HIGH TONNAGE FOREST BIOMASS PRODUCTION SYSTEMS FROM SOUTHERN PINE ENERGY PLANTATIONS

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INTRODUCTION

The topic of declining fossil fuels and the absolute need for renewable energy sources is very evident in today's society. The utilization of bio-fuels is necessary to meet goals set forth in the Energy Independence and Security Act of 2007. Included in the act are standards in which bio-fuels will play a major role in ensuring national energy security and the reduction of green house gases. One of the main goals of the act is to have 36 million gallons of bio-fuel produced each year by 2022. A portion of the 36 million gallons will be derived from biomass feedstocks composed of woody biomass.

Woody biomass is available in such forms as urban residues, mill residues, short rotation woody crops, and logging residues. Currently, the availability of these types of biomass is not readily obtainable to meet the large scale quantities set forth. Eventually, short rotation crops must be utilized to conquer the United States requirements for energy. Short-rotation woody crop (SRWC) supply systems were first described in the late-1960s and early 1970s as a means of rapidly producing lignocellulosic fiber for use in the wood products industry and for energy (Tuskan 1997). These stands are harvested on 10-14 year rotation which will be attractive to landowners looking for a quick return on investment when compared to other product types from timber.

The problem lies in the harvesting, processing, and delivering of biomass to the mill in a form that is economically feasible. Harvesting systems must be balanced for the characteristics of the forest, machine types and intensity of the harvest to reflect the equipments productivity (Akay et al., 2004). Current estimated costs of this harvesting and handling system ranged from $19 to 38 U.S. per dry metric ton, less the transportation costs (Tuskan 1997). These traditional harvesting systems have not been optimized for use with SRWC and improvements in types and arrangements of equipment are still possible (Tuskan 1997). Because of the high volume and low value, a high productive operation must be set in place to mitigate the low value of the material by producing high volumes in a given time period. These systems do not need to be capital intensive and have the capability to be used for conventional round wood production due to the ever increasing fragmentation of land to private landowners who manage land differently. The system envisioned for this study is a high-speed, high-accumulation feller-buncher and a modified high capacity rubber tired skidder.

To aid in this research, TigerCat Inc., Corley Land Services, Zika Biomass Energy, and the USDA Forest service has agreed to form a consortium to develop this high productive system and evaluate its viability towards a short rotation woody biomass crop. TigerCat is one of the major producers of forest machinery in the world and have a great reputation for producing quality machines. In this research, TigerCat will implement the machine needs set forth by the consortium to engineer a feller-buncher and a skidder to loan for evaluation. Corley Land Services conducts biomass harvests currently in south Alabama. They will be the company operating the newly developed equipment because of their experience in these types of harvest. This partnership will enable a greater understanding and evaluation of the proposed harvesting operation which should show the commercial viability of the system in current markets.

Costs associated with harvesting small trees were dramatically increased due to the high capital costs associated with mechanized feller-bunchers (Frederick and Stokes, 1987). Also due to the low weight of the small trees, larger stems decrease production costs with the same machine (Akay et al., 2004). Continuous saw heads incorporated on a feller-buncher have also been shown to be highly productive. The issue with these heads is the high capital costs and high operating costs when compared to the less expensive shear heads. Shear heads have been used in conventional harvesting systems for many years but previous versions of the shear head could not meet the high productivity standards needed for short rotation woody crops. Another issue with the feller-buncher is the environmental impacts that it can place on a property. The predominant feller-buncher type is the rubber-tired drive to tree model. This model has a tendency to cause unacceptable rutting in wet weather making it extremely weather sensitive as well as a producer of erosion. Since southern pine energy plantations are generally clearcut, one must take into account that clearcutting generally produces more soil disturbance than thinning or select cutting (Reisinger and Simmons, 1988). Tracked feller-bunchers also come equipped with a boom that extends far into the stand. This enables the machine to travel in a straight path while extending its boom to the maximum length to sever trees, thus increasing productivity when compared to drive-to-tree feller-bunchers (Winsauer, 1980). Another positive effect of incorporating a shear-head in place of the continuous saw-head is the lower stump it provides. This will enable the operation to achieve increased yield of wood from the same number of stems severed. The continuous saw-head cannot achieve this result due to the deterioration of the saw-teeth when the saw-teeth meet the soil. The implementation could result in an increase of up to six inches of the largest portion of the bole of the tree being felled. Another result of the lower stump is the increased productivity of the skidder operator and the decrease in health problems associated with operating the equipment.

Ergonomics has been a major issue in the forest harvesting equipment market. The mechanization of forestry work has resulted in a sharp decline in the number of accidents in the past 20 years (Folstad, 1982). Unfortunately the mechanization has caused other long term problems for forest machinery operators due to uncomfortable positioning while operating the equipment. Despite the ergonomic and industrial hygiene improvements successively introduced, musculoskeletal complaints are currently commonplace in machinery operators. Continuous saw-heads leave stumps between 4 and 6 inches in height in which the skidder operator maneuvers around or drives over causing a very uncomfortable shake. Both of these situations lead to a loss in productivity in turn driving up harvesting costs as a whole.

The piece of equipment that is common and necessary for a conventional harvesting operation is the rubber-tire grapple skidder. This type of skidder is in current practice in most conventional harvesting systems in the southeastern United States. The skidder's purpose is to drag the felled timber to the landing where it can be loaded onto tree-length trucks or chipped and placed into chip vans. Because short rotation woody biomass will be harvested at the age range of 10-14, current versions of the grapple on the skidder will make the machinery underutilized. The reason for this underutilization is the grapple located on the skidder can only handle a certain diameter of a buddle of trees. The one factor that had the greatest impact on skidding productivity was stem size (Kluender et. al 1997). Short-rotation woody crops will be shorter than trees designated as pulp wood, but may still have the same size diameter bundle. The decrease in length of the short-rotation crops will lead to a decrease in volume and weight thus underutilizing the horsepower the skidder possesses to drag a bundle of trees. Incorporating a larger grapple to the same horsepower skidder will allow for a greater diameter bundle with the same weight as a conventional pulp wood bundle to be efficiently pulled, thus increasing biomass volume skidded to the loading deck.

In this research, we intend on meeting the following objectives:

To develop an optimal system that integrates a high productivity feller-buncher with modified skidders and a chipper to minimize production costs in harvesting short rotation woody biomass.

To develop a harvesting system that is environmentally friendly.

Design of Equipment

Feller-buncher: As stated before, TigerCat has agreed to take recommendations set forth by the members of the consortium and engineer machines that are more specialized to southern pine energy plantations. The first of which is the tracked feller-buncher. The capital cost for this modified machine will not be higher than any other tracked feller-buncher designed by TigerCat to make it attractive to perspective loggers. This machine incorporates TigerCat's state of the art ER boom system to increase fuel efficiency and strength of the boom. The design will also utilize an extremely powerful hydraulic shear to sever the biomass and a higher capacity holder on the shear for accumulation of more trees before the bundle is placed on the ground. This shear head will also incorporate a new automatic accumulating arm that will aid in operator comfort and productivity. TigerCat is making the shear thinner for speed so it will be subject to damage if trees with a butt diameter of greater than 11 inches are severed. The swing to tree boom will improve the efficiency of the machine when compared to drive-to-tree fell-bunchers currently utilized. Also by placing the feller-buncher on tracks, environmental impacts should be minimized due to the increase in surface area of tracks when compared to the more conventional rubber tires. The machine will be fitted with a data recorder for the purpose of this research to perform time studies of the productivity. Lastly, the machine will be fitted with all of the ergonomic conveniences currently available to ensure operator comfort since he/she will be moving at an extremely fast pace through a variety of terrains.

Skidder: The skidder will be the current TigerCat model 620D which is their mid-sized skidder designed for high life and low maintenance. To specialize for the larger bundles felled by the feller-buncher, the 620D will be equipped with an oversize grapple to grab a larger bundle of trees. This grapple will have a maximum opening of 143 inches compared to the conventional 138 inches. Also the machine will be equipped with data recorders for the experiment. The machine will be equipped with TurnAround^{tm}, which is a two position seating system that allows the operator's seat to rotate which eliminates his/her back twisting to see the load being skidded.

METHODS

Objective 1: To develop an optimal system that integrates a high productivity feller-buncher with modified skidders and a chipper to minimize production costs in harvesting short rotation woody biomass.

Hypothesis: The implementation of the high productive harvesting system will fell, skid, and transport >25 loads per day in an efficient manner, thus decreasing the production costs of the harvesting operation to a value that ensures the economic feasibility of a short-rotation woody crop used for energy when compared to other timber product markets.

Study Sites

To investigate these systems and meet objectives, landowners in the Greenville, Alabama will be invited to attend a meeting where they will be informed of the economic benefits of short-rotation woody biomass crops and the intentions of the study. These landowners will be surveyed to discover if they have land that would be applicable to the type of system being researched and informed that the land will be clearcut. The land desired will be have the following characteristics: planted pine plantation, minimum of 600 trees per acre, age class between 10 and 15 years, and greater than 100 acres. The study will require a minimum of two parcels for complete examination. Currently, Corley Land Services pays 6 to 12 dollars per ton for first thinning to landowners. By clearcutting these stands, the landowners will be forgoing their future sawtimber income and must be compensated more per ton for this study.

The stumpage acquired will then have a 10% cruise implemented to get an accurate account of inventory located on the property. In the cruise, we will indentify trees per acre, volume per acre, total volume, average height, and species composition. From this data, we will obtain a diameter distribution to estimate volume produced hourly by the machines. These measurements will be used to determine with the system's productivity to acquire different environmental impacts and costs associated with different stand characteristics.

Production Study

Feller-buncher

To investigate the feller-buncher engineered by TigerCat, time studies will be implemented to understand utilization, production capabilities, and flexibility with varying stand characteristics. The operator of the feller-buncher will be advised to move quickly as possible to clearcut each stand. The time studies will take place over a three week period during the summer of 2011.

The manual method will use a stopwatch to time trees cut per minute, time to harvest one bundle, and travel time between stops. The number of stems cut per minute and stems per bundle dropped will be given a volume according to the diameter distribution obtained in the cruise using Smalian's formula (Segura and Kanninen, 2005).

Fuel usage will be another variable investigated. The machines will be filled in the morning before the operation begins. The machines productive hours will be measured throughout the day along with the scheduled hours set forth by Corley Land Services. At the end of the day, the machines will be filled with a pump with a fuel meter that measures the amount of fuel inputted. Comparing the productive hours and the scheduled hours with the fuel usage will be incorporated into the economic analysis of the machine. Any down time will be recorded during the day and labeled according to the situation at hand.

Skidder

The productivity of the skidder will be evaluated using the same three methods as the feller-buncher time study. First, a stopwatch will be used to gather the time needed for the skidder to leave the loading deck and return with a bundle of felled biomass. These times will be compared to distance which will be obtained by the GPS located on the machine. Each run will be assigned a number so the time and the distance will be for the same haul. Also the data recorder on the machine will take the time of the run so it can be compared with the stopwatch to ensure its viability. Also the bundle volume will be formulated by counting the stems in the bundle and applying a volume per stem based on the stand average DBH and height

Chipper

The chipper currently owned and operated by Corley Land Services will be used to chip the material prior to transportation to the delivery mill. To get an accurate account of the material chipped, a video camera will be placed on the logging deck to record the number of loads per hour. From there, the load tickets will be acquired from Corley Land Services to obtain a volume for each particular load. From this data, volume per hour can be calculated. Also Husky Precision will loan a new chipper with higher horse power to the consortium. This chipper will be evaluated by the same process to compare productivity and cost per hour.

Economic Analysis

A complete economic analysis will be performed on both of the TigerCat machines. First, the scheduled machine hours (SMH) will be determined before the machines begin the research. Any down time for either of the machines will be identified and subtracted from the SMH to deduct productive machine hours (PMH). The down times will be classified as maintenance, breakdown, stand hindrance, weather, other machine interference, or human caused. By computing a ratio from PMH and SMH, one can determine the production efficiency and based on the qualities of the downtime, lacking features of the system can be identified.

Using the time study data gathered via stopwatch, measurements, data recorders, and video camera, the consortium will formulate a volume per hour produced by each machine as well as the entire system. Because of the varying stand characteristics, the volume will be calculated in a stratified form so conclusions can be made on the influence of stand density and maneuverability. Furthermore, costs associated with operating the equipment encompass labor, fuel, capital costs and depreciation, maintenance, and overhead will be calculated on a per ton basis. By calculating both volume and costs to obtain that volume, an accurate estimate can be developed to understand the viability of the system at current delivery prices set forth by the biorefinery.

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