WILL NONWOODS BECOME AN IMPORTANT FIBER RESOURCE FOR NORTH AMERICA?

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Presented at 1998 World Wood Summit, August 31 - September 2, 1998, Chicago, Illinois (published in Summit Proceedings)

ABSTRACT

Total global papermaking fiber consumption is projected to increase from about 300 million tonnes for 1998 to about 425 million tonnes by the year 2010. All fiber resources will be required to meet projected demand including fast growth wood plantations, increased recycling and nonwood plant fibers from crop residues as well as fiber crops. An overview of the following topics is provided to address some of the issues faced by North American pulp and paper producers considering the use of nonwood plant fibers:

- Estimated availability of nonwood fiber raw materials
- Global wood versus nonwood paper pulp capacity
- Leading countries with nonwood fiber pulping capacity
- Constraints on global trade in nonwood fiber raw materials
- Current and possible uses for nonwood fibers
- Some issues relating to nonwood fiber use in the North American pulp and paper industry
- Some typical projects which could be considered for the U.S. and Canada

INTRODUCTION

Why are nonwood plant fibers on the agenda of the 1998 World Wood Summit? I believe that it is because your conference organizers have the foresight to recognize that, in the near future, all fiber resources will be needed due to increasing demand for papermaking fiber and tightening wood supplies.

Jaakko Poyry (1) predicts that total global consumption of papermaking fibers will increase from about 300 million tonnes for 1998 to about 425 million tonnes by the year 2010, an increase of 125 million tonnes. They project that the bulk of the new fiber requirement will come from recovered paper. But, is this realistic, or possible?

Table 1 Global papermaking fiber consumption [1]
(million metric tonnes)

	Year	Consumption
Actual	1970	135
	1980	180
	1990	250
Projected	1998	300
	2000	330
	2010	425

According to the American Forest & Paper Association, U.S. wastepaper recovery rates for corrugated and newsprint are already about 74% and 63%, respectively. The only remaining area where a significant increase in recovery rate may be achieved appears to be printing and writing papers which currently are recovered at a rate of only about 25%. While an increase in the recovery rate for these grades may be possible through more effective office waste recovery, a large amount of this paper is consumed in the home and discarded in regular trash.

So, the big question is, **"Where will we find the additional 125 million tonnes of fiber needed by the year 2010?"**

In my opinion, all fiber resources will be required to meet projected demand including fast growth wood plantations, increased recycling and nonwood plant fibers from crop residues as well as fiber crops.

This paper presents an overview of various topics which I hope will allow your companies to consider the use of nonwood plant fibers:

- Estimated availability of nonwood fiber raw materials
- Global wood versus nonwood paper pulp capacity
- Leading countries with nonwood fiber pulping capacity
- Constraints on global trade in nonwood fiber raw materials
- Current and possible uses for nonwood fibers
- Some issues relating to nonwood fiber use in the North American pulp and paper industry
- Some typical projects which could be considered for the U.S. and Canada

It should be noted that throughout this paper I use the term nonwood or nonwood fiber to refer to nonwood plant fibers as opposed to other nonwood materials such as synthetic fibers or fillers which may be used in papermaking.

ESTIMATED NONWOOD FIBER AVAILABILITY

Nonwoods can be classified in several manners. For supply side issues, I have classified them into three categories:

- agricultural residues such as cereal straws, corn stalks, sugarcane bagasse and flax straw
- fiber crops such as kenaf, sisal, abaca, hemp, bamboo and switch grass
- natural stands such as reeds, grasses and bamboo

In this paper, I will not address natural stands.

Agricultural Residues

Globally, there is an abundance of agricultural residues suitable for pulp and paper production.

Per table 2, Atchison (2) estimates that the global supply of agricultural residues which could be used for papermaking is in the order of 2.45 billion bone dry metric tons (bdmt). Of this, about half is straw which, in fact, it the most widely used nonwood plant fiber raw material in the pulp and paper industry.

The U.S. has an abundance of agricultural residues which could be used for pulp and paper production. As reported by Rowell and Cook (3), table 3 provides estimates of the total amount of agricultural residues produced in the U.S. The difference between the U.S. estimates result from the methods of estimation used:

- Atchison's estimates are based on average field yields of collectable fibrous raw material and areas harvested

- Rowell & Cook's estimates are based on grain production statistics and estimates of harvest indexes (ratio of grain to total above ground biomass).

Using Atchison's method, table 4 provides my (4) estimate of the total amount of agricultural residues available in Canada.

Table 4 Estimated availability of agricultural residues in Canada (1996) [4]

Raw Material	Estimated Availability (bdmt)		
	Minimum	Maximum	Average
Corn stalks	7,944,000	9,798,000	8,870,000
Wheat straw	27,322,000	37,257,000	32,289,000
Barley straw	9,434,000	13,102,000	11,268,000
Oat straw	3,681,000	5,113,000	4,397,000
Seed flax straw	592,000	888,000	740,000
Rye straw	480,000	672,000	576,000

Table 2 Estimated global availability of agricultural residues [2]

Raw Material	bdmt
Straws	
Wheat	600,000,000
Rice	360,000,000
Barley	195,000,000
Oat	55,000,000
Rye	40,000,000
Grass seed	3,000,000
Flax (oilseed)	2,000,000
Subtotal Straw	**1,255,000,000**
Corn stalks	750,000,000
Sorghum stalks	252,000,000
Sugarcane bagasse	102,000,000
Cotton stalks	68,000,000
Cotton staple	18,300,000
Cotton linters	2,700,000
TOTAL RESIDUES	**2,448,200,000**

Table 3 Estimated U.S. availability of agricultural residues (bone dry metric tons) [3]

Raw Material	Atchison	USDA
Straws		
Wheat	76,000,000	78,900,000
Rice	3,000,000	7,500,000
Barley	7,000,000	12,000,000
Oat	5,000,000	6,000,000
Rye	400,000	400,000
Grass seed	1,100,000	900,000
Flax (oilseed)	500,000	700,000
Subtotal Straw	93,000,000	106,400,000
Corn stalks	150,000,000	300,800,000
Sorghum stalks	28,000,000	33,700,000
Sugarcane bagasse	4,400,000	3,000,000
Cotton stalks	4,600,000	7,100,000
Cotton staple	3,500,000	3,500,000
Cotton linters	500,000	500,000
TOTAL RESIDUES	284,000,000	455,000,000

Fiber Crops

Per table 5, Atchison (2) estimates that stem fibers account for some 13.7 million bdmt globally of which 3.0 million bdmt is the bast fiber component. Another 580,000 bdmt comes from leaf fibers.

Most of the current fiber crops such as abaca (Manila hemp), jute, sisal and industrial hemp were developed for "traditional" industries such as the rope, twine and carpet backing industries and to a lesser extent for the specialty pulp and paper market.

Table 5 Estimated global fiber crops [2]

Raw Material	bdmt
Stem Fibers (jute, kenaf, hemp etc.)	
whole stalk	13,700,000
bast fiber	3,000,000
Leaf Fibers	
sisal, henequen, maguey	500,000
abaca (Manila hemp)	80,000

Summary

The issues surrounding the use of agricultural residues and/or fiber crops are many and include both technical and economic matters. Most of the technical issues have been addressed and it is largely economic factors which may inhibit the broader use of nonwood fibers in North America. With a decrease in wood availability and the resulting increase in wood cost, use of nonwood fibers may prove economically viable.

Agricultural residues offer a huge potential fiber resource for the pulp and paper industry, for example:

- all of the wheat straw in the U.S. would produce about 25 million tonnes of hardwood substitute pulp assuming a 33% yield to account for storage, preparation, pulping and bleaching losses.

- residues offer different types of fibers which could be used for different applications.

Adding fiber crops increase the potential to develop specific pulps to meet specific quality requirements.

Tables 6 and 7 list some currently available agricultural residues and potential fiber crops for the U.S. and Canada.

Table 6 Currently available agricultural residues

Long fiber	cotton linters	U.S.
	oilseed flax (bast)	U.S. & Canada
Short fiber	bagasse	U.S.
	cereal straws	U.S. & Canada
	corn stalks	U.S. & Canada
	grass seed straw	U.S.
	rice straw	U.S.
	sorghum stalks	U.S.

Table 7 Potential fiber crops

Long fiber	bamboo	U.S.
	hesperaloe	U.S.
	hemp (bast)	Canada
	kenaf (bast)	U.S.
	ramie (bast)	U.S.
	textile flax (tow)	U.S. & Canada
Short fiber	bamboo	U.S.
	hemp (core)	Canada
	kenaf (core)	U.S.
	ramie (core)	U.S.
	switch grass	U.S. & Canada

WOOD AND NONWOOD PULPING CAPACITY

Until the mid to late 1800's, nonwood plant fibers in the form of linen and cotton rags and hemp ropes were the main fiber raw materials for the pulp and paper industry. Increasing demand and developments in low cost wood pulping resulted in a large expansion of the wood-based pulp and paper industry during the early to mid 1900's. Today, wood is the dominant fiber resource for the pulp and paper industry accounting for about 90% of the world's fiber utilization.

Table 8 (2), however, shows that nonwood pulping capacity has been making significant gains over the past two decades and that nonwood pulping capacity is growing at a faster rate than wood pulping capacity.

Table 8 World papermaking pulp capacity [2]
(million metric tons)

	1975	1988	1993	1997
Wood	126.8	160.1	176.4	187.6
Nonwoods	9.3	15.6	20.7	23.0
Total	136.1	175.7	197.1	210.6
% Nonwoods	6.7%	8.6%	10.5%	10.9%

LEADING COUNTRIES PULPING NONWOODS

Many countries including the U.S. pulp nonwoods. In the U.S., wood pulping forms the basis of the industry and nonwood pulping is limited to specialty fibers such as cotton linters and flax bast. However, some countries such as Pakistan, Egypt, Cuba and Iraq rely on nonwoods for 100% of their domestic fiber supply. In other countries such as China and India, nonwoods are the largest source of papermaking fiber.

Table 9 (2) identifies the top five countries in terms of their estimated nonwood pulping capacity for 1993. In China and India, their nonwood pulping capacity amounted to 86.9% and 55.5%, respectively, of their total pulping capacity.

It should be noted, however, that although China and India combined account for about 80% of the total global nonwood pulping capacity most of the mills in these countries are smaller mills of less than 50 to 100 tons per day using relatively old technology. The largest, most modern nonwood pulping facilities are located in countries such as Indonesia, Peru, Colombia and South Africa and are sugarcane bagasse-based mills. Exceptions in India include a very few mills such as the 180,000 metric ton per year Tamil Nadu bagasse-based printing and writing and newsprint mill.

While China and India as well as other countries are trying to reduce their reliance on nonwoods by planting fast growing wood species, it is expected that nonwoods will remain important fiber resources in these countries as food production and the resultant agricultural residues will continue to dominate land usage versus tree farming.

Table 10 (2) identifies nonwood pulping capacity by fibre raw material. As mentioned earlier, cereal straw is the predominant fiber used, accounting for almost half of the total world nonwood fiber capacity.

Table 9 Leading countries with nonwood pulp capacity [2]

Country	Nonwood Pulping Capacity (1000 mt)	% of Total World Nonwood Capacity
China	15,246	73.5%
India	1,307	6.3%
Pakistan	415	2.0%
Mexico	321	1.6%
Peru	296	1.4%
Top 5	17,585	84.8%
Total World	20,736	100.0%

Table 10 Total 1993 nonwood pulping capacity by raw material [2]

	1000 mt	% of World Nonwood Capacity
Straw	9,576	46.2%
Bagasse	2.984	14.4%
Bamboo	1,483	7.2%
All other	6,693	32.2%
Total World	20,736	100.0%

CONSTRAINTS ON TRADE IN NONWOODS

The low bulk density of most nonwoods such as cereal straws and corn stalks is the key factor which prevents global trade in nonwood plant fiber raw materials.

Historically, small bale sizes and low bulk density were a major factor in the delivered cost of nonwood raw materials and a significant limiting factor on the economic collection radius for nonwood raw materials. Today, large 1200 to 2000 lb rectangular or cylindrical high density bales have changed the economics of using many nonwoods such as cereal straws and corn stalks. Nevertheless, the bulky nature and low bulk density of these raw materials still prevents global trade, and their use is limited to pulp and paper mills built within a reasonable distance of the farming community.

There are a few nonwood fiber raw materials which can and are being traded globally.

- High value bast and leaf fibers such as flax and hemp bast fiber, abaca and sisal are traded globally. Although these fiber raw materials are costly, as they are used in specialty pulp and paper production, the cost is absorbed in the end-product price.

- Bamboo offers the potential to become a globally traded commodity. Unlike most nonwoods, bamboo when chipped looks and handles like a wood chip.

CURRENT AND POSSIBLE USES FOR NONWOOD PLANT FIBERS

Generally, nonwood plant fiber pulps can be grouped into two broad categories:

- common nonwoods or hardwood substitutes such as cereal straws, sugarcane bagasse, bamboo, reeds and grasses etc.

- specialty nonwoods or softwood substitutes such as cotton staple and linters, flax, hemp and kenaf bast fibers, sisal, abaca, bamboo etc.

As with wood, there are differing chemical and physical properties within the two groups depending on the nonwood fiber raw material. Also, typically the specialty nonwoods have physical properties superior to softwoods and can be used in lower amounts in the furnish when used as a softwood substitute.

The current uses of nonwood pulps include virtually every grade of paper produced including:

- printing and writing papers
- linerboard
- corrugating medium
- newsprint
- tissue
- specialty papers

Typically, common nonwood pulps or hardwood substitutes are produced in integrated pulp and paper mills and softwood kraft is added to the furnish to provide the strength requirements to the paper. In some cases, wastepaper pulp is blended in the furnish. The nonwood portion of the furnish can vary from 50 to 90% and even up to 100% depending on the grade and required quality The possible combinations are endless and can be adjusted to meet market requirements.

Specialty papers such as currency, cigarette papers, tea bags, dialectric paper etc. may be made from a furnish of 100% nonwood specialty pulps.

Combinations of common and specialty nonwood pulps will permit the production of virtually any grade of paper to meet any quality requirements demanded in the global market. Adding possible combinations which include wood pulp, nonwood pulp and recycled wastepaper pulp increases the possibilities for developing paper with specific sheet properties designed to meet specific customers needs.

SOME ISSUES RELATING TO NONWOOD USE IN NORTH AMERICAN PULP & PAPER INDUSTRY

Although nonwood plant fibers can be used to produce a wide range of pulp and paper products, there are a number of issues relating to their use which must be considered by the North American pulp and paper industry.

Nonwood plant fiber raw material supply

Assuring a sustained long term nonwood fiber supply is critical. Some issues which one must consider are:

- What is the regional distribution of the nonwood raw material? For example, although there is an estimated 75 million bone dry metric tons of wheat straw in the U.S., in which States are there concentrations of wheat straw which could support a project?
- What is the local distribution of the nonwood raw material - i.e. in which counties are there sufficient quantities of the selected raw material within a reasonable collection radius of the mill site?
- What are average amount of the raw material produced in a given year and the amounts produced when there is drought or other crop failures?
- What are typical farming practices used in the project area regarding tillage?
- What are other uses for the raw material such as animal feed and bedding or other industrial uses which could impact on fiber supply?

As the bulky nature of most nonwoods restricts the economic collection radius to about 50 to 100 miles, the key is to determine various locations with sufficient nonwood raw material at a reasonable cost to support a mill over the long term even under the most severe conditions of partial crop failures. Also, one must consider what alternatives may be available if there is a total crop failure of the selected nonwood raw material.

Nonwood fiber harvesting, transportation & storage

Most nonwoods are annual crops which must be harvested in a 6 to 8 week period and then stored for an entire year. Some issues which must be considered include:

- Is there sufficient existing baling equipment of the type required to provide for the pulp mill's raw material requirements?
- Will all of the years raw material requirement be delivered to the mill and stored on-site or will farm storage be used for much of the raw material?
- Can the local infrastructure support the truck traffic if all of the raw material is delivered to the mill during harvesting?

- Will covered storage be required both on-site and in remote locations?
- What are typical storage losses?

Responses to the above and other questions affect issues such as the on-site storage area requirements, on-site material handling, quality control, capital expenditures and working capital requirements.

Nonwood plant fiber raw material preparation

Debarking, chipping and chip screening and washing are well established for wood pulping. However, wood chip preparation systems do not work for nonwoods with the exception of bamboo which can be processed in modified wood chippers.

Similarly, there are well established systems for preparing nonwood plant fiber raw materials prior to cooking.

As there is a wide range of nonwood plant fiber raw material types which are delivered in various forms and which contain various amounts of non-fibrous material, there is a wide selection of nonwood fiber raw material preparation systems. For example, cereal straws must be chopped and then dry cleaned or wet cleaned or dry and wet cleaned. Sugarcane bagasse is moist depithed, wet cleaned, put in storage and then wet cleaned again before pulping. Bast fiber plants such as flax, kenaf and hemp may be decorticated to extract the bast fiber for pulping. Kenaf or hemp may be chopped and pulped whole.

Selection of the most appropriate preparation system will depend on the nonwood fiber raw material and the end-product to be produced.

Also, it is critical to be aware of the losses which occur in storage and in the nonwood raw material preparation system. Incorrect assessment of these losses typically is the main reason for the economic failure of a nonwood plant fiber pulp mill..

Pulping technology

Pulping equipment used to produce woodpulp typically is not suitable for pulping nonwoods. Again, bamboo chips are the exception.

Nevertheless, pulping technology for nonwoods is well established.

The kraft, soda and sulfite processes are used throughout the world to produce a range of semi-chemical and chemical pulps from a wide range of nonwood raw materials. Unlike wood, the characteristics of pulps produced using the kraft and soda process are similar and the process selection is based mainly on make-up chemical cost and availability. Most nonwoods are pulp using the soda process.

Nonwoods may be pulped using either batch rotary digesters or continuous horizontal tube digesters. It is likely that any significant project built in the U.S. would use continuous horizontal tube digesters which will produce chemical pulps from cereal straws in 15 to 20 minutes.

In addition to commercially established technologies, there are a number of new "emerging" pulping technologies which may be applied to pulping nonwood raw materials. Most of these technologies have been tested in the laboratory and a few have reached the pilot plant stage. The most notable is the steam explosion technology which Weyerhaeuser has installed at a pilot facility in their Springfield Oregon mill to produce pulp for corrugating medium from rye grass straw.

Pulps from nonwoods such as cereal straws and bagasse contain are slower draining than wood pulps thus requiring larger brown stock washer areas. But, pulps produce from materials such as flax, hemp and kenaf bast are faster draining and require smaller surface areas. The same applies to bleach plant washers.

Bleaching technology

Nonwood pulps are easier to bleach than wood pulps. Shorter bleaching sequences and lower chemical charges are used to bleach nonwoods.

Globally, most nonwoods still are bleached using chlorine in a typical CEH or CEHH bleaching sequence. There are a few exceptions such as the CELESA mill in Spain which produces flax, hemp, sisal and abaca specialty pulps using either ECF or TCF bleaching.

Ongoing work at the University of Washington on ECF bleaching of soda cooked wheat straw and at North Carolina State University on TCF bleaching of cereal straws and other nonwoods shows that nonwoods can be easily bleached to high brightness using either ECF or TCF bleaching.

For cereal straws, bagasse and other similar nonwoods, a critical feature of bleach plant design will be to avoid mechanical action on the pulp. These types of pulps are highly susceptible to mechanical action which will reduce the pulp freeness and high shear mixers used in the woodpulp industry should be avoided.

Silica and chemical recovery

Nonwoods typically contain more silica than wood and the silica is contained in the black liquor after pulping.

Silica can cause a number of problems including scaling in the evaporators and recovery boil, reduction in settling rate in the recausticizing system and impairs operation of the lime kiln.

Efforts have been made to commercialize black liquor desilication systems of various types but none are operating commercially on a large scale. One approach developed in Austria is to use a submersed bubble reactor to bubble flue gas into the black liquor to effect a pH adjustment which causes silica precipitation. Control over the pH is critical however as pH at which lignin precipitates is very close to that of the silica.

Careful design of the fiber raw material preparation system will remove most of the tramp silica (dirt) which comes in the bales and careful design of the recovery island can overcome most of the silica problems if the inherent silica content of the nonwood raw material is not too high. One exception is rice straw which has a silica content of 9 to 14% and for which there is no recovery system available to date.

From a North American perspective, one should consider the implications of an add-on line to a wood-based pulp mill. If one were to add-on a 100 ton per day wheat straw pulping line to an existing 1000 ton per day woodpulp mill, what would be the implications of the higher silica content of the wheat straw to the black liquor. Using an average 5.5% silica in the wheat straw and assuming that the wheat straw constitutes about 9% of the fiber input to the pulp mill, then the silica content of the total amount of fiber charged to the pulp mill - wood and wheat straw - would increase by about 0.5%. The question is would this cause any significant problems in the chemical recovery system if the black liquors from wood pulping and wheat straw pulping are combined prior to evaporation. In my opinion, it is unlikely that there would be any significant problems.

Paper Machine Operation

The design of paper machines will differ for furnishes with a high nonwood content. For example, a longer wet end with more drainage elements will be required for papers with a high cereal straw or bagasse content. Press loading will be lower to avoid sheet crushing and the dryer section will require more sections to account for the higher shrinkage of the mainly nonwood sheet.
Also, machine speeds for high nonwood content sheets typically are lower than for woodpulp papers.

However, if the percentage of nonwood pulp in the sheet is in the order of 10 to 30% with the balance being woodpulp and/or recycled pulp, there should be little or no effect on the design and operation of the paper machine.

In fact, there may be some quality improvements. For example, 20% cereal straw in the furnish will help to improve opacity and sheet density. On the other hand, 10% flax bast pulp as a replacement for softwood kraft may allow for reduced basis weights or lower overall long fiber usage in the furnish.

Capital costs

As most of the equipment included in a typical wood-based pulp mill cannot be used to process nonwoods, capital expenditures will be required to process nonwood plant fibers at existing wood-based pulp and paper mills. In fact, a completely separate line likely will be required.

An exception which would require minimum capital investment is bamboo. Bamboo will produce chips similar to wood chips and can be pulped in existing stationary or continuous digesters used for pulping wood. In fact, it is possible to pulp bamboo chips in combination with wood chips. In this instance, a separate bamboo chip pile would be required, chip washing and a blending station to arrive at the required bamboo/wood blend.

Operating costs

The question of whether or not the operating costs of a nonwood pulp mill would be higher than those of a wood pulp mill needs to be resolved on a case-by-case basis.

Some factors which could increase operating costs include:

a) Smaller Mill Size

   For various technical and economic reasons, nonwood pulp mills typically are smaller than woodpulp mills. For example, due to drainage rates, a washer which will process 1000 tons/day of woodpulp will only process about 300 tons/day of wheat straw pulp. Also, there are limits on the economic collection radius for nonwood fiber raw materials which will limit the size of the line which could be built.

b) Operating Labor

   Essentially, it takes the same number of people to operate a 1000 ton/day woodpulp mill as it does to operate a 300 ton/day nonwood pulp mill.

c) Debt Service

   As the nonwood mill size is smaller, typically the debt service per ton of pulp produced is higher for a nonwood pulp mill than for a woodpulp mill.

d) Chemical Recovery Energy Generation

   In a wood-based kraft pulp mill, the chemical recovery system generates sufficient steam and power to run the entire mill. However, due to the different nature of black liquors from nonwoods, the amount of energy generated is barely sufficient to run the chemical recovery island.

Factors which decrease operating costs include:

a) Pulping and Bleaching Energy Consumption

Pulping and bleaching nonwood fibers requires less energy than wood fibers.

b) Chemical Consumption

Pulping nonwood fibers requires a lower chemical charge than wood fibers. Also, bleaching nonwood fibers is easier than wood fibers. Most nonwoods can be bleached to high brightness in short bleach sequences and using lower chemical charges.

Assuming that the cost of fiber is the same, it is likely that producing nonwood pulps will be more expensive than producing woodpulps. However, over time, the economics of using nonwood fibers may improve as a result of increasing wood costs.

The overall effect of using nonwoods on operating costs will have to be studied on a case-by-case basis as it will change depending on the raw materials, processes used, end products and line size. Also, the costs of processing nonwoods as compared to woodpulp production will be location specific.

Summary

While to foregoing may appear to present a dim picture for the potential use of nonwood plant fibers in North America, the projected increase on papermaking fiber demand and potential increase in wood costs may force the North American industry to seriously consider the use of nonwood plant fibers as a way to extend wood supplies over the long term.

A vast body of knowledge has already been developed on the use of nonwood plant fibers. Most of the technical questions raised above have been addressed many times in many countries throughout the world by engineering consultants and equipment suppliers with expertise in the use of nonwood plant fibers. As this expertise can be brought to projects in North America, it is not necessary to completely reinvent the technology for use in North America.

SOME POSSIBLE NONWOOD PLANT FIBER PROJECTS FOR THE U.S. AND CANADA

Given the wide variety of nonwood plant fibers, the possible nonwood-based projects which could be developed in North America are limited only by ones' imagination. The following illustrates only three of the many possibilities.

Add-on hardwood substitute nonwood pulp line

By far the largest amount of nonwood plant fibers available in the U.S. and Canada are agricultural residues such as cereal straws and corn stalks. For mills which are facing a hardwood shortage, these nonwoods offer a potential fiber substitute.

To make use of these nonwoods, the mill in question could install a separate semi-chemical or chemical pulping line of between 100 and 300 tons/day to process cereal straw or corn stalks into pulp for a variety of end-uses such as fine papers, newsprint, corrugating medium and linerboard.

The size of the nonwood line will depend on the amount of nonwood fiber in the furnish and the paper mill capacity; however, to reduce impact on paper machine operation it is recommended that the nonwood furnish component is limited to 20 to 25% of the total furnish.

Greenfield integrated pulp and paper mill

The possible configurations of a greenfield integrated pulp and paper mill based on nonwood plant fibers are endless and depend only upon the desired end-product and available fiber raw materials.

One greenfield project already announced is the whole stalk kenaf newsprint mill proposed for Texas.

Another project worth considering is a fine paper mill of about 150,000 tons/year based primarily on agricultural residues such as cereal straw or corn stalks. The mill could be designed to produce a 100% nonwood fiber paper or papers which include post consumer recycled pulp. This mill would:

- include a chemical pulping and TCF bleaching line for the cereal straw
- may include a separate chemical pulping and TCF bleaching line for a "specialty" nonwood fiber such as flax, hemp or kenaf bast fiber which would provide the softwood substitute
- or may include a slushing line for cotton linters pulp as the softwood substitute
- include a slushing line for recycled post consumer waste

As mentioned, the possible combinations for a greenfield mill are endless and depend only upon ones' imagination, nonwood fiber availability and desired end-products.

Bamboo co-pulping

As mentioned previously, bamboo can be chipped in a similar manner to wood, and the bamboo chips handle and pulp like wood chips.

As such, the last project which I am offering for your consideration is co-cooking bamboo and wood chips at an existing wood-based chemical pulp mill.

The clear advantage of this type of project is that there is virtually no capital investment required to co-cook a blend of say 20% bamboo and 80% wood chips other than a possible chip blending station.

To date, over 1200 bamboo species have been identified globally of which only about 35 are used as raw material for the pulp and paper industry. Both tropical and temperate species exist, and bamboo comes in many sizes from small diameter "fishing poles" to large diameter bamboo which grows 100 feet tall in 3 to 4 years. More interesting perhaps is that the fiber characteristics of bamboo can range from fibers similar to hardwoods in some species to other species with fibers similar to softwoods.

Technology exists to clone bamboo which means that one could clone various species to meet specific pulp requirements. This technology can be used to develop bamboo farms designed to produce fiber suited for specific wood-based pulp mills.

To serve pulp mills in the eastern U.S. and Canada, cloned bamboo farms could be developed in the U.S. southeast, various Caribbean islands including Puerto Rico and Jamaica, eastern Mexico, and on the east coast of various Central American and South American countries. Similarly, locations in Hawaii, western Mexico and on the west coast of various Central American and South American countries could provide chips to west coast mills.

Bamboo farming offers the potential to develop a new, fast growing fiber resource for the pulp and paper industry. And, depending on the species, some farms may also produce bamboo shoots for food.

For the environmentalist, it should be noted that the use of bamboo chips could be restricted to chips from certified farms to prevent usage of natural stands. Also, cloning technology could be used to redevelop some of the depleted natural stands. Finally, as the giant Panda relies on bamboo for food, it should be noted that the species on which the Panda feeds has no value for any other use but Panda food.

I believe that careful planning of cloned bamboo farms offers the pulp and paper industry with a potentially vast new fiber resource which could be cost competitive with wood even at today's prices.

CONCLUSION

In conclusion, I wish to remind you of the following:

- global demand for papermaking fiber is projected to increase by 42% or 125 million tonnes during the next 12 years
- nonwood fiber raw materials offer a huge fiber resource globally and in North America
- nonwood fiber raw materials offer both hardwood substitutes and softwood substitutes
- virtually any grade of paper can be produced using combinations of nonwood fiber pulps
- nonwood fiber pulps can be used in combination with virgin woodpulp and recycled post consumer pulp thus stretching wood resources
- technology exists for producing pulp and paper from nonwood fiber raw materials, technology which can be applied in the U.S. and Canada
- opportunities for developing nonwood projects are endless and depend only on the nonwood raw materials available and end-products

In response to the question raised in the title of this paper "Will Nonwoods Become an Important Fiber Resource for North America?", I believe that the answer is **Yes**.

Over the next decade all fiber resources will become increasingly more important to our industry. It will be incumbent upon you, the members of our industry to make the commitment and take the initiative necessary to investigate the opportunities offered to us by the vast resources of nonwood plant fibers. We must define our targets and begin to organize our efforts soon if we are to continue to meet global demand for our paper products in the year 2010.

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