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Sub-Study Series

7 The Potential of the Non-Wood Fibre Paper Sector

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THE POTENTIAL OF THE NON-WOOD FIBRE PAPER SECTOR

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The Potential of the Non-Wood Paper Sector: its sustainability and advantages and disadvantages compared to the wood-based sector

EXECUTIVE SUMMARY

For over 1,700 years all paper was made from non-wood fibres. Today less than one percent of paper produced in developed countries is made from non-wood fibres, although half of the production in developing countries relies on them. Paper production from non-wood fibres is particularly significant in China and India where there are a large number of very small mills.

This report looks in detail at the current use of non-wood fibres in both developed and developing countries, examines the merits of the conflicting claims about the economic, social and environmental advantages and disadvantages of using non-wood fibres for paper-making and assesses the sustainability of, and potential for, an increased use of non-wood fibres for pulp and paper production in the future.

Almost any fibre can be made into paper. Those currently in use can be divided into three categories, annual crops such as hemp and kenaf, agricultural residues such as straw and bagasse (sugar cane residue) and naturally occuring or wild plants such as wild grasses and bamboo. Globally the most common non-wood fibre used in paper-making is straw, followed by bagasse and bamboo. Different fibres have different characteristics and produce pulps of varying qualities, some of which can be used for high quality speciality papers and some which could substitute for hardwood or softwood pulp.

The main difference between wood and non-wood fibres is the lower proportion of lignin and higher level of silica in non-wood fibres. Lower lignin levels means that lower amounts of chemicals are required to bleach the paper and less energy is required to pulp the fibres, a significant advantage in mechanical pulping where energy is a major cost of production. This is less of an advantage in chemical pulping since a large proportion of the energy used in the production process is generated from burning the recovered lignin. Higher silica levels complicate the effluent treatment process causing significant environmental problems.

Few major paper companies use non-wood fibres since wood offers significant economies of scale, can be procured (and stored) all year round, has well established supply chains and markets and is a fibre source over which companies have considerable control. In contrast, most types of non-wood fibre are available only at certain times of the year and procurement involves a large number of small producers. This restricts mill size and results in significant administrative burdens, storage requirements and transport costs. The majority of non-wood fibre mills are in poorer countries and tend to be small and reliant on out-dated equipment and techiques. Consequently non-wood fibre products are generally uncompetitive in global mass markets, although some fetch premium prices due to their special qualities.

However, the smaller scale nature of these mills may make them more appropriate in capital-poor economies. Non-wood mills also tend to be relatively labour intensive and most source their fibres from the local area, generating income for a significant number of farmers, which has led to renewed interest in their use from organisations in rural areas in developed countries. However, the cost of installing effluent treatment facilities is beyond the means of most small mills, resulting in significant pollution.

In the future non-wood fibres will continue to play an important role in paper production in developing countries so the development of appropriate processes, particularly for chemical recovery, is very important. There seems to be some scope for increasing the use of non-wood fibres as a complement to wood for papermaking, in particular utilising agricultural residues which are already in surplus. This could either be achieved through purpose built mills in agricultural areas or additional capacity being added to existing wood based mills. With paper demand predicted to rise for the foreseeable future the utilisation of a range of fibre sources is desirable and investment in research and development in to non-wood fibre papermaking should be encouraged.

1 INTRODUCTION

Paper was first made in the first century AD in China from old rags, fishing nets, mulberry bark and grass (Lines and Booth 1990). For the next 1700 years paper was entirely made from a variety of non-wood fibres, including hemp, flax, grass, cotton and old rags. In America, the first two drafts of the Declaration of Independence were printed on paper made from hemp, a crop which is now banned there. It wasn't until 1857 that a process was invented to pulp wood, yet wood quickly became established as the dominant paper making raw material. Although non-wood fibre is still the main paper material in some parts of Asia, today 90% of the fibre used in global pulp production is wood fibre. The non-wood sector is often dismissed as insignificant, comprised of inefficient highly polluting producers of low quality paper.

However, there are a variety of groups including environmental organisations, national governments, farmers and entrepreneurs who believe that increased use of non-wood fibres offers substantial benefits. There are numerous organisations and individuals interested in the potential of non-wood fibre for papermaking but the information is scattered and much less readily available than information on the wood based industry.

The aims of this report are:

- To provide an overview of the current use of non-wood fibres;
- To examine the conflicting claims about the economic, social and environmental benefits and problems of using non-wood fibres to make paper;
- To examine the sustainability of, and the potential for, an increased use of non-wood fibre for pulp and paper production in the future.

The report covers the following areas:

Section 2 reviews the current use of non-wood fibres around the world, describes the technical characteristics of the fibres commonly used for pulp production and outlines the range of products made from non-wood pulp.

Section 3 describes the structure of the non-wood fibre paper sector in developing countries.

Section 4 explores the interest in non-wood fibres in developed countries and recent initiatives to increase their use.

Section 5 discusses the advantages and disadvantages of using non-wood fibre compared to wood fibre for pulp and paper production, in terms of their relative costs, technical qualities and environmental and social impacts.

Section 6 discusses the sustainability of producing paper from non-wood fibre and examines the potential for an expansion of the non-wood sector in the future.

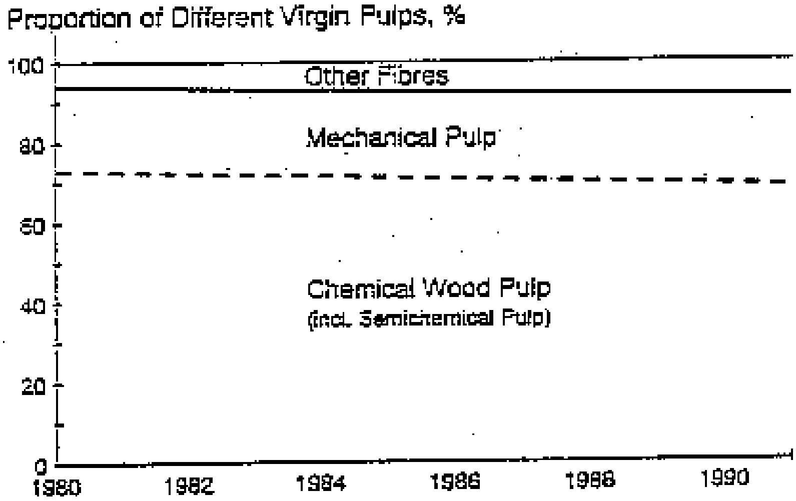
2 CURRENT USE OF NON-WOOD FIBRE IN PULP AND PAPER PRODUCTION

2.1 Introduction

This section examines the current global use of non-wood fibres for pulp and paper production. The most commonly used non-wood fibres and the technical characteristics of different fibres for pulp and paper making are described, followed by a review of the different types of paper which are made from non-wood fibres.

Estimates of the proportion of non-wood fibre currently used in global pulp production vary between 5% and 11% (e.g. PPI 1995, Hagler 1995, Ayres 1995). FAO (1993) put the figure at 11% and UNIDO at 6-7% (Assumpçaõ 1993). However these estimates conceal significant regional variation. In the developed world, non-wood fibre accounts for less than 1% of all fibre used to produce paper whereas in developing countries over half of all paper making fibre is from non-wood sources. Between 1981 and 1992 non-wood pulp production increased at an average annual rate of 8.3% per annum in developing countries, whilst decreasing at nearly 5.3% per annum in developed countries (Assumpçaõ undated). In many cases the development of an industry based on non-wood fibres has been in countries with a shortage of wood.

Figure 2.1a Global Consumption of Different Pulps



Source: Göttsching (undated)

Small amounts of non-wood fibre are exported for use in the production of speciality papers but in general non-wood pulp and paper mills rely on locally produced fibres. There is very little trade in non-wood pulp. In 1993, 304,000 tonnes of non-wood pulp or 1.6% of the total produced was traded compared to 152,316,000 tonnes or 19.2% of wood pulp produced (FAO 1993).

The use of non-wood fibre is particularly significant in Asia where over ninety percent of non-wood pulp is produced. China produces over twelve million tonnes of non-wood pulp non-wood pulp is produced. China produces over twelve million tonnes of non-wood pulp per year, dwarfing the output of the other major producers (see Table 2.2a below).

The non-wood fibre sector in selected countries is discussed in more detail in sections three and four of this report.

2.2 Types of Non-Wood Fibre Used in Pulp and Paper Production

Almost any fibre can be made into paper. Those currently in use can be divided into three categories:

1. Annual crops such as hemp (*cannabis sativa*), kenaf (*hibiscus cannabis*), flax (*linum usitatissium*) and jute.
2. Agricultural residues such as straw from wheat and rice and bagasse from sugarcane.
3. Naturally occuring or wild plants such as abaca (*musa textilis*), sisal (*agave sisalana*), grasses and bamboo.

Globally, the most common non-wood fibre used in pulp and papermaking is straw, accounting for 47% of total production in 1993, followed by bagasse (12%) and bamboo (6%) (Hagler 1995).

Table 2.2a The Ten Largest Producers of Non-Wood Pulp in 1993

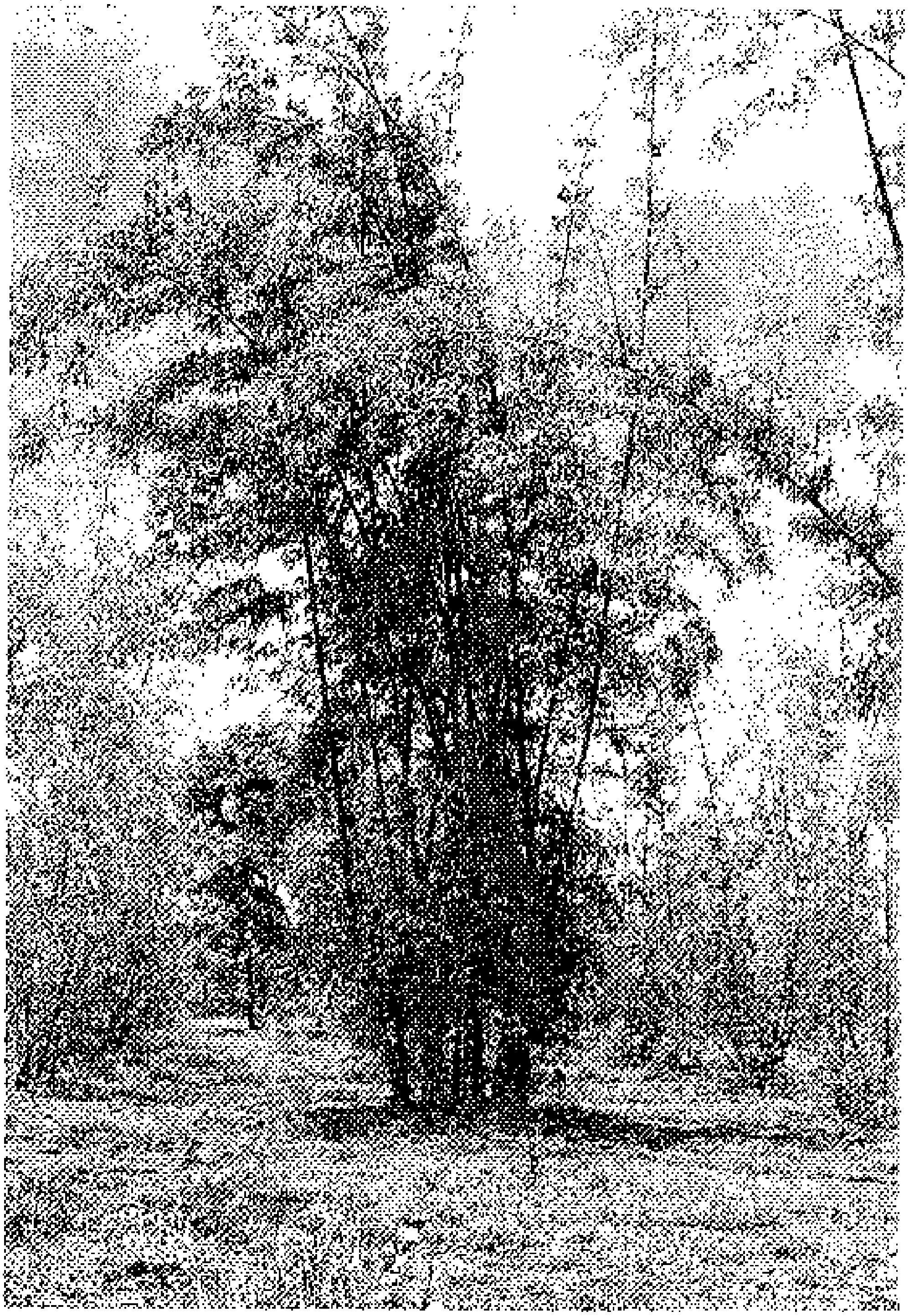
Country	Production of non-wood pulp (1000 tonnes)	% of total pulp production which is non-wood	Main fibres used
China	12,150	89	straw, kenaf, reed
India	1,100	48	bamboo, bagasse, straw
Mexico	240	45	bagasse
USA	170	0.3	cotton
Indonesia	141	8	bagasse
Thailand	140	36	bamboo, bagasse, kenaf
Colombia	131	35	bagasse, hemp
Brazil	120	2	bamboo, bagasse
Argentina	112	15	bamboo, bagasse
South Africa	100	4	bagasse

Source: Hagler 1995

Figure 2.2b   Hemp Growing in Kent, UK 1994

Photograph courtesy of Sue Riddlestone, Bioregional Development Group

Figure 2.2c Bamboo Clump, Thailand 1995



Photograph courtesy of Dr Subhash Maheshwari, Phoenix Pulp and Paper Public Company Ltd, Thailand

2.3 Technical Characteristics of Different Fibres for Paper Making

Table 2.3a below summarises the key physical and chemical differences between various non-wood fibres that determine their suitability for papermaking. The widely differing characteristics mean that different fibres produce very different types of pulp. Certain non-wood fibres such as bamboo and kenaf are similar in length to softwood fibres such as pine, whereas bagasse and straw are more similar to hardwoods such as eucalyptus. The wide range of figures for hemp and kenaf is due to these plants containing two distinct sets of fibres, the long bast fibres (e.g. hemp 15-55 mm) and the shorter core fibres (e.g. hemp 0.7 mm). In terms of chemical composition, wood fibres generally have higher proportions of cellulose and lignin than non-wood fibres, which are instead characterised by their high ash, hemicellulose and silica content.

Table 2.3a Physical and Chemical Characteristics of Different Fibres

	Pine	Eucalyptus	Bamboo	Bagasse	Kenaf	Straw	Hemp
Fibre Length (mm)	4.0	0.7 -1.4	2.9-4	1.2-1.5	0.6-3	1.2-1.5	0.7-55
Cellulose (%)	42	46	50	40-43		33-40	45-72
Hemicellulose (%)	25	27	16-21	30-32		24-28	7.7-17.8
Lignin (%)	28	26	22-30	24	9-18	10-17	2-20
Silica (%)	0.03 - 0.1	0.03-0.1	1.5-3.5	1.5-4	0-0.03	3	1.5-3.5
Ash	1	1	3-5	3-8	2.2-6.2	4-7	

Sources: Atchison 1995, Chivrall 1994, FAO 1989a & 1989b, Judt 1994, Khaitan 1994, Lawther 1994, PPI 1994, Robson 1994, Sawhney 1988, Tandon *et al.* 1991.

The effect of these different characteristics on pulp and paper production is discussed in Section 5.

2.4 Types of Paper made from Non-Wood Fibres

The quality of non-wood pulp depends on both the fibre and pulping process used, with chemical pulps being stronger than mechanical pulps for the same fibre. Different non-wood fibres exhibit a range of different characteristics, consequently, any type or grade of paper could be made from a combination of non-wood fibres (Atchison 1995). Currently, non-wood fibre is being used in almost all grades of paper from tissues to linerboard (Assumpçaõ 1993).

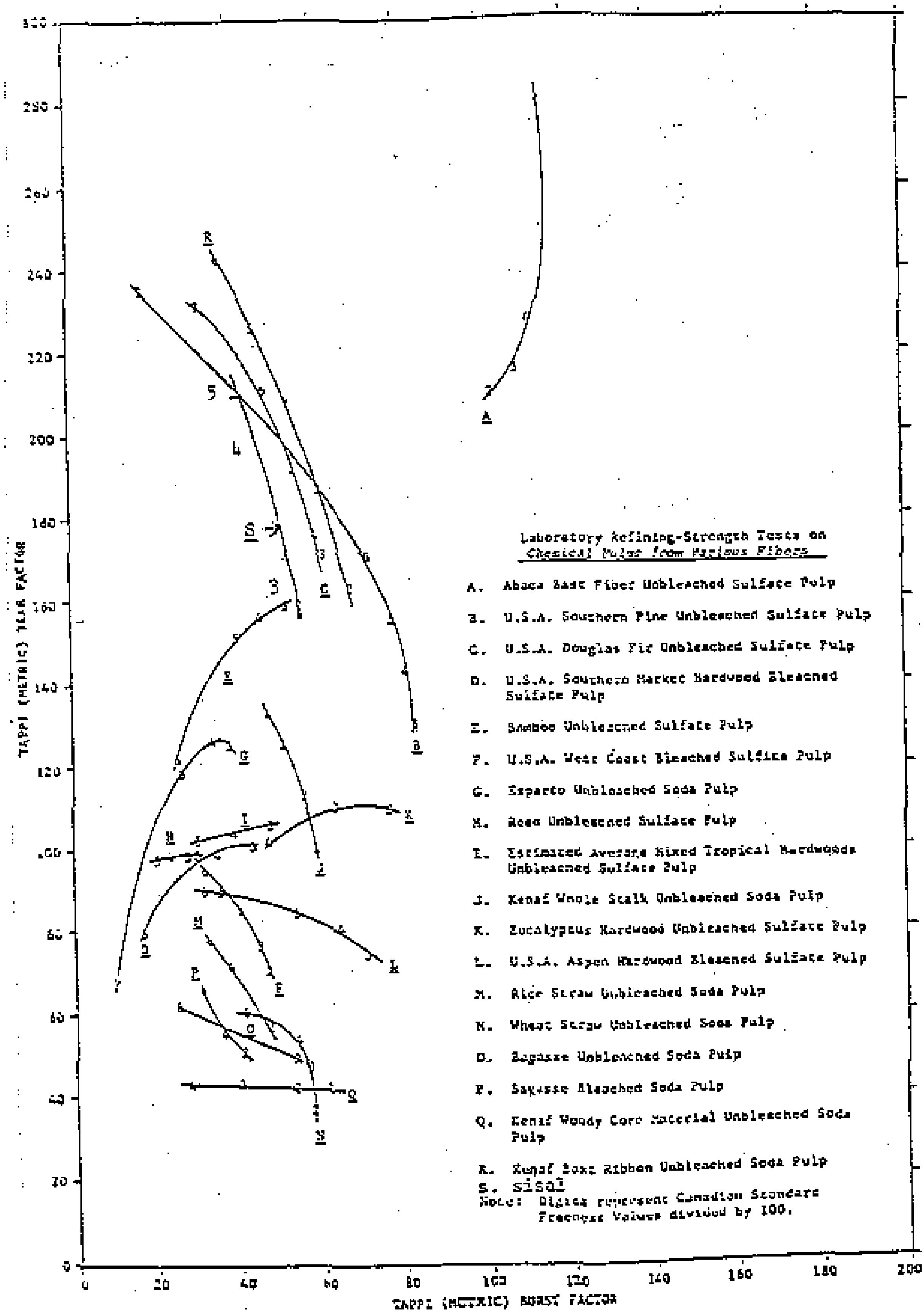
Jaakko Pöyry reports that some non-wood fibres such as abaca, flax, sisal and hemp linters have superior properties compared to wood fibres (Paavilainen 1993). They have a particular advantage in applications requiring a high tear and tensile strength such as teabags, currency papers and cigarette and bible papers (FAO 1989a, Onna 1994). Table 2.4a compares wood and non-wood fibres in terms of various factors used by industry to evaluate pulp quality. The breaking length and the burst and tear factors are indications of the strength of the pulp (the higher the stronger). Opacity is a measure of the transparency of the paper, the higher the opacity the less transparent the paper. Figure 2.4b illustrates the comparative strength characteristics of various pulps. It has been found that this kind of graphical representation of the burst-tear relationship gives a reasonable indication of the relative strength characteristics of the pulps and an indication of their usefulness in different grades of paper and paperboard (Atchison 1995).

Table 2.4a Pulp Qualities of Various Fibres

	Pine	Eucalyptus	Bamboo	Bagasse
Fibre length (mm)	4.0	1.4	2.9	1.2
Breaking Length (m)	8800	4900	7600	6100
Burst Factor	83	30	81	40
Tear Factor	120	90	150	60
Fold Number	1800	50	700	350
Opacity (%)	72	83	72.5	75

Source: FAO 1988

Figure 2.4b Strength of Chemical Pulps from Various Fibres



Source: Atchison 1995

Abaca produces an extremely strong pulp for which there are no substitutes. However, it is very expensive and it is only used for speciality applications which sell at high prices. Long fibres such as bamboo, sisal and kenaf bast fibre produce pulp with strength properties comparable to softwood pulp. These can be used as substitutes for softwood pulps or as supplementary pulps in places where softwood is in short supply. Thermo-mechanical pulp (TMP) or chemi-thermo mechanical pulp (CTMP) made from wholestalk hemp or kenaf have similar properties to hardwood pulp or pulp with a high percentage of recycled fibre. These would be suitable for newsprint and there have been various attempts to establish a newsprint industry based on kenaf, see Section 4.2. Kenaf is currently being used for printing and writing paper and for specialist applications such as paper with a high ink absorbency (Kaminokawa 1995 pers comm). Companies which use kenaf paper include Esprit, The Gap, Birkenstock, Sony and Warner Bros (Ayres 1995). In most cases different pulps (both wood and non-wood) are mixed together to make paper with the desired characteristics.

Straw and bagasse have short slender fibres which produce pulps with good printing properties and adequate strength (Paavilainen 1993). They have very similar properties to hardwood pulps and could replace them in most grades of paper and paperboard (Atchison 1995). Cereal straw is often used to make fluting for corrugated boxes (PPIC 1993). Pulps from reeds and some grasses are of medium fibre length and make excellent blending pulps for many grades of paper (Atchison 1995).

High quality printing and writing paper has been produced from a variety of non-wood fibres in countries ranging from India and Japan to the USA, Canada and the UK. (For examples, see the Bioregional Development Group, Bioregional Fibres report printed on *hemp/straw/recycled* paper, *the Japanese Association for Non-Wood Paper Promotion's* literature printed on kenaf paper, Arbokem's 'agri-pulp' paper). In some countries grades such as school book paper are made from 100% bleached bagasse pulp and bagasse is also used for newsprint and widely used in high percentages in tissue paper manufacture (Atchison 1995).

2.5 Conclusions

The term non-wood fibre encompasses a range of plants with widely differing qualities. Different non-woods produce pulp with different characteristics. Some of these could be used as direct substitutes for hardwood or softwood in a wide range of paper and paperboard grades or alternatively they could be blended with wood pulp or used as complements to recycled fibre. Others produce pulps with superior qualities and are used for speciality papers. All grades of paper can be made from a combination of non-wood fibres. The main difference between wood and non-wood fibres is the lower proportion of lignin and higher level of silica in non-wood fibres.

3 THE NON-WOOD PULP AND PAPER SECTOR IN DEVELOPING COUNTRIES

3.1 Introduction

As described in Section 1, the non-wood pulp and paper sector is much more significant in developing countries than in developed countries, accounting 56% all pulp produced in the former. In developing countries, the non-wood sector is generally characterised by small integrated pulp and paper mills producing relatively low quality paper for domestic consumption. The machinery used is often outdated or second hand and originally designed for wood fibres, there is little chemical recovery and high pollution levels. However, there are significant exceptions to this. This section will focus on China and India since they are by far the biggest producers of non-wood pulp (see Table 2.2a).

3.2 China

In 1993, China was the third largest producer of paper and paperboard in the world. Nearly 90% of China's pulp production is from non-wood raw materials, predominantly straw (Hagler 1995) and it accounts for over three quarters of the world's non-wood pulp (Zhong 1994). Almost all mills in China are integrated pulp and paper mills but the exact number is unknown. Estimates vary, but can be as high as 10,000. According to figures from the National Statistic Agency, if village paper mills which tend to shut down and re-open frequently are ignored, the total number of mills is approximately 6,000. Over half have a capacity of less than 5,000 tonnes per annum. Small mills with a capacity of less than 10,000 tonnes per annum account for over 57% of production (Zhang 1995). The majority of Chinese mills use alkali or alkali with anthraquinone pulping processes and single stage hypochlorite bleaching. The use of chlorine dioxide or oxygen bleaching is rare (Kuang 1995).

The Chinese pulp and paper industry is highly polluting, in most cases discharging their wastewater directly into neighbouring waterbodies (Zhong 1994). In 1992, the pulp and paper sector accounted for 17% of the total wastewater discharged by all Chinese industries and nearly 60% of total Chemical Oxygen Demand (COD). Only a tiny minority of Chinese mills have any form of chemical recovery (63 according to statistics from the early 1990's) and those in operation are inefficient, recovering only about 27% of the sodium hydroxide (Zhang 1995), compared to maximum recovery rates of up to 100% depending on the fibre in use. The general consensus in China is that recovery systems are only justified for mills with a capacity of over 30 tonnes per day (Kuang 1991) which rules out the majority of non-wood mills.

The Chinese authorities regard such pollution as a serious problem and are taking steps to reduce it, including closing down mills and obliging them to treat their wastewater. However, it is unlikely that many mills would be able to meet the standards (COD 100mg/l, BOD 30 mg/l) even if secondary treatment was adopted. Few small mills could afford even this level of treatment and closure of such mills would lead to the loss of a large number of jobs. Therefore the Chinese are taking steps to restructure their paper industry. Although there is a shortage of wood fibre and China's forests have been overexploited, government policy is to increase the ratio of wood pulp to non-wood pulp in the future. It is also encouraging mills with capacities above 10,000 tonnes per annum and attempting to increase market pulp supply. By the end of the 1980s approximately 210,000 ha of artificial forest had been planted by 20 paper companies and China is looking for joint ventures with foreign partners. Other proposals include preventing the erection of mills with a capacity of less than 50 tonnes per day, combining small mills, promoting the reuse of paper and paperboard and shutting down heavily polluting mills. Pulp mills without chemical recovery systems have been banned in most big cities (Kuang 1991, Zhang 1995, Zhong 1994).

3.3 India

The pulp and paper industry is one of the most important sectors in India's industrial economy (Rao 1992) and is based on a wide range of raw materials including bagasse, straw, bamboo and wild grasses. It produces most types of paper and paperboard but is not a significant player in the global market (Bangur 1994). There are 340 pulp and paper mill units in India with a total installed capacity of 3.4 million tonnes per annum (Papermaker 1994). However in 1993 capacity utilisation was less than 60% with approximately 100 units closed (Kariyappa and Vhandra 1993, Rao 1995). The majority of mills are integrated with an average capacity of less than 30 tonnes per day. In addition there are approximately 400 hand made paper units which produce paper from cotton rags, cotton linters and jute waste. It is estimated that they produce about 4,000 tonnes of paper per year and employ approximately 700 people (Agarwal and Narain 1995).

There are currently 89 mills in India based on agri-residues, accounting for 28% of total production. The 39 mills based on forest products (i.e. wood and bamboo) account for 43% of total production and the remainder are based on waste paper and imported pulp (Rao 1995). Most mills are flexible and change the grade of pulp they produce as prices change (Wyman 1995).

Mills in India are often based on very old machinery, some dating back to the beginning of the century. They are generally not mechanised and are large employers. It has been estimated that for small mills 53.5 people are employed for every 1000 tonnes of annual production (Rao undated).

During the 1970s and 1980s the government provided fiscal incentives to actively encourage pulp and paper mills based on agri-residues. During this period 80 second hand machines were imported duty free and about 200 mills, with a combined capacity of 200,000 tonnes, were set up (Wyman 1995). Mills using 75% non-conventional raw materials were exempted from excise duty. There were a number of reasons for these measures including; concern about the overexploitation of natural forests and resistance to plantations, fibre and paper shortages, lack of foreign exchange to import pulp or waste paper and the desire to encourage small industries, especially in rural areas (Rao 1995, Sadawarte 1995 pers comm).

Until recently the Indian industry has been protected by high import duty on paper and rules such as the two:one rule for newsprint (which has has no import duty) which requires buyers to purchase two tonnes of Indian newsprint for every tonne of cheaper imports. However support for the industry as a whole is gradually being reduced. In March 1995, the import duty on paper was reduced from 65% to 40% and many in the industry believe that it will be further reduced in the next few years (Wyman 1995). Incentives for non-wood mills have also been reduced but most states still have some kind of prefential conditions, for example in the Punjab, agro-based mills pay 5-10% less excise duty (which currently stands at Rs 2,500) than wood based mills as part of a policy to discourage wood use and support non-wood mills (Khaitan 1995 pers comm). On average the price of paper from agro-based mill is between Rs 1,000- 2,000 per tonne less than paper from wood mills. This is usually a reflection of the difference in quality (Agarwal and Narain 1995).

Some of the largest mills in India are based on bagasse (sugar cane residue). Sugar mills usually burn the cane residue in order to power the mill but any surplus can be sold to paper mills. India pioneered the use of 'substitution' bagasse, which entails a paper mill providing sugar mills with fuel in order to utilise their bagasse. The Tamil Nadu mill (see Box 3.3a below) was the first to do this and there are plans to increase the number of these type of mills, with two 100,000 tonne per year mills scheduled to begin operation within the next five years.

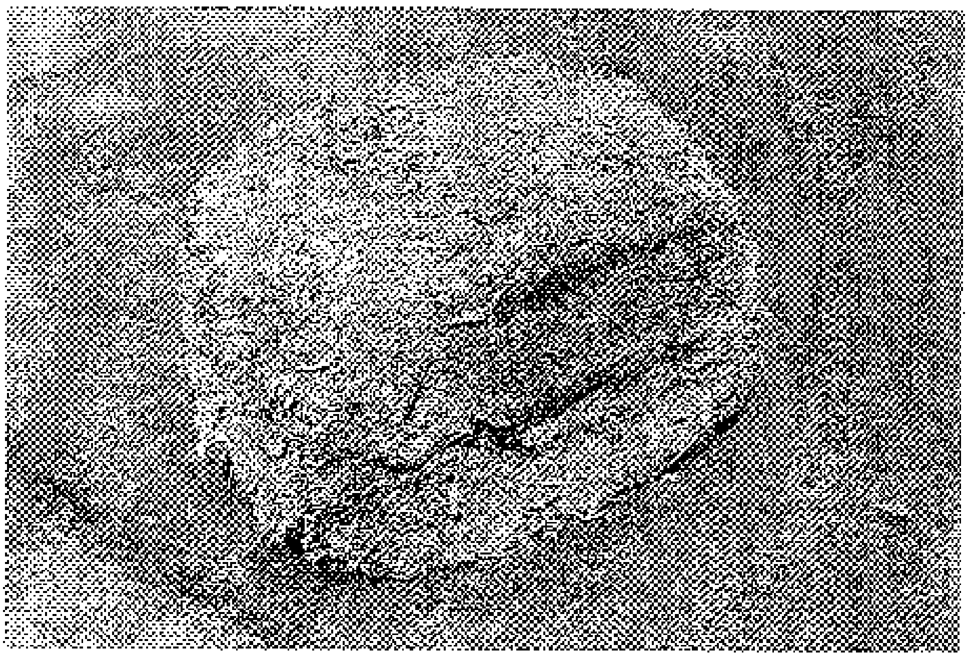
Box 3.3a Case Study: The Tamil Nadu Bagasse Mill, India

The Tamil Nadu Newsprint Mill began operation in 1984 and currently has a production capacity of 50,000 tonnes per year of newsprint and 40,000 tonnes per year of writing and printing paper. The Rs 2,300 million project was initiated by the state and supported by a Rs 1,000 million loan (US$100 million) from the World Bank. State support is now nominal and it is run as a profitable private company.

The most suitable furnish for the production of newsprint was found to be 50% mechanical bagasse pulp, 35% chemical bagasse pulp and 15% chemical hardwood pulp. Bagasse is supplied by eight sugar mills within a 100km radius of the paper mill, in return the paper company installs and operates coal fired boilers to supply the steam required by the sugar mills. The bagasse is depithed at the sugar mills since the pith is of no use in paper production. This reduces the amount of materials which have to be transported and the pith can be used as a fuel by the sugar mills. The hardwood comes from the Tamil Nadu eucalyptus plantation with which the paper mill has a 15 year agreement.

Sources: Matharu 1995 pers comm, Rao 1989, Sawhney 1988.

Figure 3.3b Bales and Loose Bagasse Stored at Pudumjee Pulp and Paper Mill, India



Photographs courtesy of Dr Khanolkhar, Pudumjees Pulp and Paper Mill Ltd, India.

The vast majority of non-wood mills in India employ chemical or chemi-mechanical pulping using sodium hydroxide as the cooking agent. There is very little chemical recovery so the pollution load from these mills is high. A study of four pulp and paper mills by the National Productivity Council found that a typical 30 tonne per day mill using 75% agri-residues generates approximately 5000 m^3/day of waste water with a BOD concentration of 1200mg/l (Gupta undated), far higher than most standards (of e.g. 100mg/l in Mexico and Sri Lanka).

Effluent standards are increasingly strictly enforced consequently most mills are taking steps to control their pollution (Papermaker 1994) but small mills have particular problems (Rao 1995). Although financial assistance is available for investment in pollution control, achieving the standards stipulated using traditional end-of-pipe measures is often beyond the technical and economic capabilities of small mills (Gupta undated).

The National Productivity Council (NPC) estimated that it would cost a typical 30 tonne per day mill 1140 rupees per tonne of paper (approx. 10% of total turnover) in treatment costs to achieve a final BOD concentration of 50mg/l. At present, operating profit margins for agro-based mills without wastewater treatment are in the range of 12-14% with net profit margins below 10%, thus the installation of wastewater treatment under these conditions would make the mills economically unviable (Gupta undated). However, the NPC concluded *that if waste minimisation measures were adopted, operational profits would rise to a level* where chemical recovery would become economic, see Box 3.3c below.

Box 3.3c Case Study: Waste Minimisation Options for a 25 Tonne per day Agro-Based Pulp and Paper Mill

The waste minimisation options for a 25 tonne per day pulp and paper mill, producing an average of 15 tonnes per day of bleached printing and writing paper and 10 tonnes per day of unbleached kraft paper using 67% mixed agri-residues (rice and wheat straw, bagasse and elephant grass) were analysed as part of the National Productivity Council/United Nations Industrial Development Organisation (UNIDO) Cleaner Production Technology Initiative.

Sixteen waste minimisation options were identified as being technically and economically viable. These included recovery of fibre from various sections of the machine to reduce overall fibre loss, water conservation and reuse, raw material cleaning and solar evaporation of the black liquor. Eight of the feasible options were implemented and a pollution audit carried out before and after. It was found that after the implementation of the measures BOD, COD and suspended solids were reduced by over 30% and the operational profit increased from between 12 and 14% to over 16%. The net profit increased from under 10% to above 14%. Due to the reduction in pollutant load the initial investment cost of a waste water treatment plant was estimated to be reduced by 24% and the annual operation and maintenance costs reduced by 34%.

Hence, the study concluded that installing a waste water treatment plant for this mill would be economically viable after the implementation of waste minimisation measures as a net profit of 8% could still be achieved.

Source: Gupta undated.

Box 3.3d Case Study: Amrit Paper Mill, Punjab, India

Amrit Paper Mill is an integrated pulp and paper mill which was set up in 1950 and is part of a diverse family business which includes vegetable oil and potato crisp production. It originally produced 30 tonnes per day of pulp and now produces 90 tonnes per day and employs approximately 1000 people.

It uses a mixture of raw materials, usually 20-25% rice straw, 20-25% wheat straw, 10% bagasse and 20% sarcandia, a wild grass. Procurement of the raw materials requires the involvement of a large number of people. The bagasse is supplied by local sugar mills where it is in surplus but the rest of the raw materials are collected from local people. Amrit has contracts with between 500 and 600 farmers for their straw. Nearby farmers deliver directly to the mill and receive cash. Middlemen are used for more distant farms where the farmer will be paid 0.8 rupees per kg of straw. Approximately 1kg of straw is obtained per kg of rice so this increases a farmers' income from the rice crop by about a fifth, the current price being approximately 4 rupees per kg of rice. The limiting radius of economic collection is approximately 100km.

Using a range of raw materials has the advantage that they are not all harvested at the same time, however a large amount of organisation and storage facilities are still required. Of the 300 acre mill site 250 acres are used for storage. Some of Amrit Paper's wastewater is used for irrigation and the company has been researching alternative methods of chemical recovery. None of the processes mentioned in Box 3.4a seemed worthwhile investing in so Amrit is developing an alternative in which the black liquor can be concentrated sufficiently to be burnt by the addition of rice husks. They have patented the pilot process and are currently seeking funding to develop a commercial plant.

Amrit produces paper at reasonable costs which is of lower quality than wood pulp but which can be used for a variety of paper products. The company specialises in low grammage paper with 1200 tonnes per month going to newsprint for the Economic Times of India, 600 tonnes per month going to lottery printings and 500 tonnes per month going to notebooks and printed books. Amrit is marketing its paper as treefree using the slogan 'no tree is cut to make Amrit paper' and there has been interest in this from the hamburger chain, McDonalds. The mill is profitable although they rely on government subsidies to some extent.

Source: Interviews with Mr Khaitan and colleagues, Amrit Paper.

Box 3.3e Case Study: Pudumjees Pulp and Paper Mill, Pune, India

Pudumjees Pulp and Paper is one of the largest speciality paper manufacturers in India, controlling 80% of the speciality market. It produces approximately 35 tonnes per day of bagasse pulp and 65 tonnes per day of speciality paper from bagasse pulp, waste pulp and market wood pulp. It had an annual turnover of Rs 854.7 million in 1993-94 and is one of the most profitable mills in the country (Economic Times of India 1992).

Bagasse is procured from 4-5 sugar mills within a 200km radius of the mill and the mill produces a range of speciality papers including, glassine paper, bond, security and passport papers. Their products are mainly consumed in the domestic market and one of their major customers is the Indian government.

Pudumjees have used various alternatives to a conventional chemical recovery system in order to reduce their pollution. In the 1970s the mill set up demonstration plots to convince local farmers to use their effluent as irrigation water, allowing more than one crop per year. This was partially successful but as the amount of agricultural land in the area began to decrease it became insufficient for the volume of waste water produced by Pudumjees. As an interim measure the mill offered interest free loans to local farmers for sugarcane cultivation and guaranteed the marketing of their produce in a bid to increase the area under production.

By the mid eighties the mill was treating its effluent using an anaerobic system to generate biogas. However, this will not be sufficient if the mill expands its bagasse pulping capacity which it is hoping to do and Pudumjees are considering installing a 30 tonne per day pilot pulping plant based on ethanol and water. This procees gives a higher pulp yield than sodium hydroxide pulping, produces solid lignin as a by-product which can be used as a fuel or converted into value added products and allows chemical recovery.

Sources: Correspondence with Dr Khanolkar, Pudumjees Pulp and Paper, Economic Times of India 1992, Pudumjee Pulp and Paper Company Literature.

3.4 Thailand

There are currently four pulp mills in Thailand with a total production capacity of 238,000 air dried tonnes per annum. Of this 10,000 air dried tonnes is rice straw, 69,000 is bagasse and the remaining 160,000 is a mixture of bamboo, eucalyptus and kenaf pulp from the Phoenix Pulp and Paper Company (see Box 3.4a below). Total capacity utilisation is between 80% and 90%. The Phoenix Pulp and Paper Company was the first company in the world to produce kenaf pulp commercially and it is the only company in Thailand producing market pulp.

Box 3.4a Case Study: Phoenix Pulp and Paper Corporation, Thailand

The Phoenix Pulp and Paper Corporation was the first company to produce kenaf pulp commercially. It originally solely pulped kenaf but due to a variety of problems the company recently introduced eucalyptus and bamboo pulping streams and kenaf now accounts for only 5-10% of pulp production.

The Phoenix Pulp and Paper Corporation was established in 1975 as a joint venture between Ballapur Industries, India, the European Overseas Development Corporation (Asia), and Thai partners from the Ministry of Finance and the Industrial Finance Corporation. A mill was built in north east Thailand as part of a government initiative to develop the north of the country and it began production in 1982.

The mill was purpose built to pulp kenaf, which was grown by local farmers under a scheme where Phoenix guaranteed to buy the crop. Although the use of kenaf by Phoenix was featured in numerous publications there were significant problems in pulping and marketing kenaf. Production of kenaf reached a maximum of over 13,000 tonnes per annum in 1986. By 1993 this had dropped to approximately 2,000 tonnes.

The main problem was guaranteeing a continuous supply of high quality kenaf at an affordable price. During the planning of the mill Phoenix estimated that annual kenaf cultivation in the area, which was primarily grown for bag manufacture and to supply hessian mills, varied from approximately 520,000 to 1,360,000 acres. The variation in annual production depended mainly on farmers anticipation of a worthwhile market for their produce. Since the total annual requirement for Phoenix was approximately 10% of the normal area under cultivation, the company was confident that the procurement of an assured supply would be relatively straightforward if the current market price was matched and would not lead to unhealthy competition with established industries. In addition they thought that from the farmer's point of view harvesting kenaf for Phoenix would be easier than for other industries as it could be left until the crop had seeded, hence the seed could provide an additional income and the rice crop could be harvested first.

Phoenix purchases kenaf directly from farmers either at the mill itself or at one of 10 collection centres within a 165 km radius of the factory site. Payment is in cash, immediately if the kenaf is delivered directly to the mill or after seven days if delivered to the collection centre. The minimum guaranteed price was based on the previous year's growth rate and the area of kenaf under cultivation although the actual purchasing price may be higher than this due to outside factors such as the price of alternative crops.

In the event, the price that Phoenix had to pay their suppliers turned out to be far higher than they had anticipated. In their calculations Phoenix had assumed that they would be able to procure 200,000 tonnes of kenaf stalks at a price of 590 Baht per tonne. During the start up of the plant the mill was paying 800-900 baht per tonne and during the year 1981-82 was only able to procure approximately 100,000 tonnes at a price of 900-1000 Baht per tonne, a 60% increase in price. During the year, 1989-90 the purchase price of kenaf was 1200 Baht per tonne at a 10% moisture basis when delivered directly to the mill and 1,100 at a collection centre (average price of transportation from the collection centre to the mill was 200 Baht per tonne). It seems that although Phoenix had guaranteed to buy kenaf from the farmers alternative crops such as cassava took precedence.

Although kenaf produces high quality pulp, this is dependent on the quality of the raw material, particularly on the moisture content. A freshly cut kenaf stalk contains up to 75% moisture and will only be accepted from farmers when they have dried it to 40% moisture content maximum. It has to be stored very carefully to prevent large losses as it is very vulnerable to fungal and micro-biological attack.

The mill uses the sulphate pulping process and there were a variety of production problems associated with using a new material such as pitch being deposited and choking the felts and wires and the slow drainage of the pulp. However, these were much easier to overcome than persuading conservative paper makers to make the parameter changes required for their machines to use kenaf pulp and marketing kenaf pulp and paper. Despite efforts to expand the market for kenaf it is currently only really competitive in the specialist paper market. It makes a cheap substitute for hemp cigarette papers and a small niche market has been established for 'treefree' kenaf paper, particularly in Japan.

These problems led Phoenix to diversify its raw material supply base and it now has pulping lines for bamboo and eucalyptus as well as kenaf. It took time to get the pulping process right for bamboo and they are now trying to develop the market for bamboo pulp. The markets for eucalyptus are well established but ensuring a continuous supply requires a farm scheme similar to that which they had in operation for kenaf, in which the company supply seedlings, give advice to growers and guarantee to buy the crop since public land is no longer allowed to be leased for plantations.

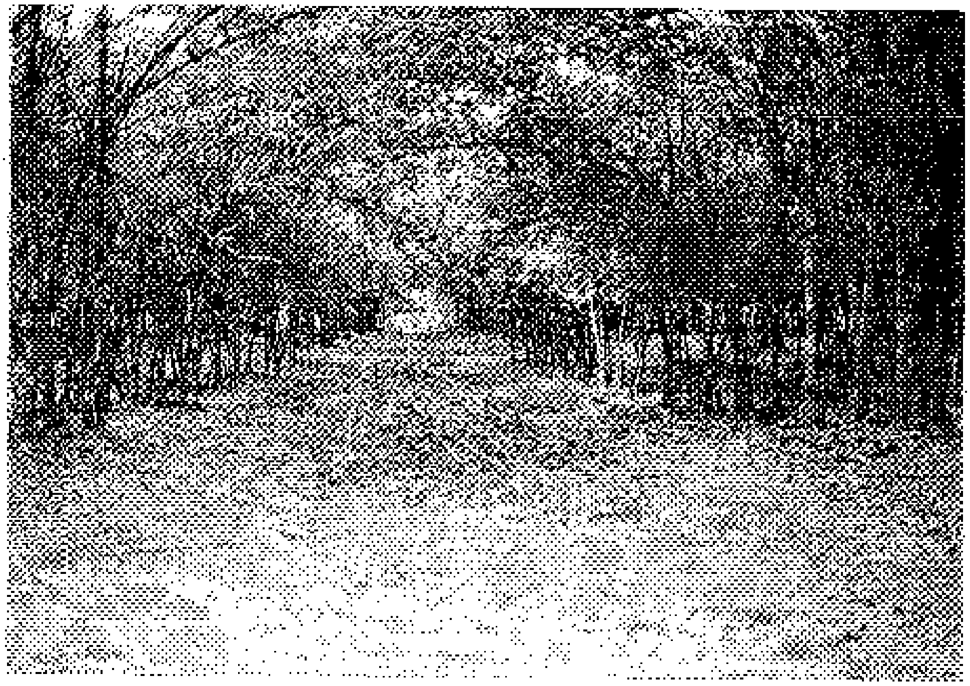
Phoenix was able to invest in research, develop new purpose designed technology, marketing strategies, survive near bankruptcy, expand production capacity and build a second plant due to highly preferential terms from both local and international investors. The corporation received Thai Board of Investment priviledges, including an 8 year exemption from corporate income tax and the right to carry forward any losses and also secured US$ 155 million worth of interest free and low interest loans.

Sources: Interview with PK Paul, Managing Director Phoenix Pulp and Paper Corporation February 1995, Swiss Bank Corporation Equity Research March 1994, Mittal 1990, Paul 1994a, PPI June 1994.

Figure 3.4b Kenaf Plantation and Kenaf Stack at Phoenix Pulp and Paper Public Company Ltd, Thailand

Photograph courtesy of Dr Subhash Maheshwari, Phoenix, Thailand

Figure 3.4c Bamboo Nursery and Bamboo Plantation, Phoenix Pulp and Paper Public Company Ltd, Thailand



Photograph courtesy of Dr Subhash Maheshwari, Phoenix, Thailand

3.5 The Philippines

The three main non-wood fibres used to produce pulp and paper in the Philippines are abaca (*musa textilis* also known as manilla hemp), salago (*wikstroemia*) and maguey (*agave cantala*). Abaca and maguey are both farmed whereas salago is gathered from the wild.

It is estimated that there are approximately 48,000 abaca farmers, 1,800 maguey farmers and 1,600 salago gatherers in the Philippines. Most abaca farms are very small with the average land holding being approximately 1-2 ha. Large farms may employ fibre strippers during harvest time otherwise all the work is done by the farmer. There are also some farmers cooperatives which organise collective marketing of abaca and are able to provide farmers with greater access to finance.

Abaca is the most lucrative fibre to farm with established markets for its use in speciality papers such as teabags, meat-casings and cigarette papers. Maguey fibres produce low grade papers and salago is used to make speciality papers such as currency and bond papers (Fibre Industry Development Authority undated).

Traditional varieties and methods of extraction are used resulting in low productivity and returns to farmers are low. Consequently, fibre crops are not usually the main source of income but provide a ready source of additional cash (Marges 1995 pers comm).

3.6 Conclusions

In developing countries a significant proportion of pulp is produced by small mills from locally available non-wood fibres, the majority of which are agricultural residues. The provision of non-wood fibres and the production of paper from these fibres is a relatively important source of income in many cases, particularly in rural areas.

Many non-wood mills in developing countries are inefficient and highly polluting due to their use of inappropriate or inefficient technology and lack of resources. As environmental pressure grows and any state support is reduced, small non-wood mills are likely to find it increasingly difficult to compete and survive in the future.

However, some mills in developing countries show that paper production from non-wood fibre is not inherently inefficient and dirty. Examples such as Phoenix's production of bamboo and kenaf pulp and the Tamil Nadu bagasse mill in India show that paper production from non-wood fibre can be clean, efficient and competitive, although both required financial support from governments or international agencies to start up. There are relatively simple measures which can be taken to reduce the pollution intensity of non-wood mills and improve their productivity (as illustrated by the case study in Box 3.3c). More research is needed into chemical recovery for small mills and alternative pulping technologies. Financial assistance will be required if small mills are to meet environmental standards without going out of business.

4 THE USE OF NON-WOOD FIBRES IN DEVELOPED COUNTRIES

4.1 Introduction

At present only a tiny proportion, approximately 1% (Assumpçaõ undated), of the pulp produced in developed countries is made from non-wood fibres. However, there have been various initiatives on both agricultural residues and fibre crops in countries ranging from the USA and Canada to the UK, the Netherlands and Australia. A diverse set of interest groups with different motivations for their involvement have been working on these initiatives.

The interest from environmental organisations stems from the belief that a greater utilisation of non-wood fibre would reduce the pressure on natural forests and the need for large scale plantations (e.g. Friends of the Earth, Rainforest Action Network) and that small mills based on locally produced non-wood fibres could support the local economy and reduce the need for long distance transportation of fibre, pulp and paper products (e.g. Bioregional Development Group).

The impetus for governmental initiatives and farmer interest in non-wood fibres often stems from declining farm incomes and the scale of food surpluses. Initiatives such as those taken by the Dutch, United States, British and Australian governments have investigated the possibilities of fibre crops as a means of supporting farm incomes whilst producing a useful product which could potentially supply a local industry.

The fibres which have been researched in each country are those which are already available there or are particularly suited to the local climatic conditions. This section outlines some of the studies that have been made into the potential for non-wood fibres in various countries, the reasons for their inception and the outcome of the initiative.

4.2 Fibre Crops

4.2.1 Hemp

The non-food crop sector is very small in the EU, currently accounting for less than 1% of the total agricultural area (Riddlestone and Desai 1994), however there are measures to promote non-food crops as they are seen as a potential means of reducing agricultural surpluses, maintaining rural prosperity and broadening the economic base of the countryside (e.g. Onna 1994). The UK government has a budget of £5 million for its LINK Crops for Industrial Use Programme, one of the principal aims of which is to research the production and processing of plant fibres, the main applications of which are likely to be in paper, particle board and construction materials (LINK 1993).

Hemp is one of the crops which has been traditionally grown for paper in the EU and attracts one of the highest subsidies, approximately £600/ha for the 1995/96 growing season (NFU 1995). For some uses, including paper, it can be grown on set-aside land. Some hemp is being grown in France and Spain and in 1992 the first licences were granted to British farmers to grow a low narcotic variety of hemp since it was banned under the Misuse of Drugs Act in 1971.

In 1989, the Dutch Ministry of Agriculture set up a research programme to examine the feasibility of a pulp and paper industry based on hemp. The programme is funded by the Ministry of Agriculture and local authorities and aims to determine whether a pilot plant should be established. Results from the marketing review found that chemi-thermo mechanical pulp (CTMP) produced from hemp had slower drainage properties than wood pulp due to the presence of short fibres from the core. Quality advantages could be gained by separating the core and bast fibres, although this would be expensive. The report concluded that the best market for hemp would be the speciality paper market where the bast fibres are highly valued as whole stalk hemp could not compete with wood pulp under present market conditions (Onna 1994).

Box 4.2a Case Study: Hemcore, UK

Hemcore was founded in 1993 by two East Anglian businessmen. The three reasons which were given for the move into hemp production were:
1) farmers were looking for alternative crops to alleviate the pressure from over-production in the main food crop arable markets;
2) there were a variety of market openings for hemp, including fibre for paper and textiles, the core as livestock bedding and the seed for bait and birdseed;
3) environmental benefits were seen as coming from hemp production both in the growing of the crop and in the replacement of synthetic or imported products in the market place.

Farmers needed quite a lot of convincing that it was worthwhile growing hemp. Farmers grow it under contract to Hemcore who guarantee the price, currently £55 per tonne. In 1995, there were about 50 farmers involved who together grew 2,500 acres of hemp. Hemcore are hoping to triple this area in the near future. Most farmers involved are growing it as a break crop between cereals, switching from crops such as peas and beans and oil seed rape. Yields are approximately 3 tonnes of whole stalk hemp per acre and in terms of profit it is on a par with the crops that it has replaced.

Hemcore separate the bast fibres from the core fibres as they have two distinct markets. The high value long bast fibre can be used in the paper and textile industry and the core fibre is used for animal bedding. So far the biggest market has been for horse bedding. For the fibre to be used for pulp production it has to be processed in continental Europe as there are no facilities for pulping hemp in the UK. The current market for the pulp is the specialist market e.g. tea bags, bank notes, bible paper, but Hemcore believes that there could be a significant market for hemp pulp as a paper improver i.e. mixed with other types of pulp to improve properties such as strength but this would require new pulping facilities. At present the fibre is being sold to pulp companies for approximately £300 per tonne but the company would like to double this price as the process of separating the bast from the core fibres is very expensive and hemp pulp prices are around £1000 per tonne.

Hemcore's biggest constraints at present are the lack of processing facilities and the need to develop the markets for hemp fibre.

Sources: Ian Low PIRA Conference 1994, Stuart Carpenter pers comm, Hemcore pers comm, interview with Robert Lukies, Hemcore Chairman, March 1995, Financial Times 1994.

Box 4.2b Case Study: The Bioregional Fibres Project - Local Production for Local Needs

The Bioregional Development Group, an NGO based in southern England is investigating the potential for UK grown hemp and flax crops to provide a local alternative to imported wood pulp and textiles. They envisage the long fibres going into textile production with the textile waste being mixed with hemp core fibres to produce high grade pulp which could be combined with locally collected waste paper or straw pulp.

The potential benefits of such a project are said to include:

- reducing imports
- reducing transport and therefore pollution and global warming
- creating small-scale rural industries and jobs, encouraging rural regeneration
- helping to reduce the exploitation of people and the environment of less developed countries.

The Bioregional Development Group concluded that the most appropriate technology was the Bivis machine which is being used in France. They are currently investigating alternative pulping technologies. They have estimated the costs and potential revenue of an 8 and 24 tonne per day pulping plant (see Table 5.3e below for their estimation for an 8 tonne per day mill) and are now seeking partners and funding for a pilot plant.

Source: Riddlestone and Desai 1994, Bioregional Fibres leaflet.

4.2.2 Kenaf

In both the USA and Australia, a significant amount of money and research has gone into developing a kenaf newsprint industry. So far none of the intiatives have resulted in any commercial production due to the lack of industrial partners and financial backing.

Australia

The Australian Northern Territories Department of Primary Industry and Fisheries began investigating the feasibility of establishing a pulp industry based on kenaf and other non-wood crops in 1987 after the devaluation of the Australian dollar in the mid 1980s. Some imported grades of printing paper had become prohibitively expensive and this had led publishers to seek alternatives. The local newspaper publisher, News Corporation was initially involved in the project but subsequently lost interest. The investigation included studies into crop agronomy and growth, pulping tests and paper production technology, mill location analysis, marketing and farm and mill economics (Hooper 1988). Although the study showed positive prospects for a pulp and paper industry based on kenaf the project lapsed in 1991 for want of a commercial partner and was disbanded during a round of government austerity measures (Hooper 1995 pers comm).

Another study into kenaf took place in Queensland between 1984 and 1988 where the possibilities of introducing it as a new crop into the Burdekin River Irrigation Area were investigated by the Queensland Department of Primary Industries and a Sydney based company, Ankal Pty.

There were two motivations for this initiative. The first was Ankal's interest in the construction of a Aus$240 milllion mill which would require 300,000 tonnes per annum of dry stem kenaf. The second was the interest in alternative crops in the Burdekin River Irrigation Area where a dam had been constructed to enable an expansion of sugar cane whose prices had slumped (Hazard *et al.* 1988).

Although this study concluded that kenaf would be profitable for farmers in the area it also illustrated the difficulties in establishing an industry based on kenaf. Farmers will not be willing to risk introducing a new crop unless they have an assurance that there is sufficient infrastructure for harvesting, handling and processing the crop and that the returns to them will be at least as good as for alternative crops (Hazard *et al.* 1988). The investment required to establish a commercial mill is usually estimated in the hundreds of millions of pounds which companies will not be willing to risk unless they have an assured supply of high quality raw material resulting in a 'Catch 22' situation.

USA

Research into kenaf has been going on in the USA since the 1950's when the US Department of Agriculture concluded that it was the plant that had the greatest potential as a renewable fibre resource. Research continued during the 1960s and 1970s and in 1979 the American Newspaper Publishers Association and the paper company International Paper carried out newspaper manufacturing runs at an International Paper mill. In 1981, they carried out a commercial scale newsprint run which demonstrated the feasibility of a newsprint system based on kenaf (Kugler 1988).

In 1986, the USDA (in a consortium which included Agrifuture Inc. and the Bakersfield Californian newspaper) started a $225 000 demonstration project which aimed to promote the use of kenaf for pulp and paper making at established mills in the southern US. This included demonstrating the potential of kenaf newsprint by running pulping trials and printing 60,000 copies of the Bakersfield Californian on kenaf newsprint and comparing copies printed on wood-based newsprint. Sprout Bauer, the pulping company, reported that kenaf pulp cost less to make than typical pine newsprint pulp, saving money in energy and chemicals and was superior in quality in most tests (Mayberry 1987). As for the newsprint, the USDA reported that the kenaf sheet '*was brighter and better looking with better ink lay down, extremely good print contrast, reduced rub-off and deeper, richer looking process color reproduction*' (Mayberry 1987).

However, the consortium failed to convince paper mills of the commercial viability of kenaf pulping and after visiting a number of mills the team admitted that '*the costs and risks were... unjustifiable from an industry perspective*' (Kugler 1989).

This led to the involvement of a paper company and paper machinery company in the project and a new aim; to investigate the feasibility of setting up a greenfield kenaf mill in Texas. The project investigated the attractiveness of kenaf to farmers in the area and technologies for harvesting the crop.

From field budgets and interactions with farmers, it was estimated that the projected returns for kenaf compared favourably with the returns that could be expected from white grain sorghum and upland cotton in the area. However although there were evident advantages in kenaf, it is high yielding, has lower input requirements, is less vulnerable to climatic and pest factors and requires relatively low management compared to other crops in the area, other factors such as the effect of kenaf on crop rotations and the risks associated with the introduction of a new crop needed to be taken into account in considering the likelihood of farmers adopting kenaf. The project also concluded that the one of the most immediate requirements was to build a machine which was specifically designed to harvest kenaf rather than relying on models designed for other crops (Kugler 1988, Scott and Taylor 1988).

By 1988, 400 acres of kenaf were being grown in Texas. To supply the $360 million mill that they were planning to build would require 35,000 acres. The project members felt that they would only be able to find the financial backing for the mill if they had gained market acceptance for kenaf newsprint. To date this has not been achieved and although permission to build the mill has been granted, the project has no financial backing. Some of the kenaf grown in Texas is now being used to produce recyclable mouldings for car interiors and in board production (McClory 1995 pers comm).

4.3 Agricultural Residues

The agricultural residue with probably the best potential for papermaking is straw. Straw has been used as a paper making material in Europe for hundreds of years but there are very few straw mills remaining. One of the most well known was the Fredericia mill in Denmark which produced 40,000 tonnes of cereal straw pulp per year until 1989 when it was closed down on environmental grounds as it was discharging its wastewater directly into a river. It is estimated that it will cost £10 million to get it and running again. The company was a 50:50 venture with a farmers cooperative, with the farmers receiving a share of the profits as well as a basic per tonne price for their straw. The paper produced from this pulp was a direct alternative to eucalyptus paper (O'Brien 1995 pers comm).

There has been periodic interest in developing a straw based paper industry in various countries. The two biggest factors driving this seem to be the price of pulp and the availability and allowable means of disposal of straw. In the 1970s, four UK mills and a paper machinery company joined the Department of Trade and Industry in sponsoring work at the Paper Industry Research Association (PIRA) to develop a low pollution process for non-wood fibres. The main motivation for this venture appears to have been the high price of pulp which had tripled between 1972 and 1976. Once the price peaked the commercial investors lost interest (Dean 1995 pers comm). Interest in straw pulping has risen in several countries where the burning of straw has been banned (Paper Technology, July 1990).

Box 4.3a Case Study: Proposal for a Straw Mill in Hull, UK

In the early 1990s there was been another attempt to set up a straw pulp mill in the UK. This venture was spearheaded by S&W Berisford, a commodity trading company which owned British Sugar, in partnership with a Finnish consultancy and supported by farmers. British Sugar seemed the ideal company to be involved in such a project as they had the facility and expertise to organise the collection and transportation of the straw due to their experience in collecting 8 million tonnes of sugar beet a year from 11,000 farmers. The company employed 100 people to liaise with farmers and monitor the deliveries of 500,000 lorry loads of beets a day during the 120 day beet processing season. Berisford estimated that there was at least four million tonnes of available straw, over half of which was in the Eastern region where they collected their beet. Many of the beet farmers they were already involved with also had surplus straw.

However after an estimated four million pounds had been spent on research the project was abandoned. There are various interpretations as to why the project has not come to fruition. Certainly, whilst it was under discussion the pulp price dropped significantly and Berisford had financial problems and had to sell British Sugar. Some within the industry believe that the failure of this project indicates that non-wood mills will never be viable in developed countries, others that it was the design of the project that was at fault.

There is certainly debate about the scale of the project. The original conception was for a mill with 100,000 tonne per annum capacity, however this subsequently rose to 300,000 tonnes per annum and correspondingly costs rose from approximately £100 million to £300 million. In the wood based sector, new mills would not be built with a capacity below 300, 000 tonnes per annum due to the economies of scale associated with this level of capacity, however the logistics of procuring the raw materials for a straw mill and the need to develop the market for the product may have meant that a smaller capacity with the potential for expansion may have been a better bet.

Sources: O'Brien 1995 pers comm, Paper Technology July 1990.

Box 4.3b Case Study: Straw Mills in Canada

Al Wong left the wood pulp industry to set up Arbokem, a company which is developing an alternative process for pulping non-wood fibres. His ultimate aim is for a network of small regionally based mills producing pulp from agricultural fibres.

The Arbokem process is based on potassium pulping with hydrogen peroxide bleaching. The Arbokem process is based on the more expensive potassium, rather than sodium, chemicals because it dramatically reduces the effluent problems, producing by-products of potassium carbonate and potassium sulphate which can be sold as fertiliser components. The build up of silica is prevented by 'bleeding' the liquor.

A commercial demonstration plant, costing Can$ 2 million has been operating since 1994 and is currently producing 1500 tonnes of bleached wheat straw, flax straw and abaca pulp annually. The abaca pulp is used for teabags and some of the wheat pulp is used as food fibre. Finding appropriate equipment for the plant was difficult as Western machinery manufacturers do not tend to make small scale equipment. The digester was custom made in China and the extruder used for handling the long flax fibres was purchased from a food processing plant in the USA.

Arbokem has produced several types of paper; an agri-pulp paper from 75% wheat straw with 25% flax straw, a 'Downtown I' paper comprising 50% wheat straw, 20% non-deinked mixed office waste paper and 10% softwood kraft pulp and a 'Downtown 2' paper from 50% wheat straw pulp and 50% old corrugated cartons for commercial printing trials. The long flax fibres in the agri-pulp increases the tear and breaking strength of the paper. Arbokem can produce straw pulp for £250 per tonne which would seem to indicate the potential to make a decent profit as deinked recycled paper is currently selling for £500 per tonne.

Mr Wong estimates that to build a 20,000 tonne per annum mill would cost Can$12 million and require 45,000 tonne of straw per annum. Wong estimates that the effective economic radius for the transportation of straw is 20km. Farmers in the area seem interested in the venture and 20 have joined forces to provide Arbokem with the straw needed for the tests. Mr Wong estimates that selling straw to pulp mills could increase the income from one tonne of wheat by $15 and raise net farm incomes from $20.70 per acre to $45.70 per acre, a 220% increase.

Sources: Wong 1995, Riddlestone and Desai 1994, Riddlestone and Cox 1995 , Pulp and Paper 1993, Central Manitoba Farmer 1994.

4.4 Conclusions

There are two main motivations for interest in non-wood pulp initiatives in developed countries, a high pulp price (which occurs periodically) and the feeling in some circles that producing pulp and paper from non-wood fibre is more sustainable and environmentally benign than producing it from wood.

This latter factor has led to environmental groups from countries ranging from the USA and UK to Japan promoting the use of non-wood fibres. The potential fibre requirements of a paper industry based on non-wood fibres has led to support from governments and farmers, who see fibre crops as a means of supporting farm incomes whilst reducing food surpluses.

The striking feature of all the initiatives which have begun in developed countries in recent years is that despite the interest shown, the research that has been done and the money which has been spent, not a single project has become a commercial reality. The main reasons for this seem to have been; lack of an industrial partner, lack of money and lack of an established market for the products. The critical factor seems to be the lack of an industrial partner. In some cases, pulp and paper companies have been involved at the beginning of the projects, usually when the pulp prices were high but have lost interest as the project has progressed. It seems unlikely that there will be any significant development in non-wood fibre pulp and paper without the support of established companies.

5 COMPARISON OF NON-WOOD AND WOOD FIBRES FOR PULP AND PAPER MAKING

5.1 Introduction

Sweeping claims about the relative merits, sustainability, technical characteristics and costs associated with using non-wood fibres for pulp and paper production, have been made by people on all sides of the non-wood fibre debate. Examples from those advocating their use include:

- 'kenaf could provide a more environmentally acceptable and cost effective means of meeting a large proportion of Australia's pulp requirements than timber' (Hazard *et al.*, Agriculture Branch, Queensland Department of Primary Industries 1988)
- 'non-wood pulps offer an impressive range of potential environmental benefits: saving forests, adding nitrogen to soil, producing natural herbicides, reducing the use of toxic chemicals in bleaching, reducing energy use in the pulping process and providing a means of adding strength to recycled fibre without using virgin wood' (Ayres, WorldWatch 1993)
- 'non-wood pulp is used as a substitute for wood pulp in consideration for preservation of the environments of the earth' (Association of Non-Wood Paper Promotion, Japan, undated)

Alternative viewpoints include:

- There are many NGOs who think that kenaf and other annual plants are the solution for future fibre needs. I do not believe this because the properties, costs, mill sizes effluents of straw and bagasse pulps all are not sustainable (Claes Hall, Aracruz International, 1995 pers comm)
- 'My suggestion is to go carefully and separate fiction from fact. The kenaf "bubble" re-occurs like the bamboo bubble ... the wheat straw bubble. One can't say that they will not work but experience has shown that most of the enthusiasm is in the minds of the proponents rather than usable, factual information......my suggestion is that you stick with eucalyptus and pine.' (Bruce Zobel, Zobel Forestry Associates, USA 1995 pers comm)

This section examines the basis for competing claims about the relative merits of alternative fibres by looking at the economic, environmental and social aspects of producing pulp and paper products from non-wood and wood fibres. The advantages and disadvantages of using non-wood fibre are summarised in Table 5.1a below.

Table 5.1a Advantages and Disadvantages of Using Non-Wood Fibres for Pulp and Paper Making

Stage of the Cycle	Advantages	Disadvantages
FIBRE SUPPLY		
Based on annual or perennial fibres or agri-residues.	Reduces need to exploit natural forest and for tree plantations.	May be problems associated with monocultures of annual fibres for example, fertiliser and pesticide use, impact on crop rotations, biodiversity. This varies with fibre, area and management regime.
	Use of agri-residues in some cases makes use of what otherwise would be a waste product.	Use of agri-residues may reduce the fertility of the soil if some are not ploughed back in
	Using agricultural land for annual fibres in developed countries can contribute to reducing food surpluses.	Replacing food crops with fibre crops could be detrimental in areas where food security is a problem.
	Can alter amount produced annually.	Harvested over a short period, therefore large storage space required to ensure year round supply. Significant deterioration problems may occur.
		Non-wood fibres tend to be bulkier than wood which increases transport and storage costs.
	Can support small scale mills, therefore a much lower level of capital investment is required. Small mills employ more people per tonne of pulp than large ones.	Unlikely to be able to support large scale mills; therefore do not get the benefits of economies of scale.
Contract with large number of growers required.	Provides growers with and additional/alternative income.	Dependent on growers. Fibre crops will only be grown and residues sold if farmers are coonvinced that the opportunity costs are higher and the risks and efforts involved lower than for alternative crops. This may vary from year to year.
	May support rural employment and economic viability.	

Stage of the Cycle	Advantages	Disadvantages
PRODUCTION		
Lower proportion of lignin than wood.	Less energy required to pulp fibre. Less energy and chemicals required to bleach fibre	If a chemical pulping method is used the lower amount of lignin results in less being able to be used as a fuel.
Higher proportion of silica than wood makes conventional chemical recovery systems inappropriate.		If alternative treatment is not utilised mills are highly polluting and chemical costs will be higher due to lack of recovery.
		Appropriate production technologies may not be readily available and may be more expensive than the wood equivalent.
	Alternative pulping systems which reduce the need for chemical recovery may produce useful byproducts.	Alternative pulping systems tend to use more expensive chemicals.
Industry is dominated by wood pulp producers and is conservative.		Little interest, research or investment in non-wood fibres by industry.
		Non-wood fibres perceived to be high risk. Papermakers reluctant to make required changes to their machinery to enable them to use non-wood pulp.
DEMAND	Niche markets for high priced speciality paper for which certain non-wood fibres have inherent advantages over wood.	Speciality market is small.
	Niche market for 'treefree' products for which premiums are payable.	Size of treefree market is unclear as is the level of premiums which may be paid.
	Market for long fibres to strengthen recycled fibres.	Very difficult to compete in the mass market due to the establishment of the wood based industry with their large economies of scale and cost of non-wood materials generally being higher than wood.

5.2 Fibre Supply

5.2.1 Logistics and Assured Supply

Advocates of non-wood fibres cite the fact that they can be supplied from agricultural residues and annual fibres grown by a large number of individuals as amongst the greatest advantages of the non-wood option. To the established paper industry this is perhaps its greatest disadvantage.

As discussed in Section 3, advocates of non-wood fibre argue that such fibres have the potential to provide raw material for paper production whilst reducing the exploitation of natural forest and the need for tree plantations. They further argue that non-wood fibres could provide farmers with an alternative or additional income and contribute to the rural economy (e.g. Rainforest Action Network 1995a, Rice *et al.* 1995, Ayres 1993). In some parts of Asia, non-wood fibres already contribute significantly to farm income. In contrast, for the established paper industry non-wood fibres pose a number of difficulties.

One of the most important issues for mill owners is guaranteeing an assured supply of consistently high quality raw materials. Probably the biggest constraint is the logistics of supplying a mill. The average capacity of wood based pulp and paper mills in 1992 were 149,000 and 60,000 tonnes per annum respectively and a typical modern softwood kraft mill has a capacity of 300,000 tonnes per annum (PPIC 1993). The industry is geared to working at these capacities which offer them considerable economies of scale.

It would be virtually impossible to supply a mill of this size using non-wood fibres. With the exception of bamboo, non-wood fibres are annual plants and can be harvested only during a few months of each year. Consequently, approximately 9 months supply needs to be stored in order to operate the mill continuously throughout the year. This problem can be addressed to some extent by using a range of non-wood fibres with different harvesting periods as Amrit Paper does (see Box 3.3c) but a large amount of fibres still need to be stored. Non-wood fibres are less dense than wood, hence transport and storage costs are high and a large storage area is required (raw material storage space takes up over two thirds of the Amrit Paper site). These costs can be reduced by baling and compacting the fibres. Although storage techniques are improving, significant deterioration of most non-wood fibres occurs during storage, for example up to 30% for kenaf.

Another major issue for mills is control over their raw material supply. Although some wood pulp producers have efficient outgrower schemes, the majority of wood still comes from corporate or state owned forests or plantations. The converse is true for non-wood mills. Almost all fibre used in non-wood mills comes from small scale growers selling relatively small amounts to the mill. Even for mills with a low capacity this requires formidable logistics. For example, Amrit Paper have contracts with over 500 farmers for their straw, which nevertheless only provides half the amount of fibre required by their 90 tonne per day mill.

Fibre supply is usually the limiting factor in the capacity of non-wood mills. Estimates of the distance over which it would be economic to collect raw materials range from a 30km to a 200km radius from the mill, with the most common estimate approximately 100km (e.g.

Khaitan 1995 pers comm, Paul 1995 pers comm, Wong 1995, Sadawarte undated). Beyond this, transport costs are too high and there are associated logistical and storage problems. This is one of main reasons that non-wood mills tend to be relatively small. The exception to this are mills based on bagasse which rely on sugar mills rather than farmers for their raw material. Bagasse is one of the easiest non-wood fibres to collect store and process which has resulted in large scale plants of over 300 tonnes per day being established in countries such as India, China, Taiwan and Mexico and new bagasse mills are scheduled to start up in the next few years in India and China (Sadawarte 1995). However, there are constraints to the expansion of this sector as bagasse mills require a cluster of sugar mills to be viable. There are plans to integrate the paper, sugar and alcohol industries in India in order to reduce potential conflicts of interest. Since most of the bagasse used by the paper industry is 'substitution' bagasse (see Section 3.3 above) another potential drawback of bagasse mills is the link between their raw material and fuel: if fuel prices rise, so too does the price of bagasse (Matharu 1995 pers comm).

Since the majority of non-wood fibres used to make paper are procured from agricultural crops, pulp producers are dependent on farmers' willingness to plant sufficient amounts of fibre crops and to sell them at a price that mills can afford. This in turn will depend on the financial return to farmers of fibre crops as well as the risks and management time involved compared to alternatives crops. The introduction of a new crop is usually seen as a high risk undertaking due to farmers lack of experience with the crop, possible changes to crop rotations and the potential for disease problems. Hence, farmers will require a financial return at least as good as they were getting for their traditional crops and an assured market if they are to be persuaded to introduce fibre crops.

The annual or perennial nature of non-wood fibres increases the risks associated with their use in the eyes of mill manager since the price and availability of these fibres can vary considerably from year to year which can cause pulp mills severe problems. If, after a fibre crops has been harvested a farmer decides to plant something different, the mill loses part of its raw material supply. The Phoenix Pulp and Paper Corporation nearly went bankrupt during the first few years of its existence due to raw material supply problems as the price of kenaf was substantially above, and the availability substantially below, what they had estimated when planning the mill (see Box 3.4a above). Clearly, the same applies to wood from private forest owners but the longer growing cycle of trees makes planning easier. If agricultural residues as opposed to fibre crops are used, these risks may be reduced since the primary reason that they are grown is for food.

In some areas of the developing world, selling crops or residues to paper mills makes a significant difference to farmers incomes. For example, Amrit Paper estimates that their purchase of straw adds an extra 20% to the value of a farmers rice crop (Khaitan 1995, pers comm). Recently, there has been increasing interest in the utilisation of annual fibre crops by the paper industry from governments and farmers in developed countries due to overproduction of food crops resulting in surpluses, falling prices and decreasing farm incomes (e.g. Onna 1994). Wong (1995) has estimated that if farmers in Alberta were paid $40 per tonne of straw delivered to his agri-pulp mill, the net income to farmers could be $35 per acre which in some cases could represent an increase of more than 50% in net farm income. In developed countries the substitution of food crops by fibre crops can contribute to a reduction in surpluses.

In almost every instance non-wood fibres have alternative uses which need to be taken into account in any assessment of their potential use in paper production. Bagasse is used as a fuel, bamboo has a myriad of applications including utilisation as a construction material and straw is used as animal fodder and bedding and as a soil improver. The availability of agricultural residues such as straw and bagasse for paper production depends on the price that mills will pay, the alternative uses of the residue and the effort involved in collecting the residue. In India, it took considerable effort to persuade sugar mills that it was worthwhile exchanging their bagasse for alternative fuel sources. There is a large amount of straw potentially available for the paper industry but a high proportion of that will be ploughed back into the fields, some may be used of as animal bedding and much of it is burnt. As straw burning has been seen as more and more undesirable, its utilisation in paper production is being seen as a way of reducing pollution and disposal costs.

5.2.2 Yield

There have been claims made about the greater productivity of certain non-wood fibre crops compared to the same acreage of wood. Comparisons need to made with care however, since the yield per acre of any species depends on the location, climate and the way that the crop is managed. Table 5.2a below shows average fibre and pulp yields per ha per annum. Care must also be taken to compare fibres which are used is similar paper applications, such as kenaf and hemp bast fibres with high quality softwood and straw to hardwood In general there does not seem to be a great difference in pulp yield per acre between non-wood fibres and comparable wood fibres in the same area.

Table 5.2a Average Annual Yields of Different Paper Making Fibres

Fibre	Fibre Yield (t/a/ha)	Pulp Yield (t/a/ha)
Scandanavian Softwood	1.5	0.7
Fast growing Softwood	8.6	4.0
Temperate Hardwood	3.4	1.7
Fast Growing Hardwood	15.0	7.4
Wheat Straw	4	1.9
Rice Straw	3	1.2
Bagasse	9	4.2
Bamboo	4	1.6
Kenaf	15	6.5
Hemp	15	6.7
Elephant Grass	12	5.7
Canary Grass	8	4.0

Source: Paavilainen and Torgilsson 1994

Atchison (1994) compared yields for kenaf and pine in the US and found that the productivity of an acre of land in producing fibre for chemical pulp was very similar. He estimated that pine plantations on good land yield up to 2 bone dry tonnes per acre per year and that the average commercial yield of kenaf was 6 bone dry tonnes per acre, somewhat lower than above. However, he concluded that the chemical pulp yield for the two plants was similar since only the bast fibre (approximately 30% by weight) is suitable for chemical pulp, approximately 1.8 tonnes per acre. Since pine is grown on a 20-25 year rotation only one twentieth of the crop needs to be cut annually whereas the whole kenaf crop needs to be cut and replanted each year.

5.2.3 Environmental Impact of Fibre Crops

There are potential pollution and disease problems associated with the growing of large areas of fibre crops although the extent of the problem depends on the individual crop and management practices. Most fibre crops are relatively hardy and disease resistant. Both hemp and kenaf are capable of outgrowing most weeds and their only significant disease problem is root knot nematodes. According to French growers, hemp needs no insecticides, fungicides or herbicides, however in the Ukraine insecticides are sometimes used and seed is routinely treated with fungicide (Riddlestone and Desai 1994).

It is very difficult to judge whether non-wood or wood fibres require more external inputs as the the amounts used seem to vary between individual growers and companies. Plantations that are not managed intensively might receive little or no pesticides and fertilisers whereas those that are intensively managed might use herbicides before planting and apply fertiliser at intervals during the rotation. Most hemp and kenaf growers seem to apply some fertilisers to the crop.

In the USA, the USDA project found that kenaf was less vulnerable to climatic and pest factors, had lower input requirements and required relatively little management compared to other crops in the area (Scott and Taylor 1988). In Australia, kenaf was grown using fertilisers and preliminary results showed that it had a lower than anticipated demand for nitrogen and a very low potassium requirement (Hazard *et al.* 1988, Hooper 1989). However, Aracruz Celulose which makes pulp from eucalyptus in Brazil estimates that in Espirito Santo eucalyptus requires less than one third of the triple superphosphate and one tenth of the potassium chloride fertilisers required by sugarcane in the same area.

Input requirements and disease problems can be minimised or exacerbated by management practices. In the report 'Kenaf Production in the Burdekin River Irrigation Area' the authors state '*It is assumed that kenaf will not be grown as a monoculture because of the likely agronomic problems, including an increase in the incidence of diseases, insect pest and weeds invariably associated with such a system.*' (Hazard *et al.* 1988). They suggest that kenaf should be rotated with crops such as maize and grain sorghum rather than sunflowers or cotton which have similar disease and insect spectrums to kenaf. The New Oji Paper Company in Japan which has also been running kenaf trials suggest that after growing kenaf for two years it should not be grown in the same place for a year (Tajima 1995 pers comm).

In some cases, insecticides and herbicides are also used when harvesting and storing crops. For example, kenaf contains up to 75% moisture when it is first harvested. Phoenix will only accept kenaf with a moisture content below 40% so farmers keep it until it has dried sufficiently. Whilst the crop is being stored it is very susceptible to fungal and microbiological attack and the ground is sprayed with insectiside before the kenaf is stacked. The extent of deterioration and moisture content significantly affects the pulp quality (Paul 1994a). In Australia, Ankal Pty harvested the kenaf dry by aerially spraying it with a herbicide to kill it rather than waiting for it to dry naturally (Hazard *et al.* 1988). This method increases the use of unpleasant chemicals, is extremely wasteful and spray drift causes the herbicide to fall in places that it is not required.

5.3 Pulp and Paper Production

5.3.1 Pulping

The difference in chemical composition accounts for some of the major differences in the ease with which wood and non-wood fibres can be pulped. The useful part of the fibre for the papermaker is the cellulose, which is held together by lignin, a tough resinous adhesive. To make paper the cellulose fibres must first be separated, which requires breaking down the lignin. Hence, the the lower the proportion of lignin, the lower the amount of energy required to pulp the fibre although the structure of the lignin and the exact process used also influences the ease with which it is broken down. It is easier to degrade the grass and straw lignin molecules than wood lignin molecules (Paavilainen and Torgilsson 1994). Table 5.3a below compares the pulping of reed canary grass which is grown as a forage grass in Scandanavia with birch which is imported from Russia to Scandanvia to produce pulp. The grass required a much lower cooking time to produce pulp with lower lignin content (indicated by the kappa number) than birch.

Table 5.3a Comparison of Birch and Canary Grass Pulping

	Reed Canary Grass	Birch
Yield (%)	50-53	51
Viscosity (dm^3/kg)	1300	1200
Cooking Time (minutes)	10	90
Effective Alkali Charge (NaOH %)	18	18
Kappa Number	9	18
Silicate (%)	3	0.03

Source: Paavilainen and Torgilsson 1994

The extent to which this is an advantage is dependent on the pulping process used. Mechanical pulping requires significant amounts of external energy and energy costs can be as much as 30% of total pulp production costs (Lahaussois and Kyrklund 1988). Therefore the lower lignin content of non-wood fibres confers an advantage in this respect. FAO (1989b) estimated that power consumption for mechanical pulps is approximately 30% lower for kenaf than wood. Mechanical pulps are usually used for applications such as newsprint which do not require high degrees of strength or long term brightness sicne mechanical pulps are weaker than chemical pulps and contain more lignin which which can lead to discolouration over time.

In modern chemical wood mills there is no need for external power generation since their entire demand can be supplied from energy generated by burning the black liquor (the spent pulping liquor) containing the removed lignin in the recovery boiler (Fellegi 1991).

Wood pulping technology is not totally suitable for non-wood fibres. Long fibres such as hemp and kenaf pose particular problems and have to be shortened before pulping on existing machines. This complicates the manufacturing process, uses more energy and increases the cost of production (Rice *et al.* 1995).

Pulp yields are dependent on the fibre and process used. Much higher yields are produced from mechanical pulping (over 90%) compared to chemical pulping. FAO found that the yield of chemical kraft kenaf pulp at 48% is comparable to that of softwood (Lahaussois and Kyrklund 1988) and similarly Paavilainen and Torgilsson found that the kraft process produced almost identical yields of reed canary grass pulp and hardwood pulp, see Table 5.3a above. In Thailand, pulp yields using the sulphate process yielded 46-47% kenaf pulp, 46-48% bamboo pulp and 45-47% eucalyptus pulp for the Phoenix Pulp and Paper Company (Paul 1994b).

5.3.2 Bleaching

Pulping alone cannot remove all of the lignin from the cellulose without damaging the fibres so unless the pulp is bleached it will be brown in colour. The amount of lignin remaining in the pulp and hence the amount of chemicals and energy required to bleach the pulp to the desired degree of whiteness depends on the fibre and pulping process used. Chemical pulp contains approximately 5-10% lignin and mechanical pulp significantly more (Kroesa 1990). Again the smaller proportion of lignin in non-wood fibres gives it an advantage over wood in this respect, as lower amounts of chemicals and energy will be required to bleach the pulp (Fellegi and Judt 1991). Some non-wood fibres are naturally very bright, for example sisal pulp can be up to 80% bright before bleaching (Wong 1995 pers comm).

5.3.3 Effluents and Chemical Recovery

Most modern wood based chemical pulp mills operate a chemical recovery system which retrieves the chemicals used during the pulping process from the effluent. There are three reasons for this, firstly, chemical recovery substantially reduces the level of pollution from the mill, secondly it significantly reduces the cost of chemicals since those that are recovered can be reused and thirdly the combustion of the black liquor provides power to the plant. It is estimated that incineration of black liquor and recovery of chemicals in advanced kraft pulp mills can eliminate over 95% of the BOD and COD load from pulping (Fellegi 1991).

Conventional chemical recovery systems used by wood mills concentrate the black liquor to approximately 65% (Khaitan 1994). Once it has reached this level it can be burned and the energy used by the mill. The presence of higher proportions of silica and hemicellulose and the lower proportion of lignin in non-wood fibres makes this process inappropriate for many non-wood mills. Most of the silica dissolves during the cooking process and remains as an undesirable constituent of the black liquor. This results in a black liquor with a high viscosity making it difficult to concentrate the liquor sufficiently to allow it to be burnt. This in turn deprives the mill of a low cost source of energy and requires an alternative means of disposing of the black liquor. The silica also leads to problems in washing the black liquor and the formation of silica deposits on the evaporators, pipes and storage tanks all of which reduces the efficiency of the recovery process (Assumpçaõ undated, unreleased).

These problems are most severe for agricultural residues, which have particularly fine fibres, exacerbating the viscoscity of the black liquor, increasing operational costs and reducing efficiencies (Khaitan 1994). The larger the mill the more likely it is to have efficient chemical recovery systems. Pulp and Paper International report that the large bagasse mills described in Section 2 all have efficient chemical and heat recovery systems (Sadawarte 1995).

The United Nations Industrial Development Organisation (UNIDO) reports that there are problems in designing a continuous, practical and economic recovery system for mills with a capacity below 3,000 tonnes per year. In modern large scale pulp mills the investment required for a chemical ecovery system is approximately 30% of total investment costs (Fellegi and Judt 1991). The estimated cost of a modern recovery system for a 10,000 tonne per year mill is approximately US$ 4.5 million (Assumpçaõ 1993). These have been designed for large mills and scaling down results in lower efficiency and increased relative investment costs per tonne of pulp (Fellegi and Judt 1991). The majority of non-wood mills have capacities of less than 10,000 tonnes per year and very few are able to afford a modern recovery system. Consequently, most non-wood mills are highly polluting. The situation is exacerbated for mills in developing countries which often use outdated or second hand machinery which was originally designed to pulp wood (Sadawarte 1995).

Environmental standards and enforcement in most countries are being increasingly tightened posing a considerable problem for non-wood mills. In India, it has been estimated that the load of suspended solids, BOD and COD is about six times higher, and the colour about ten times darker, from an agro-based mill without recovery compared to a wood based mill with recovery, see Table 5.3b below (Sadawarte 1995). High pollutant levels have led to restrictions in expansion of non-wood in India (Khaitan 1995 pers comm) and mills in China and Denmark have been forced to close on environmental grounds (Zhang 1995, O'Brien 1995).

Table 5.3b Pollutant Loads per Tonne of Pulp from Wood and Non-Wood Mills in India

		Agro-based without recovery	Wood based with recovery
Volume	(m^3)	200	130
Total Solids	(kg)	680	195
COD	(kg)	500	80
BOD	(kg)	160	20
Organics	(kg)	350	40
Sodium	(kg)	90	20

Source: Sadawarte 1995

No doubt, many of these problems could be minimised or eliminated with better technology. However, in comparison with the level of investment in research and development in wood based technology the amount spent on non-wood based technology is very small (Smith 1995). Nevertheless, there are numerous initiatives being undertaken by individual mills, and government research institutes, many under the auspices of UNIDO which are attempting to address the problem of pollution from non-wood mills.

Two main areas of research may be singled out: the development of an efficient and economic chemical recovery process for non-wood mills and the development of alternative pulping techniques which would remove the need for chemical recovery. Box 5.3c outlines some of the current research initiatives into chemical recovery for small non-wood mills and Box 5.3d some alternative pulping processes.

Other alternatives which have been suggested include common chemical recovery plants shared by a number of non-wood mills in the same area or for the effluent to be sent to a wood based mill with a modern chemical recovery system. Mixing the effluent with that from the wood mill could allow it to be sufficiently concentrated to be burnt.

Box 5.3c Chemical Recovery for Small Non-Wood Based Mills

Prior Desilication of Black Liquor
This can be achieved by lowering the pH, by flocculation or by the addition of various chemicals. The disadvantage of all of these methods is that none of them ensure selective precipitation of silica without co-precipitating lignin. If lignin (the main organic component) is removed, less energy can be generated from burning the black liquor and the operation becomes uneconomical.

Direct Alkali Recovery System
In this case the black liquor is burned with iron oxide in a fluidised bed combustion furnace and sodium hydroxide is regenerated from the complex. The system is relatively simple but DARS has been a commercial failure for mills which have used it. In one case the mill introducing it went bankrupt, unable to cope with initial teething problems.

Copeland Fluidised Bed Process
In this system a fluidised bed reactor is used for thermal oxidation of the organic matter with the formation of sodium carbonate. Commercial operators have found that the fluidised beds frequently crash without warning, requiring long shut-downs.

Gasification and Cracking Processes
These involve subjecting the black liquor to high temperatures (300-800 degrees Celsius) in the absence of air whilst maintaining it in a liquid state. Experience in the US and Europe has found these techniques to be unreliable and their operation sporadic.

Sources: Khaitan 1994, Chaudhuri 1995.

Box 5.3d Alternative Chemical Pulping Techniques

Alcohol Pulping
This process separates the cellulose from lignin and other non cellulosic fibres using alcohol and water. The alcohol can be easily recovered and reused and the lignin can be sold as a by product. This has the advantage that an innocuous effluent is produced, however, it is relatively expensive. Alcohol pulping is being used on a semi-commercial basis in Germany and Canada using wood as a raw material and in India, Pudumjees Pulp and Paper Company has patented the PUNEC process which is based on alcohol and water and are considering establishing a 30 tonne per day plant based on this process to pulp bagasse (see Box 3.3e above).

Potassium Pulping
If sodium hydroxide is replaced by potassium hydroxide, effluent problems can be dramatically reduced as the potassium forms by-products of potassium carbonate and potassium sulphate which can potentially be sold as fertiliser components. However, the price of potassium hydroxide is much greater than sodium hydroxide so this process is unlikely to be financially viable unless sufficient revenue can be generated from the potassium by-products. The potassium pulping process is currently being used in Arbokem's demonstration plant in Canada. See Box 4.3b above.

Sources: Riddlestone and Desai 1994, Pulp and Paper September 1993, Wong 1994.

5.3.4 Paper Making

The problems with using non-wood pulps for paper making include, slow drainage, a limit to the dryness on the press, poor wet strength, a tendency to blister when dried rapidly and high shrinkage problems (Sadawarte 1995). The low drainability characteristics of non-wood fibres causes runnability problems which decreases paper making productivity (Assumpçaõ 1993). These problems can be reduced by using a mixture of long and short fibres and keeping the short fibre component below 50% (Paavilainen 1993). In China, Kuang (1991) recommends four ways of improving the runnability of straw pulp, removing the fine fraction, blending in some long fibres, removing some of the hemi-cellulose or adding dewatering agents.

5.3.5 Costs and Competitiveness

The costs of producing pulp and paper from wood and non-wood fibre cannot be easily compared. The differences in scale, subsidies (both implicit and explicit) and the dominance of the wood based industry makes it almost impossible to judge whether or not non-wood fibre would be able to compete on a 'level playing field' basis. However, in terms of current economic competitiveness the consensus appears to be that in most countries non-wood pulps cannot compete with wood pulps in the mass market under current conditions (e.g. Onna 1994, Rice *et al.* 1995).

From the few direct comparisons that have been made, production costs do not vary greatly between different types of fibre. The major difference lies in the raw material costs with non-wood fibres being significantly more expensive.

The most comprehensive comparison undertaken was the FAO study in the late 1980s which compared the investment costs for a kenaf and a wood mill. The study stressed that the figures should be taken as an estimation only due to the difficulties in obtaining data and the wide variation in costs between countries looked only at investment costs, not operating costs. They found that the main differences were:

- Transport and storage costs would be higher for kenaf
- The low density and low drainage rate of kenaf pulp means that a kenaf chemical pulp mill would need a larger digester and higher washing capacity, screening and dewatering equipment than a wood based mill
- The preparation of kenaf (assuming whole stalk pulping), which only requires cutting, is simpler than the preparation of wood, which requires debarking, slashing and chipping
- The energy requirements of a kenaf mill would be lower.

Overall, the investment costs in a kenaf mill would be between 5% and 7% higher depending on the pulping process (see Table 5.3e below).

Table 5.3e   Investment Cost Comparison Between a Kenaf and a Wood Mill

Transport	+10	--
Storage	+10	--
Preparation	--	+15
<u>Pulping</u>		
Cooking	+10	--
Screening	+10	--
Washing	+10	--
Dewatering	+10	--
Refining	--	+15
<u>Power Plant</u>	--	+10
Chemical Recovery	+5	--
Bleaching	--	+5
Paper Machine	+3	--
<u>Total</u>		
Total Kraft Mill	+7	--
Total CTMP Mill	+5	--

Source: Lahaussois and Kyrklund 1988

FAO concluded that one of the main difficulties in setting up a kenaf mill would be the supply of raw materials. According to their calculations, the payments which would be required before farmers would grow kenaf would be double the amount that the mill would be prepared to pay. These calculations were based on the assumption that 6 bone dry tonnes/ha of kenaf would be obtained and FAO conclude that with higher yields the costs of growing kenaf on a per ton basis would be much lower and farmers and pulp manufacturers could reach a mutually acceptable price (Lahaussois and Kyrklund 1988).

More recently, a Dutch Ministry of Agriculture study which examined the feasibility of a pulp and paper industry based on hemp in the Netherlands similarly concluded that although production costs do not vary much between fibres, non-wood fibrous material purpose grown for the paper industry are invariably more expensive than wood and therefore the cost of non-wood fibre paper will be higher. Like FAO, they felt that the main reasons for this were the lower packing density of the fibre and the cost of storing it for nine months of the year. This conclusion is supported by the Japan Kenaf Association which estimates that kenaf imported from Thailand costs between 10% and 20% more than imported wood fibre.

Table 5.3f *Global Costing of Chemo-Thermo Mechanical Pulp based on Softwood and Hemp*

Costs (US$/tonne pulp)	Softwood	Hemp
Raw material	105	200
Processing	110	100
Overheads	75	80
Capital	150	155
Total	*440*	*535*

Source: Onna 1994

It is not clear whether similar conclusions would apply to countries for whom importing wood resources, pulp or wastepaper is prohibitive. For example, one of the reasons given for the encouragement of of non-wood based mills in the India in the 1970s and 1980s was a lack of foreign exchange to import alternatives (Sadawarte 1995 pers comm).

In contrast, the United States Department of Agriculture kenaf newsprint project found that the production costs for kenaf pulp were lower than for typical pine newsprint pulp due to the savings in energy and chemicals (Mayberry 1987) and the Sichuan Pulp and Paper Journal, Sichuan Zaohzhi, in China reported in 1993 that kenaf pulp costs one third as much to produce as imported wood pulp (Ayres 1995). A 1990 study which compared the costs of wood and plant fibre in Thailand found that kenaf pulp cost 12% less than pulp from Thai eucalyptus plantations (Ayres 1995).

The Bioregional Development Group's estimated the costs involved in setting up an 8 tonne per day pulping plant based on locally grown hemp and flax and the revenue which could be generated (see Table 5.3g) in 1994. Their figures seem to indicate that such a venture could generate a reasonable rate of return for the production of high value pulp although the price of raw materials and pulp has changed considerably since then.

Although different studies have come to different conclusions on costs, on balance it appears that in most countries, relative investment costs in non-wood mills are higher than in wood mills, non-wood fibre is usually more expensive than wood fibre (although this may not be the case in some developing countries) whilst production costs may be lower for non-wood fibre pulping particularly if mechanical processes are used.

Table 5.3g Estimated Costs of and Revenue from an Eight Tonne per Day Pulping Plant Based on Hemp and Flax

Estimated Capital Cost	**Price (£)**
Bivis Pulping Machine	400 000
Ancillary Equipment	1 150 000
Secondary effluent treatment	600 000
Total	*2 150 000*
Estimated Annual Costs	
Raw Materials: flax tow (160 tonnes)	128 000
hemp tow (450 tonnes)	315 000
hemp hurds (2250 tonnes)	450 000
hemp machine tow (315 tonnes)	220 500
Labour (six semi-skilled workers @ £10 000 per annum) + overheads	78 000
Total	*1 191 500*
Estimated Annual Revenue	
Tow pulp (693 tonnes @ £1 400 per tonne)	970 200
Hurd pulp (1687 tonnes @ £ 300 per tonne)	506 000
Total	***1 476 200***

Source: Riddlestone and Desai 1994

It is not clear to what extent the non-wood fibre sector is subsidised above the wood sector in the main producing countries and whether removal of all subsidies would affect the competitiveness of the non-wood sector. Subsidies to the wood based paper industry (such as cheap land concessions or support for infrastructure development in forest or plantation areas) are not well documented or quantified. However, as the case studies in Section 2 illustrate, it seems clear that in most developing countries fiscal incentives and state support is a factor in the survival of non-wood mills, particularly in their initial stages of development.

For example, the Phoenix Pulp and Paper Company was started as part of a government initiative to develop the north of the country and would not have survived without the preferential terms it received. In India, agro-based mills received a variety of preferential conditions during the 1970s and 1980s (see Section 3.3). Fiscal incentives for agro-based mills have been substantially reduced as part of the liberalisation of the economy (Sadawarte 1995) although the extent of the reduction varies from region to region so it is difficult to judge how much of a role they still play. Evidence from the Punjab suggests that the reduced rate of excise duty for agro-based mills compared to wood based mills is a factor in the competitiveness of agro-based mills (Khaitan 1995 pers comm) and Capital Market (September 1994) reports that the budget which abolished the non-wood mills' exemption from excise duty and made them liable for 10% duty profoundly shocked the industry. However, despite the overall reduction in incentives which apply solely to agro-based mills, the use of agri-residues has been continually increasing whilst the use of bamboo and hardwood has been steadily declining (Sadawarte 1995).

5.3.6 Employment

Large modern mills give less employment opportunities than small mills (Fellegi and Judt 1991). It has been estimated that a 20,000 tonne per annum agri-pulp mill could provide 25 manufacturing jobs in Canada (Wong 1994). In India, Rao estimates that in small mills 53.5 people are employed for every thousand tonnes of pulp production per year.

5.4 Demand and Markets

One difficulty in asssessing the viability of using non-wood fibre for paper production is a lack of information on the potential demand for paper products from these fibres. A major weakness in most recent research into non-wood mills is the lack of hard data from the market about the likely response to their products.

There are two distinct markets for pulp, the specialist paper market and the mass market. As described in Section 2, some non-wood fibres have inherent advantages for certain specialist applications, such as for products requiring high tensile strength. Non-wood fibres can fetch premium prices in these markets (see Table 5.4a below). France and Spain currently produce 4000 ha and 1000 ha of hemp respectively, most of which goes into producing high priced speciality papers (Riddlestone and Desai 1994). One of the most profitable mills in India is Pudumjees Pulp and Paper Mill which produces speciality paper from bagasse, waste and wood pulp (Economic Times of India 1992).

Table 5.4a UK Prices for Various Pulps, April 1994

Type of Pulp	Price (£) per tonne
Flax	1400
Hemp	1350
Sisal	1290
Cotton	800
Straw	400
Hardwood	305
Softwood	313

Source: Riddlestone and Desai 1994

However, although profitable, the specialist market is small. In developing countries, the vast majority of non-wood fibre pulp and paper products are produced for the mass market where they compete with wood products. Most recent proposals for non-wood mills in developed countries are aimed at the mass market.

One of the motivations for the research initiatives into the potential for a kenaf newsprint industry in Australia outined in Section 4.4 was the high price of imported printing grades of paper. It was thought that kenaf could be utilised for the production of many of the imported paper products and so change Australia from a net importer to a net exporter of paper (Hazard *et al.* 1988). A study by Jaakko Pöyry for the Northern Territories government concluded that active marketing for kenaf products would be essential for this.

Phoenix Pulp and Paper in Thailand is one of the few companies which has been exporting significant amounts of non-wood pulp and it has put considerable effort into developing the market for kenaf pulp, with limited success. Their most profitable market for it was Japan where it was marketed as 'treefree' and where the pulp fetched premium prices (Paul 1995 pers comm). However, it is not clear how big this market is or how large the premiums are.

The Japanese Association for Non-Wood Paper Promotion and the Japan Kenaf Association are promoting the use of kenaf paper products. According to the Japan Kenaf Association kenaf pulp can either be used as an environmentally friendly alternative or used to produce highly valued paper products such as printing paper with a high ink absorbency. The JKA state that kenaf paper products are beginning to be used widely despite the fact that it is estimated that using kenaf imported from Thailand costs 10-20% more than the wood fibre normally used. However, the amounts currently used are small, only 1,000 tonnes of kenaf pulp were imported in 1994 and Japan does not produce any of its own. The OG Corporation which imports kenaf pulp aims to increase this eight fold by 1997. The OG Corporation also imports straw, bamboo and algae pulp and believes that there will be a high demand for straw pulp in the fiuture as its cost is 15% lower (Association of Non-Wood Paper Promotion, 1995). The JPA are trying to secure alternative supplies of kenaf pulp from China and they believe that the cost can be brought down to the level of wood pulp in the future (Kaminokawa 1995 pers comm).

Although there are examples of non-wood pulp costing less than wood pulp (see above), in general it appears that at present non-wood paper products are more expensive then those made from wood. The Rainforest Action Network (1995b) which is promoting the use of kenaf paper estimates that kenaf paper costs about one third more than wood based paper. The main factors in this are:

- the higher price of non-wood raw materials
- the economies of scale associated with large wood mills
- the difficulties associated with designing appropriate chemical recovery systems for non-wood mills
- the lack of established distribution channels and markets for non-wood products

Despite the higher cost, various groups are already using non-wood paper products (see Section 2) feeling that it is a more sustainable or environmentally friendly option. The Rainforest Action Network are using kenaf paper '*because it embodies our commitment to reducing wood consumption in the United States*'. In the UK the Bioregional Development Group believe that hemp paper can be marketed on the fact that is locally produced on a small scale and the iuse of alternative fibres have environmental benefits (Riddlestone 1995 pers comm). Friends of the Earth have called on the UK government to 'ensure volume markets for high quality paper made from non-wood sources and recycled paper (or a blend of both). All public bodies such as parliament and the Post Office, for example should be legally obliged to use 100% recycled and/or non-wood fibre paper' (Counsell 1995).

5.5 Conclusions

There are advantages and disadvantages in using non-wood fibres to make paper. At present non-wood paper products are generally more expensive than those made from wood although it is possible that if non-wood fibres had a bigger share of the paper market the difference in price might be reduced.

The annual nature of most non-wood fibres means that, compared to trees which are harvested on a minimum seven year cycle, there is more flexibility as to how much, and which, land is covered with fibre crops. However, as with trees the environmental impact of their cultivation is very dependent on the management practices used. Currently, the majority of non-wood mills are much more highly polluting than wood mills. The major factors in this is the lack of an appropriate chemical recovery system for small scale mills, inappropriate or outdated technology and lack of capital.

Non-wood mills currently have a significant social role in many developing countries being relatively big employers in rural areas and providing farmers with an alternative source of income. This is one of the main reasons for the interest in non-wood fibres being shown in developed countries.

6 CONCLUSIONS

It is clear that non-wood fibres can be used to produce a range of paper products ranging from very high quality speciality applications for which they have no substitutes to lower grades of paper and paperboard where they could substitute or complement virgin wood or recycled fibres.

Presently, almost all non-wood mills are situated in developing countries where they play an important role in pulp and paper production. However, many of these mills are inefficient, highly polluting and reliant on state support and are likely to come under increasing pressure in the future. It is currently difficult for non-wood fibres to compete with wood fibres on economic grounds. With support non-wood fibre paper may become more competitive in the future. The question is, are there any grounds for supporting paper production from non-wood fibres?

The environmental case appears ambiguous. A greater use of non-wood fibres may contribute to a reduced need to exploit natural forests and for tree plantations but it is not clear that the resulting increase in fibre crops will be more environmentally benign. In the case of agricultural residues, most have some alternative uses and utilising them for paper production may not always be the best option. For example, turning straw into paper may be better than burning it in the fields or landfilling it but whether substituting bagasse in sugar mills with a fossil fuel in order to use the bagasse for paper production is desirable is more debatable. In terms of the environmental impact of production most non-wood mills are currently more polluting than wood mills. However, if mills in the future have sufficient capital to invest in appropriate technology there seems to be no reason why this should continue to be the case.

On social grounds non-wood mills seem to have some advantages. The most appropriate size for a non-wood mill seems to be relatively small with the result that huge amounts of a capital need not be available to start one up and fibre could be procured from the local area. Small non-wood mills employ proportionately more people that large wood mills and the income received by farmers who supply the mills can be significant to some rural areas. However similar social benefits could occur from social forestry schemes.

In some places such as rural agricultural areas with few wood resources, there may be benefits to be accrued from small non-wood mills procuring their fibre from, and supplying paper to, their local area, rather than investing in a huge wood mill and importing wood fibre or importing pulp and paper.

In the future, non-wood fibres will continue to play an important role in paper production in developing countries so the development of appropriate processes, particularly for chemical recovery, is very important. Small mills are likely to require financial help to reduce their pollution levels. In developed countries only a very small amount of non-wood fibres are used for papermaking at present and although there is considerable interest in expanding their use, little of this comes from the paper industry. There seems to be some scope in increasing the use of non-wood fibres as a complement to wood fibres for papermaking, in particular utilising agricultural residues which are already in surplus. This will either require purpose built small scale non-wood mills in agricultural areas along the lines of those proposed by Arbokem in Canada, or wood based mills investing in the capacity to pulp non-woods alongside wood as the Phoenix Pulp and Paper Company have done in Thailand. With paper demand predicted to continue growing for the foreseeable future, the utilisation of a range of fibre sources is desirable, so investment in research and development of non-wood fibre paper making should be encouraged.

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