (1,071,827.616)
- Combined_Mill = (PCT_Draw + PCT_Relative) / 2
- PCT_BA = (Slash_BA_Per_Acre + Longleaf_BA_Per_Acre) / BA_Per_Acre
- PCT_GT15 = IF (GT15 > 0,((Slash_Sample + Longleaf_Sample) / GT15), 0)
- PCT_CUT = IF (Trees_Cut > 0,((Longleaf_Cut + Slash_Cut) / Trees_Cut), 0)
- PCT_PAST_CUT = IF (Past_Trees_Cut > 0,((Past_Longleaf_Cut + Past_Slash_Cut) / Past_Trees_Cut), 0)
- Scenario_1 = (PCT_CUT + PCT_PAST_CUT) / 2
- Scenario_2 = (PCT_GT15 + PCT_BA) / 2
- Scenario_3 = (PCT_GT15 + PCT_PAST_CUT) / 2
- Scenario_4 = (PCT_BA + PCT_GT15 + PCT_CUT + PCT_PAST_CUT) / 4
- Scenario_5 = (PCT_GT15 + PCT_CUT + PCT_PAST_CUT) / 3
- Scenario_6 = (PCT_GT15 + PCT_CUT) / 2
- Scenario_7 = (PCT_GT15 + PCT_Draw) / 2
- Scenario_8 = (PCT_GT15 * .45) + (PCT_PAST_CUT * .45) + (PCT_Relative * .10)
- Scenario_9 = (PCT_BA * .30) + (PCT_GT15 * .30) + (PCT_PAST_CUT * .30) + (PCT_Relative * .10)
- Composite = (PCT_BA + PCT_GT15 + PCT_CUT + PCT_PAST_CUT + PCT_Draw + PCT_Relative) / 6
Christopher Ryan King was born in Knoxville, Tennessee on September 14, 1987 to Dale and Rhonda King. Upon graduating from Farragut High School in May of 2006, he entered Pellissippi State Technical Community College. In 2008, he transferred to the University of Tennessee, Knoxville to pursue a degree in Forestry. In 2012 he was awarded a B.S. degree in Forestry, Resource Management. During his undergraduate career he stayed active within the department. He competed in timber sports, served in the Forestry Club, did extra-curricular GIS work, and helped other students in course-groups.

In 2010 he began working as a Forestry Technician for the USDA Forest Service – Forest Inventory & Analysis unit of the Southern Research Station in Knoxville, TN. Here he was able to gain experience in the field taking FIA Phase 2, Phase 3 FHM, and Q.A. plots. He also served in the Pre-field Section using GIS to prepare materials for field crews, and worked on multiple special projects performing research and analysis. During this time he also completed his coursework for a Master’s degree in Forestry with a focus in Forest Policy under Dr. Don Hodges at the University of Tennessee, Knoxville.

FIA’s Knoxville office was approached by Pinova, Inc. in July 2014 to explore the use of their data to improve material sourcing for the company. King, with help from Dr. Christopher Oswalt, took the lead on this project which would later become the material for his thesis. He then accepted a job offer from Pinova, Inc. in October 2014, continuing the project under the title of Forester – Supply Analyst. The work continued for 6 months, after which Pinova hired him as their permanent Forester in North Carolina.

Chris married Heather Dawn Moore, from Knoxville, Tennessee, in April 2015. They currently live in Wilmington, North Carolina where he works across 10 counties procuring resinous stumpwood for Pinova’s plant in Brunswick, Georgia. He works daily with consultants, timber buyers, loggers, and landowners to procure wood for harvest. Upon completion of his Master’s degree in May 2017, he intends to continue a career in forestry while exploring research to improve the industry as a whole.