CHANGING TIMES: HOW TECHNIQUE AND TECHNOLOGY ADVANCEMENTS COULD PROMOTE WOODY BIOMASS HARVESTING IN THE UNITED STATES

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1. Abstract

As the need for woody biomass continues to develop, so do the techniques and technologies that are used to harvest it. This paper discussed the potential for the woody biomass market in the United States with regards to alternative factors that could be used to decrease planting and harvesting costs. Small-scale harvesting machines such as skid-steer loaders were used for harvesting small tracts of land where residual damage, small diameter wood, and transport costs contribute to high overall costs. In addition to small-scale machines, adaptations in planting methods, using the FlexStand™, have proven to provide landowners with two effective techniques to alleviate residual tree damage while simultaneously increasing final sawtimber value. Woody biomass tonnage data was collected and compared from both harvested and modeled stands. Results depicted a significant amount of biomass tonnage was removed from all stands indicating high potential for woody biomass in the future.

Keywords: Flex Plantations, Rectangularity, Small-scale Harvesting, Woody Biomass, Ptaeda Modeling

2. Introduction

The innate interest in woody biomass as a form of renewable energy is not a new concept. In fact, it can be considered cyclical and has been referred to as far back as the introduction of settled agriculture (Dickmann 2006). Woody biomass, defined in this paper as small-diameter trees (≤ 9 inches) at diameter breast height (dbh), was first used by the Neolithic people for fuelwood and poles in winter months because they found these small trees were more versatile and easier to handle. The Roman and Chinese Empires maintained detailed records how they systematically calculated re-occurring growth and harvest yields for woody biomass to meet societal needs with influxes occurring during times of war (Dickmann 2006). In more recent years, interest in woody biomass has tended to cycle with high prices for natural gas and petroleum. Overall, however, interest has and will continue to rise as the growing interest in utilizing renewable resources for energy also increases.

As the need for woody biomass continues to develop, so do the techniques and technologies that are used to harvest it. Dimensional spacing and density stocking research are being conducted to alter planting specifications for plantation pine trees. This avenue may provide more realistic results for promoting woody biomass, especially as the forest equipment industry continues to increase the power and size of their machines. This study analyzed the number of green tons that were produced after a biomass harvest was conducted at year 8 for both a FlexStand™ as well as a normal stand configuration. This data was then compared against a modeling tool to emphasis result accuracy and better portray the potential for the woody biomass market in the United States from a tonnage potential rather than its cost effectiveness.

3. Methods

Case Study Site Description:

The field study was conducted on the Solon Dixon Forestry Education Center in Covington County, Alabama. The site consisted of a total of approximately 2.66 acres on Dothan and Malbis sandy loams. Stand 1 was 1.02 acres in size and contained a loblolly pine plantation with 8ft x 6ft spacing. Stand 2 was 1.64 acres in size and was considered a flex plantation stand. The spacing configuration consisted of every third row being 10ft by 4ft spacing while all other rows were 10ft by 8ft spacing. Both stands were established with their rows facing in an east-west direction with a twenty-foot corridor separating the two stands. The stands were approximately eight years old at the time of harvest, in May of 2017, with minimal mortality found in either stand.

Every third row was removed from both stands using a Caterpillar 279D skid-steer that had a Fecon FBS1400 Single Knife Tree Shear attachment head. The sheared trees were collected in the shear heads' accumulating arm until full where the bundle would then be laid down within the row. A turbo forest mini skidder was used to collect the bundles and remove them from the site. Approximately two bundles per row in stand 1 and three bundles per row in stand 2 were randomly selected to be measured for a total of 16 bundles in stand 1 and 12 bundles in stand 2. Individuals trees were measured out of each selected bundle recording their total height, weight, and dbh. Overall, 88 trees were measured in stand 1 and 79 trees were measured in stand 2.

Ptaeda Study Model Description:

The comparison model study was conducted using a loblolly pine plantation modeling tool named Ptaeda 4.0. Four separate models were run with this tool; one each for stands 1 and 2 with a biomass harvests at year 8, thinning's at year 16 and final harvests at year 28. The other two conducted pulpwood thinning's at year 16 with final harvests at year 28 for each stand. Each model incorporated specific parameters relating the models as close to field conditions as possible. These specifications included site productivity of 85, total rotation lengths of 28 years, physiographic regions based in the Coastal Plain, pulpwood tops at 2 inches with minimum dbh at 5 inches, chip and saw tops at 4 inches with dbh at 8 inches, and sawtimber tops at 6 inches with dbh at 11 inches. All trees were calculated using green weight (tons/acre with bark) measurements. Biomass harvests were conducted using a 3rd-row thin method at year 8 while thinning's were conducted with a targeted residual basal area of 70 square feet.

Harvest Yields Analysis

Data were recorded and analyzed in Microsoft Excel. Results for the field data were analyzed by grouping trees by dbh class using 1-inch intervals from 3-9 inches. Basal area was calculated per size class as was the overall basal area that was removed from each stand. The average weight per tree was calculated for each size class and protracted out to determine the overall tonnage harvested per size class for one acre. Total tons removed per stand were calculated to use as a reference for comparison. A stump count was conducted in each row per stand to use a reference for actual tree removal data.

Ptaeda data that was recorded into excel included: the site index, the treatment conducted, dominant height, average dbh, average height, average crown ratio, tree number, basal area, total weight (ton), pulpwood weight harvested (ton), chip n saw weight harvested (ton), sawtimber weight harvested (ton) and total tons harvested (tons). A comparison of the data was made to determine differences and similarities within the Ptaeda model as well as against the field data.

4. Results

88 trees were measured in Stand 1. Of the harvested trees 6 were within the 3-inch dbh class, 9 were in the 4-inch dbh class, 26 were within the 5-inch class, 34 within the 6-inch class, 12 were in the 7-inch class, 1 in the 8-inch class and none were found to be within the 9-inch dbh class. The average dbh for the stand was 6 inches with an average height of 39 feet. The residual basal area was approximately 70 down from the original 120 before harvesting. Tree weights for each dbh class were averaged to calculate the average weight per tree in each dbh class as well as the average dbh weight per acre. A final weight for Stand 1 was calculated at 84,690 pounds or 42.35 green tons that were removed from a one-acre tract.

Table 1. Summary data for the 8x6 stand of harvested trees.

DBH Class	Harvested Tree Count	Basal Area	Tons Harvested
3	6	0.99	0.78
4	9	2.65	1.97
5	26	11.95	10.69
6	34	22.51	18.92
7	12	10.81	8.99
8	1	1.18	1.00
9	0	0.00	0.00

79 of the 568 harvested trees were measured in Stand 2. Of those trees 3 were within the 3-inch dbh class, 16 were in the 4-inch dbh class, 32 were within the 5-inch class, 16 within the 6-inch class, 10 were in the 7-inch class, 1 in the 8-inch class and 1 was found to be within the 9-inch dbh class. The average dbh for the stand was also 6 inches with an average height of 40 feet. The residual basal area was approximately 70 down from the original 120 before harvesting. Tree weights for each dbh class were averaged to calculate the average weight per tree in each dbh class as well as the average dbh weight per acre. A final weight for Stand 2 was calculated at 105,158 pounds or 52.58 green tons that were removed from a one-acre tract.

Table 2. Summary data for the 10x6 harvested stand.

DBH Class	Harvested Tree Count	Basal Area	Tons Harvested
3	3	0.05	0.52
4	16	0.09	6.33
5	32	0.14	19.81
6	16	0.20	12.59
7	10	0.27	11.80
8	1	0.35	1.50
9	1	0.44	0.03

The Ptaeda model that included biomass in the harvest for Stand 1 had an average dbh of 5 inches with an average tree height of 31.5 feet after year 8. The model for Stand 2 had an average dbh of 5.6 inches with an average tree height of 32 feet. Residual basal areas for Stands 1 and 2 were 77 and 73 trees per acre after removing approximately 32.6 and 31.3 green tons of biomass from each one-acre tract. Approximately 58.3 green tons were thinned from Stand 1 in year 16 and 110 green tons were harvested from Stand 1 in year 28. Almost 58.8 green tons were thinned from Stand 2 in year 16 but 121.7 green tons were harvested in year 28.

Conventional Ptaeda models that did not include biomass had an average dbh of 6.46 inches and an average height of 51.4 feet for Stand 1 and an average dbh of 7.17 inches with an average height of 52.7 feet for Stand 2 at year 16. Residual basal areas for each stand were 74.9 trees per acre after a pulpwood thinning had been conducted removing 55.9 green tons from Stand 1 and 56.0 green tons from Stand 2. Final harvest tonnage was approximately 99.6 green tons for Stand 1 and 106.1 green tons for Stand 2.

Table 3. Summary Data for all Ptaeda Models.

Trees Per Acre	Site Index	Treatment	Basal Area	Tons Harvested
908	85	Pre-Biomass Thin	94.2	26.8
908	85	Biomass Thin	77.2	32.6
908	85	Pre-Pulpwood Thin	145	97.9
908	85	Pulpwood Thin	74.9	58.3
908	85	Final Harvest	107.8	110.1
908	85	Pre-Pulpwood Thin	173.1	112.7
908	85	Pulpwood Thin	74.9	55.9
908	85	Final Harvest	100.3	99.6
727	85	Pre-Biomass Thin	89.3	29.5
727	85	Biomass Thin	73.4	31.3
727	85	Pre-Pulpwood Thin	142.9	98.6
727	85	Pulpwood Thin	74.6	58.8
727	85	Final Harvest	116.3	121.7
727	85	Pre-Pulpwood Thin	171.4	116
727	85	Pulpwood Thin	74.6	56
727	85	Final Harvest	105.9	106.1

5. Discussion

A significant amount of biomass was removed from each stand by conducting a third row thinning. In fact, as much biomass tonnage was removed from the field studies as what was removed from the pulpwood thinning's in the non-biomass conventional timber harvests conducted in the Ptaeda models. Extrapolating this information out to a tract size of at least 20 acres, as is preferred for standard sized equipment, and woody biomass harvests has the potential of becoming a cost-efficient product if market demand were to occur. An increase in market price would allow stands less than 20 acres the opportunity to become cost-efficient as well, especially if they were harvested with small-diameter equipment.

Both of the Ptaeda models supported the field data in stating that utilizing the FlexStand^{TM} technique provided landowners with higher overall volumes with regards to the number of tons removed on a per acre basis. Ptaeda modeling results also indicated that incorporating woody biomass thinning's into landowners harvesting rotation would increase their final volume by at least 10 tons per acre. This information combined with previous studies promoting higher initial plantings for density stocking to produce higher quality sawtimber trees could result in providing landowners with a substantially greater final product value. If loggers chose to conduct biomass thinning's with small-scale equipment to reduce the amount of residual damage that was conducted and minimize equipment hauling costs, the profit margin that could be realized would theoretically continue to increase.

6. Conclusion

The woody biomass market will continue to grow in the United States as the demand for biomass increases around the globe. Advances in technology have created alternative machines that are more compact and ideal for harvesting woody biomass, have a low environmental impact, and fewer transportation costs. Adaptations in harvesting and planting methods have provided landowners with two effective techniques to choose from in order to alleviate issues regarding residual tree damage caused by today's large machine size as was seen in the experiment above. If market prices and the number of biomass facilities rise in the United States in the next few decades' landowners will have little reason not to harvest biomass, especially when biomass thinning's result in just over half as much tonnage as a pulpwood thinning and increase final sawtimber harvests by a minimum of 10 tons.

7. References

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