Technical / Economic Analysis of Bamboo Fiber in Pulp and Paper Manufacture

Part 2 - Economic Potential for Bamboo Utilization in an Uncoated Freesheet Mill

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What must you believe to become interested in Bamboo Utilization in an Uncoated Freesheet Mill?

1. **Bamboo species tested are better than or equal to mixed southern hardwoods**
   - ***Bamboo fibers can substitute for a significant portion of hardwood fibers with equal or better fiber and paper properties***
2. **Bamboo chips at $70-80 per BDT are generally lower cost than the highest cost hardwood chips to the digester**
3. **Mill performance in USA is largely unknown and remains to be tested**
   - ***Prove pulp Yield and bleachability superiority***
   - ***Prove retention of bamboo fines released in pulping are retained in final product***

Outline

- **Pulping and Fiber Properties**
- **Bleaching**
- **Handsheet properties**
- **Economic application scenarios**

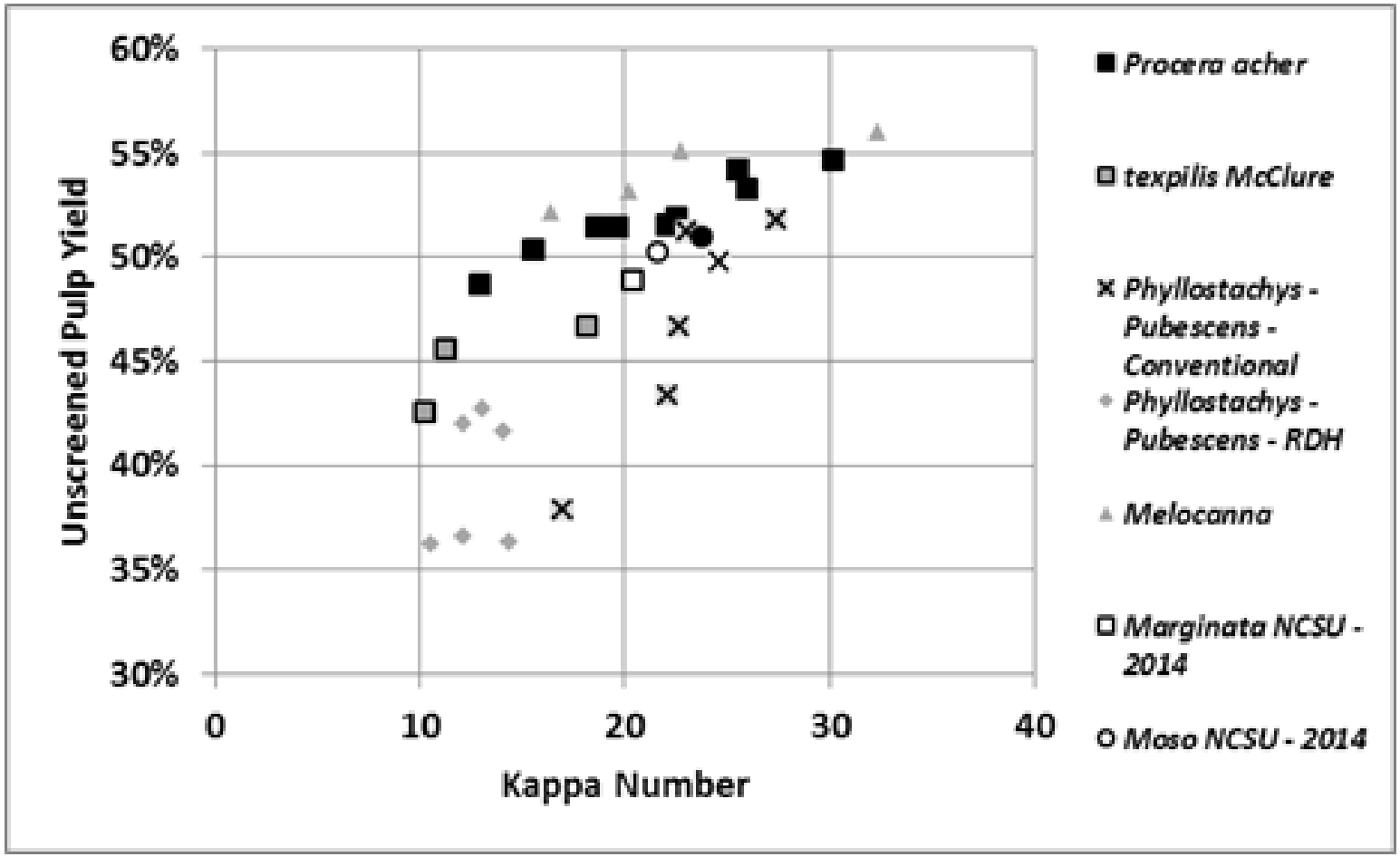
Pulping and Fiber Properties

Yield >= than mixed southern hardwood

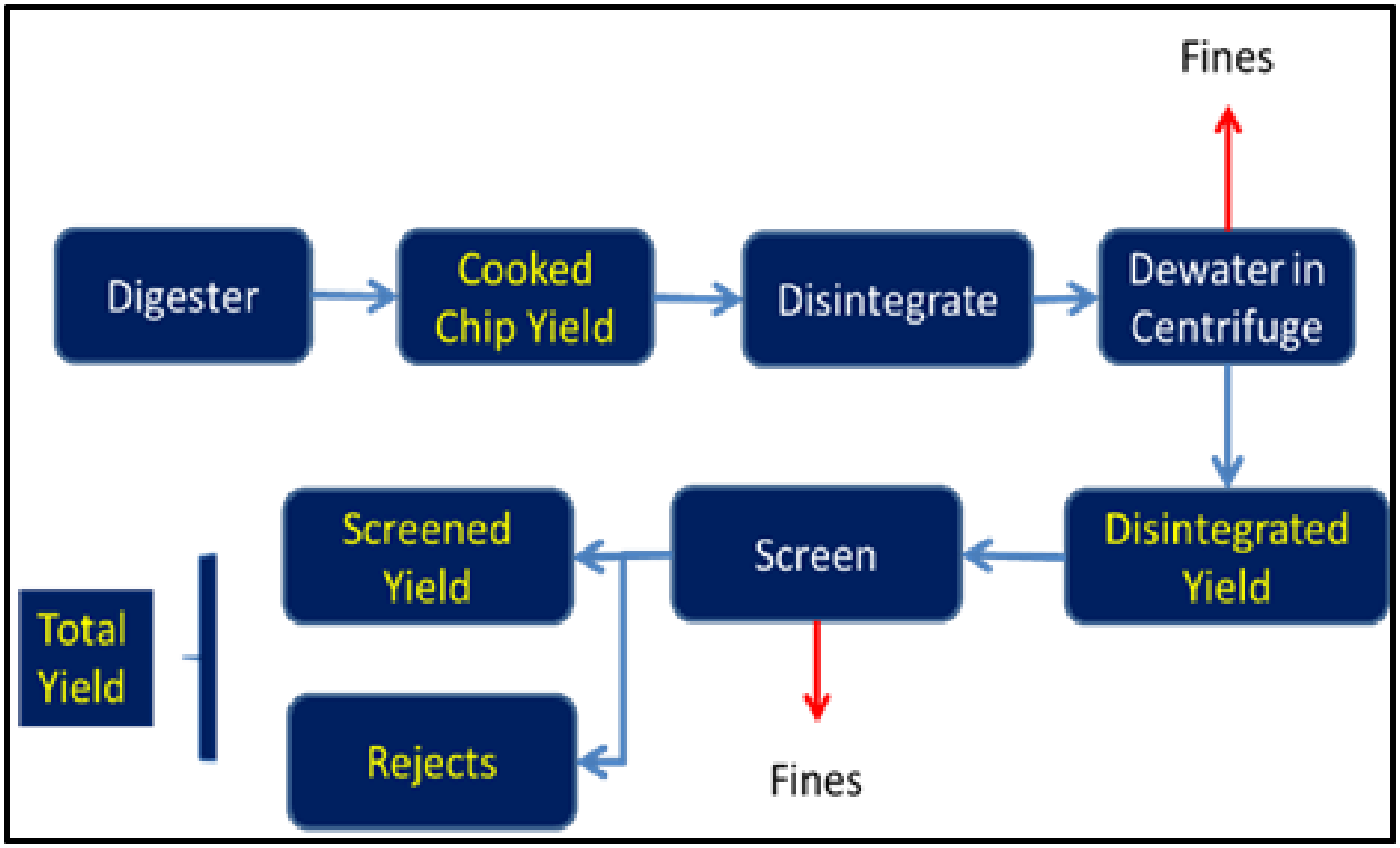
Fiber properties between hardwood and softwood

Very low coarseness

Literature pulp yield is all over the map



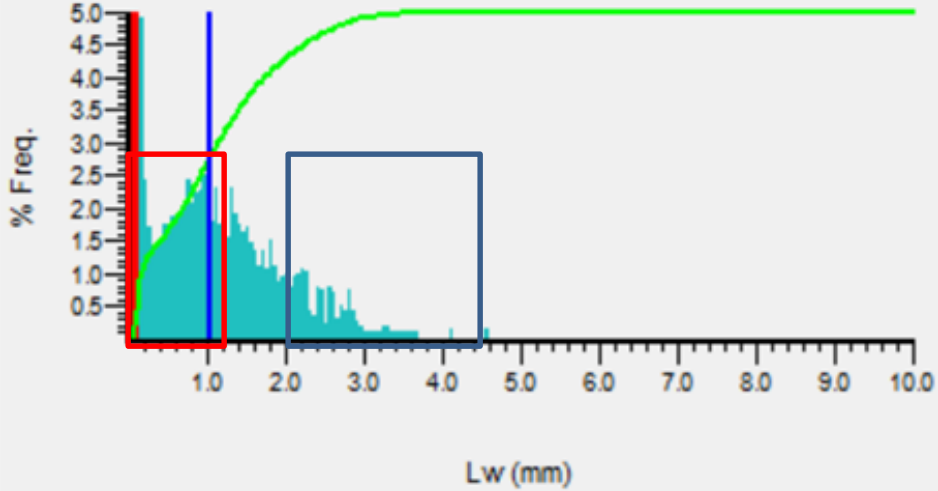
Likely because fines have great potential for loss in lab process



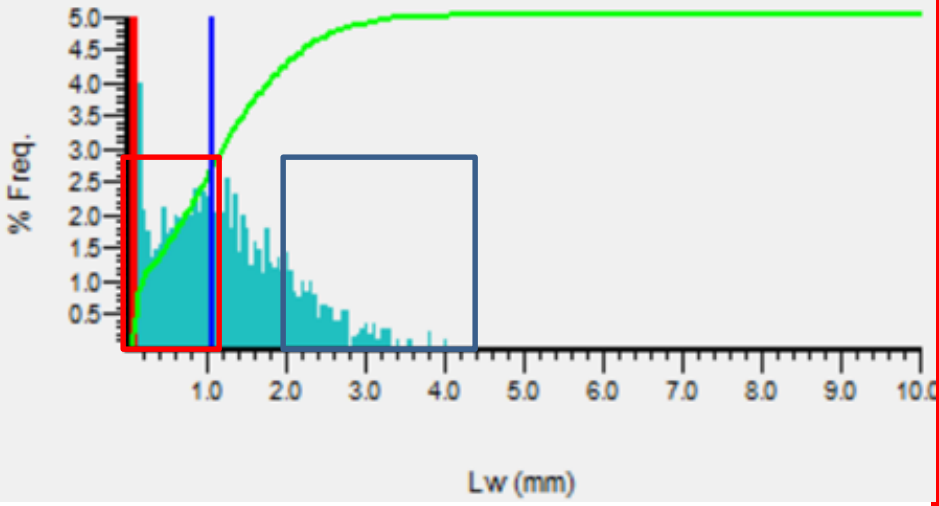
High Fines content requires careful pulping and bleaching lab technique`

Unusual Fiber Length Distribution

Henon



Rubromarginata



Both long fiber (blue box) and fines (red) are higher than mixed southern hardwoods

Fiber Properties

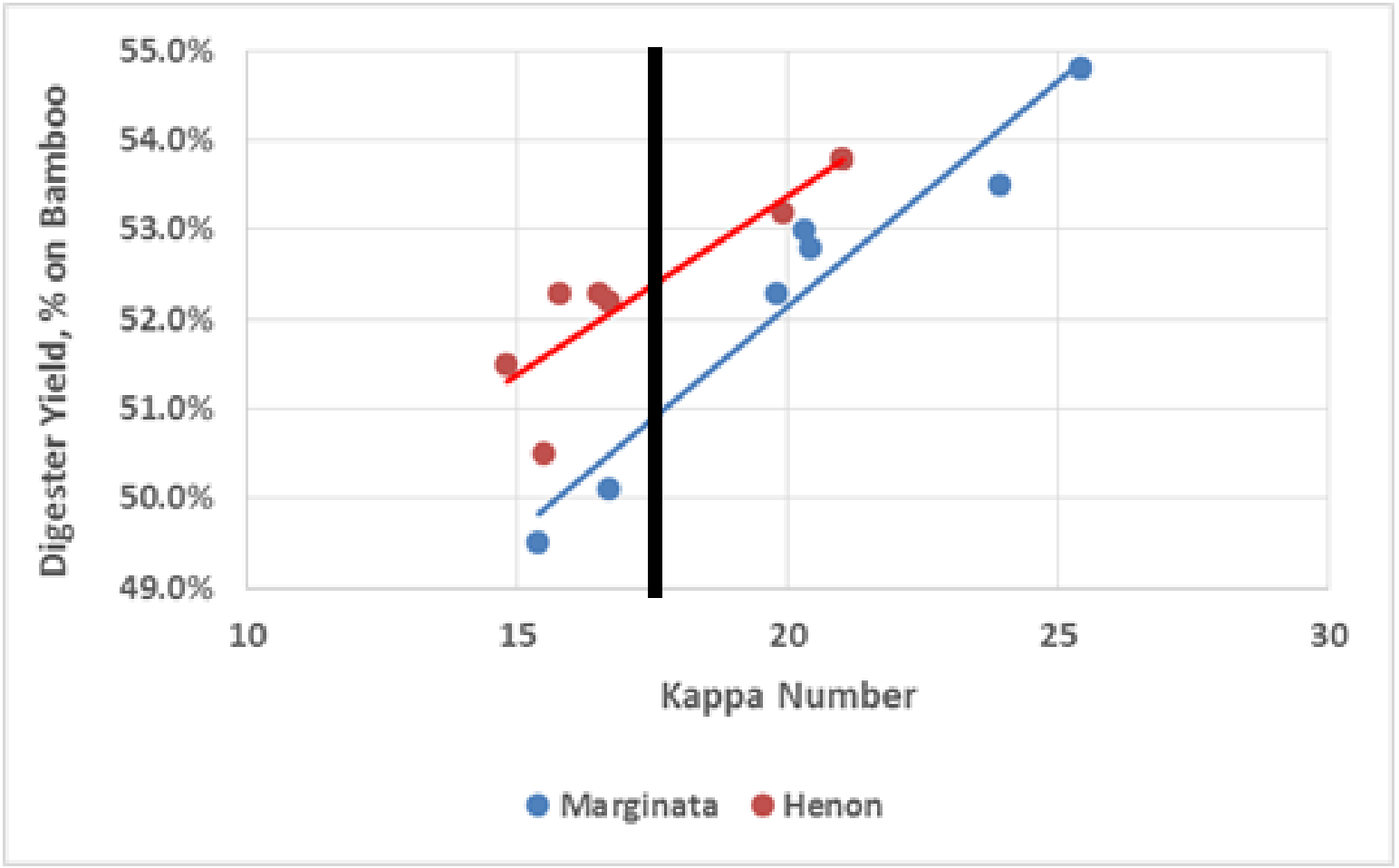
Equal or better for fine papers than BHKP/BEK

World of Market Pulp [2]					
	NBSK Black Spruce	SBSK Loblolly Pine	SBHK,	BEK Globulus	Bamboo Blue Meana
Fiber Length$_{w,}$ mm	2.3	2.45	.978	0.719	1.1
Length – Weighted fines, %	3.34	4.41	13.7	5.25	20.5
Coarseness, mg per 100m	14.3	23.8	10.2	7.45	9.32

	This Study	
	Henon	Rubro-Marginata
Fiber Length$_{w,}$ mm	**1.246**	1.198
Length – Weighted fines, %	**12.61**	14.74
Coarseness, mg per 100m	**4.5**	5.1

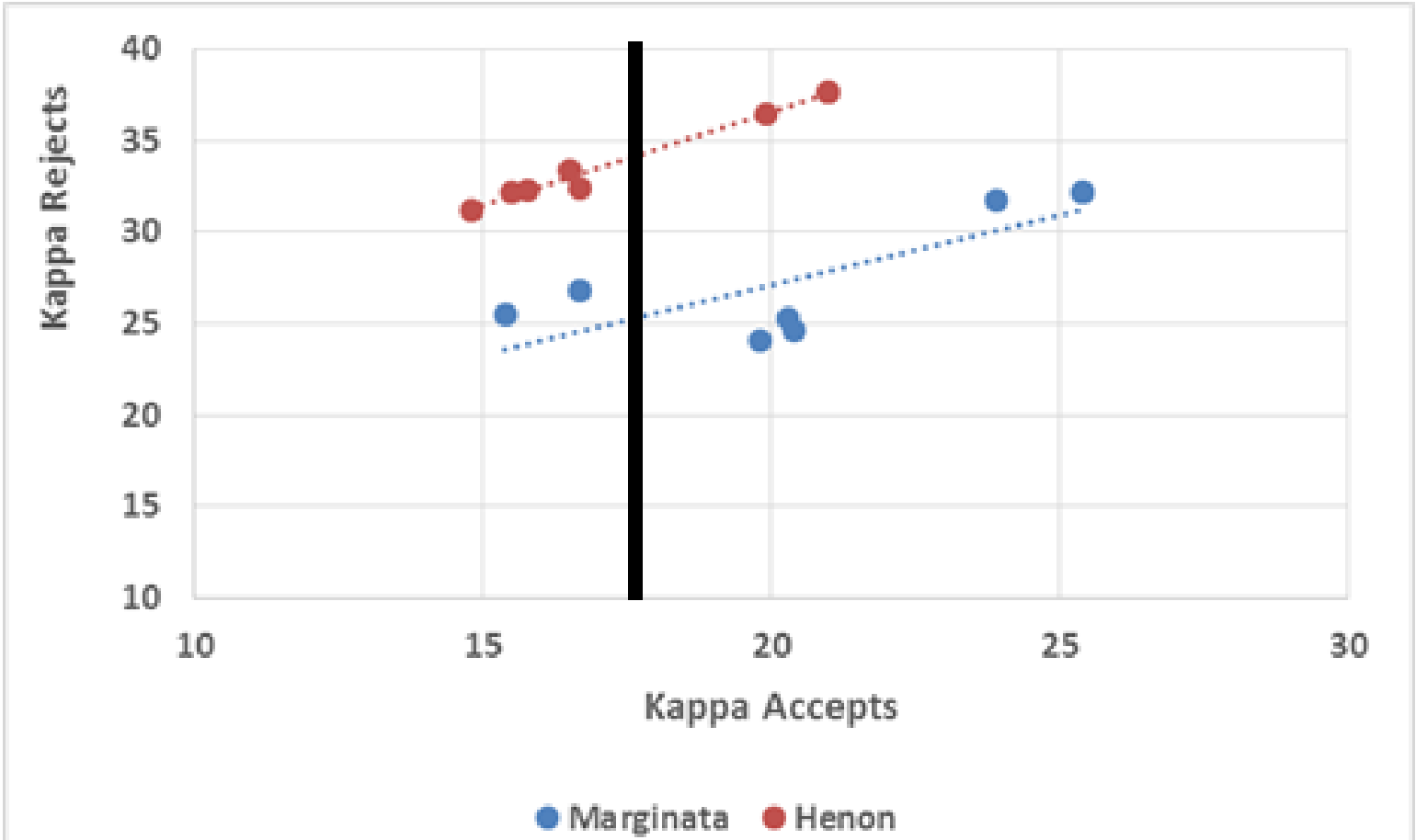
- **Weight-Average Fiber less than SBSK but greater than SBHK and BEK**
- **Fines content in our study ~ SBHK**
- **Coarseness lower than comparisons**

Digester Yield vs Kappa Number



- **Yield is “Cooked Chip Yield” in flowchart**

“Rejects” are not really “rejects”



- **Rejects are after British Disintegrator but can be broken up by hand to fibers**
- **Visualize simple refiner before screening**

Bleaching

Bleachability >= mixed southern hardwoods

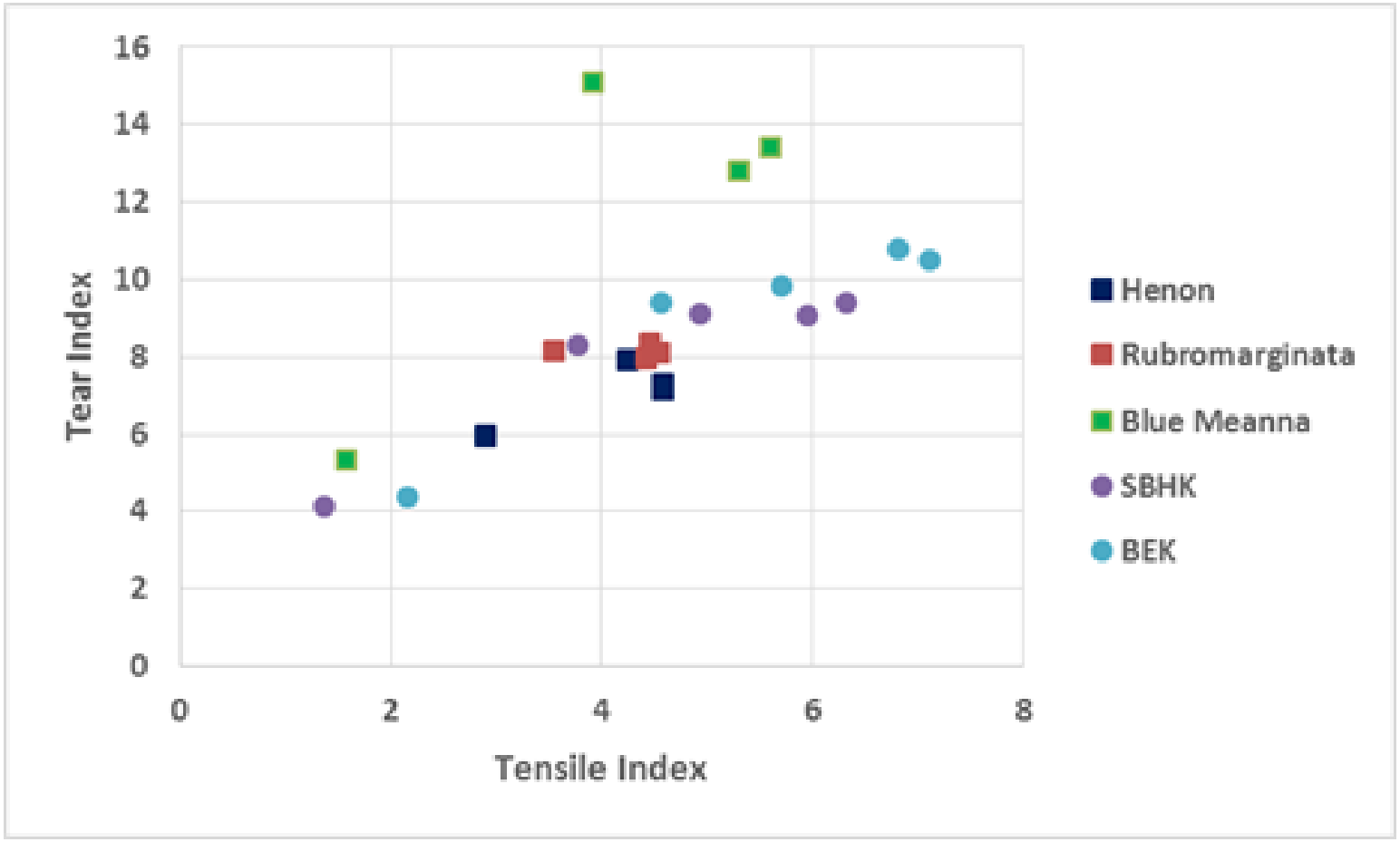
Bleachability

Henon	
Oxygen Delignification:	**2% NaOH-10% Cons-100 psig-100C-60 min**
Henon-14.3% AA-25% S-H1200-152C-17.8K	
Oxy Pulp Yield%-94.8	**Kappa number-8.3**
Bleaching	
Do stage: 0.22kf (0.69% ClO2), 70C, 10% cons., 1 hr.	
Final pH	3.4
Residual gpl	0.02
EoP stage: 0.91% NaOH, 0.5% H2O2, 70C, 10% cons., 1 hr. O2-70 psig	
Final pH	10.9
P#	1.0
% Iso-brightness	74.0
D1 stage: 0.75% ClO2, 0.3% NaOH, 70C, 10% cons., 3 hrs.	
Final pH	3.5
% Iso-brightness	88.1
Residual gpl	0.02

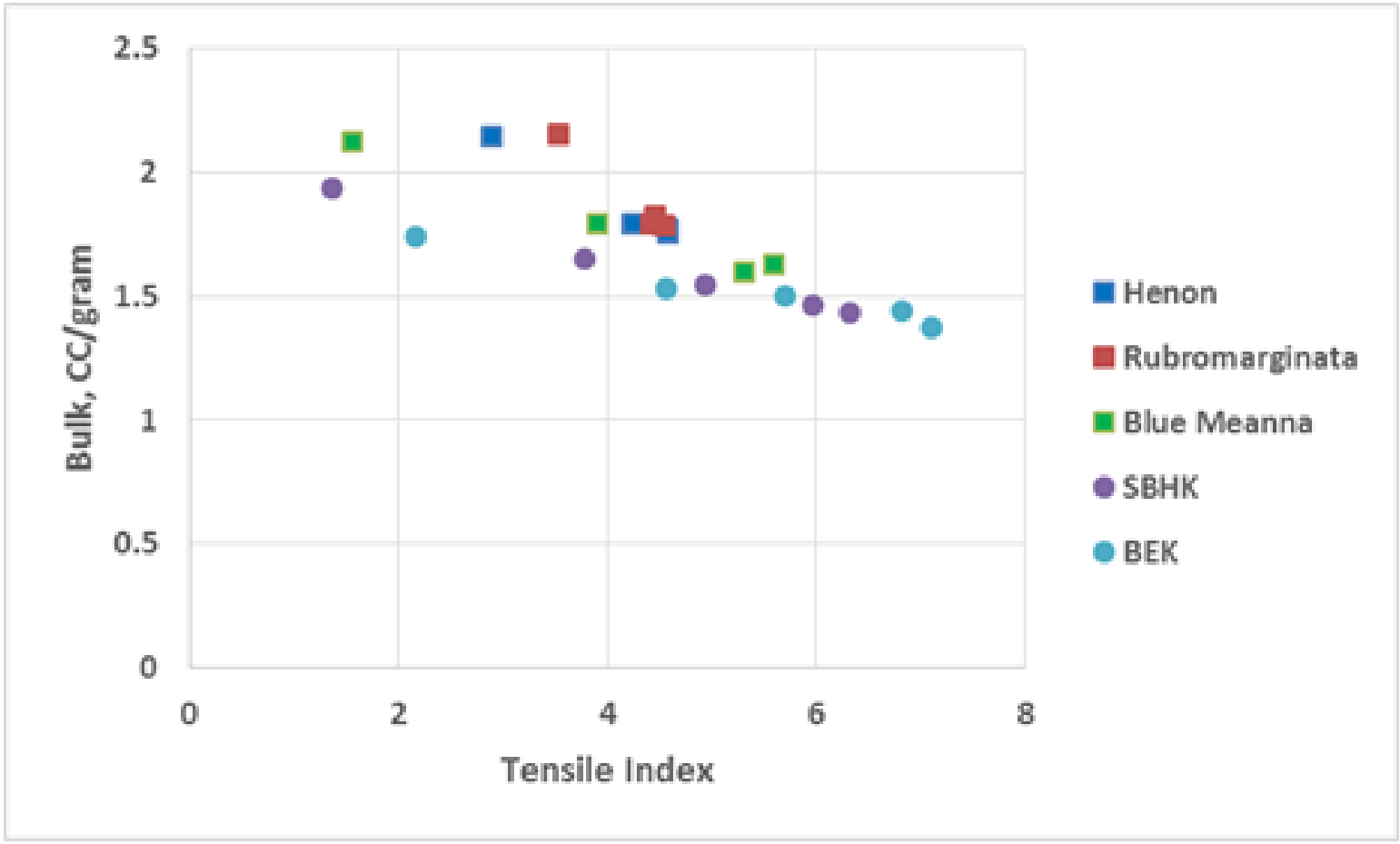
Paper Properties

>= Mixed southern hardwood

Paper properties => than mixed southern hardwood and BEK



Bulk => NBHK and BEK



Fiber Cost

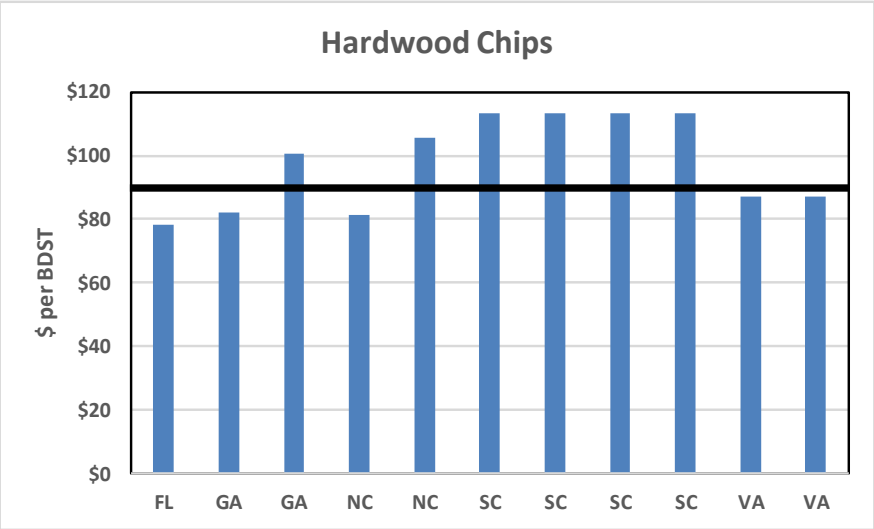
In the real world there are two fiber costs:

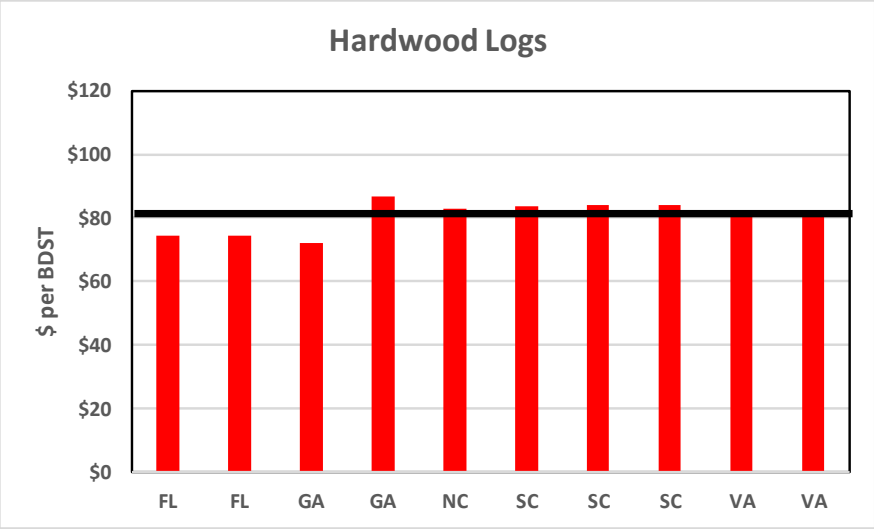
1. **Weight Average Fiber Cost for all tons purchased**

2. **Incremental fiber cost as function of distance of forest from the mill**

SE Atlantic USA Hardwood Costs

Weight Average



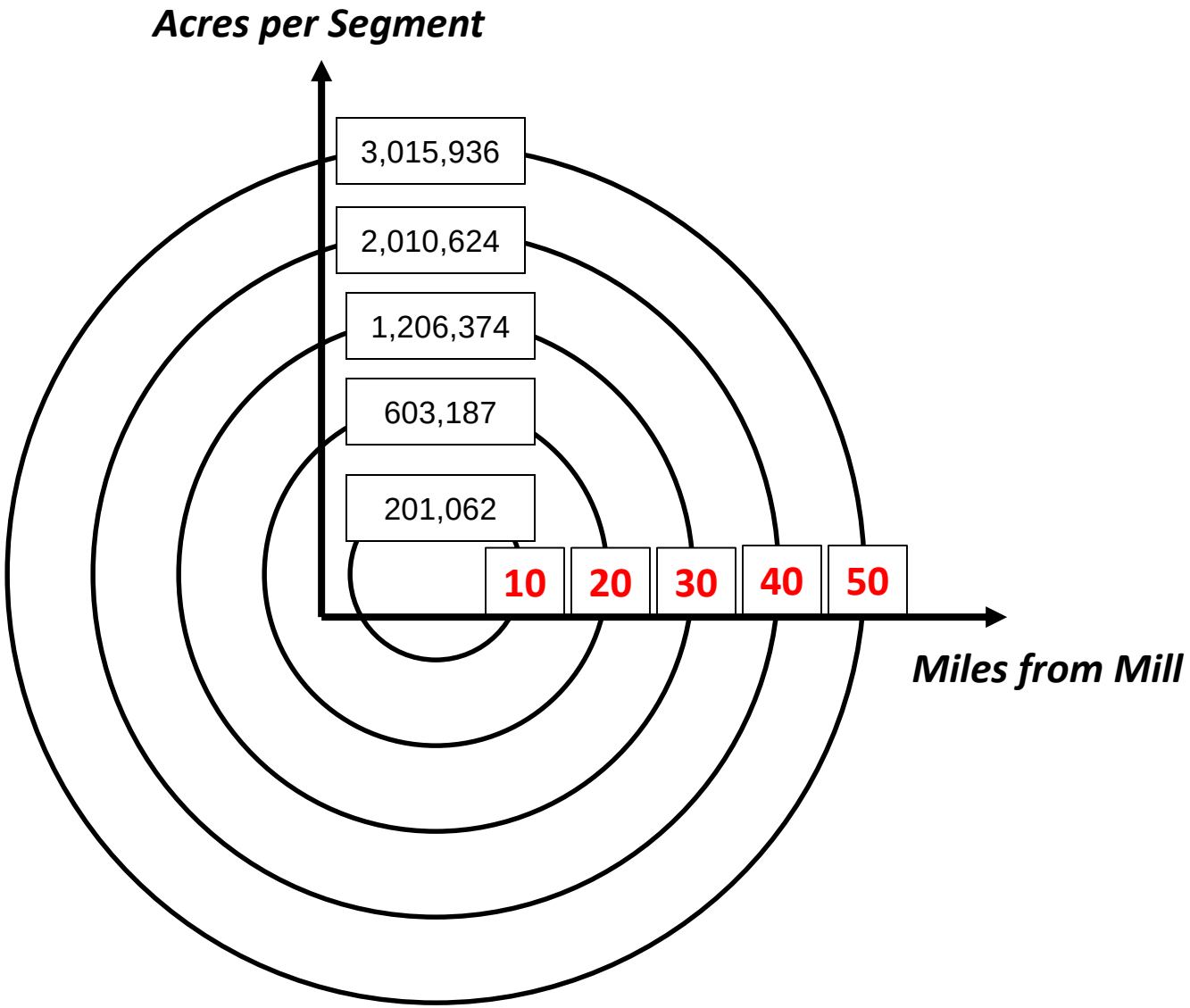


- **Hardwood Chip prices highly variable and depend on the proximity of a sawmill to the pulp mill (and to other pulp mills)**

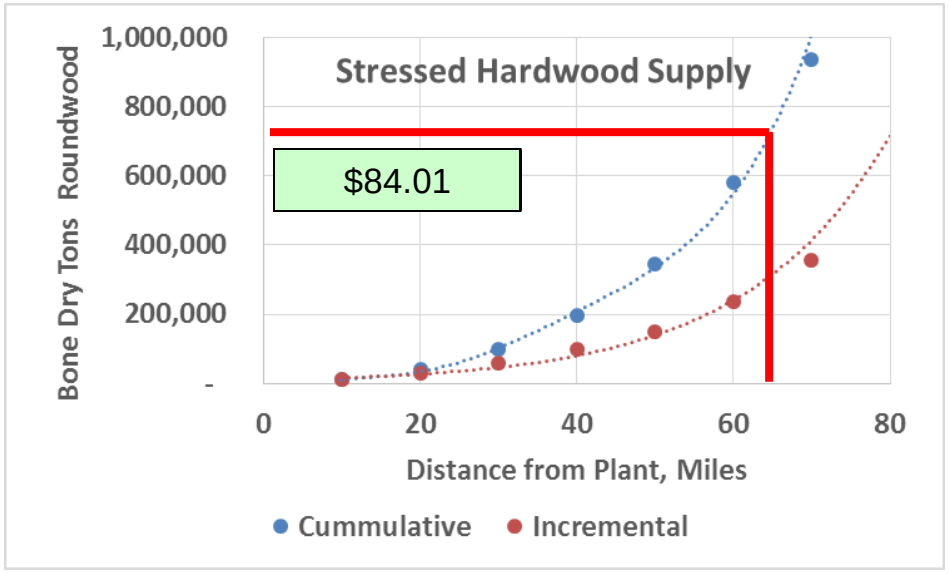
- **Hardwood Roundwood prices depend on forest density surrounding mill, sustainable harvest rates, local contractor costs and distance to the mill**

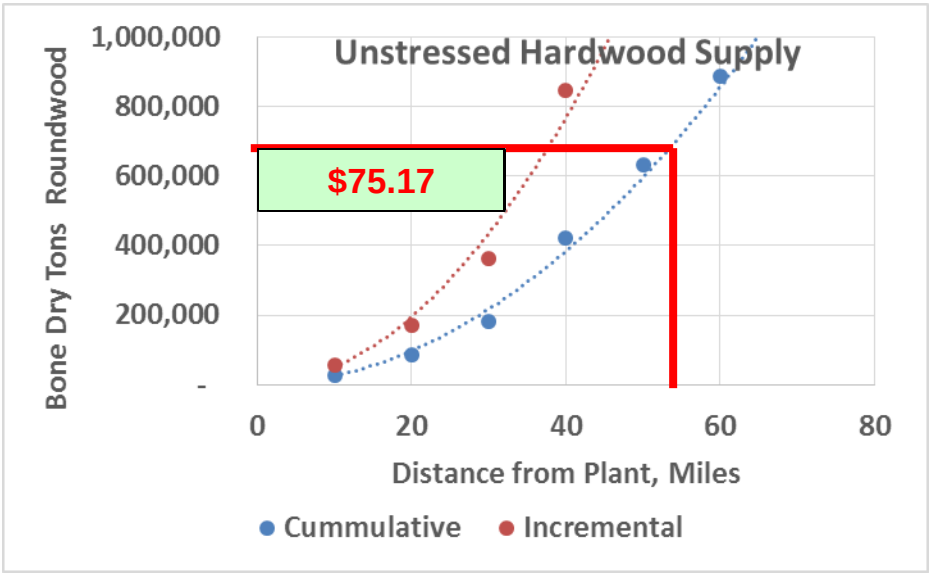
Source: FisherSolve, Q3 2014

Acreage in 10 Mile radial sectors



Hardwood Roundwood Supply Curve





Median Price Per BDST, Coastal Southeastern USA

Southeast Atlantic Region (FisherSolve)

$74.46

High Price Per BDST, Coastal Southeastern USA

$84.01 (South Carolina)

Mill Model Results

1. “Stressed” Base Case vs “Unstressed Base Case

2. Impact of Bamboo substitution for 100% of Hardwood on PM1 (offset roll production)

Carolina Pulp and Paper Company

- **A Technical / Economic Model developed over past 10 years for teaching undergraduates about cost and investment strategy in pulp and paper mills**
- **Basic model is generic, but can be converted to any of eight pulp and paper products, any of four different fiber species, up to four paper machines**
- **Costs and product pricing assumptions updated annually**
- **Forest model embedded in pulp and paper mill model**
- **For this study, two uncoated freesheet mill models were created, identical in every respect except for hardwood cost**
  - ***"Stressed" drain area is slower growing, less forest cover than "Unstressed" drain area***
  - ***Leads to one mill with median USA-Southeast hardwood cost ("Unstressed) and one with the highest hardwood cost ("Stressed")***

For this study we created two forest and one Uncoated Freesheet Mill Model

- **Mills are identical in every respect except wood cost**

Base Assumptions – 2020	
Machines	PM1 (1991 Startup) – 334,000 Finished Tons per Year Offset Rolls PM2 (1996 Startup) – 262,000 FT per Year Cutsize sheets
Pulp Mill	Hardwood Line – 308,000 BDT per Year Bleached Pulp Softwood Line – 128,000 BDT per Year Bleached Pulp
Recovery	Two Low Odor boilers – production limiting at 4,360,00 Tons Black Liquor Solids per Year

Base Case vs Base Case – 100% Roundwood

	Stressed	Unstressed
Average Cost per BDT	$84.02	$75.17
Miles to last increment	60	40
Cost of fiber in last increment	$87.84	$78.43
Volume of fiber in last increment	349,665	162,476
Total Hardwood , BDT per Year	756,104	756,104
Hardwood Cost, $ per Year	$63,528,486	$56,836,134

Yield Inputs to Model

	Raw Material		
	Bamboo	**Pine**	**Mixed Southern Hardwoods**
Bleaching Yield, %	98.0%	95.0%	97.0%
Screening Yield, %	100.0%	98.9%	99.0%
Oxygen Yield, %	94.8%	98.5%	98.5%
Pulping Yield, %	51.5%	45.3%	50.0%
Overall Yield, %	47.9%	41.9%	47.3%
Woodyard Yield, %	95.0%	85.0%	83.0%
Purchased Fiber, BDT per BD BT	2.20	2.81	2.55

Model Results – Stressed with Bamboo at $70 per BDT

	Base Case - Stressed			Bamboo - $70 per BDT - Stressed		
Fiber	$162.01	$156.76	$159.70	$128.34	$145.65	$135.94
Chemicals	$153.20	$166.15	$158.89	$142.31	$165.36	$152.43
Energy	$64.93	$68.29	$66.41	$71.13	$74.92	$72.79
% EBITDA Margin	*19%*	*14%*	*17%*	*23%*	*15%*	*19%*
% Profit Margin	*10%*	*6%*	*8%*	*13%*	*6%*	*10%*
EBITDA			*$45,047,980*			*$56,895,064*

- **Significant reduction in fiber cost on <u>both</u> machines due to reduction of fiber cost to the digester (bamboo and hardwood)**
- **Modest Reduction in chemical cost due to lower bleaching cost**
- **Energy penalty for lower black liquor and loss of bark fuel credit**

Model Results – Unstressed with Bamboo at $70 per BDT

	Base Case - Unstressed			Bamboo - $70 per BDT - Unstressed		
Fiber	$149.02	$145.80	$147.61	$128.94	$141.63	$134.51
Chemicals	$153.20	$166.15	$158.89	$140.08	$166.46	$151.26
Energy	$64.93	$68.29	$66.41	$70.04	$73.67	$71.63
% EBITDA Margin	21%	16%	19%	23%	16%	20%
% Profit Margin	11%	7%	9%	13%	7%	10%
EBITDA			$49,787,248.73			*$57,785,976*

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- **Modest Reduction in chemical cost due to lower bleaching cost**
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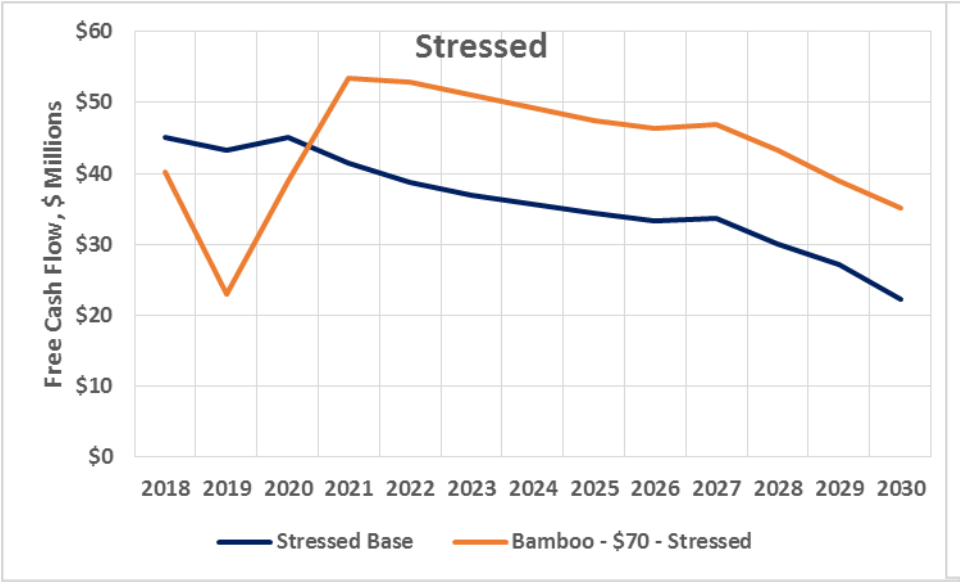
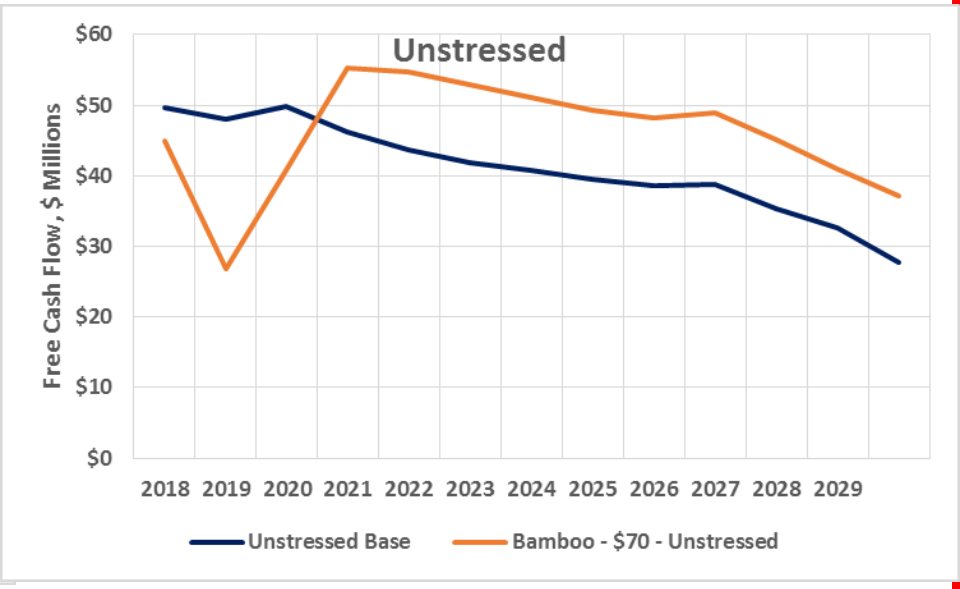
Free Cash Flow improvement due to Bamboo

(Capex at $41 Million)





NPV @15% and Internal Rate of Return on $41 Million Capital Investment

	Financial Parameters for Stressed Case		
Bamboo Price, $ per BDT	$70	$75	$80
NPV at 15%	$52,228,352	$40,693,296	$29,158,241
IRR, %	34%	30%	26%

	Financial Parameters for Unstressed Case		
Bamboo Price, $ per BDT	$70	$75	$80
NPV at 15%	$26,614,207	$14,975,202	$3,336,198
IRR, %	25%	21%	16%

Conclusions

- **Bamboo at $70 per BDT displacing highest cost hardwood has significant economic potential**
  - ***$8-12 Million improvement in EBITDA***
- **Compared to Mixed Southern Hardwood:**
  - ***Pulp Yield equal or better***
    - **Assuming fines are retained on papermachine**
  - ***Fiber properties between hardwood and softwood but less coarseness than even BEK***
  - ***Paper strength equal or better***
  - ***Bulk equal or better***
- **Questions remain, but study suggests they are well worth additional work to answer**

Acknowledgement

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