Using short-rotation, intensively managed hardwood plantations as 'green' inventory for southeastern U.S. pulp mills

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ABSTRACT: As a routine wood source for a pulp mill, recent studies have shown that intensively managed, short-rotation hardwood plantations are not cost effective. The objective of this study was to determine if these plantations may be cost effective as "green" inventory, replacing some portion of high cost remote woodyard inventory. Three southeastern U.S. pulp mills were used as case studies in a net present value analysis. Short-rotation hardwood plantations of eastern cottonwood (Populus deltoides) were simulated to replace a portion of remote woodyard inventory, with wood delivered to a pulp mill from this "green" inventory only when pulp mill inventory levels became critical. If this "green" inventory is not used, these plantations continue to grow until needed. With current yield from an experimental fiber farm, short-rotation plantations were not cost effective as "green" inventory. However, if yield could be increased approximately 33% through either genetic or cultural improvements, all three pulp mills could have reduced overall wood cost by establishing a fiber farm.

Application: This study demonstrates some of the potential benefits and limitations of short-rotation hardwood plantations as a fiber source.

Procuring wood, especially hardwood, during the winter months for a pulp mill in the southeastern United States presents some difficulties. Soft ground reduces the operational feasibility of many sites, forcing companies to store hardwood in woodyards for retrieval during wet weather. Short-rotation, intensively managed hardwood plantations (fiber farms) grown on dry sites that are operable year-round could replace some volume companies are storing in remote woodyards.

A recent study determined that hardwood fiber farms are expensive to establish and the cost of wood from these hardwood plantations delivered to a pulp mill is well above that of normal delivered furnish [1]. The study estimated chips delivered from a fiber farm would arrive at the mill for approximately US$84/green ton. Increasing fiber farm yield over time as silvicultural practices improved could drop the cost to US$66/ton.

Because cottonwood typically has 100% moisture content [2], delivered cost per bone-dry ton would be US$168, or optimistically US$132 with the higher yield. These costs were much higher than those determined in an earlier study, probably due to yield differences [3].

Both reports indicate that it could be several years before hardwood stumpage prices in the southern United States increase to the level necessary to justify intensive culture plantations as a daily source of fiber. However, short-rotation hardwood plantations could be used as a "green" inventory alternative to supply a pulp mill during severe weather, thereby possibly saving the costs associated with storing excess winter inventory on remote woodyards. "Green" inventory refers to a strategically located, intensively managed, short-rotation hardwood plantation (fiber farm) that could be harvested at any time to provide a short-term emergency supply of wood into the pulp mill. For year-round operability, these plantations would be established on dry sites and use a drip irrigation system to add nutrients and water [4]. A site with good operability will allow harvesting to occur with conventional systems that might otherwise be rendered unfeasible in wet conditions.

At a time when many companies are divesting their lands, a +/- 200 hectare fiber farm controlled by the pulp mill can still have a place. The major advantages of fiber farms in the Southeast are likely to be achieved when they are used to supplement short-term hardwood inventory systems. Typically, in the fall of every year, pulp mills will significantly increase the amount of wood in storage at remote woodyards to maintain the wood supply through the winter when logging production may be slowed due to wet weather. In the event of a "dry" winter, this winter inventory wood must be consumed in a timely manner because it will deteriorate and become unusable. If a portion of the expensive "winter building" wood inventory could be replaced by "green" inventory, there could be annual savings due to the reduced quantity of expensive remote woodyard inventory that must be purchased (and subsequently used) to provide sufficient furnish through the winter months. Wood cost savings should accrue since the company will buy less wood to be stored on remote woodyards (a more expensive option) and will replace it with wood purchased directly from timberland to the pulp mill. If less wood is purchased during the inventory building phase in a given year, savings should occur in total wood cost. The additional volume in "green" inventory hardwood plantations would be harvested only when the procurement manager for each pulp mill determines inventory levels at the pulp mill have reached a critical stage. If a dry winter occurs, and the pulp mill wood inventories do not drop below acceptable levels, the hardwood plantation will be left standing to grow another year. Then, the following winter, a reduced volume will need to be purchased for storage on remote company woodyards. Assuming this occurs over a period of several years, a substantial reduction in total, overall wood cost may be achieved.

Wood stored in remote woodyards typically carries a US$10/ton premium over deliveries directly to the mill from the woods [5]. Wood stored at a remote woodyard must be unloaded, stored, and then reloaded onto trucks or railcars. These additional operations, along with some deterioration as the wood ages in the woodyard, add cost to the material. Additionally, remote woodyard material must then be transported to the pulp mill, further increasing costs. The amount of additional costs will vary with age of the wood (amount of deterioration), distance to the mill, and size of the woodyard, but US$10/ton is typical. Thus, if 10,000 tons of material were available in "green" inventory and could replace an equal amount of remote woodyard inventory, a potential US$100,000 savings in wood cost during the year (US$10/ton savings x 10,000 tons) could be realized. Some mills have established large "wet" woodyards near the pulp mill for inventory needs. While these yards will have a lower transportation costs, water storage costs and rehandling of the wood can still add a significant costs to the delivered cost of the material.

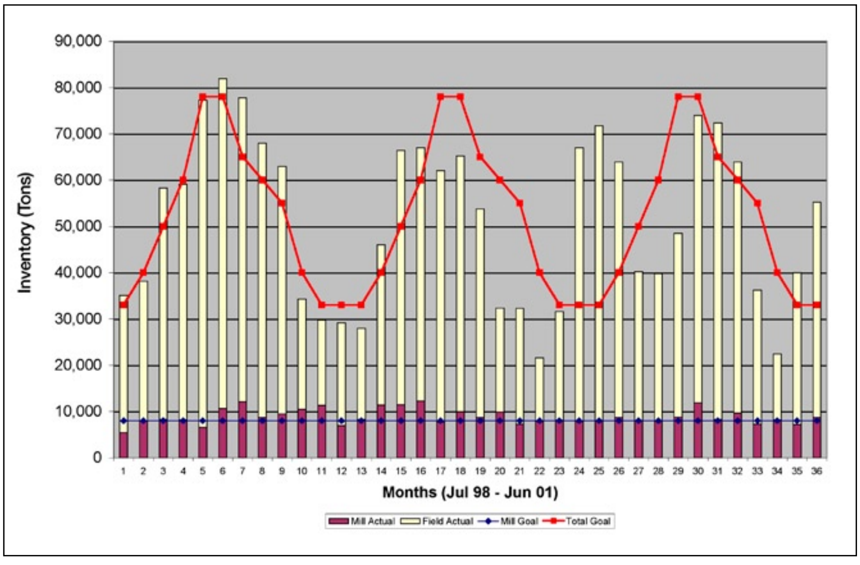
LeBel and Carruth used a stochastic model to help determine the amount of inventory for a pulp mill [6]. They had three categories of suppliers bringing wood to a pulp mill and used a random number process to assess the effect of weather on deliveries. By customizing the logging force in the woods, they were able to maintain inventory and minimize putting production quotas on in-woods operations. If a fourth type of supplier were "green" inventory that minimized risk to the company by ensuring deliveries during any adverse weather period, total inventory might be further optimized.

The pulp and paper industry is continually searching for ways to reduce its wood cost while ensuring a reliable raw material supply, and woodyard inventories have long been a valuable resource in this goal. Short-rotation, intensively managed hardwood plantations may also present an opportunity to optimize the inventory strategy for a pulp mill. Even though delivered costs for this material to the pulp mill may seem high (US$132/bone-dry ton), there are potential savings in operational and carrying costs. Evaluating whether "green" inventory is cost-effective and operationally feasible for certain Southeastern pulp mills should be determined by this analysis.

Research objectives

The objective of this research project was to develop an approach for determining if strategically located, short-rotation, intensively managed hardwood plantations are economically and operationally feasible in the southeastern United States as a cost-effective alternative to the annual storage of large volumes of hardwood pulpwood inventory. For example, if the procurement organization for a pulp mill has determined that it requires 150,000 tons of hardwood fiber available to carry the mill through the winter, savings could occur if alternatively, 130,000 tons were inventoried in conventional storage methods, and 20,000 tons were readily available from a strategically located hardwood plantation. During a mild winter, the plantation wood may not be used, allowing the trees to grow for another year. That annual growth along with possible in-growth from a new age class might total 30,000 tons. Thus, only 120,000 tons would need to be inventoried the next year before winter arrives. Analyses will allow us to determine the possible cost benefits involved in short-term wood storage versus long-term plantation establishment.

This research project had the objective of using a modified version of the decision model developed by Gallagher et al. [4] to determine the cost feasibility of using short-rotation, intensively managed plantations as "green" inventory in actual pulp mill inventory situations. While Lebel and Carruth [6] studied inventory in a theoretical sense, we used actual hardwood inventory and costs for



1. Hardwood inventory levels for pulp mill 1. The actual mill and field (woodyards) inventory are stacked as a bar against the lines that indicate inventory goals.

Year 1	AGE Class	HECTARES	MANAGEMENT COST per ha^{-1}	MANAGEMENT COST Age Class	AVAILABLE TONS per ha^{-1}	AVAILABLE TONS Age Class	HARVESTED ha^{-1}	HARVESTED Tons
	1	23	1755	40,371				
	2	23	1200	27,634				
	3	23	1148	26,449				
	4	23	1117	25,729				
	5	23	1135	26,048	92.6	2,129		
	6	23	1152	26,376	122.0	2,805		
	7	23	1160	26,714	147.3	3,389		
	Total	160		199,321		8,323		
Year 2	**AGE** Class	**HECTARES**	**MANAGEMENT COST** per ha^{-1}	Age Class	**AVAILABLE TONS** per ha^{-1}	Age Class	**HARVESTED** ha^{-1}	Tons
	1	0	0	0				
	2	23	1200	27,565				
	3	23	1148	26,383				
	4	23	1117	25,665				
	5	23	1135	26,310	92.6	2,161		
	6	23	1152	26,310	122.0	2,798		
	7	23	1160	26,647	147.3	3,381		
	8	23	1174	26,994	169.3	3,894	23	3,894
	Total	160		186,002		12,234		
Year 3	**AGE** Class	**HECTARES**	**MANAGEMENT COST** per ha^{-1}	Age Class	**AVAILABLE TONS** per ha^{-1}	Age Class	**HARVESTED** ha^{-1}	Tons
	1	23	1755	40,271				
	2	0	0	0				
	3	23	1148	26,383				
	4	23	1117	25,665				
	5	23	1135	25,983	92.6	2,123		
	6	23	1152	26,771	122.0	2,847		
	7	23	1160	26,647	147.3	3,381		
	8	23	1174	26,994	169.3	3,894	23	3,894
	Total	160		198,713		12,245		

I. Three years of plantation costs, yield available, and harvested material from the low yield short-rotation hardwood fiber farm for pulp mill 1 (Scenario 1).

three southeastern U.S. pulp mills as case studies to investigate the feasibility of "green" inventory.

RESEARCH METHODS

We analyzed the cost feasibility of short-rotation hardwood plantations as "green" inventory for Southeastern pulp mills by determining the total wood cost savings of keeping "green" inventory instead of roundwood inventory on remote woodyards. Three cooperating Southeastern U.S. pulp mills that supplied hardwood wood cost and inventory levels over a three-year period were used as case studies to determine if using short-rotation hardwood plantations as "green" inventory would have reduced wood cost.

Data for all three pulp mills were available on a monthly basis from July 1998 until June 2001. Hardwood inventory levels were analyzed for each of the three years to determine if pulp mill inventory ever reached a critical level and to determine the cost savings (if any) that could be attained through implementation of a "green" inventory system. The critical level was defined by procurement personnel from each mill and was determined to be when actual inventory levels dropped below 50% of the inventory goal; however, it will vary slightly with season. Inventory goals are set by management and are determined to be the amount of wood the pulp mill needs to store each month to effectively buffer day-to-day and week-to-week inventory fluctuations, and these goals provide a set probability that the mill will not run out of wood, causing a curtailment in paper production. Actual inventories, of course, vary due to consumption and deliveries. Only when inventory reached a critical level would "green" inventory be harvested and delivered to the pulp mill.

Savings could occur each year for the available volume of "green" inventory as an equivalent volume of roundwood would not be purchased and stored at remote woodyards. The savings for this volume was the US$10/ton additional cost associated with remote woodyard roundwood.

Each pulp mill was analyzed as a separate operation, first using low yield and then high yield plantations. For each analysis, we assumed that a fully operational fiber farm was already established with equal hectares in each age class for the selected rotation length in the decision model, as though the "green" inventory system were already up and running after initial establishment, to understand how a working fiber farm could influence annual operations and costs. For each year at each pulp mill, there are three potential cash flows:

1) costs to operate the fiber farm,

2) annual savings from the volume of wood in hardwood plantations, and

3) replacement of high cost deliveries.

Costs each year to operate the fiber farm were summarized and considered as expenses. These costs were calculated on the hectares in each age class of plantation on the fiber farm. Savings were totaled by multiplying the amount of volume available from the hardwood plantations by the woodyard premium (US$10/ton). Volume was only included from plantations that were age five years and older.

The last annual cash flow in the decision model came from offsetting wood purchases with plantation wood. This occurred only during a year when "green" inventory was harvested. All the costs associated with the hardwood plantations were already accounted for on an annual basis in the decision model as an expense. When the "green" inventory wood was harvested, it was then delivered to the pulp mill at the average harvesting cost for the area (all stumpage cost was included as expenses). This plantation wood offset the highest priced hardwood delivered during a similar time period (within 2-3 months). Therefore, any price savings between plantation wood and high-cost suppliers were included as wood cost savings.

All the costs and all the savings over the three-year period were used as cash flows in a net present value (NPV) analysis, similar to the way Lothner analyzed plantations in his study [7]. Two scenarios were analyzed with the decision model for each pulp mill. The first analysis was done using the lower yield plantations that are representative of current operational industry fiber farms located on dry sites in the southeastern United States. A second scenario was completed for each pulp mill using higher yield plantations, assuming that genetic improvements and operational efficiencies result in higher yielding fiber farms similar to those found on the West Coast [8].

While the decision model was being used, if a dry winter occurred and critical levels were not reached, the volume was carried over to the next year and additional volume was added due to biological growth. Also, in the event of several dry years in a row, an assumption was made to harvest any plantations reaching 10 years of age.

RESULTS AND DISCUSSION

Pulp mill #1 analysis

Pulp mill 1 (**Fig. 1**) had the lowest hardwood inventory goal of the three mills, peaking at 80,000 tons during the winter. For this first analysis with the low yield decision model, we assumed a 160 ha^{-1} plantation was already established. This assumption was made because there were only three years of cost and pulp mill inventory data available for this project. If more data covering more years were available, a user could consider starting the analysis from year zero with fiber farm establishment.

Year 1

Table I shows the costs and volume of fiber available in "green" inventory during the first year of this analysis. All plan-

	Plantation costs	Inventory savings	Wood cost savings	Annual cash flow
Year 1	199,321	83,229	0	-116,092
Year 2	186,002	122,335	85,294	+21,627
Year 3	198,713	122,454	84,656	+8,397
	NPV =	(US$83,694)	Average=	-28,689

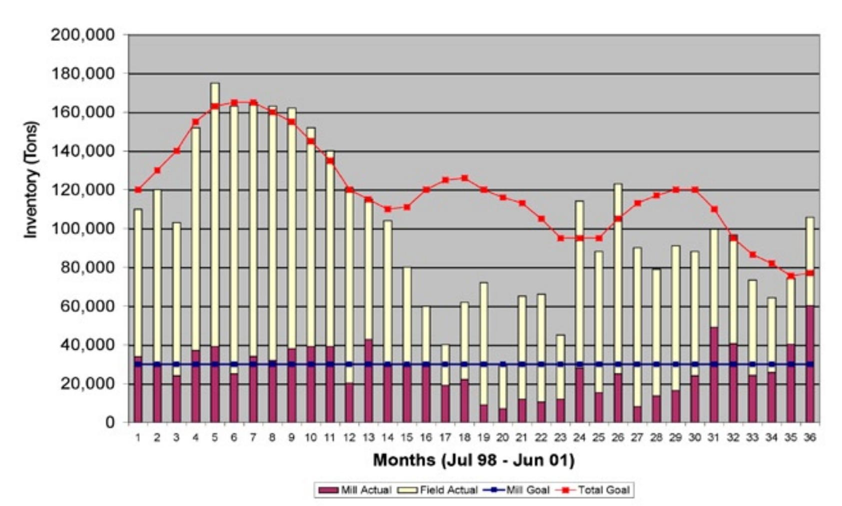
II. Summary of all cash flows (US$) for a net present value (NPV) analysis of "green" inventory for pulp mill 1 with low yield plantations on a 160-ha fiber farm.

	AGE	HECTARES	MANAGEMENT COST		AVAILABLE TONS		HARVESTED	
	Class		per ha^{-1}	Age Class	per ha^{-1}	Age Class	ha^{-1}	Tons
Year 1								
	1	23	1755	40,371				
	2	23	1200	27,634				
	3	23	1148	26,449				
	4	23	1117	25,729				
	5	23	1135	26,048	123.5	2,823		
	6	23	1152	26,376	162.7	3,719		
	7	23	1160	26,714	196.5	4,491		
	Total	160		199,321		11,033		
Year 2	AGE	HECTARES	MANAGEMENT COST		AVAILABLE TONS		HARVESTED	
	Class		per ha^{-1}	Age Class	per ha^{-1}	Age Class	ha^{-1}	Tons
	1	0	0	0				
	2	23	1200	27,565				
	3	23	1148	26,383				
	4	23	1117	25,665				
	5	23	1135	26,310	123.5	2,823		
	6	23	1152	26,310	162.7	3,719		
	7	23	1160	26,647	196.5	4,491		
	8	23	1174	26,994	225.8	5,161	23	5,161
	Total	160		186,002		16,194		
Year 3	AGE	HECTARES	MANAGEMENT COST		AVAILABLE TONS		HARVESTED	
	Class		per ha-1	Age Class	per ha-1	Age Class	ha-1	Tons
	1	23	1755	40,271				
	2	0	0	0				
	3	23	1148	26,383				
	4	23	1117	25,665				
	5	23	1135	25,983	123.5	2,823		
	6	23	1152	26,771	162.7	3,719		
	7	23	1160	26,647	196.5	4.491		
	8	23	1174	26,994	225.8	5,161	23	5,161
	Total	160		198,713		16,194		

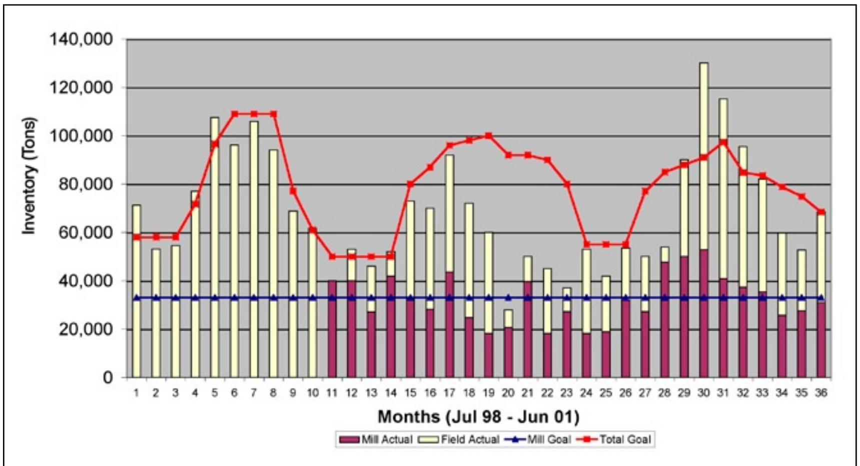
III. Three years of plantation costs, yield available, and harvested material from the high yield short-rotation hardwood fiber farm for pulp mill 1 (Scenario 2).

	Plantation costs	Inventory savings	Wood cost savings	Annual cash flow
Year 1	199,321	111,029	0	-88,292
Year 2	186,002	163,175	111,702	+88,875
Year 3	198,713	163,333	112,896	+77,516
	NPV =	US$63,485	Average =	+26,033

IV. Summary of all cash flows (US$) for the NPV analysis of "green" inventory for pulp mill 1 with high yield plantations on a 160-ha fiber farm.



2. Hardwood inventory levels for pulp mill 2. The actual mill and field (woodyards) inventory are stacked as a bar against the lines that indicate inventory goals.



3. Hardwood inventory levels for pulp mill 3. The actual mill and field (woodyards) inventory are stacked as a bar against the lines that indicate inventory goals.

	Plantation costs	Inventory savings	Wood cost savings	Annual cash flow
Year 1	261,764	124,843	0	-136,921
Year 2	240,686	183,523	478,590	+421,427
Year 3	324,254	32,035	0	-292,219
	NPV =	(US$584)	Average =	-2,640

V. Summary of all cash flows (US$) for the NPV analysis of 240 ha of "green" inventory for pulp mill 2 with low yield plantations.

	Plantation costs	Inventory savings	Wood cost savings	Annual cash flow
Year 1	261,764	166,543	0	-95,221
Year 2	240,686	244,789	625,080	+629,183
Year 3	324,254	42,742	0	-281,512
	NPV =	US$236,820	Average =	+84,150

VI. Summary of all cash flows (US$) for the NPV analysis of 240 ha of "green" inventory for pulp mill 2 with high yield plantations.

tation costs (fertilization, irrigation, management, etc.) for the year were US$199,321. Because 8323 tons of "green" inventory were available, a corresponding reduced amount of wood was purchased and stored in remote woodyards, for a savings of US$10/ton and totaling US$83,229.

Although 8323 tons of "green" inventory were available during year 1, the actual pulp mill inventory level never reached the critical level of less than 50% of goal. Hence, no short-rotation plantations were harvested. All the hectares across each age class were carried into the next year, and no additional costs were incurred for replacing any harvested plantations.

Year 2

Year 2 plantation costs of US$186,002 and savings of US$122,335 (12,234 tons "green" inventory x US$10/ton) are shown in Table I and **Table II**. During year 2, low pulp mill inventory levels in February resulted in 23 ha^{-1} (1 age class) of hardwood plantation being harvested with a total of 3984 tons of fiber. Looking at hardwood deliveries to the pulp mill during that same period showed that some woodyard wood was delivered for US$34.21/ton. Roundwood from the plantations offset that woodyard material and delivered for US$12/ton (because all the other plantation costs were already accounted for), so an additional wood cost savings of US$85,294 was realized.

Year 3

During year 3, plantation costs were US$198,713 and savings from "green" inventory were US$122,454 (12,245 tons x US$10/ton). Low pulp mill inventory levels in October caused by reduced deliveries of wood resulted in 23 ha^{-1} of hardwood plantation being harvested with a total of 3984 tons of fiber. These fiber farm deliveries offset some roundwood that arrived at the mill at a cost of US$33.74/ton and generated a wood cost savings of US$84,656.

Table II shows a three-year summary of the costs and savings. The net present value of this cash flow (5% discount rate) was a negative US$83,694. Even though annual cash flows were positive for two of the three years, the fiber farm with a low yield was never able to make up for the first year loss.

Finding a negative NPV for the low yield plantations was expected given the high delivered cost for hardwood plantations. A second scenario was run using the assumption of higher yielding plantations and therefore lower costs per unit. These higher yields should come through genetic improvements and operation optimization [9]. The same 160 ha^{-1} farm is established (Table III), so plantation costs for the three years of the analysis are the same. Inventory savings are higher because there is additional volume available each year from the higher yielding plantations.

The need to harvest follows a similar pattern to the first scenario: no wood was cut in year 1, 23 ha^{-1} were harvested in year 2, and 23 ha^{-1} were harvested in year 3. Wood cost savings for the offset deliveries amounted to US$111,702 in year 2 and US$112,896 for year 3. The NPV (5% discount rate) for this scenario is US$63,485 (**Table IV**). While year 1 again resulted in a negative cash flow, years 2 and 3 had much higher positive cash flows from inventory and wood cost savings, thereby resulting in a positive three-year average.

The benefit of getting additional volume from the high yield plantations for the same plantation costs, thereby allowing more woodyard inventory to be offset annually and more deliveries offset when plantations are harvested, is shown by the positive NPV. While the volume is still nowhere near what Bar estimated [3], the additional volume from improved genetics and cultural operations is enough to justify a fiber farm as "green" inventory.

	Plantation costs	Inventory savings	Wood cost savings	Annual cash flow
Year 1	261,764	124,843	0	-136,921
Year 2	240,683	183,403	297,594	+240,314
Year 3	281,168	124,768	0	-156,400
	NPV =	(US$47,533)	Average =	-17,669

VII. Summary of all cash flows (US$) for the NPV analysis of 240 ha of "green" inventory for pulp mill 3 with low yield plantations.

	Plantation costs	Inventory savings	Wood cost savings	Annual cash flow
Year 1	261,764	166,543	0	-95,221
Year 2	240,683	244,629	390,562	+394,508
Year 3	281,168	166,443	0	-114,725
	NPV =	US$168,040	Average =	+61,521

VIII. Summary of all cash flows (US$) for the NPV analysis of 240 ha of "green" inventory for pulp mill 3 with high yield plantations.

Pulp Mill #2 and #3 Analyses

The hardwood inventory for pulp mills 2 and 3 are displayed in **Figs. 2** and **3**, respectively. Both mills were able to keep actual inventory at or near the inventory goal most of the time during years 1 and 3. But for both pulp mills, year 2 was impacted by a very wet winter that slowed deliveries and pulp mill inventory fell to critical levels. For these analyses, both mills required multiple age classes of "green" inventory to be harvested in year 2 to prevent curtailment of pulp mill operations.

The year-to-year costs and savings for each individual analysis from the decision model are not listed due to space limitations; they can be found in Gallagher [4]. A summary of the costs and savings for both pulp mills with low yield and high yield plantations are found in **Tables V**, **VI**, **VII**, and **VIII**. Pulp mills 2 and 3 were similar to pulp mill 1 in that they all had negative NPVs (5% discount rate) with low yielding hardwood plantations. All three mills had a positive NPV once the higher yielding plantations were involved.

The underlying effect that drives the savings for fiber farms is not having to store large quantities of wood on woodyards to prevent pulp mill curtailment. It is the stochastic nature of wood deliveries that Galbraith and Meng first reported when performing inventory analysis that allows this assumption [10]. And while supply, demand and production lead time change regularly due to environmental restraints, as shown by LeBel and Caruth [6], some wood deliveries will still make it to the pulp mill. Only in the event of an extended drop in deliveries would fiber farms then support procurement efforts and prevent the mill from possible curtailments.

CONCLUSIONS

The objective was to examine the cost and operational feasibility of establishing a strategically located, intensively managed, short-rotation hardwood plantation ("fiber farm") on a dry site to serve as "green" inventory for a southern U.S. pulp mill. Even at a time when many companies are divesting their lands, a +/- 200 hectare fiber farm controlled by the pulp mill can still have a place. Once established, the "green" inventory should allow the company to reduce the traditional amount of purchased and stored woodyard "winter" inventory that *may* be needed to ensure an adequate raw material supply. During the winter, if and when pulp mill inventory declines to a predetermined "critical" level, some portion of the "green" inventory would be harvested, otherwise it would remain growing for potential use in a future year.

The results of the "green" inventory analyses on three cooperating southern U.S. pulp mills show that the concept may be operationally feasible and cost-effective under the following conditions:

a. Yields from the fiber farm increase over time above volumes previously reported by the limited operational trials in the South. This is reasonable to expect, given the documented increase in yields realized from existing, large-scale operations in the Pacific Northwest through genetic manipulation and optimized cultural operations.

b. Wood from the fiber farm would not be needed or used every year, allowing substantial cost savings from reduced woodyard inventory to accrue and additional growth to occur during periods of the rotation. If (expensive) fiber farm wood deliveries had to be used too frequently, any woodyard inventory savings would likely be depleted.

In summary, wood from intensively managed, short-rotation hardwood plantations is currently too expensive to become a routine source of furnish for southern pulp mills, but may, as yields increase due to genetic improvements, be strategically used in a limited capacity as "green" inventory to reduce overall wood cost through inventory savings for some mills.

This research was funded by the Department of Forestry at Virginia Tech and the U.S. Department of Agriculture Southern Forest Experiment Station in Auburn, Alabama, USA.

Received: January 20, 2007
Accepted: September 9, 2007

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INSIGHTS FROM THE AUTHORS

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Improving availability and lowering cost of furnish to a pulp mill are important aspects for the forestry community, and procuring hardwood during the winter has always been a challenge.

Several mills on the West Coast are using short rotation crops for their furnish. They have attained very high growth rates, something the East Coast has not been able to do. Plus, we have some cheap sources of hardwood, just not year-round. Using these hardwood plantations, a green inventory may give the pulp mills more options.

Determining growth rates for these plantations was difficult because there were so few fiber farms in operation. I was able to use some research data to fill in the gaps.

From this study, we discovered that the growth rates from the West Coast far exceed what we have been able to get on the East Coast, and that surprised me. But if we can make up some of that growth, these hardwood plantations could be a very valuable asset to a wood procurement organization for a pulp mill, and an opportunity for a landowner that wants to grow trees in a sustainable fashion.

For mills that are consuming large quantities of hardwood, this could be an opportunity to reduce costs. It could also further strengthen the argument that their furnish is coming from a sustainable source. Lastly, it might give them a chance to improve the quality of the furnish by reducing the variability of the hardwood resource.

The next step is finding the additional growth needed to justify the expenditure – this only works if we can improve growth rates like the West Coast plantations did once they began operations.

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